Original Article

Effects of Inspiratory Muscle Training on Hand and Mobility Functions in Subacute Stroke

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ABSTRACT

Objectives: To study the effects of inspiratory muscle training (IMT) on peripheral muscle functions in subacute stroke patients.

Setting: Clinics of Neurology and Physical Medicine and Rehabilitation at Hasan Sadikin General Hospital, Bandung.

Study design: Double blinded clinical trial.

Subjects: Consecutive sampling of 32 subacute stroke patients were recruited into the study and 31 completed the study.

Methods: Participants were divided into two groups of an intervention (n=15) and a control (n=16). Both groups received a conventional exercise and ambulatory program. The intervention group performed an 8-week home-based IMT program with intensity of 40% of PI-max (maximal inspiratory pressure) whereas the control group performed IMT program with intensity of 10% of PI-max. Primary outcomes indicating peripheral muscle functions were grip strength of the paretic side assessed with a hand grip dynamometer and mobility function assessed with a sit-to-stand test. Secondary outcome was inspiratory muscle strength measured as PI-max. Outcome measurements were done before and after the intervention ended.

Results: After 8 weeks the grip strength of the paretic hand and the score of the sit-to-stand test increased significantly in both groups but there were no differences between the two groups. However, the PI-max significantly increased only in the intervention group (p=0.000) and there was significantly different between the two groups (p=0.003).

Conclusion: A home-based inspiratory muscle training was effective in increasing inspiratory muscle strength. However, it did not demonstrate any effect on peripheral muscle functions, grip strength and ability of sit-to-stand in subacute stroke patients.

Keywords: hand grip strength, inspiratory muscle training, sit-to-stand, subacute stroke, exercises

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Introduction

Stroke is the most common cause of disability worldwide.[1] It is defined as a non-traumatic brain injury caused by occlusion or rupture of cerebral blood vessels that results in sudden neurological deficits characterized by loss of motor control, altered sensation, cognitive and/or language impairment, disequilibrium, or coma.[2] According to the Riskesdas (National Basic Health Research) report in 2007, stroke was the highest (15.4%) cause of death in Indonesia compared with other diseases. The prevalence of stroke in Indonesia was 8.3% in 2007 and increased to 12.1% in 2013.[3]

Stroke patients commonly have impairment on motoric functions, such as weakness of peripheral muscles and also respiratory muscles on paretic side of the body.[1,4] A decline in physical activities after stroke is associated with decreases in mobility, walking ability, cardiorespiratory fitness, and balance; and increased depression.[5] Subacute stroke phase, especially during the first 3 months is the fastest period of nerve tissue repair and functional recovery.[6] Exercises given in this phase will increase functional ability of the patients.

Weakness of respiratory muscles may result in impairment of breathing mechanics from asymmetry or inadequate movement of diaphragm and intercostal muscles on paretic side.[1,7] These might cause the decline of respiratory functions in stroke patients.[4,7,8]

The main inspiratory muscles, diaphragm and external intercostal, are skeletal muscles of which almost 80% are type I fibers and type IIA fibers. These fibers are oxidative and resistant to fatigue.[9,10] However, muscle fibers functions and structures are not always permanent and could be modified through the response of physiological and pathological condition.[10,11] In stroke patients, a change of muscle fiber type to IIX causes easily fatigue.[11] Like other locomotor/skeletal muscles, the inspiratory muscles need exercise and have the same exercise responses.[12] Inspiratory muscle training (IMT) could increase respiratory muscles strength, pulmonary functions, cardiorespiratory endurance, and affects peripheral muscle strength.[4,9,13] It was reported that exercise given to stroke patient could change the composition of muscle fibers, from previously dominated with type II fibers (glycolytic) to type I fibers (oxidative),[11] and the IMT was expected to have the same effect in subacute stroke patients. Many patients are discharged from hospital at this phase despite the fact that an intensive rehabilitation program is required to promote neurological recovery. Home based training is therefore a common alternative due to patients' psychosocial, economic and demografic issue. There was no previous study about a home based IMT which might affect peripheral muscles functions in

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subacute stroke patients. Therefore, our objective of this study is to determine the effects of home based IMT on the functions of respiratory and peripheral muscles in subacute stroke patients as during this period it could provide more comfort for the patients and optimize recovery.

Methods

Participants

Stroke patients admitted at Hasan Sadikin General Hospital, Bandung who gave informed consent to participate in this study.

