Ventilatory Muscle Training Effect on Respiratory Status and Functional Mobility Following a CVA: A Case Study

Nancy A. Nuzzo, PhD, PT
Lisa A. Bronson, MS, PT
Theresa McCarthy, DO, MS, PT
Mary Massery, PT

Each year in the United States, approximately 550,000 adults are diagnosed with cerebral vascular accident (CVA), three-quarters of whom exhibit manifestations of hemiparesis. (1) While most of these persons receive rehabilitation services to maximize their functional independence, 25 - 50% continue to require varying degrees of assistance to perform their activities of daily living. (1) Despite the existence of a large body of literature related to postCVA rehabilitation, few reports have been published which address the rehabilitation of the cardiopulmonary system following a CVA. In the few studies that have discussed respiratory sequelae following CVA, evidence of decreased lung volumes, (2) altered thorax mechanics, (2) decreased pulmonary diffusing capacity, (2) and depressed respiratory muscle strength and endurance (3,4) have been noted. Interestingly, the leading cause of death within one month of a CVA is respiratory infections and pneumonia. (5)

The respiratory system plays a critical role in the supply of oxygen to all tissues of the body including those which support movement for the performance of functional activities. (6,7) Hemiparetic weakness associated with CVA decreases the strength and function of the trunk muscles, and thus significantly influences respiratory capabilities on that side. (3) Thus, if the patient cannot supply enough oxygen to the musculoskeletal system secondary to decreased ventilatory support, it would follow that their progression in physical therapy mobility training may also be impaired or delayed.

Our purpose for this case study was two fold: 1) to determine whether exercising the inspiratory muscles through the use of a ventilatory muscle trainer would show improvement in the patient's pulmonary function and 2) to determine whether an improvement in respiratory status indirectly support an improvement in functional mobility. This case report is taken from a pilot study conducted at Oak Forest Hospital of Cook County. This study was approved by the Oak Forest Hospital of Cook County Institutional Review Board for Clinical Investigation and the Northern Illinois University Institutional Review Board.

Nancy A. Nuzzo, PhD, PT, Assistant Professor, Northern Illinois University, College of Health and Human Sciences, School of Allied Health Professions, Physical Therapy Program, DeKalb, IL. Lisa A. Bronson, MS, PT, Assistant Director of Physical Therapy, Oak Forest Hospital of Cook County, Oak Forest, IL. Theresa McCarthy, DO, MS, PT, Attending Physician, Director of Spinal Cord Services, Oak Forest Hospital of Cook County, Oak Forest, IL and Assistant Professor, Rush Presbyterian St. Luke's Medical School, Chicago, IL. Mary Massery, PT, Adjunct Faculty, Programs in Physical Therapy, Northwestern University, Chicago, IL. Address correspondence to: Nancy A. Nuzzo, PhD, PT, Northern Illinois University, College of Health & Human Sciences, School of Allied Health Professions, Physical Therapy Program, Dekalb, IL 60115.

Methodology

Subject description

The subject was a 58-year old African-American male with a diagnosis of a left basal ganglia infarction (12-day post). Written reports from the referring institution indicated an uncomplicated course of acute medical care. While the subject had no known previous history of CVA, coexisting medical problems were peptic ulcer disease and a ten-year history of hypertension. The subject was determined to be medically stable, by the physician in charge of the pilot study, who obtained his informed consent to participate in this study. The subject was taking the following medications throughout the duration of the study: Ecotrin, Vasotec, Procardia, Hydrochlorothiazide, and Surfak.

An initial physical therapy evaluation was completed by the subject's primary physical therapist in accordance with Oak Forest Hospital Physical Therapy Department policy. The subject was found to be alert, oriented in all spheres, and able to follow complex directions. Initially, the subject was nonambulatory but was able to propel his wheelchair with supervision on level surfaces and ambulate using a left hemirail with contact guard assistance from the therapist. In addition, the subject performed transfers with contact guard/close supervision assist and was independent in bed mobility.

