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Recovery process of respiratory muscle strength in patients following stroke: A Pilot Study

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ABSTRACT. Objective: To determine the recovery process of respiratory muscle strength during 3 months following stroke, and to investigate the association of change in respiratory muscle strength and physical functions. Additionally, we compared respiratory muscle strength with those of healthy subjects. Method: In this prospective, observational study, 19 stroke patients and 19 healthy subjects were enrolled. Maximal inspiratory pressure (MIP), maximal expiratory pressure (MEP), motricity index, trunk control test, 6-minute walk test (6MWT) and functional independence measure were assessed at 1, 2, and 3 months from stroke onset in stroke patients. MIP and MEP were assessed at arbitrary times in healthy subjects. Repeated one-way analysis of variance with Bonferroni post-hoc test was used to compare the change in respiratory muscle strength in each period in stroke patients. Pearson's correlation coefficient was computed for changes in respiratory muscle strength and physical functions. Student's t-test was used to compare respiratory muscle strength between stroke patients at 3 months from onset and healthy subjects. Results: MIP was significantly increased at 3 months compared to 1 month. MEP was significantly increased in 2 months and 3 months, compared to 1 month. MIP changes associated with 6MWT changes. Compared to healthy subjects, MIP and MEP at 3 months were significantly lower in stroke patients. Conclusion: Respiratory muscle strength significantly increased during 3 months following stroke. However, the trend of recovery may be different. MIP changes may associated with walking endurance changes. During 3 months following stroke, respiratory muscle strength did not recover to healthy subjects.

Key words: respiratory muscle strength, recovery process, stroke, Rehabilitation, 6-minute walk test

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Stroke results in variable disabilities such as limb weakness, spasticity, pain, psychosocial issues (including depression, cognitive decline, and social isolation), language impairments, and functional limitations, including problems with walking, standing, and inability to perform several activities of daily living (ADLs)[1)]. Respiratory dysfunction is also one of the impairments seen in stroke patients. The respiratory muscle functions of the diaphragm and intercostal muscles more decreased in the paretic side compared to the healthy side in stroke patients[2,3)]; chest wall kinematics were also decreased in the paretic side[4)]. Additionally, forced vital capacity (FVC) and forced expiratory volume in 1 sec ($FEV_{1.0}$) were reduced by at least 10% and 15%, respectively, in stroke patients compared with healthy subjects[5)]. Thus, respiratory dysfunction for stroke patients may be largely due to respiratory muscle impairments.

In patients with chronic stroke, inspiratory and expiratory muscle strength can be markedly decreased. Teixeira-Salmela et al. reported a maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) of 74.2% and 66.7%[6)], respectively, in stroke patients compared with controls. Whereas, Lista et al. reported these values as

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55.5% and 60.6%[7], respectively. Respiratory muscle strength is also related with cough capacity, which is linked with aspiration pneumonia, walking speed, walking tolerance, and physical activity[7-12]. Additionally, respiratory muscle strength has been associated with sarcopenia in older adults[13]; hence, it may also be associated with stroke. Since reduction in respiratory muscle strength may cause limitations the daily lifestyle of stroke patients, respiratory muscle strength should be monitored during stroke rehabilitation.

Respiratory muscle strength is significantly increased from the onset of stroke in sub-acute stroke patients[14]. However, the inspiratory and expiratory muscle strength recovery process is poorly understood. Expiratory muscle strength is associated with trunk control and cough, while inspiratory muscle strength is associated with walking endurance[7,15,16]; hence, there may be different associations with physical functions between the expiratory and inspiratory muscle strength, in patients with stroke. Thus, a knowledge of the difference between inspiratory and expiratory muscle strength may be helpful in stroke rehabilitation. The effort for breathing is lower during expiration than during inspiration[17], and the expiratory muscle strength is higher than the inspiratory muscle strength. Therefore, our hypothesis is that the expiratory muscle strength may be easier to recover than the inspiratory muscle strength. Respiratory muscle strength may also be more decreased in severe stroke patients; hence, this knowledge may be important for patients requiring long-term hospitalization.

