ORIGINAL ARTICLE

Inspiratory Muscle Training and the Perception of Dyspnea in Parkinson's Disease

Rivka Inzelberg, Nana Peleg, Puiu Nisipeanu, Rasmi Magadle, Ralph L. Carasso, Paltiel Weiner

ABSTRACT: ***Background:*** Pulmonary and respiratory muscle function impairment are common in patients with Parkinson's disease (PD). Inspiratory muscle training may improve strength, dyspnea and functional capacity in healthy subjects and in those with chronic obstructive pulmonary disease. This study investigated the effect of specific inspiratory muscle training (SIMT) on pulmonary functions, inspiratory muscle performance, dyspnea and quality of life, in patients with PD. ***Patients and Methods:*** Twenty patients with PD (stage II and III Hoehn and Yahr scale) were recruited for the study and were divided into two groups: a) ten patients who received SIMT and b) ten patients who received sham training, for three months. Pulmonary functions, the respiratory muscle strength and endurance, the perception of dyspnea (POD) and the quality of life were studied before and within one week after the training period. All subjects trained daily, six times a week, each session consisting of 1/2 hour, for 12 weeks. ***Results:*** Following the training period, there was a significant improvement, in the training group but not in the control group, in the following parameters: inspiratory muscle strength, (PImax, increased from 62.0±8.2 to 78.0±7.5 cm of H_2O ($p<0.05$), inspiratory muscle endurance (increased from 20.0±2.8 to 29.0±3.0 cm of H_2O ($p<0.05$), and the POD (decreased from 17.9±3.2 to 14.0±2.4 units ($p<0.05$). There was a close correlation between the increase in the inspiratory muscle performance and the decrease in the POD. ***Conclusions:*** The inspiratory muscle performance may be improved by SIMT in patients with PD. This improvement is associated with a significant decrease in their POD.

RÉSUMÉ: Effet de l'entraînement des muscles inspiratoires sur la perception de la dyspnée chez les patients atteints de la maladie de Parkinson. ***Introduction:*** L'atteinte de la fonction pulmonaire et des muscles respiratoires est fréquente chez les patients atteints de la maladie de Parkinson (MP). L'entraînement des muscles inspiratoires peut améliorer la force musculaire, la dyspnée et la capacité fonctionnelle chez des sujets sains et chez des patients atteints de maladie pulmonaire obstructive chronique. L'objectif de cette étude était d'étudier l'effet d'un entraînement spécifique des muscles inspiratoires (ESMI) sur la fonction pulmonaire, la performance des muscles inspiratoires, la dyspnée et la qualité de vie (QDV), chez des patients atteints de MP ***Patients et méthodes:*** Vingt patients atteints de MP (stade II et III à l'échelle de Hoehn et Yahr) ont été recrutés et divisés en deux groupes, soit dix patients qui ont reçu l'ESMI et dix patients qui ont reçu un entraînement factice pendant trois mois. Les fonctions pulmonaires, la force des muscles respiratoires et l'endurance, la perception de la dyspnée (PDD) et la QDV ont été évaluées avant et au cours de la semaine qui a suivi la période d'entraînement. Tous les sujets s'entraînaient 1/2 heure à tous les jours, six jours par semaine, pendant 12 semaines. ***Résultats:*** Après la période d'entraînement, on a observé une amélioration significative des paramètres suivants chez le groupe avec ESMI et non chez le groupe témoin : la force des muscles inspiratoires [IP max. augmentée de 62,0 ± 8,2 à 78,0 ± 7,5 cm de H_2O ($p<0,05$)], l'endurance des muscles inspiratoires [augmentée de 20,0 ± 2,8 à 29,0 ± 3,0 cm de H_2O ($p<0,05$)] et la PDD [diminuée de 17,9 ± 3,2 à 14,0 ± 2,4 unités ($p<0,05$)]. Il existait une étroite corrélation entre l'augmentation de la performance des muscles inspiratoires et la diminution de la PDD. ***Conclusions:*** L'ESMI peut améliorer la performance des muscles inspiratoires chez les patients atteints de MP. Cette amélioration est associée à une diminution significative de leur PDD.

Can. J. Neurol. Sci. 2005; 32: 213-217

Parkinson disease (PD) is a progressive extrapyramidal disorder characterized by bradykinesia, rigidity, tremor, and impaired postural reflexes.[1]

It has been shown that PD patients may have an array of respiratory abnormalities, such as reduced maximal inspiratory and expiratory flows,[2,3] upper airways dysfunction,[4] a restrictive pattern of pulmonary function[5] and diminished strength of the respiratory muscles.[6,7] Treatment with dopaminergic drugs consistently increases the strength of the muscles.[8]

Although these pulmonary and respiratory muscle function impairments are commonly reported in PD,[9-12] most patients do not report respiratory symptoms such as dyspnea. Probably, because of their sedentary life, intense effort is never used and dyspnea is not reported.

In a recent study, our group[13] has shown that PD patients have

From the Department of Neurology (RI, PN, RLC), Department of Medicine A (NP, RM, PW), Hillel Yaffe Medical Center, Hadera, and Rappaport Faculty of Medicine (RI, RLC, PW), Technion, Haifa, Israel.