Ventilatory Muscle Training Device

A ventilatory muscle trainer (VMT), called the PFLEX (Figure 1), was chosen to be used for this study. Although VMT is a common device used in clinical practice to strengthen respiratory muscles in patients with quadriplegia, (8,9) cys-

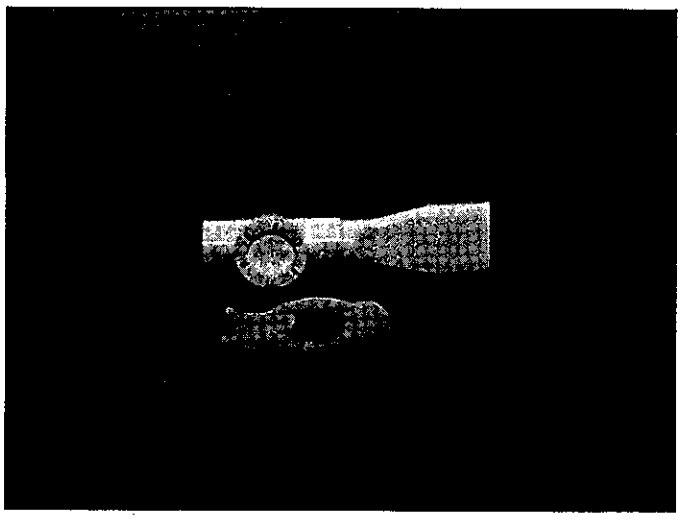

FIG. 1 The ventilatory muscle trainer, PFLEX.

tic fibrosis, (10) and COPD, (11-13) it has not been used on persons with CVA. The ventilatory muscle training device is a small, hand-held, plastic device that provides resistance during the inspiratory phase of respiration while a one-way valve prevents resistance during expiration. Resistance is controlled by a dial selector. Setting 1, the largest aperture, provides the least resistance while setting 6, the smallest aperture, provides the most resistance. A nose clip was used to insure air exchange occurred only through the PFLEX.

Daily Training Procedure

A 15-minute ventilatory muscle training session using PFLEX was performed at 7:30 every weekday morning by one of the investigators. The sessions continued for four weeks. The subject was positioned on his bed in supine with his upper body elevated to approximately 45 degrees. Heart rate and oxygen saturation were constantly monitored via a pulse oximeter. In addition, the subject's respiratory rate, heart rate, oxygen saturation, and blood pressure were measured and documented before treatment, after 7 minutes into treatment, immediately following treatment, and 10 minutes posttreatment.

During the first training session, the PFLEX was set on 1 for the subject to adapt to the device and nose clip. The subject was instructed to breathe at a comfortable rate (normal tidal volume) through the PFLEX. He was informed he should feel some resistance when inhaling through the PFLEX, but should immediately notify the investigator if he began to feel uncomfortable, light headed, or anxious. Half way through the session, the PFLEX was adjusted to setting 2 at the subject's request. Change in resistance throughout the study was directed by the subject according to his tolerance. At the end of the second week, the subject had progressed in resistance to setting 6. He remained at 6 for the duration of the study.

Description of measurement procedures

After each 15-minute training session using the PFLEX, the subject was asked to rate his intensity of exertion according to a revised Rating of Perceived Exertion (RPE) Scale. (14) This scale was developed to subjectively measure a person's perception of how hard he/she is working. It has been used successfully to determine exercise tolerance levels in patients with cardiac disease. (15) The revised rating scale from 0 - 10 was used with 0 (no exertion), 3 (moderate), 5 (strong), and 10 (very, very strong). (14)

Pulmonary function measurements were calculated using a Respirodyne II Plus. Maximal respiratory muscle strength was measured by negative inspiratory force (NIF) which is the greatest amount of negative pressure produced when the subject inhales with maximal effort. Respiratory muscle endurance was measured by maximum voluntary ventilation (MVV) which is the volume of air the subject exchanges during 15 seconds of maximal inspiration and expiration. Forced vital capacity (FVC) was also measured which is the maximal volume output following a maximal inspiration.

Pulmonary function testing was performed the day before the ventilatory muscle training sessions began to establish baseline measurements. The testing was repeated every 7 days for the duration of the study.

The functional mobility testing began with the subject, seated in his wheelchair, positioned with his unaffected side next to a treatment mat. The time and amount of assistance required 1) to transfer toward the unaffected side from the wheelchair to the mat and 2) to move from short sitting to supine were documented. The subject was then positioned in supine with his upper body elevated to approximately 45 degrees on a wedge for pulmonary function testing. Although standardized pulmonary function tests are performed in independent sitting or standing, this subject was placed in a semi-sitting position to support weakened trunk musculature. Pulmonary function tests were conducted in the following order: NIF 3 times, FVC 3 times, MVV 1 time. Depending on the pulmonary function being measured, the subject either inhaled or exhaled through a disposable flow sensor. The pressure developed in the flow sensor was sensed at the end of a connecting tube by the pressure transducer which, with the assistance of a microprocessor, calculated flows and volumes. A nose clip was used to insure that air exchange occurred only through the flow sensor. A printout was obtained after every pulmonary function test was completed. (Figure 2)

FIG. 2 The subject during pulmonary function testing.