Moreover, respiratory muscle strength was related to cough function[8] which could lead to respiratory complications[9]. Thus, by investigating the amount of muscle strength recovery and comparing with healthy subjects, valuable insights may be provided on the effects of respiratory dysfunction.

The present study aimed to determine the recovery process of respiratory muscle strength during the 3 months after stroke onset in recovery stage stroke patients; we also investigated the association between changes in respiratory muscle strength and physical functions. Additionally, we compared the respiratory muscle strength of these patients with healthy subjects of the same age.

Method

Study design and subjects

The present study had a prospective observational design with an initial and two follow-up assessments (within 3 months). Although neurological recovery was gradual, with 95 % of stroke patients gaining complete functional recovery within 12.5 weeks from onset, the pattern of recovery depends on the time from stroke onset and the stroke severity[18]. Therefore, 3 months from stroke onset were divided into three measurement periods; 1 month (30 days), 2 months (60 days), and 3 months (90 days) after stroke onset. The study involved consecutive patients with stroke who were admitted to the rehabilitation unit at Itami Kousei Neurosurgical Hospital between October 2016 and August 2017. A total of 119 patients were initially enrolled. The inclusion criterion was patients who were admitted to the rehabilitation unit within 30 days from stroke onset. The exclusion criteria were as follows: 1) a history of severe musculoskeletal disease; 2) severe cardiopulmonary disease; 3) psychiatric diseases; 4) a premorbid modified Rankin Scale (mRS) score of >2 implying moderate to severe disability[19]; 5) patients who could not understand the measurement because of aphasia, which was assessed by their medical records, and those who could not give informed consent due to loss of consciousness, dementia, or non-cooperation; and 6) those who were discharged in less than 90 days from stroke onset due to the absence of severe disability requiring long-term hospitalization (Fig. 1). Healthy subjects were also recruited via hospital-based advertisements; 24 subjects were initially enrolled, and the inclusion criterion was >40 years of age. Additionally, healthy subjects who had cardiopulmonary disease were excluded, because the condition could affect the measurement of respiratory function; the subjects with lower respiratory functions (predicted FVC < 80% and $FEV_{1.0}$/FVC < 70 %) were also excluded. Finally, 19 healthy subjects were included. This study was approved by the Konan Women's University Research Committee (acknowledgment number: 2015020), and all participants provided informed consent according to the ethical standards set forth in the Declaration of Helsinki.

Patient demographics and clinical characteristics

Patient characteristics were recorded as follows; age, sex, height, weight, stroke type (cerebral infarction and intracerebral hemorrhage), affected side, and National Institutes of Health Stroke Scale (NIHSS) at stroke onset. The body mass index (BMI) was calculated by dividing the body weight by the square of the height (kg/m^2). FVC and $FEV_{1.0\%}$ were assessed in the upright position using a spirometer (Autospiro AS-507, MINATO Medical Science Corporation, Osaka, Japan) at 30 days (1 month) from stroke onset. For healthy subjects, age, sex, height, weight, BMI, and respiratory function (FVC and FEV 1.0) were assessed in arbitrary timing.

Outcome measurements

Respiratory muscle strength

Respiratory muscle strength was assessed with the patient in an upright position using a respiratory muscle measurement unit of a spirometer (Autospiro AS-507, MINATO Medical Science Corporation), which measures the MEP and MIP in cm H_2O units. These methods were in accor-

