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Version: Accepted version

Please cite the original version:

Lista-Paz, A., Kuisma, R., Canosa, J., García, RS., Doniz, LG. (2022). Pulmonary function in patients with chronic stroke compared with a control group of healthy people matched by age and sex. Physiotherapy Theory Practice. Published online: 29 Jan 2022.
https://doi.org/10.1080/09593985.2022.2031363

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Käytä viittauksessa alkuperäistä lähdettä:

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https://doi.org/10.1080/09593985.2022.2031363

TITLE

Pulmonary function in patients with chronic stroke compared with a control group of healthy people matched by age and sex

RUNNING HEAD (short title)

Pulmonary function in patients with chronic stroke

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ABSTRACT

Background. Effects of chronic stroke on pulmonary function are largely unknown.

Aim. To compare lung volumes in people with chronic stroke with a control group of healthy people matched by age and sex, as well as to investigate the relationship between the lung volumes and functional capacity.

Methods. A cross-sectional study involving people with chronic stroke. Cases were matched to a control group of healthy people. Lung function and the distance walked during the Six-Minute Walk Test (6MWD) were the main outcomes. Independent t-tests were used to compare pulmonary function between groups and the Pearson correlation coefficient was used to assess any relationship between lung volumes and the 6MWD in the stroke group.

Results. Sixty-six participants (24 males in each group; 56.5±15.5 years) were included. People with stroke presented significantly lower lung volumes when compared to the control group. The median of forced vital capacity (FVC) was 79% and peak expiratory flow was 64% of the reference value. The 6MWD was found to be weakly correlated with inspiratory reserve volume ($r=0.39$, $p=0.03$) and peak inspiratory flow ($r=0.35$, $p=0.05$).

Conclusions. People with chronic stroke show decreased lung volumes when compared with healthy people and this likely impacts on their functional capacity.

Keywords: Stroke; Respiratory Function Tests; Lung Volume Measurements; Physical Therapy Modalities; Spirometry.

INTRODUCTION

Stroke is a major worldwide cause of disability in adults and the second most common cause of death (Mozaffarian et al., 2015). Consequences after a stroke can be highly diverse, including motor impairments, sensory and perceptual problems, emotional, affective and cognitive changes;, speech, language and swallowing difficulties (Chung et al., 2013; Morone, Paolucci, & Iosa, 2015); most of which are managed with rehabilitation (Veerbeek et al., 2014). Furthermore, pulmonary alterations early after a stroke (during acute and subacute period) have been broadly reported. These may include: 1) altered ventilatory patterns (Hardavella, Stefanache, & Ianovici, 2006), 2) high risk of aspirations (Smith Hammond et al., 2009), 3) sleep disorders (Rola et al., 2007) and 4) high incidence of chest infections (Hannawi et al., 2013). Most of these issues are identified and addressed in clinical practice given that they pose a critical risk for patients (Pelosi, Severgnini, & Chiaranda, 2005). However, neurological rehabilitation for people with chronic stroke (beyond six months of the onset of stroke (Kwakkel & Kollen, 2013)) rarely take into account the assessment and treatment of pulmonary function, perhaps because patients do not report respiratory symptoms frequently (Rochester & Mohsenin, 2002).

Over the past decades, several authors have suggested that the presence of stroke sequelae, such as a decrease in respiratory muscle strength as well as a reduced mobility of the affected diaphragmatic dome, could affect lung volumes in this population leading to a restrictive ventilatory pattern. Spasticity and contractures of the trunk muscles and the biomechanical disruptions of the thoracic cage may also contribute (Fugl Meyer & Grimby, 1984; Haas, Rusk, Pelosof, & Adam, 1967; Korczyn, Hermann, & Don, 1969). Although some studies seem to support this hypothesis (Annoni, Ackermann, & Kesselring, 1990; Kim, Fell , & Lee, 2011; Odia, 1978; Voyvoda et al., 2012), others have failed to find a significant reduction in lung volumes in the chronic period after a stroke (Da Silva et al., 2015; De Almeida et al., 2011; Jandt et al., 2011; Pinheiro et al., 2014). Fugl Meyer, Linderholm, and Wilson (1983) and Ezeugwu, Olaogun, Mbada, and Adedoyin (2013) reported a restrictive abnormality only in part of their study sample. Nevertheless, assessing pulmonary function after a stroke should be regarded as an integral part of evaluation of these patients. Several systematic reviews and meta-analyses published in the last five years support the effectiveness of respiratory muscle training in this population (Menezes et al., 2018; Wu, Liu, Ye, & Zhang, 2020). However the impact of stroke on lung function, especially beyond the acute phase, is still unclear. It is of great interest to study pulmonary function in patients with chronic stroke since it has been suggested that the optimisation of pulmonary function after a stroke could improve the results obtained during the neurorehabilitation process (Narain & Puckree, 2002).