Received June 21, 2004. Accepted in final form December 15, 2004.

Reprint requests to: Paltiel Weiner, Department of Medicine A, Hillel Yaffe Medical Center, Hadera, Israel 38100

an increased perception of dyspnea (POD) compared to normal subjects. Treatment with L-dopa resulted in a decrease in the POD, although it remained higher than in normal subjects. Since pulmonary function and strength was not altered by treatment, we speculated that L-dopa may improve POD by correcting either central drive or thoracic and abdominal muscle coordination.

Several previous studies have suggested that dyspnea, as perceived by the patient, is related to the respiratory muscle effort.[14,15] It is well documented that the degree of breathlessness, subjectively reported by the patients, is related to the activity and the strength of the inspiratory muscles.[16]

Dyspnea was recently defined[17] by the medical section of the American Lung Association as "a subjective experience of breathing discomfort that derives from interactions among multiple physiological, psychological, social and environmental factors". Studies performed in the past have suggested that dyspnea results from a mismatch between central respiratory motor activity and afferent feedback from peripheral sensory receptors in the lungs, airways and chest wall structures.[18,19] This phenomenon may be similar to the sensory-motor mismatch observed in the function of limb muscles in PD.[20]

Since the relation between the POD and inspiratory muscle performance is obvious, it remains obscure whether patients with PD are able to train their inspiratory muscles. The present study was designed in order to evaluate the effect of specific inspiratory muscle training (SIMT) on pulmonary functions, the respiratory muscle strength and endurance, POD and quality of life, in patients with PD.

Methods

Patients

Twenty consecutive ambulatory patients with long-standing PD [12 males and eight females, mean±SEM age 62.3±2.7 y, stage II and III Hoehn and Yahr scale,[21] mean disease duration 8.6±1.8 years], all naive to the purpose and the methodology of the study, participated in the study. Patients with known cardiac or chronic lung disease were excluded from the study. None of the patients had chest x-ray evidence of pulmonary or pleural fibrosis. All patients were optimized and on stable doses of levodopa before the initiation of the study. Their characteristics are summarized in Table below. Written informed consent was obtained in all cases, and ethical approval for the study was granted by our hospital's Human Ethics Committee.

Measurements

All measurements were performed in the morning, about two hours after L-dopa intake (during "on"), prior to the training period, each month during the training period and within one week following the termination of the training period, in all PD patients. Since L-dopa has a very short half-life and the fact that

Table: Characteristics of patients with PD

Patient	Age (y)	Sex	Severity Hoehn &Yahr	Duration of disease (y)	Treatment	Compliance (%) with the training regime
Training group						
1	62	M	II	1.8	Dopicar, Selegiline	100
2	57	F	II	4	Selegiline	80
3	53	M	II-III	12	Dopicar, Selegiline	100
4	65	M	II-III	5	Dopicar, PK-Merz	90
5	60	M	II-III	8	Dopicar, Sinemet, Requib	30
6	67	M	II	10	Dopicar, Paritel, Sinemet, Pergolide	100
7	45	M	II	5	PK-Merz, Jumex	35
8	52	M	II	20	Dopicar, Sinemet	30
9	64	M	II	5	Dopicar, PK-Merz	50
10	69	M	III	15	Dopicar, Flutin, Lithium	40
Mean±SEM	59.4±2.4			8.58±1.8		65.5±9.8
Control group						
1	71	F	II-III	3.5	Dopicar, Pergolide	90
2	68	M	III	13	Dopicar, PK-Merz, Requib	80
3	67	M	II	4	Dopicar, PK-Merz	60
4	65	M	II	1	Jumexr, PK-Merz	100
5	60	M	II-III	20	Jumexr, PK-Merz, Pergolide	100
6	67	M	II	15	Dopicar, Lithium	50
7	45	M	III	5	Sinemet, Requib	40
8	52	M	III	2	Dopicar, Selegiline	80
9	64	M	III	10	Dopicar, PK-Merz, Parilac	70
10	69	M	III	8	Dopicar, Pergolide, Sinemet	50
Mean±SEM	65.2±3.6			8.15±2.0		72.0±5.3

https://doi.org/10.1017/S0317167100003991

all patients were outpatients, we arbitrarily chose to assess the effect of the morning dose. The patients were unaware of the purpose of the measurements.

Spirometry. Maximum expiratory and inspiratory flow-volume curves were measured at least three times, according to the American Thoracic Society (ATS) guidelines, on a computerized spirometer (Compact, Vitalograph, Buckingham England) and the best trial was reported.

Inspiratory muscle strength. Inspiratory muscle strength was assessed by measuring the maximal inspiratory mouth pressure (PImax) at residual volume (RV) as previously described by Black and Hyatt.[22] The best of three efforts was recorded.