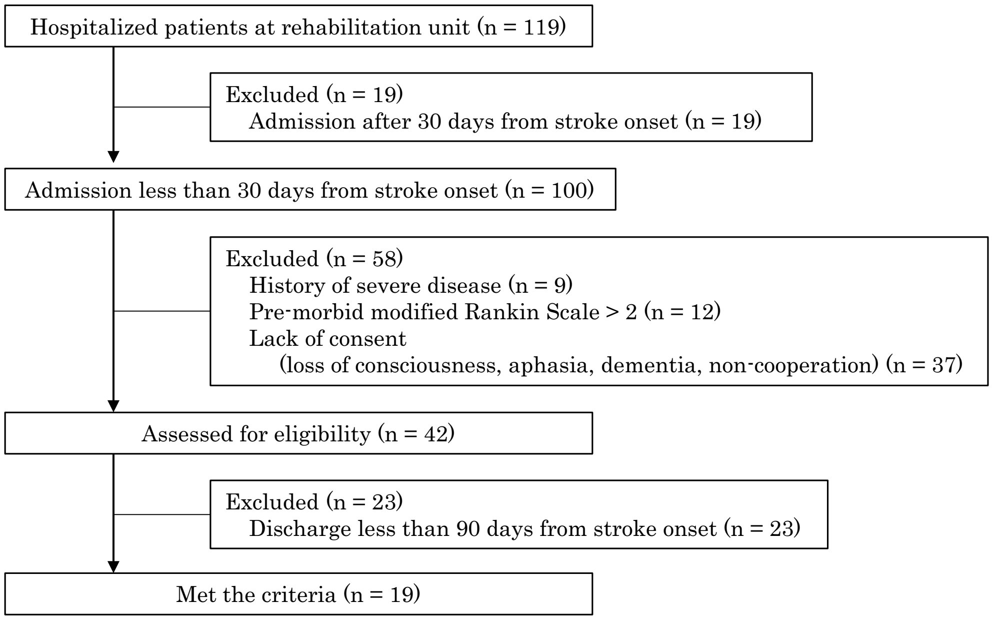

Figure 1. Patient's flowchart.

dance with the suggestions of the American Thoracic Society/European Respiratory Society[20]. A nose clip was attached to the patients' noses, while the mouthpiece was supported by their non-paretic upper limb. Assistance was rendered by the evaluator when required. For the measurement of MIP, subjects performed maximal expiratory breathing until the residual volume (RV) was reached; thereafter, maximal inspiratory effort was performed for at least three seconds from the RV. Subsequently, for the measurement of MEP, subjects performed maximal inspiratory breathing until the total lung capacity (TLC) was reached; maximal expiratory effort was then performed for at least 3 seconds from the TLC. At least two practice measurements were conducted before the actual measurement. Measurements were performed twice, with a 30-s rest period in between. The higher value of MIP and MEP were used for statistical analyses. MIP and MEP measurements were assessed at 1 month (30 days), 2 months (60 days), and 3 months (90 days) from stroke onset. However, for healthy subjects, respiratory muscle strength (MIP and MEP) were assessed at arbitrary times, and the predictive value of MIP and MEP were calculated by the following formula[21] to confirm normality.

Men: MIP = 131 – 0.79 * age.

MEP = 149 – 0.59 * age.

Women: MIP = 102 – 0.69 * age.

MEP = 93 – 0.33 * age.

Physical Functions

The motricity index (MI) on arm and leg[22] were assessed as weakness on the hemiplegic side at 1 month (30 days), 2 months (60 days), and 3 months (90 days) from stroke onset. Each section was scored from 0 to 100, where 0 designates complete motor function loss. The arm (pinch grip, elbow flexion, and shoulder abduction) and leg (ankle dorsiflexion, knee extension, hip flection) were used for the assessment in this study. There were six levels on the scale for each joint: 1) no movement (scores 0); 2) palpable contraction but no movement (scores 9); 3) movement seen but not full range (scores 14); 4) movement against gravity but not resistance (scores 19); 5) movement against gravity and resistance but weaker than on the other side (scores 25), and 6) normal power (scores 33)[23,24]. The addition of the scores for all the joints for one limb plus 1 point yields an "arm score" or "leg score".