Inclusion criteria:

- Aged 35 - ≤ 59 years old[14]
- Having the first stroke with the onset at least 2 weeks until 4 months prior to the study based on anamnesis and CT scan examination[2]
- Having hemiparesis after stroke determined by the presence of weakness on the limb with manual muscle testing (MMT)
- Being able to perform hand grip test and sit-to-stand test with or without assistive device.
- Having an ability to perform an exercise procedure in sitting position without leaning for 30 minutes
- Having a maximal inspiratory pressure (PI-max) lower than 70% of predictive value by age and gender[15]
- Having the Mini-Mental State Examination (MMSE) score of 22-30
- Being cooperative

Exclusion criteria:

- Hearing loss
- Having a history of pulmonary obstruction, chest or abdominal surgery, unstable/uncontrolled cardiovascular disease, and other contraindications for IMT[15]
- Having musculoskeletal disorders inhibiting exercise or outcome measurement procedure,
- Having done inspiratory and/or expiratory breathing exercises in the past 6 months

Materials

- A Micro-RPM (CareFusion™) for measuring inspiratory muscle strength
- Respironics® for threshold IMT device
- A hand grip dynamometer (Sammons Preston®) for measuring grip strength
- A finger pulse oximeter (Onemed) for measuring oxygen saturation and heart rate
- A timer stopwatch

Steps of intervention (Figure 1 Flow of the study)

1. At baseline, participants' PI-max, pulmonary functions, grip strength and sit-to-stand were assessed as follows:

a. A micro-RPM (Respiratory Pressure Meter) was used to assess patients' PI-max to determine inspiratory muscle strength. Its mouthpiece was positioned between the lips and the participants were asked to breathe 3 times so that the Researcher could determine the inspiratory muscle strength.

b. A hand grip dynamometer was used to assess grip strength on paretic side while sitting on a chair with an elbow in a 90° flexion position. They held the hand grip dynamometer, made a forceful grasp as hard as possible, repeated 3 times; and a mean value was calculated for statistical analysis.[13]

c. Mobility function measurement was assessed by using the sit-to-stand test when the participants sat on a chair without a handrail. They were asked to stand up from sitting position and sit down for 30 seconds. The score recorded from how many times they could do within 30 seconds.

2. The participants were selected consecutively into an intervention and a control group by a clinician. Researchers and participants did not know which group allocation for each participant.

3. The IMT protocol:

a. The researcher explained the participants about the threshold IMT device components used for inspiratory muscle exercise, then applied a nose clip to close the participants' nostril, told them to breathe via mouth and observed general circumstances; if there were no signs of hypoxia, they were asked to breathe in via a mouth piece of the IMT device until its valve was open and the air was inhaled. This breathing exercise consisted of 5 sets of 10-15 respiratory repetitions per minute in each set, with a one-minute break between each set. The total duration of each session was approximately 15 minutes. They were asked to perform the IMT at home for 2 consecutive days, resulting in 3 days of total familiarization day. During this period, a pulse oximeter was placed on the participants' finger for monitoring their oxygen saturation during the exercise.

b. A clinician set the exercise intensity: the intervention

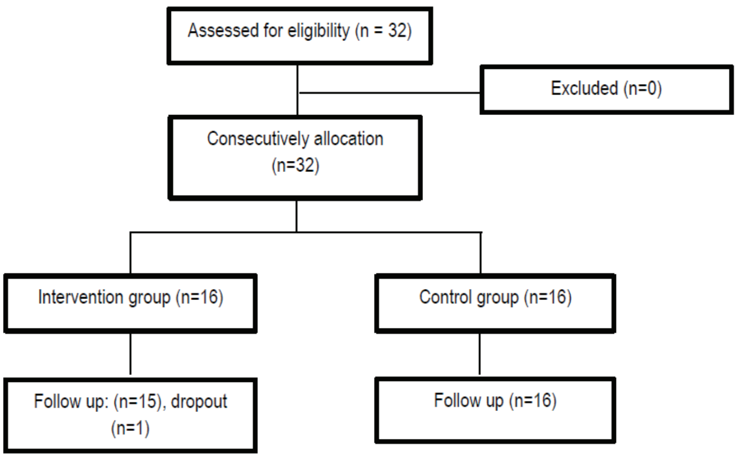

Figure 1. Flow of study

group did the inspiratory exercise with intensity of 40% of PI-max whereas the control group exercised with intensity of 10% of PI-max; and told them how to do a home-based IMT, performing 5 sets of 10-15 repetitions per session, 2 times a day, 5 days a week for a duration of 8 weeks; and then researcher explained them how to fill an exercise diary when they started the IMT program at home according to a determined intensity.

c. The clinician monitored them by telephone or communication media or messenger for training support every day, and evaluated the exercise technique and participants' adherence to IMT based on the exercise diary every week at the Physical Medicine and Rehabilitation (PMR) clinic. If they could not attend the clinic, the clinician made a home visit to conduct an evaluation. If the IMT was deviated, the researcher re-explained the exercise techniques and program.

d. During the intervention, a physiotherapist was provided a conventional rehabilitation program for ambulation training and flexibility exercise twice a week in PMR clinic to all participants.

