Respiratory Muscle Strength and Endurance Following a CVA

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ABSTRACT

Most adults diagnosed with cerebrovascular accidents (CVA) receive rehabilitation services to maximize their functional independence. However, few reports specifically address respiratory muscle strengthening following a CVA. The purpose of this pilot study was to compare the pulmonary function of adults following their first CVA with established normal adult standards to explore whether respiratory muscle strength and endurance are depressed following an initial CVA. Thirteen adults 40-60 years of age admitted to the rehabilitation unit within 3 weeks of having their first CVA participated in the pilot study. Pulmonary function was tested using negative inspiratory force (a measure of respiratory muscle strength), maximal voluntary ventilation (a measure of respiratory muscle endurance), and forced vital capacity (a measure of maximal voluntary output). Paired samples t-test analysis showed a significant difference ($p<0.002$) between predicted and actual pulmonary function test values. The results indicate that respiratory muscle strengthening should be included in the medical management of adults following a CVA.

INTRODUCTION

Approximately 550,000 adults are diagnosed with a cerebrovascular accident (CVA) each year in the United States.[1] Respiratory dysfunction occurs in one third of these individuals and may contribute to the development of pneumonia, the third major cause of death, within one month of a stroke.[2] Altered breathing patterns,[2] altered thoracic mechanics,[3] decreased lung volumes,[4] and decreased pulmonary diffusing capacities[4] have been reported in people who have had strokes. Respiratory dysfunction may be a result of: (1) the infarct directly affecting the neurologic control of respiratory function, (2) hemiparesis of the trunk musculature, (3) changes in trunk muscle tone, and/or (4) the development of abnormalities in trunk alignment. While most people who have had strokes receive rehabilitation services to maximize their functional independence,[1] few reports have been published that specifically address respiratory muscle strength and endurance in acute hemiplegia.[1] It is possible that specific exercise programs that increase the strength and endurance of respiratory muscles might improve respiratory function following a CVA and might minimize the incidence of pulmonary complications such as pneumonia.[2]

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The pilot study was approved by the Oak Forest Hospital of Cook County Institutional Review Board for Clinical Investigation and Northern Illinois University Human Subject Institutional Review Board and was conducted between September 1, 1995 and July 31, 1996.

SUBJECTS

All individuals between 30 and 80 years of age who were admitted to the Comprehensive Rehabilitation Unit of Oak Forest Hospital of Cook County within three weeks of having a CVA were screened for participation in the pilot study. More than 60 individuals were excluded by the screening process because they either: (1) had been diagnosed with a previous CVA, (2) had a pulmonary disorder identifiable on admission chest x-ray, (3) had a severe thoracic cage disorder, or (4) required more than moderate assistance either to propel a wheelchair or to ambulate. Smoking history was not a consideration in subject selection due to the high percentage of smokers in the convenience population (ie, 100% of the individuals who were potential subjects for this study were smokers).

The study physician met individually with all potential subjects to discuss participation in the pilot study and to obtain written informed consent. Seven females and six males consented to participate in the pilot study (Table 1).

Table 1. Subject Data

FEMALES			MALES		
YEARS OF AGE	RACE	SIDE OF LESION	YEARS OF AGE	RACE	SIDE OF LESION
41	A	L	54	A	R
44	C	R	55	A	L
44	A	R	57	A	R
47	A	L	58	A	R
54	A	L	58	A	R
58	C	L	59	C	R
67	A	R			

N=13
A=African-American, C=Caucasian; R=Right, L=Left

MATERIALS AND METHODS

Pulmonary function tests (PFT) were performed by the same two investigators in the Physical Therapy Department on the Wednesday afternoon following the subject's

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admission to the unit. Three PFTs were measured: 1) negative inspiratory force (NIF) - the greatest amount of negative pressure produced during maximal inspiration, 2) maximal voluntary ventilation (MVV) - the volume of air exchanged during 15 seconds of repeated maximal inspiration and expiration, and 3) forced vital capacity (FVC) - the maximal volume of forceful and rapid expiration following a maximal inspiration.[5] These PFTs are measures of respiratory muscle strength, respiratory muscle endurance, and maximal voluntary output, respectively. Additionally, a fourth pulmonary function, forced expiratory volume in one second (FEV_1), which refers to the volume of air forcefully expired during the first second of FVC,[5] was calculated from the FVC test value.

PFTs were conducted in the following order: NIF 3 times, FVC 3 times, and MVV once. A Respirodyne II Plus*, a solid-state, self-calibrating instrument designed for bedside use, was used to measure pulmonary function (Figure 1). The Respirodyne II Plus met the American Thoracic Society's PFT standards. Depending on the PFT being measured, the subject either inhales or exhales through a disposable flow sensor. A nose clip was used to insure air exchange occurs only through the flow sensor. The pressure developed in the flow sensor is detected at the end of a connecting tube by the pressure transducer which, with the assistance of a microprocessor, calculates flows and volumes. Extrapolated volume percents calculated by Respirodyne II Plus were always less than 5% (recommended value of the manufacturer) thus guaranteeing the values obtained were lung values and were not produced by mouth pressures.