The trunk control test (TCT)[25] was assessed as trunk movement at 1 month (30 days), 2 months (60 days), and 3 months (90 days) from stroke onset. The patient lies supine on the bed, and is asked to perform the following movements: 1) roll to the hemiplegic side, 2) roll to the non-hemiplegic side, 3) sit up from lying down, and 4) sit in a balanced position on the edge of the bed with the feet off the ground for a minimum of 30 seconds. There are three levels on the scale for each movement: 1) unable to perform movement without assistance (scores 0); 2) able to perform movement, but in an abnormal style (scores 12); and 3) able to complete movement normally (scores 25).

The 6-minute walk test (6MWT) distance was assessed as ambulatory function at 1 month (30 days), 2 months (60 days), and 3 months (90 days) from stroke onset. A 30-m indoor walkway was used during the test, which was introduced to patients according to the American Thoracic Society guidelines[26]. Patients were instructed to walk from the start line to the end of the walkway as far as possible for 6 minutes; no verbal encouragement or feedback was given. The distance covered within the 6 minutes was subsequently recorded.

The functional independence measure (FIM)[27] was assessed as the ADL score at 1 month (30 days), 2 months (60 days), and 3 months (90 days) from stroke onset. The score measures 18 items, with each item ranging in value from 1 to 7, where 1 indicates complete dependence and 7 for complete independence in that item. The scale was designed so that the ratings on 18 to 126. The FIM was rated by clinical observation in the rehabilitation unit.

Statistical analyses

Descriptive statistics were represented as number (percentages) and means (standard deviations (SD)). Student's *t*-test and chi-squared test were used to compare the characteristics between stroke patients and healthy subjects. Repeated one-way analysis of variance (ANOVA) was used to compare the change in respiratory muscle strength during each period in stroke patients. When a statistically significant effect was found, the difference were determined with Bonferroni *post-hoc test*. The change of respiratory muscle strength and physical functions were calculated by subtracting the value at 1 month from the value at 3 months (ΔMEP, ΔMIP, ΔMI on arm score, ΔMI on leg score, ΔTCT, Δ6MWT, ΔFIM). Pearson's correlation coefficient was computed for changes in respiratory muscle strength and physical functions. Student's *t*-test was also used to compare respiratory muscle strength between stroke patients at 3 months from onset and healthy subjects. Statistical significance was set at $p < 0.05$; all analyses were performed using JMP version 10.0 software (SAS Institute Japan, Tokyo, Japan).

Results

Patient demographics and clinical characteristics

During the study period, 119 patients were admitted to the rehabilitation unit at Itami Kousei Neurosurgical Hospital. Among these, 100 patients were excluded from this study, while 19 met the inclusion criteria (Figure 1). Demographics in stroke patients and healthy subjects are presented in Table 1.

Recovery process of respiratory muscle strength after stroke

Changes in respiratory muscle strength in each period are presented in Figure 2. Mean values (SD) of MIP data were 37.6 (19.6) cmH_2O, 44.3 (24.8) cmH_2O, and 48.1 (25.1) cmH_2O at 1 month, 2 months, and 3 months, respectively. Mean values of MEP data were 46.1 (19.8) cmH_2O, 55.8 (26.5) cmH_2O, and 63.1 (30.1) cmH_2O in 1 month, 2 months, and 3 months, respectively. Repeated one-way ANOVA showed significant differences among each period in inspiratory ($p = 0.006$) and expiratory muscle strength ($p = 0.001$). Paired *t*-test with Bonferroni's method showed that inspiratory muscle strength significantly increased at 3 months compared to 1 month ($p = 0.004$). However, there were no significant changes between 1 and 2 months, and between 2 and 3 months. Additionally, expiratory muscle strength significantly increased at 2 ($p = 0.015$) and 3 months ($p = 0.004$), compared to that at 1 month. Although there were no significant changes between 2 and 3 months ($p = 0.058$).

Association of respiratory muscle strength changes with physical functions changes

Table 2. shows the changes in respiratory muscle strength and physical functions during 3 months from stroke onset. Table 3. shows the association of the changes between respiratory muscle strength with physical functions. ΔMIP was significantly associated with Δ6MWT (r = 0.597, $p = 0.007$), whereas ΔMEP was not significantly associated with any physical functions changes.