Therefore, the main purpose of the current study was to compare lung volumes in people with chronic stroke with a control group of healthy people matched by age and sex, as well as with their own reference values. We also investigated whether a relationship exists between lung volumes and the distance walked during the six-minute walk test (6MWD) in the stroke group, since a positive correlation between the 6MWD and the maximal inspiratory pressure in this population has been previously described (Lista et al., 2016).

MATERIAL AND METHODS

Study design

This was a cross-sectional observational study conducted in patients who have had a stroke and healthy subjects matched by age and sex. Approval from the local Ethics Committee was obtained prior to the beginning of the study (reference 2011/081) and all participants signed informed consent before any formal testing.

Participants and setting

Patients who have had a stroke were recruited from a private neurological rehabilitation centre and a public association for people with acquired brain injury.

Inclusion criteria. People aged over 18 years old, diagnosed with hemiplegia/hemiparesis at least six months prior to participation, who were receiving neurological rehabilitation at the moment, were able to walk with or without assistance, were able to understand instructions for spirometries and 6MWD and demonstrated a willingness to participate were screened.

Exclusion criteria. Current or former smokers less than a year, people who did not walk regularly in daily life, who had a diagnosis of a pulmonary disease, severe cardiac disease, or any other neurological impairments, had undergone thoracic or abdominal surgery in the previous three months, presented with chest infections in the previous two months, had severe facial paralysis, severe kyphoscoliosis and who were receiving specific cardiovascular training or respiratory physiotherapy were excluded from the study. People who presented contraindications for any of the tests included in this study were also excluded (Graham et al., 2019; Holland et al., 2014).

The process for the allocation of the stroke group is shown in Figure 1. Participants in the control group were recruited by e-mail among university staff. Staff and their relatives were invited to volunteer for the study and to contact the researcher if they met the inclusion criteria and wanted to participate. From a potential sample of 2,118 healthy people, 76 volunteered of whom 33 were randomly selected. The control group was matched by age and sex with subjects who have had a stroke, as those two variables are known to influence the results of respiratory function tests (Chinn, Jarvis, Svanes, & Burney, 2006).

Sample size

We hypothesised that people with chronic stroke would show a restrictive ventilatory defect, hence the sample size calculation was based on the forced vital capacity (FVC) as this is used to determine a restrictive ventilatory abnormality (Pellegrino et al., 2005). Cordero et al. (1999) found a mean of FVC=4.2 l±1.01 l in a healthy Spanish population with a selection criteria similar to our control group. Following the international statements to spirometry interpretation (Pellegrino et al., 2005), we expected to observe a mean of FVC =3.3 l in the stroke group, which represents 79% of the mean expected in the control group (4.2 l). Taking these data into account and assuming an alpha error of 0.05%, 90% of power, using a two-tailed hypothesis and 15% of withdrawals, a sample size of 33 participants in each group was needed.

Procedure

Participant assessments were carried out by a highly trained physiotherapist, in two separate sessions, less than a week apart.

First visit. All participants underwent a standardised interview regarding their demographic and clinical characteristics. Anthropometric and vital signs were also recorded. Two six-minute walk tests were then performed by both groups in a quiet 30-metre long indoor corridor in line with the international guidelines (Holland et al., 2014), and the longest distance of the two tests was selected for analysis. Participants in the stroke group were allowed to use their usual walking aid and/or to walk supported by another person (normally a relative), trained beforehand to avoid any influence in their gait speed.

