Original Article

Oxygen Consumptions of 30 Task-Oriented Exercises for Walking Training in Stroke

Thin Thin Moe MMedTech[1,2], Chutima Jalayondeja DrPH[1], Sopa Pichaiyongwongdee MSc[1], Jarugool Tretriluxana PhD[1], Vimonwan Hiengkaew PhD[1]

[1] Faculty of Physical Therapy, Mahidol University, Bangkok, Thailand

[2] Department of Physiotherapy, University of Medical Technology, Yangon, Myanmar

Objective: To examine the peak oxygen consumption [VO_{2peak}] and heart rate [HR_{peak}] performing 30 structured and progressive task-oriented exercises [SPTOE] for walking training in individuals post-stroke and compare the intensity among three steps of exercise.

Materials and Methods: Subjects with ambulatory first stroke who registered at the Faculty of Physical Therapy, Mahidol University were invited to participate. Each exercise was sequentially five minutes for performance and five minutes for resting in between. Subject performed 10 tasks per step a day and continued step I, II, and III of exercise. The VO_{2peak} and HR_{peak} were measured using the Oxycon Mobile portable and polar heart rate monitoring. Data were used to estimate the metabolic equivalent of tasks [METs] and percentage of heart rate reserve [%HRR]. The Friedman's ANOVA and Wilcoxson signed-rank tests were used for statistical analysis.

Results: Of 134 patients registered at the Physical Therapy Clinic, 10 subjects participated (39 to 70 years of age and 30 to 570 days post-stroke). The authors findings demonstrated significant differences of VO_{2peak}, METs, HR, and %HRR among the three steps of SPTOE (p<0.001). Three steps were serially arranged according to the VO_{2peak} (5.5 to 8.4 $ml \cdot kg^{-1} \cdot min^{-1}$ for step I, 6.4 to 10.1 $ml \cdot kg^{-1} \cdot min^{-1}$ for step II and 7.7 to 12.1 $ml \cdot kg^{-1} \cdot min^{-1}$ for step III).

Conclusion: Regarding to the American Stroke Associations for exercise recommendations, low-to-moderate intensity of 30 task-oriented exercises can be used for walking training in individuals with post-stroke.

Keywords: Metabolic equivalent, Oxygen consumptions, Stroke, Task-oriented exercise, Walking

J Med Assoc Thai 2018; 101 (9): 1255-62
Website: http://www.jmatonline.com

Walking deficit is the most common challenge caused by stroke worldwide. Approximately one-third of individuals post-stroke are unable to walk without supervision and are a burden to the community(1). Regaining independent community living and improving walking competency are the most common challenges for stroke rehabilitation. Based on the International Classification of Functioning, Disability and Health [ICF] model, walking activity and community participation are considered an optimal outcome for stroke rehabilitation(2). These are highly influenced by certain impairments of body function(2).

Walking competency is defined as the ability to perform walking-related tasks successfully or to navigate an adequate distance in the community in a skillful and safe manner, speed, and stability(3). Lower extremity [LE] strengthening and intensive mobility training can improve walking function resulting in greater community involvement(4,5). Receipt of a physical therapy program, including walking training, for stroke rehabilitation is the predictive factor for determining community participation(6). Repetitive, task-oriented mobility training is a well-known and feasible approach to walking training in physical therapy rehabilitation(3,7-9).

Salbach et al(9) listed ten walking tasks such as step-ups and obstacle course, improved walking in term of distance and speed in patients with moderately severe strokes. Blennerhassett et al(7) investigated the effect of practicing additional mobility tasks on functional mobility and walking in inpatient stroke rehabilitation. The results demonstrated significant improvements in distance, speed, and stepping after four weeks of task-related practice. Rose et al(8) reported task-oriented mobility training improved walking speed and was feasible in acute stroke rehabilitation.

The effect of task-oriented training on walking competency was related to task complexity and

Correspondence to:

Jalayondeja C. Faculty of Physical Therapy, Mahidol University, 999 Phuttamonthon 4 Road, Salaya, Nakhon Pathom 73170, Thailand.
Phone: +66-2-4415450 ext. 21806, **Fax**: +66-2-441-5454
Email: chutima.jal@mahidol.ac.th

How to cite this article: Moe TT, Jalayondeja C, Pichaiyongwongdee S, Tretriluxana J, Hiengkaew V. Oxygen consumptions of 30 task-oriented exercises for walking training in stroke. J Med Assoc Thai 2018;101:1255-62.

interconnected to cardiorespiratory workload and exercise intensity[10-12]. According to the physical activity and exercise recommendations of the American Stroke Association [ASA], low-to-moderate intensity aerobic exercise is recommended to improve functional capacity, recover ability to perform activities of daily living, and reduce the risk of a secondary stroke event[13]. Low-to-moderate intensity exercise is defined as 20% to 59% of heart rate reserve [HRR] or 2.0 to 5.9 metabolic equivalent of tasks [METs][13,14]. Routine physical therapy programs for sub-acute stroke survivors, including both contemporary task-oriented and traditional neuromuscular facilitation techniques, do not reach the lower zone of the target heart rate (40% of HRR) nor provide adequate cardiovascular stress to induce training benefit[15].