Comparison of respiratory muscle strength to healthy subjects

Table 4. presents the comparison of respiratory muscle strength between stroke patients at 3 months from stroke onset and healthy subjects. The mean (SD) predictive values of MIP and MEP in healthy subjects were 91.9% and 94.3%, respectively. Mean (SD) values of MIP and MEP at 3 months from stroke onset were 48.1 (25.1) cmH_2O and 63.1 (22.3) cmH_2O, respectively; these were respectively 75.3% and 73.7% of measurements of healthy subjects. Additionally, inspiratory ($p = 0.048$) and expiratory ($p = 0.016$) muscle strength were significantly lower at 3 months in stroke patients than in healthy subjects.

Discussion

This study determined the recovery process of respiratory muscle strength during the 3 months after stroke onset in recovery-stage stroke patients. We also investigated the association between changes in respiratory muscle strength and physical functions. Additionally, we compared the respiratory muscle strength of these patients to that of healthy subjects. Consequently, inspiratory muscle strength was significantly increased at 3 months compared with 1 month from onset, and expiratory muscle strength was significantly increased at 2 and 3 months compared with 1 month from onset. This study indicated that respiratory muscle strength is recovered during the first 3 months after stroke onset. However, the recovery trends may vary and the expiratory muscle strength may be recovered faster than inspiratory muscle strength. ΔMIP was positively correlated to Δ6MWT, which implies that the recovery of inspiratory muscle strength may be related to walking ability. Compared with healthy subjects, inspiratory and expiratory muscle strength of stroke patients at 3 months after stroke were lower. Hence, the present study indicates that respiratory

Table 1. Clinical characteristics

	Stroke Patients (mean (SD))	Healthy Subjects (mean (SD))	p value
Age (year)	66.6 (11.6)	66.8 (9.0)	0.951
Sex (female), n(%)	8 (42.1)	8 (42.1)	1.000
Height (cm)	161.8 (7.0)	160.4 (7.4)	0.544
Weight (kg)	63.8 (11.8)	59.6 (7.4)	0.203
Body mass index (kg/m^2)	24.2 (3)	23.1 (1.8)	0.186
Type of stroke, n (%)			
Cerebral infaction	10 (53)		
Intracerebral hemorrhage	9 (47)		
Affected side, n (%)			
Right	5 (26)		
Left	14 (74)		
NIHSS at stroke onset (score)	10.1 (3.8)		
NIHSS at admitted to recovery unit (score)	6.4 (3.7)		
Respiratory function at 1 month from stroke onset			
FVC (L)	2.55 (0.67)	3.05 (0.61)	0.022
Predicted FVC (%)	82.6 (16.6)	100.7 (11.7)	<0.001
$FEV_{1.0}$ (L)	2.07 (0.68)	2.60 (0.50)	0.013
$FEV_{1.0}$/FVC (%)	80.9 (12.6)	84.9 (7.0)	0.229
Physical function at 1 month from stroke onset			
MI on arm (score)	48.2 (34.5)		
MI on leg (score)	59.3 (27.7)		
TCT (score)	81.8 (27.8)		
6MWT (m)	153.3 (173.3)		
Walking independence, n (%)	3 (15.8)		
FIM (score)	76.1 (21.8)		

Student's t-test and chi-squared test were used to compare the characteristics between stroke patients and healthy subjects. Statistical significance level was set at <0.05.
NIHSS; National Institutes of Health Stroke Scale, FVC; Forced vital capacity, FEV; Forced expiratory volume, MI; Motricity index, TCT; trunk control test, 6MWT; 6-minute walk test, FIM; functional independence measure

muscle strength may recover to approximately 80% of that of healthy subjects during the 3 months after stroke onset; however, it did not recover to the full level of healthy subjects.