Motor function in the stroke group was assessed through the Motricity Index (Demeurisse, Demol, & Robaye, 1980), a simple, validated and reliable method to measure motor function after a stroke, based on Medical Research Council grades (Brigadier, 1976). The protocol described by Collin and Wade (1990) was used where the score range is from 0 (no movement) to 100 (normal power).

The Stroke Impact Scale version 16.0 (Duncan et al., 2003) was used to assess the consequences of the stroke. This scale has been validated for the Spanish population (Palomino, 2010). Participants had to mark each item on a 5-point Likert scale from 1 (an inability to complete the item) to 5 (no difficulty experienced at all). The global score ranged from 16 to 80.

Second visit. During the second visit, all functional respiratory tests were performed while sitting using a nose clip. Simple and forced spirometries were performed in accordance with the international guidelines (Graham et al., 2019), using a digital spirometer, Datospir® 120C (Sibelmed Group, Barcelona, Spain). The reference values for the Spanish population of each parameter of pulmonary function were calculated using the predictive equations proposed by Roca et al. (1986), for the parameters derived from forced spirometry and by Cordero et al. (1999), for those derived from simple spirometry.

In accordance with the acceptability criteria, participants performed a maximum of eight repetitions of forced spirometry, with a minimum of three acceptable manoeuvres, two within 150 ml of the two largest values of FVC and forced expiratory volume in one second (FEV_1). All the forced spirometries had grade A quality (Graham et al., 2019).

Data analysis

Demographic continuous variables are presented as mean±standard deviation, and categorical values are shown as absolute values and corresponding percentages. After testing normal distribution of interval and ratio variables using Kolmogorov- Smirnov test, independent t-tests were used to determine differences in lung volumes between patients who have had a stroke and control group, and to explore possible group differences in age, weight and height. In addition, a paired t- test was also performed to assess differences in lung volumes between patients with stroke and their own reference values.

To determine the clinical significance of differences, effect sizes were estimated in terms of Cohen's *d* to identify differences in group mean values. Small effect sizes (d=0.2), medium effect sizes (d=0.5) and large effect sizes (d=0.8) benchmarks were used to interpret the effect size magnitude (Cohen, 1988). The Pearson correlation coefficient was used to explore the relationship between lung volumes and 1) the distance walked in the 6WMT, 2) the Motricity Index and 3) time elapsed since the stroke. Dancey and Reidy's (2004) categorisation was subsequently used to interpret the strength of the correlations.

All statistical analyses were performed using SPSS software version 22.0 for Windows (IBM S. A., Spain). Significance level was set at $p < .05$ for all analysis.

RESULTS

The final sample for this study compromised 66 participants, 33 in each group. The average age of participants who have had a stroke was 56.9±15.7 years. There were no significant differences between groups regarding age, weight, height and body mass index (BMI). A summary of the main characteristics of the population included in the study can be found in Table 1.

In terms of smoking, there were 19 ex-smokers in the stroke group and 15 in the control group (time as ex-smokers 14.5±12.8 years and 22.9±13.7years; 25.8±10.9 packs/year and 15.5±5.9 packs/year, respectively). There were no significant differences between groups.

Results of the pulmonary functional tests from both groups are presented in Table 2. Comparison between the two groups showed significantly lower values in patients who have had a stroke in the main parameters of simple spirometry. The effect sizes of all these pulmonary parameters were large (Cohen, 1988). There was also a significant decrease in vital capacity (VC), expiratory reserve volume (ERV), inspiratory capacity (IC), FVC and FEV_1 in participants with stroke as compared with their own reference values. Individual analysis of the lung volumes in people with stroke showed that 17 people had a VC below 80% of their reference value. The median FVC and FEV_1 in people who have had a stroke was 79% and 82% of the reference values, respectively. The median peak expiratory flow (PEF) was 64% of the reference value. These findings would suggest a ventilatory defect. The mean 6MWD in people with stroke was 266.2 ±123.9 metres. A positive weak correlation was found between the 6MWD and the inspiratory reserve volume (IRV) ($r = 0.39$; $p<.026$) and peak inspiratory flow (PIF) ($r=0.35$; $p< .048$) in people who have had a stroke using Pearson's correlation coefficient test (Table 3). No correlation was found between lung volumes and time elapsed since the stroke (chronicity), nor with the Motricity Index.