A few studies found that stroke populations demonstrated significant increases of walking distance and speed after receiving high intensity, task-specific training without serious adverse events[10,11]. Outermans et al[11] reported a great improvement in score on the 6-minute walk test and 10-meter walk test in a high intensity training group (70% to 80% of HRR) compared with one receiving low intensity training. Billinger et al[10] recommended high intensity training for the improvement of aerobic fitness and motor function in stroke populations. Therefore, the intensity of task-related exercise for optimal influence on walking competency should be evaluated. The objectives of the present study were 1) to measure the oxygen consumption [VO_2] and heart rate [HR] for determining intensity of a structured and progressive task-oriented exercise [SPTOE] program in individuals post stroke, and 2) to compare the intensity estimated by the METs and the percentage of HRR [%HRR] among three steps of SPTOE program.

Materials and Methods

A quasi-experimental repeated measure study was conducted to measure the VO_2 and HR during exercise in individuals post-stroke. Data were collected between July and August 2016. The present trial was registered at the ClinicalTrials.gov (NCT 02781077) and approved by the Mahidol University Institutional Review Board (COA No. MU-IRB 2016/072.3105).

Individuals with their first stroke who registered at the Physical Therapy Center of the Faculty of Physical Therapy, Mahidol University, Thailand, were approached for enrollment in the present study. Eligibility criteria were a) unilateral stroke lesion diagnosed by CT or MRI, b) age above 20 years, c) moderate disability with independent walking measured by the modified Rankin Scale (mRS-3), d) LE motor control measured by the Fugl-Meyer Assessment scale (FMA_LE ≥21), and e) good cognition measured by the Thai Mini Mental State Examination (TMMSE >23). Exclusion criteria were a) diagnosis of other central and peripheral neurological disorders such as Parkinson's disease or peripheral nerve injury, b) serious cardiac conditions such as angina pectoris and/or myocardial infarction during the last month, resting HR greater than 120 bpm, or blood pressure greater than 180/100 mmHg, c) limited range of motion [ROM] at the hip, knee or ankle joints (FMA_ROM of less than 1), and d) pain with/without weight bearing at hip, knee or ankle (FMA_pain of less than 1).

The eligible subjects were informed of the study's objective and procedures. They gave written informed consents before entering the study and starting the exercise program. Baseline characteristics recorded included age, gender, weight, height, stroke type, lesion side, comorbidities, time (days) since stroke, and type of ambulation aids. Muscle tone was measured by the Modified Ashworth Scale [MAS] at hip, knee, and ankle. All subjects received the usual care rehabilitation program that contained stretching, general exercises for upper and lower extremities, balance, and walking for one hour per day, two to three days a week.

VO_2 and HR were measured as subjects performed each exercise in steps I, II and III of the SPTOE. Each step contained 10 exercises and progressed from simple to difficult activities. The subjects were not allowed to have a large meal for two hours nor drink caffeinated or alcoholic beverages for six hours before testing. For the VO_2 testing, subjects were resting in a quiet sitting position for five minutes, followed by each exercise for five minutes, and a break for five minutes or more prior to the next exercise. Exercises were from task 1 to 10 of step I, followed by steps II and III. Each step was completed in one session and subsequent steps were at least one to two days apart. The rating perceived exertion [RPE] was used to identify their effort during performance of each exercise with scores ranging from 0 to 10. Subjects were allowed to stop or remove the facemask during testing if they felt discomfort or pain. The total time of testing was 120 minutes per session.

A SPTOE program

A SPTOE program was developed and contained 30 exercises in a functional goal-oriented approach for walking training (Table 1). These were exercises commonly prescribed by physical therapists for stroke rehabilitation. Exercises were categorized and arranged progressively into three steps (I, II, and III) based on task complexity and balance challenging activities. Each step was comprised of 10 exercises that were related to basic activities in daily living and environmental demands of community walking. Step I was the preparatory phase to improve trunk and LE motor control. The exercises were designed to increase trunk mobility, weight bearing and shifting, with emphasis on the affected leg. Step II was the intermediate phase to promote functional mobility and postural control. The exercises were progressive to challenge the anticipatory and adaptive balance strategies used in standing, transferring, and walking. Step III was the last phase, containing challenging motor dual-task balance training, stair climbing, and fast speed walking. Each subject was acquainted with all exercises of each step prior to testing.