Respiratory muscle strength was significantly increased during the 3 months after stroke onset. However, the trends of recovery are different, and expiratory muscle strength may recover faster than inspiratory muscle strength. Similar results were reported only in one study, in which respiratory muscle (inspiratory and expiratory muscle) strength was significantly increased from onset in subacute stroke patients[14]. These data may partially support our study. Electromyograms of the intercostal muscles and of the diaphragm and diaphragmatic movement measured by ultrasound were decreased in the paretic side compared with the healthy side in stroke patients[2,3]. Additionally, the activation of abdominal muscles on the affected side was reduced and delayed relative to the unaffected side in stroke patients[28]. These muscle impairments may be the major cause of decreased respiratory muscle strength after stroke. Although one study reported that there were changes in the thickness of the abdominal wall muscle in stroke patients[29], there are no studies on diaphragmatic activation or thickness changes. Therefore, the recovery processes of respiratory muscles are poorly understood. The present study may thus provide a hint about the recovery process of respiratory muscle strength after stroke. We were unable to confirm these mechanisms in our study. However, since the work of breathing was lower during expiration than during inspiration[17], expiratory muscle strength may be easier to recover in stroke patients. Additionally, the trunk control was associated with MEP not MIP[15]. However, this correlation of MEP with TCT was not correlated in our study, possibly due to the small sample size. Thus, further studies are needed to investigate the changes in the movements, thickness, and electromyograms of respiratory muscles including the diaphragm, intercostal, and abdominal muscles in patients after stroke.

We found a positive correlation between ΔMIP and Δ6MWT, which implies that the recovery of inspiratory muscle strength may be related to walking ability. For chronic patients with stroke, 6MWT was positively correlated to MIP[7], and non-community ambulators (walking speed < 0.8 m/s) had lower predicted MIP values than community ambulators (≥0.8 m/s)[11]. Moreover, inspiratory training can improve cardiopulmonary functions, such as FVC, $FEV_{1.0}$, vital capacity, forced expiratory flow rate 25-75%, and maximum voluntary ventilation; it could also lead to higher peak oxygen consumption ($\dot{V}O_2$ peak) in patients with stroke (time since stroke: 5 month)[30]. For patients with post-myocardial infarction, MIP showed a positive correlation with $\dot{V}O_2$ peak[31]. Thus, inspiratory muscle strength seems to contribute to walking ability or exercise tolerance in chronic patients with stroke; these studies support our current results. Our study also indicates that changes in inspiratory muscle strength and walking ability are significantly related in patients with stroke in the sub-acute phase; therefore, it should be considered that inspiratory muscle strength recovery may be associated with walking ability recovery.