Upon completion of the pulmonary function tests, the subject was placed in supine without the wedge. The time and amount of assistance required 1) to move from supine to short sitting and 2) to transfer toward the unaffected side from the mat to the wheelchair were documented. The subject's functional locomotion was then assessed by documenting the time and amount of assistance required for him to either propel his wheelchair 100' or to ambulate 100'. The test procedure ended with the subject resting for 10 minutes while seated in his wheel chair. Blood pressure was measured at the beginning of the session, after pulmonary function testing, after ambulating, and 10 minutes after testing was completed. Respiratory rate, heart rate, and oxygen saturation were measured and documented prior to and after each task or test and 10 minutes after all testing was completed. Functional activities used equipment, techniques, and assistance determined to be appropriate by the subject's primary physical therapist for that point in the subject's rehabilitation course. A hand-held stop watch was used to time the performance of tasks.

Results/Discussion

The subject described in this case study showed remarkable improvement in both respiratory status and functional ability. Using the best test out of 3 tests for each week, respiratory muscle strength (NIF) and maximal volume out-

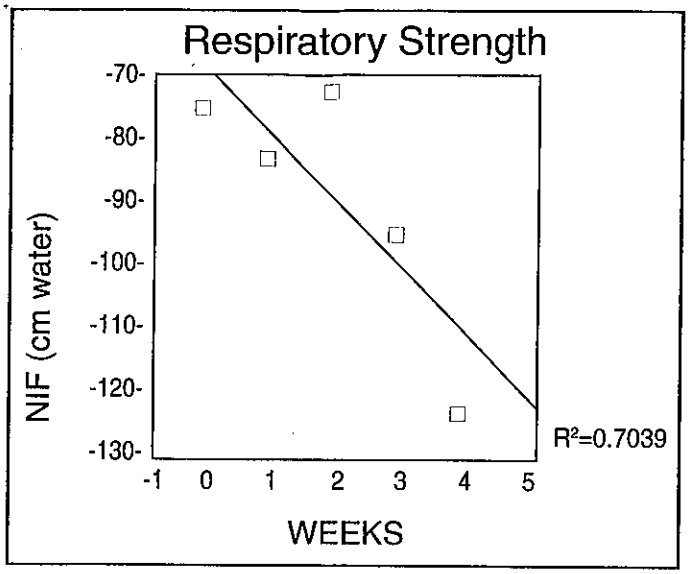

FIG. 3 Respiratory muscle strength as measured by Negative Inspiratory Force (NIF) over time (R^2=0.7039).

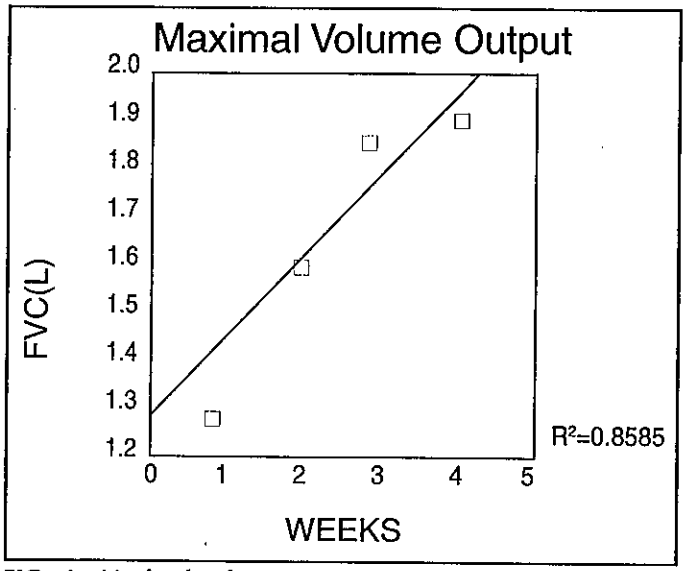

FIG. 4 Maximal volume output as measured by Forced Vital Capacity (FVC) over time (R^2=0.8585).