<u>DISCUSSION</u>

The results from this study show that the main lung volumes are significantly reduced in people with chronic stroke compared to healthy volunteers matched by age and sex (VC, IRV, IC, FVC, FEV_1 and PEF), as well as to their own reference values (VC, ERV, IC, FVC, FEV_1). Furthermore, the median values of FVC observed in participants who have had a stroke is suggestive of a restrictive ventilatory defect in this population. Our results also show a weak positive relationship between IRV and PIF with the 6MWD. However, no correlation was found between lung volumes and the time elapsed since the stroke and Motricity Index.

Few studies have evaluated the static lung volumes using spirometry (Annoni et al., 1990; De Almeida et al., 2011) or plethysmography in this population (Fugl Meyer et al., 1983; Haas et al., 1967). Our results are consistent with Annoni et al. (1990) who found a significant reduction of VC in people with stroke as compared with their reference values, as well as with Fugl Meyer et al. (1983) who reported a significant decrease of total lung capacity (TLC), functional residual capacity (FRC), VC, and ERV in patients with marked and severe hemiplegia. In their study, Fugl Meyer et al. (1983) also noted significantly reduced IC in patients who have had a stroke in the previous six months. Importantly, in this study, pulmonary functional tests were performed in supine but the results were compared with predictive equations performed in sitting. Therefore, these results are questionable since it is well-established that lung volumes are significantly lower when assessed in supine (Vilke, Chan, Neuman, & Clausen, 2000). In contrast, there was one study which did not find a significant difference in the IC between patients with chronic stroke and healthy volunteers (De Almeida et al., 2011). In this study, the authors found that people with stroke showed higher absolute values of IC as compared to the control group. However, measurements were performed in supine using an analog ventilometer simultaneously with the diaphragmatic excursion assessment with ultrasound, which could have affected the reliability of the results of IC measurements obtained.

Regarding the forced spirometry, a significantly lower PEF, was found in our study (71.2±22% of the reference value) in participants who have had a stroke as compared to healthy participants. The cut-off point for normal PEF has been established as >80% of the reference value. Our results are in line with other studies that also found a decrease in PEF among participants who have had a stroke (Annoni et al., 1990; Ezeugwu et al., 2013). In addition, the reduced PEF is consistent with the expiratory muscle weakness that has been observed in chronic stroke (Lista et al., 2016; Menezes et al., 2018). Furthermore, we also analysed values obtained from the inspirometric curve recorded during the forced spirometric manoeuvre, which highlighted a significant decrease in the participants who have had a stroke for the forced inspiratory vital capacity (FIVC), forced inspiratory volume in one second (FIV_1) and the peak inspiratory flow (PIF), when compared with the control group. As far as we know, there is only one previous study which recorded the inspirometric curve and the findings are in line with ours for the FIVC and the FIV_1 (Annoni et al., 1990).