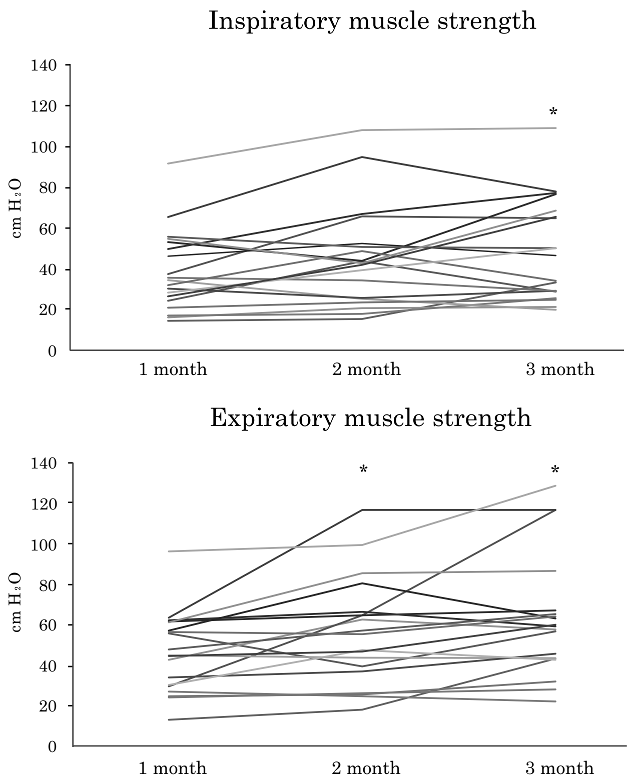

Figure 2. Recovery process of respiratory muscle strength. Recovery process of respiratory muscle strength in each of the 19 stroke patients are presented. Repeated one-way analysis of variance was used to compare the change in respiratory muscle strength during each period in stroke patients. Paired t-test with Bonferroni post hoc test was also used.
*: $p < 0.05$ vs 1 month

In comparison with healthy subjects, inspiratory and expiratory muscle strength in stroke patients were significantly decreased at 75.3% and 73.7%, respectively, at 3 months after stroke onset. Additionally, for chronic stroke patients, inspiratory and expiratory muscle strength were respectively decreased to 74.2% and 66.7%, respectively, of the levels of healthy patients in one study[6], and to 55.5% and 60.6%, respectively, in another study[7]. The predicted value of MIP and MEP were 69.8% and 71.6%, respectively, in acute mild stroke patients[32] and 42.0% and 41.2%, respectively, in subacute stoke patients[33]. These differences may be due to age, stroke severity, and time from stroke onset. The present study included patients with an average age of 66.6 years at the onset of stroke with moderate severity, and the average NIHSS score was 6.4 at admission to the recovery unit. Our study suggested that moderate stroke patients recover approximately 70% of the respiratory muscle strength of healthy subjects during the 3 months after stroke onset. Respiratory muscle strength has also been shown to be related to walking speed, walking tolerance, and physical activity[7,11,12]. Although it is highly possible that the reduction in respiratory muscle may cause limitations in daily living of stroke patients, the influence on daily living may be alleviated due to the recovery of respiratory muscle strength at 3 months from stroke onset.

Table 2. Change of respiratory muscle strength and physical functions during 3 month from stroke onset

	1 month	2 month	3 month	Changes value from 1 month to 3 month
MIP (cm H_2O), (SD)	37.6 (19.6)	44.3 (24.8)	48.1 (25.1)	10.4 (13.8)
MEP (cm H_2O), (SD)	46.1 (19.8)	55.8 (26.5)	63.1 (30.1)	17.1 (22.3)
MI on arm (score), (SD)	48.2 (34.5)	54.3 (32.4)	58.7 (30.3)	10.5 (8.2)
MI on leg (score) , (SD)	59.3 (27.7)	67.2 (24.1)	71.3 (22.2)	12.1 (10.1)
TCT (score), (SD)	81.8 (27.8)	94.6 (14.4)	97.5 (4.9)	16.1 (24.9)
6MWT distance (m) , (SD)	153.3 (173.3)	280.3 (153.8)*	314.9 (158.9)	161.6 (160.6)
FIM (score), (SD)	76.1 (21.8)	92.6 (19.0)	99.1 (16.9)	23.1 (13.1)

MIP; Maximal inspiratory pressure, MEP; Maximal expiratory pressure, MI; Motricity index, TCT; Trunk control test, 6MWT; 6-minute walk test, FIM; Functional independence measure
*; two patients could not be measured 6MWT (n=17)

The study has several limitations. First, this study had a small sample size. Patients who could not be followed up during the study period were excluded, as were those from whom consent could not be obtained. Thus, the present findings are not applicable to all stroke patients. Second, the factors related to an increase in respiratory muscle strength were not examined. Thus, a well-designed, large, cohort or interventional study is required to investigate the related factors. Third, follow-up in the present study ended at 3 months; thus, it is not clear if the process of recovery of respiratory muscle strength continues after 3 months or how long recovery lasts. Finally, other respiratory measurements such as chest wall kinematics, diaphragm, and intercostal muscles activation were not measured. Hence, additional studies are required to investigate the detailed long-term recovery of respiratory function after stroke.