The VO_2 test and exercise intensity

The VO_2 and HR were measured through the Oxycon Mobile Portable (VIASYS Health Care-Jaeger, Hoechberg, Germany) and a Polar heart rate monitor (Polar belt, Set T61, CareFusion, Germany), respectively. The oxycon mobile equipment recorded the VO_2 every 30 seconds via facemask and wirelessly send the data to a computer system. The peak value of VO_2 [VO_{2peak}] during minute 3 to 5 was determined. The VO_2 referred to the amount of oxygen that the individual utilized for aerobic metabolism during rest [VO_{2rest}] or exercise [$VO_{2exercise}$], in units of milliliter per kilogram body weight per minute ($ml \cdot kg^{-1} \cdot min^{-1}$). The VO_{2rest} can be used for estimating the resting metabolic rate [RMR] and equals 1 MET or 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$[16]. The metabolic equivalent of the task (in METs) indicates the intensity of exercise and is based on the ratio of working to resting metabolic rates. It can be calculated using the formula of the $VO_{2exercise}$ divided by the VO_{2rest}[16]. For example, the exercise intensity equals 2.2 METs calculated from the peak value of $VO_{2exercise}$ (6.5 $ml \cdot kg^{-1} \cdot min^{-1}$) divided by the peak value of VO_{2rest} (2.9 $ml \cdot kg^{-1} \cdot min^{-1}$). According to the resulting MET value, each exercise is classified as light (1.0 to 2.9 METs), moderate (3.0 to 5.9 METs), or vigorous (≥6 METs) intensity[14].

A Polar heart rate monitor was attached to the subject's chest wall and recorded the HR at rest [HR_{rest}] and during exercise [$HR_{exercise}$]. The peak value of HR [HR_{peak}] during minute 3 to 5 was calculated and represented in beats per minute [bpm]. HRR was calculated by subtracting the peak value of HR_{rest} from the maximum value of HR (HR_{max})[17], where HR_{max} is equal to (220 - age)[18]. For subjects taking beta-blockers, the calculation was modified and equal to 0.85 × (220 - age)[18]. The authors then computed the %HRR of each exercise from the formula ($HR_{exercise}$ - HR_{rest} / HRR) × 100[17]. According to %HRR, each exercise was classified as light (20% to 39% HRR), moderate (40% to 59% HRR), or vigorous (≥60% HRR) intensity[14].

Statistical analysis

The sample size was estimated using a paired t-test formula[19]. The probability of types I (α) and II (β) error were 0.05 and 0.2, $Z_{1-\alpha/2}$ was 1.96 and $Z_{1-\beta}$ was 0.84. The expected change of VO_{2peak} in individual post stroke was 0.36 mL/kg/minute[20]. The effect size was 0.5, therefore the required sample size was 11 after considering 20% of drop out.

Data were analyzed using the statistical software SPSS® (version 19.0; Armonk, NY: IBM). Baseline characteristics were described individually. All parameters that were used for determining the exercise intensities (VO_2, METs, HR, %HRR, and RPE) were described in terms of the median or fiftieth percentile and the twenty-fifth to seventy-fifth percentiles of interquartiles [IQ]. The comparisons of VO_{2peak} during each of the 10 exercises in each step were determined using the Friedman's ANOVA test and Wilcoxon signed-rank test. A *p*-value below 0.05 was considered significant.

Results

The 30 exercises are arranged in Table 1 according to the number 1 to 10 in steps I, II, and III. Of the 134 patients registered at the Physical Therapy Clinic, 10 individuals with stroke met the study criteria and enrolled in the present study. They were six males and four females, aged 39 to 70 years. Time since stroke ranged from 1 to 19 months. Mild to moderate decreases of LE muscle tone measured by the MAS was found, with MAS ranging from 0 to 2. All subjects could walk independently and six of them used ambulation aids. Table 2 shows basic characteristics of ten individuals post stroke. One subject (No. 10) declined to continue after step I because he felt discomfort at night. Two subjects (No. 3 and 7) in step II and one (No. 1) in step III were excluded from the analysis because they drank coffee before testing. Overall, the data from ten subjects in step I, seven subjects in step II, and eight subjects in step III were used for statistical analyses.

At rest, the VO_{2peak} was 2.36 $ml \cdot kg^{-1} \cdot min^{-1}$ (1.94

Table 1. A structured, progressive and task-oriented exercise program

Exercise	Step I	Step II	Step III
1	Crook lying, pelvic rolling	Standing, turning 360 degree to both sides	Walking, turning around obstacles (e.g., turning cones)
2	Sitting, reaching forward, and sideways beyond arm length	Standing, reaching forward and sideways beyond arm length.	Walking, lowering body to pick up an object (e.g., water bottle) from the floor
3	Sitting, leaning forward with equal weight transfer on the scales	Transferring from sit to stand, equal weight bearing on both legs	Transferring from sit to stand, holding tray with both hands
4	Standing, lateral weight shift to affected leg	Standing, pacing affected leg onto 4 inches step laterally	Standing, pacing affected leg onto 6 inches step laterally
5	Standing, stepping forward with unaffected leg, weight bearing on affected leg	Standing, alternate leg stepping across over 4 cm height obstacles	Standing, alternate leg stepping across over 8cm height obstacles
6	Standing, alternate stepping across forward and backward with unaffected leg	Walking in straight line, long step length	Walking in straight line, short step length
7	Standing, pacing unaffected leg forward on a 4 cm height stool and lifting body	Standing, pacing affected leg forward on a stool, lifting unaffected leg up and down	Stair climbing and descending
8	Standing, stepping affected leg backward	Walking backward with short step length	Walking backward with long step length
9	Pivot transferring from chair to chair place slightly apart	Standing up, walking straight forward, sitting on the chair, walking back to sit down	Timed standing up, walking straight forward, sitting on the chair, walking back to sit down
10	Standing, stepping forward with alternate affected and unaffected legs	Comfortable speed walking	Fast speed walking forward with long step length