According to international guidelines (Pellegrino et al., 2005), a restrictive pulmonary abnormality is defined as FVC <80% and $FEV_1/FVC \geq 0.7$. Assuming this criteria, we failed to find a restrictive ventilatory defect in the sample set of participants with stroke (mean FVC =81.3±16.6%). However, it is important to note that the median for FVC was 79% of the reference value and 17 patients with stroke showed a restrictive ventilatory defect according to the aforementioned definition. These results support the hypothesis reported by previous authors that the co-occurrence of different aftermath of stroke that affects the thoracic wall could lead to a trend towards a restrictive ventilatory defect in this population (Fugl Meyer & Grimby, 1984; Haas et al., 1967; Korczyn et al., 1969). This hypothesis is also in line with findings reported by Ezeugwu et al. (2013). In this study, 35 patients with chronic stroke were assessed of whom seven were diagnosed with a restrictive defect, six with an obstructive defect and three with a mixed ventilatory defect (Ezeugwu et al., 2013). Nevertheless, the criteria followed to determine ventilatory pattern abnormalities were non-consistent with the previous international guidelines (Pellegrino et al., 2005), which could explain the lower number of patients with chronic hemiplegia who showed a restrictive ventilatory defect in the aforementioned study (Ezeugwu et al., 2013). Kim et al. (2011) also observed a restrictive ventilatory defect in patients with chronic stroke, but they defined a restrictive ventilatory defect as $FEV_1/FVC > 79\%$. Furthermore, they did not provide the corresponding reference values, making it challenging to draw parallels with our study findings. In addition, another investigation (Odia, 1978), found a restrictive ventilatory defect in a sample of 20 patients with stroke, although they were in a subacute phase and some information was missing on relevant details, such as smoking status and the extent of the stroke. Additionally, Voyvoda et al. (2012) reported the presence of a restrictive ventilatory defect in a sample of 23 people with stroke. However, in this case, participants were older, which may have influenced the results since lung function naturally decreases with age (Quanjer et al., 2012). In contrast with the previous findings, Jandt et al. (2011) did not find any alteration in lung volumes in people with stroke using the Brazilian Society of Pulmonology spirometry procedures (Knudson, Slatin, Lebowitz, & Burrows, 1976; Souza & Pereira, 2002), and nor did the study by De Almeida et al. (2011) who reported a non-significant difference in FVC or FEV_1 between people with hemiplegia and healthy subjects. Interestingly, the values of FVC and FEV_1, expressed as a percentage of the reference value, showed a higher non-significant mean value in people with left hemiplegia compared to the control group. This fact is especially interesting since the participants with left hemiplegia were overweight comparing to the control group, and it is well-known that BMI influences lung volumes, being lower in people with overweight (Sebbane et al., 2015; Steier et al., 2014).

Finally, we found a positive correlation between IRV and PIF with the 6MWD. This correlation suggests that there might be a relationship between the magnitude of functional capacity after stroke and lung volumes, since both distance and walking speed have been shown to be indicative of the functional capacity of people with hemiplegia (Schmid et al., 2007). Different factors have been highlighted in the literature as influencers of the 6MWD after stroke: improvements in oxygen consumption (VO_2), gait efficiency, balance, muscle strength, neuromotor control, and inspiratory muscle strength, among others (Galloway et al., 2019; Lista et al., 2016). However, to the best of our knowledge, this is the first piece of evidence reporting of the relationship between lung volumes and 6MWD in people with chronic stroke. This finding adds relevant value to the clinical practise, suggesting that improving the inspiratory volumes as well as the inspiratory muscle strength, the 6MWD could be improved.

Study Limitations

According to international guidelines, plethysmography is the gold standard to accurately diagnose a restrictive ventilatory defect (Pellegrino et al., 2005). Unfortunately, we did not have access to this equipment, and, thus, this could be regarded as a limitation to the study. However, based on the results of previous studies, we do not expect that we would have obtained different results had we been able to measure TLC using plethysmography (Cabral et al., 2017).