4. Outcome measures were re-assessed after 8 weeks of intervention. The results of the measurements before and after exercise were compared and analyzed.

Statistical analysis

- Using the Sapiro-wilk test for numeric data, and Chi-square test for category data for analysis of data distribution.
- Using one sample t-test for comparison the characteristics between groups.
- Using paired t-test for numeric data and Mc-Nemar test for category data for comparison before and after study within a group.
- Using $p \leq 0.05$ as statistically significant.

Remark: The research ethics committee of the Hasan Sadikin General Hospital Bandung approved the study protocol (LB.04.01/A05/EC/218/VII/2017).

Results

Thirty-two participants (15 males and 17 females) aged between 35-59 years old with a mean age of 53.50 (SD 3.86) were recruited. However, 31 participants completed the study. During the intervention, one participant in the intervention group was dropout because of recurrent stroke, and others had no adverse event. Demographic data and characteristics of the study participants were similar between the two groups (Table 1).

From table 2, there is significant improvement on PI-max score after 8 weeks of study on intervention group (p= 0.000) but not in control group (p= 0.513). There is a significant difference in PI-max score between intervention and control group after study (p= 0.003). Hand grip strength measurement of paretic side shows significant differences within the intervention group (p=0.005) and in the control group (p=0.010) after study, but no significant difference when compared between groups after study (p=0.438).

After the intervention, mobility function assessed with sit-to-stand test also showed significant difference within group (the intervention, p= 0.001 and the control group, p=0.000). However, there was no significant difference of the sit-to-stand score between groups after study (p= 0.431) (Table 2).

Table 1. Baseline characteristics of participants in the intervention and the control groups

Variables	Groups		Total (n=31)	*p* value
	Intervention (n=15)	Control (n=16)		
Age (year)[1]	51.40 (7.98)	53.50 (3.86)	52.48 (6.19)	0.367
Sex[2]				0.200
Male	5 (33.30)	9 (56.30)	14 (45.20)	
Female	10 (66.70)	7 (43.80)	17 (54.80)	
Body weight (kg)[1]	61.32 (10.23)	54.43 (11.40)	57.77 (11.23)	0.088
Body height (cm)[1]	1.55 (0.10)	1.54 (0.08)	1.54 (0.09)	0.859
Stroke onset (month)[1]	2.60 (1.24)	3.37 (0.72)	3.00 (1.06)	0.101
MMSE score[1]	29.00 (1.07)	28.81 (1.68)	28.90 (1.40)	0.654
Infarct/hemorrhage[2]				0.685
Infarct	11 (73.30)	13 (81.30)	24 (77.40)	
Hemorrhage	4 (26.70)	3 (18.80)	7 (22.60)	
Paretic side				0.611
Right	9 (60.00)	11 (68.80)	20 (64.50)	
Left	6 (40.00)	5 (31.30)	11 (35.50)	

[1]Mean (SD), [2]number (%); * p <0.05, statistically significant different

Table 2. Comparison of outcome measures between the intervention and the control groups

Variables	Intervention group		*p* value	Control group		*p* value	*p* value between groups
	Pre	Post		Pre	Post		
Grip strength (kg)	11.00 (6.27)	13.19 (6.12)	0.005*	11.00 (5.32)	11.59 (5.20)	0.010*	0.438
Sit-to-stand (x/30 second)	7.66 (3.37)	9.60 (3.40)	0.001*	7.75 (2.86)	8.75 (2.49)	0.000*	0.431
PI max (cmH20)	47.46 (19.40)	72.08 (23.48)	0.000*	49.12 (11.68)	49.57 (10.62)	0.513	0.003*

PI max, maximum inspiratory pressure

Mean (SD); *p<0.05: statistically significant

Discussion

The results of this 8-week home-based IMT study showed that there were no differences in peripheral muscles functions (grip strength of the paretic hand and ability of sit-to-stand) between the intervention group doing a breathing exercise with an intensity of 40% of PI-max and the control group doing a breathing exercise with an intensity of 10% of PI-max. However, the inspiratory muscle strength assessing with PI-max significantly improved in the intervention group but not in the control group.