Table 2. Baseline characteristics of ten individuals post-stroke

Subject	Age (years)	Sex	Weight (kg)	Lesion side	Stroke subtype	Stroke onset (days)	Comorbidity	FMA-LE	MAS	TMMSE	Walking-aids
1	52	Female	60	Right	Infarction	90	HT/DM	24	0	29	Three-point cane
2	46	Female	57	Left	Infarction	480	HT	25	1	30	None
3	39	Male	67	Left	Hemorrhage	180	HT/DM	30	2	30	None
4	69	Male	62	Left	Hemorrhage	150	HT/DM	32	1	30	None
5	70	Female	45	Right	Infarction	270	DM	31	1	30	None
6	63	Male	58	Right	Infarction	570	HT	28	2	30	None
7	50	Male	91	Left	Hemorrhage	45	HT/DM	32	0	30	None
8	70	Male	61	Right	Infarction	180	HT/DM	25	1	30	Three-point cane
9	53	Female	50	Right	Hemorrhage	30	HT	28	0	30	One-point cane
10	44	Male	95	Right	Hemorrhage	45	HT	21	0	30	Three-point cane

FMA-LE = Fugl-Meyer assessment for lower extremities; MAS = modified Ashworth scale; TMMSE = Thai Mini-Mental State Examination; HT = hypertension; DM = diabetes mellitus

to 2.88) for step I, 2.53 ml·kg^{-1}·min^{-1} (1.95 to 3.23) for step II, and 2.60 ml·kg^{-1}·min^{-1} (1.96 to 3.28) for step III. The median HR_{peak} at rest was 67 bpm (59.0 to 78.8) for step I, 63 bpm (58.5 to 83.5) for step II, and 62 bpm (58.0 to 71.5) for step III. Table 3 listed the median and interquartile values of the VO_{2peak}, METs, HR_{peak}, %HRR, and RPE during each exercise in each step I, II, and III.

The exercise-related VO_2 increased with step from I to II to III. Of the 30 exercises, moderate intensity (3.0 to 4.9 METs) was found in 3, 8, and 8 exercises in steps I, II, and III, respectively. Table 3 demonstrates exercise intensity of steps I, II, and III of SPTOE. For step I, pelvic rolling exercise in crook lying position had low values of exercise intensity including 5.5 ml·kg^{-1}·min^{-1} of VO_{2peak}, 2.0 METs, 87 bpm of HR_{peak}, 16.7% HRR and score 2 for RPE. High values of VO_{2peak}, METs, and %HRR were associated with pivot transferring from chair to chair placed slightly apart. For step II, 2 of 10 exercises required low VO_2 (turning 360 degrees to both sides in standing and reaching forward and sideways beyond arm's length in standing). The remaining activities including standing up, walking straight forward, sitting on the chair, walking back to sit down had moderate intensity with 9.8 ml·kg^{-1}·min^{-1} of VO_{2peak}, 4.2 METs, 101 bpm of HR_{peak}, 40.5% HRR and score 4 for RPE. For step III, two exercises were light intensity (walking and turning around obstacles, and walking in a straight line with short step length). The remaining exercises had moderate high intensity

Table 3. Exercise intensity of each exercise in steps I, II, and III of a structured, progressive, task-oriented home exercise program