CONCLUSION

In conclusion, the results of this study showed that people with chronic stroke exhibit a significant reduction in most lung function parameters when compared to heathy people matched by sex and age, and also when compared to their own reference values. Furthermore, we found a positive correlation between the 6MWD and the IRV and PIF. Future studies with more precise classification of the motor impairments and functional capacity in people with chronic stroke are needed in order to corroborate the presence of a restrictive ventilatory defect in this population and also to investigate the possible factors that drive this effect. If a restrictive ventilatory defect among patients with stroke is confirmed, it would be important to determine to what extent its assessment and subsequent therapeutic approach would have an impact on the functional rehabilitation process after the stroke.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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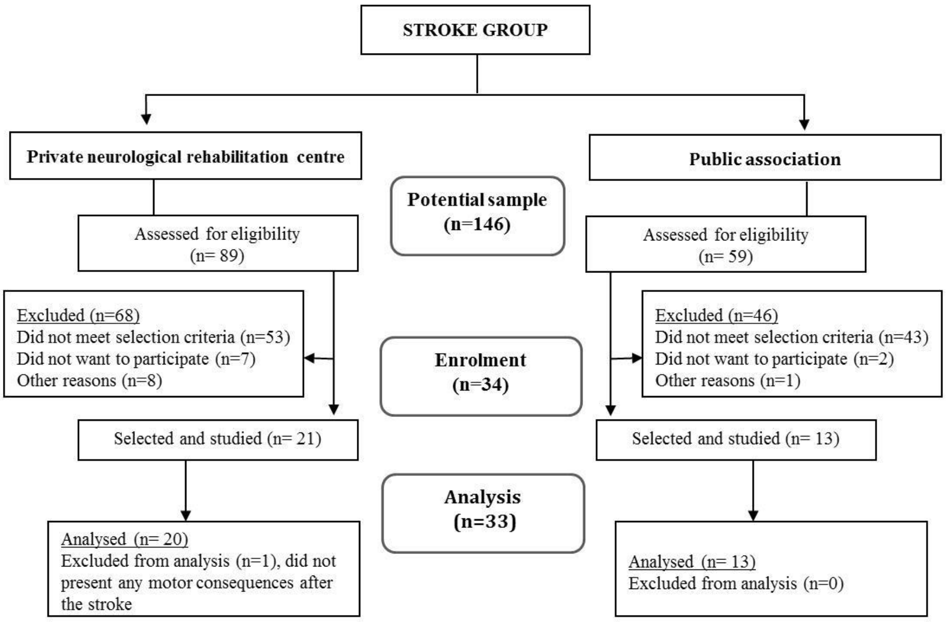

Figure 1. Flowchart of the stroke group (SG)

Table 1. Characteristics of the subjects (n=66)

	SG (n=33)	**CG (n=33)**
Male/female, n (%)	24/9	24/9
Age (years)	56.9±15.7	56.2±15.2
Height (cm)	166.3±9.1	169.1±8.7
Weight (Kg)	77.9±14.4	77.6±13.3
BMI (kg/m^2)	28.1±4.5	27.1±3.8
Type of stroke (I/H), n (%)	25/8	NA
Lesion location		
MCA/ ACA /MCA+ACA, n	22/1/1	NA
(%)	6/2/1	NA
Lobar/GB/BS, n (%)		
Affected side (right/left), n (%)	14/19	NA
Months since the stroke	48.8±68.8	NA
6MWT (m)	266.2±123.9	695.1±88.5
Speed 6MWT (m/s)	0.7±.3	1.9±.3
LL_MI	68.4±20.4	NA
UL_MI	57.5±32.3	NA
Global_MI	63.8±22.5	NA
SIS_16	67±8	NA

Values are expressed as mean ± standard deviation unless otherwise indicated.

6MWT: six-minute walk test; ACA: anterior cerebral artery; BG: basal ganglia; BS: brain stem; BMI: body mass index; Diff. Means: difference means between both groups; I/H: ischemic/hemorrhagic; LL: lower limb; MCA: middle cerebral artery; MI: motricity index; NA: not applicable; SIS-16: scale impact of stroke version 16.0; Speed 6MWT (m/s): speed gait during six-minute walk test (meters/second); UP: upper limb.

Table 2. Comparison between static and dynamic lung volumes in stroke group and control group (n=66) and also with values observed in stroke group and their own reference values