The increase in the inspiratory muscle strength found in our study supported the result from a 3-week IMT with 30% of PI-max in subacute stroke patients reported by Messaggi-Sartor et al. (2015)[13] and in chronic stroke patients by Britto et al. (2011).[1] However in our study, the intensity of 40% of PI-max was chosen for the intervention group based on a meta-analysis study done by Gomes-Neto (2016) stating that IMT with 30-60% of PI-max had significant effects in stroke patients but training at PI-max below 30% was not effective to achieve the respiratory muscle strength.[8] According to previous studies, respiratory muscle weakness can lead to respiratory muscle fatique caused by accumulation of metabolic product in diaphragm muscle. The IMT induced inspiratory muscle conditioning, might decrease inspiratory muscle metaboreflex activity by decreasing metabolic product (lactate) and might further increase peripheral muscle blood flow.[16,17] Theoretically, applying loads to respiratory muscles with the same principles as skeletal muscle exercise (overload, specificity and reversibility) should improve respiratory muscle strength.[18] According to the study done in COPD patients by Ramirez-sarmiento et al. (2002), an IMT with 40-50% of PI-max significantly increased a proportion of type I fibers and size of type II fibers of inspiratory muscle, and these changes were associated with increasing of respiratory muscle strength and endurance.[19] However, it was our objective to prove whether the IMT had also generalized effect on peripheral muscle.

In post stroke patients, there are skeletal muscle structure changes such as atrophy of myosin heavy chain (MHC)-fast twitch fibers and loss of MHC slow-twitch fibers in the hemiparetic limbs. These changes lead to easily fatique of skeletal muscles in hemiparetic limbs.[11] Chiappa et al. (2008) reported that a 4-week IMT with intensity of 60% of PI-max increased resting calf blood flow and exercised forearm blood flow in patients with chronic heart failure[20] whereas Messaggi-Sartor et al. (2015) reported that a 3-week IMT with 30% of PI-max did not increase grip strength in patients with subacute stroke.[13] In our study, we designed an 8-week IMT with intensity of 40% of PI-max with a longer duration and at a higher intensity, therefore, we expect the same result as study from Chiappa et al. However, our study did not support a positive effect on peripheral muscle functions as the grip strength score did not increase significantly when compared between the two groups. We chose hand grip strength to represent peripheral muscle function as it declined after stroke and reflected the global upper extremity strength.[21] It also predicted motoric performance and functional independency in stroke patients.[22] Our study did not show significant increase of hand grip strength in subacute stroke patients. This might be caused by other factors besides muscle strength itself such as impaired somatosensory function, spasticity and dyssynergic movements affecting the motoric control.[23]

Regarding the lower extremity function, there was no previous study measuring effects of IMT on sit-to-stand in subacute stroke patients. Messaggi-Sartor et al. (2015) measured quadriceps strength and there was no significantly difference in quadriceps strength between intervention and control groups after a 3-week of IMT with 30% of PI-max.[13] However, Bosnak-Guclu et al. (2011) reported that a 6-week IMT with 40% of PI-max increased inspiratory and expiratory muscles strength and also quadriceps strength in heart failure patients. Quadriceps femoris muscle strength improvement might be due to increased blood flow after IMT.[24]

In our study, instead of measuring quadriceps strength we chose the sit-to-stand test to reflect lower extremity function. Movements during sit-to-stand need strength of the lower extremity muscles to change the center of body mass to rise a body from sitting to standing position, coordination of the body and lower extremity movement and control of balance[25] and this activity is usually used to assess physical function.[26] It is associated with walking speed, independence in ambulation and the ability to climb stairs. Difficulty in standing up from sitting position is a predictor of disability, risk of fall and mortality in the future.[26] Moreover, lack of placing a load on the paretic limb during sit-to-stand is seen in patients with hemiparesis.[25]

The results from our study showed that the sit-to-stand scores increased significantly in both groups but were not significant difference between groups. The reason of no peripheral muscle effect is the sit-to-stand activity does not only require quadricep strength but also other lower extremity muscles and trunk strength, a lack of coordination between hip and knee while standing up, postural control alteration and asymmetrical weight bearing seen in post stroke patients.[25] In addition, other impairments might influence the sit-to-stand activity. Our study had limitations, other impairments, such as somatosensory deficit, spasticity; and physical activity limitation of the participants were not assessed. Although the participants in our study were closely monitored, the conventional stroke rehabilitation program was provided by different therapists, and this might be counted as a design bias. Further investigation with a higher intensity and a longer period and using more specific functional tasks might be needed to observe the peripheral muscle function after IMT in subacute stroke patients.

In conclusion, a home-based inspiratory muscle training with an intensity of 40% of PI-max for 8 weeks in subacute stroke patients did not increase peripheral muscle functions, assessed with grip strength of a paretic hand and a sit-to-stand test, however, it only improved inspiratory muscle strength.

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Disclosure

The authors have no conflict of interest to declare.

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