Exercise	Step I (n = 10)					Step II (n = 7)					Step III (n = 8)				
	VO_{2peak}	METs	HR_{peak}	%HRR	RPE	VO_{2peak}	METs	HR_{peak}	%HRR	RPE	VO_{2peak}	METs	HR_{peak}	%HRR	RPE
1	5.5 (3.4 to 6.1)	2.0 (1.6 to 2.6)	87.5 (72.8 to 112.8)	16.7 (14.2 to 37.8)	2.0 (2.0 to 2.3)	6.4 (5.3 to 7.9)	2.8 (2.4 to 3.1)	85.0 (74.5 to 114.5)	25.2 (18.2 to 41.4)	2 (2 to 3)	8.1 (6.1 to 10.5)	2.9 (2.3 to 3.6)	88.5 (75.3 to 100.8)	25.7 (21.1 to 40.8)	3 (3 to 3)
2	6.4 (5.2 to 7.0)	2.6 (2.2 to 3.1)	89.0 (81.0 to 110.5)	27.8 (22.5 to 36.3)	2.0 (2.0 to 2.3)	6.6 (5.7 to 7.4)	2.8 (2.5 to 3.0)	88.0 (79.0 to 121.0)	25.9 (21.6 to 44.7)	2 (2 to 3)	10.8 (9.6 to 12.1)	3.8 (3.7 to 4.7)	98.5 (83.8 to 110.3)	35.6 (32.0 to 51.7)	3 (3 to 3)
3	7.1 (6.4 to 8.4)	3.3 (2.4 to 3.6)	93.0 (84.0 to 118.0)	32.1 (29.3 to 46.1)	2.0 (2.0 to 3.0)	8.6 (7.0 to 11.6)	3.4 (3.3 to 4.2)	105.0 (83.0 to 136.5)	42.1 (25.3 to 54.1)	3 (2 to 4)	11.4 (8.5 to 13.0)	3.9 (3.4 to 4.4)	100.5 (84.8 to 114.0)	38.5 (29.9 to 53.9)	4 (3 to 4)
4	7.0 (4.9 to 7.7)	2.8 (1.9 to 3.6)	95.0 (79.0 to 120.8)	32.1 (22.3 to 41.5)	2.5 (2.0 to 3.0)	8.8 (7.8 to 9.3)	3.4 (3.1 to 3.8)	97.0 (83.5 to 132.0)	31.8 (29.7 to 60.8)	3 (3 to 4)	10.0 (6.7 to 13.0)	3.9 (3.1 to 4.3)	100.5 (86.5 to 117.0)	38.0 (33.1 to 60.0)	4 (3 to 4)
5	6.3 (5.6 to 7.4)	2.7 (2.2 to 3.2)	96.0 (75.8 to 121.5)	27.4 (20.5 to 40.0)	3.0 (2.0 to 3.0)	9.5 (7.8 to 10.3)	3.7 (3.2 to 3.8)	97.0 (83.0 to 128.5)	31.8 (29.7 to 54.3)	4 (3 to 4)	9.4 (7.9 to 12.1)	3.5 (2.9 to 3.7)	97.0 (85.5 to 114.8)	38.9 (31.0 to 52.7)	4 (3 to 4)
6	6.0 (5.0 to 7.7)	2.9 (2.1 to 2.9)	92.5 (75.5 to 119.8)	26.5 (19.8 to 35.2)	3.0 (2.0 to 3.0)	7.5 (5.8 to 8.8)	3.0 (2.5 to 3.5)	93.0 (78.5 to 120.0)	28.2 (20.3 to 46.0)	4 (3 to 4)	7.7 (4.7 to 9.5)	2.6 (2.0 to 3.2)	87.5 (79.8 to 104.0)	29.2 (25.2 to 45.2)	5 (4 to 5)
7	7.6 (6.0 to 8.9)	3.1 (2.6 to 3.6)	99.5 (83.75 to 127.5)	33.7 (25.3 to 43.4)	3.0 (2.0 to 3.0)	9.0 (8.1 to 10.0)	3.6 (3.2 to 3.9)	97.0 (83.0 to 129.0)	33.8 (28.2 to 59.6)	4 (3 to 4)	12.0 (10.0 to 13.5)	4.5 (3.6 to 5.7)	104.5 (92.8 to 119.5)	48.2 (37.9 to 55.6)	5 (4 to 5)
8	7.0 (4.8 to 7.8)	2.6 (2.2 to 3.5)	96.0 (76.8 to 123.5)	27.5 (19.5 to 42.3)	3.0 (2.8 to 3.0)	7.9 (7.2 to 8.6)	3.0 (2.8 to 3.9)	94.0 (83.0 to 123.0)	30.4 (28.2 to 53.2)	4 (3 to 4)	8.7 (5.9 to 11.7)	3.6 (2.3 to 3.9)	92.5 (83.0 to 109.0)	32.9 (27.3 to 52.8)	5 (4 to 5)
9	8.4 (6.5 to 10.9)	3.7 (3.2 to 4.1)	98.0 (84.5 to 136.8)	34.5 (22.2 to 50.8)	3.0 (3.0 to 4.0)	9.8 (9.2 to 11.9)	4.2 (3.9 to 4.7)	101.0 (83.5 to 127.0)	40.5 (28.4 to 52.7)	4 (4 to 5)	12.1 (10.1 to 15.1)	4.9 (3.9 to 5.4)	98.5 (89.5 to 121.3)	40.6 (35.1 to 62.9)	5 (4 to 7)
10	7.2 (3.7 to 8.6)	2.7 (2 to 3.5.2)	99.5 (79.8 to 121.8)	30.6 (21.6 to 42.5)	3.5 (3.0 to 4.0)	10.1 (8.2 to 10.9)	3.9 (3.6 to 4.3)	103.0 (87.0 to 129.0)	38.6 (31.6 to 59.5)	5 (4 to 5)	11.3 (10.2 to 13.0)	4.4 (3.9 to 5.0)	104.0 (86.3 to 120.3)	44.1 (34.5 to 60.7)	6 (5 to 7)

VO_{2peak} = the maximum oxygen consumption during exercise at minute 3 to 5 (ml·kg^{-1}·min^{-1}); METs = the metabolic equivalent of tasks; %HRR = the percentage of heart rate reserve; RPE = the rating perceived exertion; HRpeak = the heart rate peak during exercise at minute 3 to 5 (beats per minute)