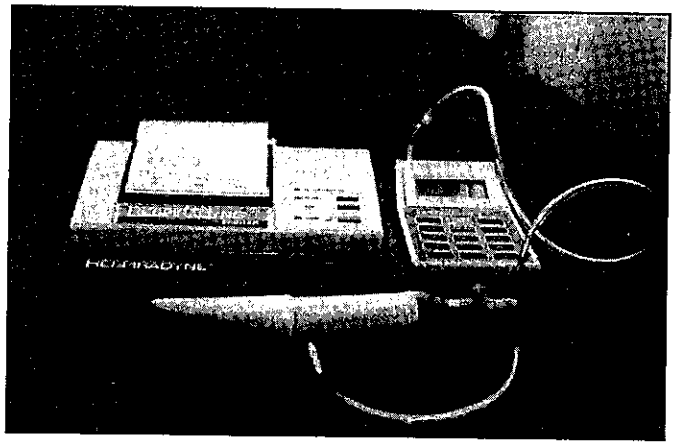

Figure 1. Respirodyne II Plus.

Subjects were positioned in supine with the upper body elevated to approximately 45° (Fowler's position[6]) when performing PFTs (Figure 2). This position was chosen over standard PFT positions (ie, standing, short sitting) to posturally support the subject's weakened trunk musculature that often occurs during the acute phase of a CVA, so the trunk muscles could be used for the sole purpose of respiration.

Blood pressure, respiration rate, heart rate, and oxygen saturation were monitored throughout testing. A printout was obtained after each test.

Figure 2. Subject during pulmonary function testing.

DATA ANALYSIS

The equations used to calculate the gender-specific predicted PFT values are presented in Table 2.

Table 2. Predicted Pulmonary Function Test Value Equations[5]

NIF (cm H_20) PREDICTED VALUE EQUATION[11]	
Males	143 - (0.55)(age)
Females	104 - (0.51)(age)
MVV (L/min) PREDICTED VALUE EQUATION[12]	
Males	(3.03)(height) - (0.816)(age) - 37.9
Females	(2.14)(height) - (0.685)(age) - 4.87
FVC (L) PREDICTED VALUE EQUATION[13]	
Males	(0.148)(height) - (0.025)(age) - 4.24
Females	(0.115)(height) - (0.024)(age) - 2.85
FEV_1 (L) PREDICTED VALUE EQUATION[13]	
Males	(0.092)(height) - (0.032)(age) - 1.260
Females	(0.089)(height) - (0.025)(age) - 1.9

A paired samples *t*-test was used to analyze the predicted values and the actual values for each PFT.

RESULTS

The mean, standard deviation, and range of actual and predicted test values for each PFT are presented in Table 3. A significant difference exists between the predicted and actual test values for NIF (t = - 4.00; df = 12; p = 0.002), MVV (t = -17.79; df = 12; p < 0.001), FVC (t = -13.97; df = 12; p < 0.001), and FEV1 (t = -11.66; df = 12; p < 0.001). One subject exceeded her predicted NIF by -74.0 cm H_2O with an actual value of -156.0 cm H_2O. The range of actual NIF values for the remaining 12 subjects was -12.0 cm H_2O to -89 cm H_2O.

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Table 3. Comparison of Acutal and Predicted Pulmonary Function Test Values

Pulmonary Function Test	Mean ± SD	Range of Values	p Value
NIF (cm H_2O)			
Actual	-50.7 + 41.4	-12.0 to -156.0	0.002
Predicted	-93.8 + 17.8	-83.0 to -24.0	
MVV (L/min)			
Actual	16.9 + 7.8	7.4 to 31.6	0.001
Predicted	113.4 + 20.8	119.0 to135.4	
FVC (L)			
Actual	1.29 + 0.52	0.69 to 2.25	0.001
Predicted	4.04 + 0.97	2.79 to 5.43	
FEV_1 (L)			
Actual	1.00 + 0.44	0.53 to 1.77	0.001
Predicted	2.96 + 0.64	2.55 to 3.82	

N=13
NIF = Negative Inspiratory Force, MVV = Maximum Voluntary Ventilation, FVC = Forced vital Capacity, FEV_1 = Forced Expiratory Volume in One Second

DISCUSSION

The respiratory system plays a critical role in the supply of oxygen to tissues that support movement for the performance of functional activities.[7] Any decrease in respiratory muscle strength or endurance compromises the respiratory system and depletes the amount of oxygen available for the body's use when performing motor tasks. The results of the pilot study indicate that respiratory muscle strength and endurance are clearly depressed in adults following an initial CVA. This may negatively affect an individual's ability to participate in a stroke rehabilitation program[8] and thus compromise an individual's ability to attain maximal independence. A decreased FVC is consistent with other studies[9,10] and indicates an individual has less reserve volume from which to draw additional oxygen when needed such as when performing functional activities. The depression noted in FEV_1, the ability to force air out at the beginning of expiration, could influence the individual's ability to generate an effective cough. These clinically relevant results indicate the need to include assessment and rehabilitation of the pulmonary system in the medical management of individuals following a stroke.

Limitations, such as positioning during pulmonary function testing, have been identified in the pilot study and will be considered in future studies. Further investigation of respiratory function on a larger scale in adults following a CVA is justified by the conclusions of the pilot study.

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