	Variable	Control group (n=33)	Stroke group (n=33)	T-Test between values observed in stroke group and control group: Diff. Means	*P*	95% CI	Effect Sizes (Cohen´s d)	T-Test between values observed in stroke group and their own reference values: Diff. Means	*P*	95% CI	Effect Sizes (Cohen´s d)
STATIC LUNG VOLUMES	VC (l)	4.3±.9	3.5±0.9	0.8	.001**	0.4-1.3	.86	0.5	.002*	0.2-0.8	.54
	VC (%)	103.5±14.2	88.7±19.5	14.8	.001**	6.4-23.2	.87	NA	NA	NA	NA
	TV (l)	0.8±0.3	0.8±0.3	-0.02	.805	-0.2-0.1	-.06	NA	NA	NA	NA
	ERV (l)	1±0.7	0.8±0.5	0.2	.251	-0.1-0.5	.28	0.2	.042*	0.01-0.3	.33
	ERV (%)	87.9±47.6	83.4±47.6	4.5	.7	-18.9-27.9	.09	NA	NA	NA	NA
	IRV (l)	2.5±0.69	1.9±0.6	0.7	<.001***	0.3-1	1.01	NA	NA	NA	NA
	IC (l)	3.3±0.8	2.6±0.7	0.6	.001**	0.3-1	.84	0.27	.031*	0.02-0.5	.42
	IC (%)	110±21.8	92.3±22.8	17.7	.002*	6.7-28.7	.79	NA	NA	NA	NA
DYNAMIC LUNG VOLUMES	FVC (l)	4.2±0.9	3.4±1	0.7	.002*	0.3-1.2	.79	0.8	<.001***	0.5-1.1	.85
	FVC (%)	95.6±13.2	81.3±16.6	14.3	<.001***	6.9-21.7	.96	NA	NA	NA	NA
	FEV_1 (l)	3.2±0.8	2.6±0.8	0.6	.003*	0.2-1	.74	0.5	<.001***	0.3-0.7	.62
	FEV_1 (%)	100.2±15.9	84.5±18.8	15.8	<.001***	7.2-24.4	.91	NA	NA	NA	NA
	FEV_1/ FVC (%)	78±6.3	77±8.2	1.1	.547	-2.5-4.7	.15	-2.3	.083	-4.9-0.3	.37
	PEF (l/s)	7.7±1.7	5.8±2.3	1.9	<.001***	0.9-2.9	.95	2.3	<.001***	1.6-3	1.18
	PEF (%)	93.3±17.3	71.2±22	22.1	<.001***	12.4-31.9	1.12	NA	NA	NA	NA
	$FEF_{25-75\%}$ (l/s)	2.9±1.1	2.5±1.1	0.5	.095	-0.1-1	.42	0.3	.046*	0.01-0.7	.32
	$FEF_{25-75\%}$ (%)	102.3±31.2	90.3±34.9	12	.147	-4.3-28.3	.36	NA	NA	NA	NA
	FIVC (l)	4.1±0.9	3.3±0.9	0.8	.001**	0.3-1.2	.87	NA	NA	NA	NA
	FIV_1 (l)	3.7±1	2.9±1	0.8	.001**	0.3-1.3	.83	NA	NA	NA	NA
	PIF (l/s)	4.9±1.7	3.6±1.5	1.4	.001**	0.6-2.1	.89	NA	NA	NA	NA

Values are mean±SD. Reference values of lung volumes were calculated using predictive equations proposed by Roca et al., (to static lung volumes) and by Cordero et al., (to dynamic lung volumes).

CI: confidence interval; Diff. Means: difference between means of both groups; ERV: expiratory reserve volume; $FEF_{25-75\%}$: mean forced expiratory flow between 25% and 75% of FVC; FIV_1: forced inspiratory volume in one second; FIVC: forced inspiratory vital capacity; IC: inspiratory capacity; IRV: inspiratory reserve volume; NA: not applicable; PEF: peak expiratory flow; PIF: peak inspiratory flow; TV: tidal volume; VC: vital capacity.

** $P<0.05$; **$P<0.01$; ***$P<0.001$*

Table 3. Correlation between static and dynamic lung volumes in the stroke group (n=33) and the metres walked during the Six-Minute Walk Test

Variable	Pearson Coefficient	Correlation Strength †	*P* (2-tailed)
VC	.24	NC	.176
IC	.32	Low	.06
IRV	.39	Low	**.026***
ERV	-.001	NC	.994
FVC	.301	NC	.089
FEV_1	.24	NC	.172
PEF	.19	NC	.281
FIVC	.29	NC	.101
PIF	.35	Low	**.048***

ERV: expiratory reserve volume; FIVC: forced inspiratory vital capacity; IC: inspiratory capacity; IRV: inspiratory reserve volume; NC: no correlation; PEF: peak expiratory flow; PIF: peak inspiratory flow; VC: vital capacity.

* *P*<0.05

† Dancey and Reidy's categorisation was used to interpret the strength of the correlation.