Data represented the median and interquartile [IQ] of each exercise in step I, II, and III, all exercises are arranged according to the number 1 to 10 in Table 1

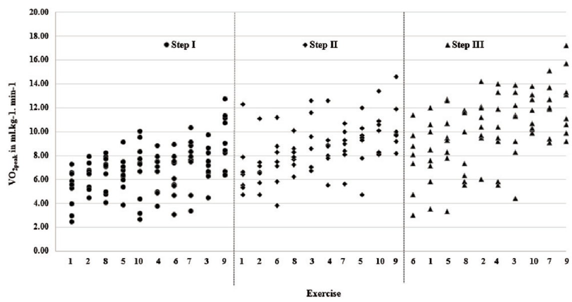

Figure 1. The oxygen consumption [VO_{2peak}] of exercises in steps I, II, and III in 10 post-stroke subjects.

(more than 10 ml·kg^{-1}·min^{-1} of VO_{2peak} and 3 METs).

There were significant differences in the VO_{2peak} among the 10 exercises in each step and between three steps (p<0.001). Pairwise comparison of VO_{2peak} demonstrated significant differences among each exercise (p<0.05). The sequences of exercises with increasing energy demand in terms of VO_2 are illustrated in Figure 1. The values of VO_2 were serially arranged from low to high intensity of the 30 exercises in the three steps and depicted in the scatter plots.

Discussion

The authors reported the exercise intensity of 30 exercises in a three-step of SPTOE program. These exercises were commonly employed in daily living and used to improve walking competency in stroke rehabilitation. All exercises in the SPTOE program, excepted three exercises in step I, were walking-related with progressive demands of antigravity muscle work. The VO_2 and HR responses during these exercises were in the range considered low to moderate intensity (5.5 to 12.1 ml·kg^{-1}·min^{-1} of VO_2 and 16.7 to 48.2 of %HRR).

Rahman et al[21] measured the VO_2 of activities involved in the Rivermead Mobility Index among stroke survivors. They reported that the VO_2 of a transferring 10 meters walk and stairs activities ranged from 6.31 to 10.71 ml·kg^{-1}·min^{-1}, sufficient to induce cardiovascular fitness. The VO_2 of submaximal exercise testing using 5-minute walk test was 6.84 ml·kg^{-1}·min^{-1} and for 6-minute walk test was 12.0 ml·kg^{-1}·min^{-1} in stroke survivors[22,23]. Similar activities in our exercise program, such as sit to stand, transfer, comfortable and fast walking, demanded 6.6 to 12.0 ml·kg^{-1}·min^{-1} of VO_2. The present study demonstrated data on energy expenditure collaborated with the previous findings. The VO_2 of mobility tasks in three steps demonstrated that the exercise program was moderately intensive and sub-maximally demanding in the stroke patients.

MacKay-Lyons and Makrides[15] examined cardiovascular stress during performance of a contemporary stoke rehabilitation program including task-oriented exercises. They found that walking, stair climbing, balancing in sitting and standing, sit to stand, and transfer activities reached the moderate intensity target HR (40% to 85% HRR). Moreover, Outermans et al[11] compared gait performances between the high intensity task-oriented training (70% to 80% HRR) and low intensity activities. They reported great improvement of walking distance and speed in high intensity training group compared to low intensity. Their interventions included stair activities, turning, making transfers, walking quickly and walking for specified distances, and exceeded gait performance targets in the high intensity training group. However, they recruited the subjects who had high physical performance and did not blind assessors, the selection bias, and measurement error might have interfered with the results of the study. The %HRR of stair activities, turning, making transfers, walking quickly, and walking for specified distances in the present study ranged from 25.9 to 48.2 and corresponded to moderate cardiovascular workload for improving walking competency of stroke survivors.

Regarding the METs, the energy demanded of our three steps exercise program were within the low to moderate intensity level of physical activity recommended for stroke rehabilitation (2.0 to 4.9 METs)[14]. This reaches the upper limit as most stroke individuals can consume energy up to a 4 to 5 METs maximum[24]. Additionally, light activities of daily living require about 3 METs whereas vigorous intensity of activities require around 5 METs[24]. This evidence supports a conclusion that the SPTOE program was enough to induce cardiopulmonary fitness required for instrumental activities in daily life.

Ducan et al[25] demonstrated the improvement in cardiovascular fitness in individuals post-stroke after three months of performing a structured and progressive exercise program. The results showed increase of aerobic capacity (1.05 $ml \cdot kg^{-1} \cdot min^{-1}$ of VO_2) and walking distance (61.61 meters of 6-minute walk test) compared to baseline data. They concluded that a structured and progressive exercise could improve the exercise capacity in individuals post-stroke. To evaluate the exercises in a progressive manner, the present study assessed intensity of 30 task-oriented exercises in each step of SPTOE program. Our findings showed that the VO_2 and METs of each exercise step significant increased gradually from step I to step III. Therefore, the present study arranged 30 exercises in our SPTOE program in a progressive order of energy demands (VO_2 and METs) from step I to III.