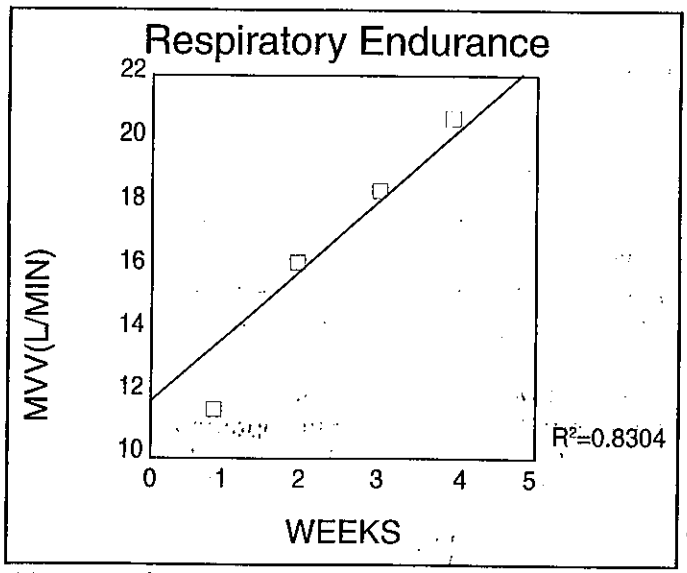

FIG. 5 Respiratory muscle endurance as measured by Maximum Voluntary Ventilation (MVV) over time (R^2=0.8304).

TABLE 1
Comparison of time and assistance for the subject to complete transfers.

Transfers	Time Wk 0 (seconds)	Time Wk 4 (seconds)	% chg time (wk 0 to 4)	Asst. Wk 0	Asst. Wk 4
WC --> bed	5.6	5	10%	CG	CS
sit --> supine	9.2	5.2	44%	CS	I
supine --> sit	15.8	7.5	53%	CS	CS
bed --> WC	4.4	5.5	(20%)	CS	CS

WC (wheel chair), CG (contact guard), CS (close supervision), I (independent)

TABLE 2
Locomotion (100-foot distance) progression of the subject.

WEEK	WC/AMB	TIME (sec)	ASSIST
0	WC	65.2	close supervision
1	AMB (metal AFO, WBQC)	147	contact guard
2	AMB (plastic AFO, WBQC)	118.2	contact guard
3	AMB (plastic AFO, WBQC)	109	contact guard
4	AMB (plastic AFO, NBQC)	83.3	close supervision

AMB (ambulation), AFO (ankle foot orthosis), WBQC (wide base quad cane), NBQC (narrow base quad cane)

put (FVC) improved over the four-week training sessions. (Figures 3,4) Additionally, respiratory muscle endurance (MVV) improved over the four-week period. (Figure 5)

Ventilatory muscle training positively affected this subject's respiratory muscle strength and endurance as evidenced by the change in his pulmonary function values between test 1 to test 5. A comparison of baseline to final measurement values showed a 64% increase in NIF, a 54% increase in MVV, and a 41% increase in FVC.

The time required for the subject 1) to transfer from the wheelchair to the mat, 2) to move from short sitting to supine, and 3) to move from supine back up to short sitting decreased between test 1 and test 5 (Table 1). Improved respiratory muscle strength and endurance may have contributed to the increased efficiency of these tasks. While the time required to transfer from the mat to the wheelchair increased by 20%, the investigators noted an improvement in the quality of the transfer. In all the tasks there was no change in amount of assistance required to complete them, however the quality and safeness of the tasks were notably improved according to the investigators. No breath holding was noted during any of the functional mobility testing.

The subject's locomotion progressed from a wheelchair level to an ambulatory level after the first week of ventilatory training. (See Table 2) The time required for the subject to ambulate 100' decreased by 43% over the next three weeks. Additionally the subject progressed from a metal ankle foot orthosis (AFO), wide-base quad cane (WBQC), contact guard supervision to plastic AFO, narrow-base quad

cane (NBQC), and close supervision. It is possible that improved respiratory muscle strength and endurance may have contributed to this subject's rate of progression.

Blood pressure, respiratory rate, heart rate, and oxygen saturations during the tests or training sessions were compatible with normal adult ranges and did not fluctuate significantly beyond normal exercise response. (16) Rating of Perceived Exertion (RPE) values were very consistent over the 4-week testing period with 3 (moderate) to 4 (somewhat strong) ratings throughout.

Conclusion

The VMT used in this study, PFLEX, is an inexpensive plastic device that is durable, simple to use, and easy to clean. The respiratory muscle program used for this pilot study is also inexpensive, simple to start, and could easily be incorporated into daily rehabilitation sessions in the clinic and then carried over in the home with minimal training.

Although this is a case study and cannot rule out the possibility of spontaneous recovery following stroke and random substantial improvement in both pulmonary and functional status, it does suggest that this relationship should be explored further. A larger study with control and test subjects is warranted. The considerable potential benefit of blending pulmonary and functional skills training following a CVA demands that we assess its true potential. In the meantime, because no negative side effects were noted, this study suggests that physical therapy treatment should emphasize respiratory strengthening along with other interventions following a CVA.

Acknowledgments

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