Table 3. Association of respiratory muscle strength change with physical functions change

	ΔMIP		ΔMEP	
	r value	p value	r value	p value
ΔMI on arm	0.361	0.129	0.059	0.810
ΔMI on leg	0.343	0.151	-0.175	0.474
ΔTCT	0.191	0.433	-0.295	0.220
Δ6MWT	0.597	0.007	0.099	0.686
ΔFIM	0.372	0.117	-0.064	0.795

Pearson's correlation coefficients were computed between respiratory muscle strength changes and respiratory, physical functions changes. Statistical significance level was set at <0.05.

MIP; Maximal inspiratory pressure, MEP; Maximal expiratory pressure, MI; Motricity index, TCT; trunk control test, 6MWT; 6-minute walk test, FIM; functional independence measure

Conclusion

This study investigated the process of respiratory muscle strength recovery and association between changes in respiratory muscle strength and physical functions in recovery-stage stroke patients. It also compared the respiratory muscle strength in these patients to that of healthy subjects. Consequently, respiratory muscle strength was increased at 3 months after stroke onset. However, the recovery trend was different as MEP recovered faster than MIP. Changes in inspiratory muscle strength and walking ability are significantly related in patients with stroke in the sub-

Table 4. Comparison of respiratory muscle strength between stroke patients at 3 month from stroke onset and healthy subjects

stroke patients						healthy subjects					
Subjects No.	Age	Sex	BMI	MIP	MEP	Subjects No.	Age	Sex	BMI	MIP	MEP
1	63	F	24.7	27.8	56.7	1	61	M	24.2	95.7	85.8
2	49	F	24.3	32.3	43.2	2	74	M	26.5	44.6	93.2
3	68	M	24.4	20.3	57.6	3	68	M	24.9	49.2	69.4
4	51	M	29.4	63.8	117	4	68	M	21.6	51.9	55.9
5	73	M	25.6	24.6	21.9	5	66	M	22.2	108	133
6	81	M	25.3	18.9	43.4	6	83	M	25.9	38.7	83
7	70	F	25.7	75.6	67.1	7	52	F	24.3	61.6	69.1
8	66	F	19.8	76.2	59.2	8	54	F	21.2	50.2	53.5
9	80	F	24.1	28.2	45.6	9	48	F	23.8	55.6	59.8
10	87	M	21.7	45.5	63.1	10	80	F	21.4	47.5	59.7
11	71	M	23.2	76.9	117	11	68	M	22.2	71.0	101
12	79	F	22.2	49.1	65.3	12	69	M	22.0	52.8	99.1
13	53	F	21.5	23.8	31.8	13	63	F	23.4	76.4	78.7
14	67	M	20.4	28.1	27.9	14	72	F	24.6	40.2	65.3
15	54	M	31.0	108	129	15	66	M	23.7	109.6	105.6
16	68	F	20.9	33.1	64.1	16	63	M	21.6	65.9	95.6
17	75	M	25.8	67.5	86.7	17	66	F	18.8	37.6	76.7
18	64	M	27.7	49.1	42.6	18	78	M	22.9	79.5	99.8
19	47	M	22.2	64.5	60	19	71	F	23.8	77.3	143
Mean (SD)	66.6 (11.6)		24.2 (3.0)	48.1 (25.1)	63.1 (22.3)		66.8 (9.0)		23.1 (1.8)	63.9 (30.1)*	85.6 (24.8)*

*: p<0.05 v.s. stroke patients at 3 monts from stroke onset

BMI; Body mass index, MIP; maximal inspiratroy pressure, MEP; maximal expiratory pressure

acute phase. Therefore, it should be considered that inspiratory muscle strength recovery may be associated with walking ability recovery. Additionally, during the 3 months from stroke onset, respiratory muscle strength after stroke did not recover to the levels seen in healthy subjects. Therefore, in the rehabilitation during the 3 months after stroke onset, the influence of respiratory muscle strength should be considered.

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Conflict of Interest: None.

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