Similar to other studies, the resting VO_2 values of the present study subjects were lower than the healthy reference value of 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$[16,26]. The finding supported the idea of Sergi et al[16] that the reference value may not be appropriate for stroke patients because it systematically underestimated intensity levels in terms of METs. The peak oxygen uptake of stroke survivors was half in age-matched healthy groups[18,20], as stroke individuals tended to have significantly low ventilation variables[27] and high body fat composition[28]. Some research studies found the relationship of VO_2 to age, sex, health fitness, hemiplegic gait, balance, and post stroke onset[17,29]. Furthermore, metabolic rate is influenced by other factors including advanced age, fat composition, reduced cardiopulmonary efficiency, and decreased muscle oxidation ability[30]. However the age, gender, chronicity, and cardiovascular fitness differences among participants of the same condition might also be responsible for the variation in energy consumption. These confounding factors should be considered in recommending exercise tests in the stroke population.

Some limitations were found in the present study. First, the small sample size might affect the normality and statistical analysis. Second, the VO_2 and METs were not stratified by the confounding factors, including age, sex, and time post stroke. However, the present study was a preliminary study for measuring the VO_2 in stroke. Therefore, further studies should be developed to investigate the influence of potential variables on the energy consumption in the individual post-stroke.

Conclusion

The present study revealed that the challenge walking tasks included in the current structured exercise program were able to provide low-to-moderate intensive training for individuals with stroke. Moreover, the sequence of exercise steps arranged in the program for walking recovery was in a progressive order based on energy demand. Thus, the protocol implemented in the present study met the recommendations for ambulatory training of post-stroke patients due to its moderate intensity demand and progressive order of arrangement. Hence, the protocol of the current study would meet the recommended expenditures to increase aerobic capacity, and the activities of this exercise program could be adopted to improve aerobic capacity of stroke individuals. However, a randomized controlled study is warranted to confirm that this exercise program, which incorporates walking related activities, can improve the walking competency of stroke survivors. Based on the present study, the authors suggest that since the intensity demands were significantly different among all mobility activities of some steps, patients with stroke should practice all tasks in a sequential order. Furthermore, the authors suggest that a future study be conducted with a larger sample size, recording any adverse events to guarantee the safety and effectiveness of conducting this exercise program in the real environment of stroke victims who often have minimal supervision.

What is already known on this topic?

Task-oriented exercises are well known and an acceptable approach for walking rehabilitation of post-stroke individuals. The effect of task-oriented training on walking competency was related to task complexity and interconnected to cardiorespiratory workload and exercise intensity. The American Stroke Association recommended low-to-moderate intensity aerobic exercise to improve functional capacity and to perform activities of daily living after stroke.

What this study adds?

The 30 task-oriented exercises composed in SPTOE program are in range of low-to-moderate intensity and consistent with the American Heart Association/the American Stroke Association [AHA/ASA] exercise recommendations for stroke rehabilitation. Therefore, these exercises can be used for walk-training in post-stroke individuals.

Acknowledgement

The present study was supported by the Capacity Building for Institutions in Myanmar [CBIM] (Norway). The authors wish to acknowledge all participants, staffs, and Mr. Surasak Boonprasop at Faculty of Physical Therapy, Mahidol University for data collection, and Dr. Arthur Brown for English editing.

Potential conflicts of interest

The authors declare no conflict of interest.

References

1. Lord SE, McPherson K, McNaughton HK, Rochester L, Weatherall M. Community ambulation after stroke: how important and obtainable is it and what measures appear predictive? Arch Phys Med Rehabil 2004;85:234-9.
2. Geyh S, Cieza A, Schouten J, Dickson H, Frommelt P, Omar Z, et al. ICF Core Sets for stroke. J Rehabil Med 2004;135-41.
3. van de Port IG, Wevers L, Roelse H, van Kats L, Lindeman E, Kwakkel G. Cost-effectiveness of a structured progressive task-oriented circuit class training programme to enhance walking competency after stroke: the protocol of the FIT-Stroke trial. BMC Neurol 2009;9:43.
4. Peurala SH, Airaksinen O, Huuskonen P, Jäkälä P, Juhakoski M, Sandell K, et al. Effects of intensive therapy using gait trainer or floor walking exercises early after stroke. J Rehabil Med 2009;41:166-73.
5. Flansbjer UB, Miller M, Downham D, Lexell J. Progressive resistance training after stroke: effects on muscle strength, muscle tone, gait performance and perceived participation. J Rehabil Med 2008; 40:42-8.
6. Jalayondeja C, Kaewkungwal J, Sullivan PE, Nidhinandana S, Pichaiyongwongdee S, Jareinpituk S. Factors related to community participation by stroke victims six month post-stroke. Southeast Asian J Trop Med Public Health 2011;42:1005-13.
7. Blennerhassett J, Dite W. Additional task-related practice improves mobility and upper limb function early after stroke: a randomised controlled trial. Aust J Physiother 2004;50:219-24.
8. Rose D, Paris T, Crews E, Wu SS, Sun A, Behrman AL, et al. Feasibility and effectiveness of circuit training in acute stroke rehabilitation. Neurorehabil Neural Repair 2011;25:140-8.
9. Salbach NM, Mayo NE, Wood-Dauphinee S, Hanley JA, Richards CL, Cote R. A task-orientated intervention enhances walking distance and speed in the first year post stroke: a randomized controlled trial. Clin Rehabil 2004;18:509-19.
10. Billinger SA, Boyne P, Coughenour E, Dunning K, Mattlage A. Does aerobic exercise and the FITT principle fit into stroke recovery? Curr Neurol Neurosci Rep 2015;15:519.
11. Outermans JC, van Peppen RP, Wittink H, Takken T, Kwakkel G. Effects of a high-intensity task-oriented training on gait performance early after stroke: a pilot study. Clin Rehabil 2010;24:979-87.
12. Heeren A, van Ooijen M, Geurts AC, Day BL, Janssen TW, Beek PJ, et al. Step by step: a proof of concept study of C-Mill gait adaptability training in the chronic phase after stroke. J Rehabil Med

2013;45:616-22.
13. Billinger SA, Arena R, Bernhardt J, Eng JJ, Franklin BA, Johnson CM, et al. Physical activity and exercise recommendations for stroke survivors: a statement for healthcare professionals from the American Heart Association/American Stroke Association. Stroke 2014;45:2532-53.
14. American College of Sports Medicine Position Stand. The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. Med Sci Sports Exerc 1998;30:975-91.
15. MacKay-Lyons MJ, Makrides L. Cardiovascular stress during a contemporary stroke rehabilitation program: is the intensity adequate to induce a training effect? Arch Phys Med Rehabil 2002;83: 1378-83.
16. Sergi G, Coin A, Sarti S, Perissinotto E, Peloso M, Mulone S, et al. Resting VO2, maximal VO2 and metabolic equivalents in free-living healthy elderly women. Clin Nutr 2010;29:84-8.
17. Tang A, Marzolini S, Oh P, McIlroy WE, Brooks D. Factors associated with change in aerobic capacity following an exercise program for individuals with stroke. J Rehabil Med 2013;45:32-7.
18. MacKay-Lyons MJ, Makrides L. Exercise capacity early after stroke. Arch Phys Med Rehabil 2002; 83:1697-702.
19. Dupont WD, Plummer WD Jr. Power and sample size calculations. A review and computer program. Control Clin Trials 1990;11:116-28.
20. Kelly JO, Kilbreath SL, Davis GM, Zeman B, Raymond J. Cardiorespiratory fitness and walking ability in subacute stroke patients. Arch Phys Med Rehabil 2003;84:1780-5.
21. Rahman FBA, Jones AYM, Pang M. Oxygen consumption and peak heart rate in stroke patients during the completion of the Modified Rivermead Mobility Index (MRMI). Hong Kong Physiother J 2012;30:76-82.
22. Eng JJ, Dawson AS, Chu KS. Submaximal exercise in persons with stroke: test-retest reliability and concurrent validity with maximal oxygen consumption. Arch Phys Med Rehabil 2004;85:113-8.
23. da Cunha-Filho IT, Henson H, Wankadia S, Protas EJ. Reliability of measures of gait performance and oxygen consumption with stroke survivors. J Rehabil Res Dev 2003;40:19-25.
24. Ivey FM, Macko RF, Ryan AS, Hafer-Macko CE. Cardiovascular health and fitness after stroke. Top Stroke Rehabil 2005;12:1-16.
25. Duncan P, Studenski S, Richards L, Gollub S, Lai SM, Reker D, et al. Randomized clinical trial of therapeutic exercise in subacute stroke. Stroke 2003;34:2173-80.
26. de Faria Coelho-Ravagnani C, Melo FCL, Ravagnani FCP, Burini FHP, Burini RC. Estimation of the metabolic equivalent (MET) of an exercise protocol based on indirect calorimetry. Rev Bras Med Esporte 2013;19:134-8.
27. Wong AA, Read SJ. Early changes in physiological variables after stroke. Ann Indian Acad Neurol 2008;11:207-20.
28. de Sant'Anna M Jr, Eboli LC, Silva JG, Dos Santos AG, Lourenço M, Moreno AM, et al. Resting metabolic rate analysis in chronic hemiparesis patients. Neurol Int 2014;6:5442.
29. van de Port IG, Kwakkel G, Wittink H. Systematic review of cardiopulmonary exercise testing post stroke: Are we adhering to practice recommendations? J Rehabil Med 2015;47:881-900.
30. Cunha FA, Midgley AW, Monteiro WD, Farinatti PT. Influence of cardiopulmonary exercise testing protocol and resting VO(2) assessment on %HR(max), %HRR, %VO(2max) and %VO(2)R relationships. Int J Sports Med 2010;31:319-26.