Inspiratory muscle endurance. Inspiratory muscle endurance, was determined by using a device similar to that proposed by Nickerson and Keens.[23] Subjects inspired through a two-way Hans-Rudolph valve whose inspiratory port was connected to a chamber and plunger to which weights could be added externally. Inspiratory elastic work was then increased by the progressive addition of 25 to 100 gr weights at two-minute intervals, as previously described by Martyn and coworkers,[24] until the subjects were exhausted and could no longer inspire. The pressure achieved with the heaviest load (tolerated for at least 60 s) was defined as the peak pressure (PmPeak).

Perception of dyspnea. The sensation of dyspnea was measured while the subject breathed through a device similar to that proposed by Nickerson and Keens.[23] Subjects inspired through a two-way Hans-Rudolph valve whose inspiratory port was connected to a chamber and plunger to which weights could be added externally. The subjects breathed against progressive loads, at one-minute intervals, in order to achieve mouth pressure of 0 (no resistance), 5, 10, 20, and 30 cm H_2O. After breathing for one minute in each inspiratory load, in a protocol similar to the one that has been previously described by Kikuchi and coworkers,[25] the subjects were required to choose a number, using a modified Borg scale,[26] that represented the level of the perceived inspired difficulty in which 0 indicated no difficulty and 10 the maximum difficulty.

Quality of life. The QOL was assessed using the SF-36 questionnaire[27], before and following the training period.

Training protocol

The patients were randomized into two groups: ten patients were assigned to receive SIMT, and a group of ten patients were assigned to be a control group and received training with very low load. All the data was collected by the same collector who was blinded to the training group, as well as the patients themselves who were also blinded to the mode of treatment. All subjects trained daily, six times a week, each session consisting of 1/2 hour, for twelve weeks. The training was performed using an inspiratory muscle trainer (POWERbreathe®, Southam, Warwickshire, UK). The subjects in the SIMT group started breathing at a resistance equal to 15% of their PImax for one week. The resistance was then increased incrementally, 5%-10% each session, to reach 60% of their PImax at the end of the first month. Specific inspiratory muscle training was then continued at 60% of their PImax adjusted monthly to the new PImax achieved. The control group trained with "low load" (fixed resistance of 7 cm H_2O).

The mean±SEM compliance to the training sessions was 65.5±9.8% (Table). Patients with compliance to training sessions of less than a third were eliminated from the data analysis.

Data analysis

The results are expressed as means±SEM. Correlations were assessed by calculating Spearman correlation coefficients. Comparisons of lung function, the inspiratory muscle strength and endurance, the POD, QOL, between the groups and before and following training were carried out using the the Anova two-way repeated measures analysis of variance.

Results

Spirometry. The mean±SEM forced vital capacity (FVC) was 2.7±0.4L (81% of predicted normal values) in the training group and 2.4±0.4L (77% of predicted normal values) in the control group and the mean±SEM FEV_1 was 2.1±0.3L (82% of predicted normal values) in the training group and 1.9±0.3L (83% of predicted normal values) in the control group. Following the training period there was no significant change in the two prameters in both groups.

Inspiratory muscle strength endurance. The mean inspiratory muscle strength, as was assessed by the PImax, and endurance, as was assessed by the PmPeak, were 62.0±8.2 (56% of predicted normal values) and 20.0±2.8 cm H_2O, respectively, in the training group, and 51.0±8. and 18.2±2.3 cm H_2O, respectively, in the control group. Following the training period there was a significant increase in the PImax and PmPeak in the training group (to 78.0±7.5 and 29.1±3.0 cm H_2O, respectively, $p<0.05$) but not in the control group (Figure 1).

Perception of dyspnea. Following training the POD was significantly decreased in the training group but not in the control group. The decrease was statistically significant at 10 ($p<0.05$), 20 ($p<0.01$) and 30 cm H_2O ($p<0.01$) (Figure 2).

There was no significant difference in the dyspnea index (the sum of all Borg scores in the 0, 5, 10, 20, and 30 cm H_2O loads) between the groups. Following training there was a significant decrease in the dyspnea index in the training group (from 17.9±3.2 to 14.0±2.4 Borg scale, $p<0.05$) but not in the control group.

There was a close correlation between the improvement in the

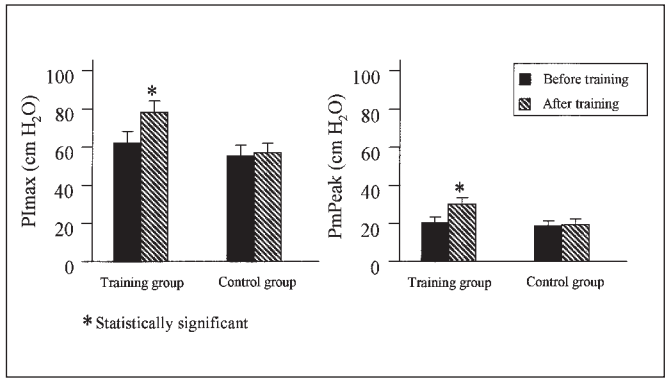

Figure 1: *Mean (±SEM) inspiratory muscle strength and inspiratory muscle endurance before and following training, in the training and in the control group.*

https://doi.org/10.1017/S0317167100003991

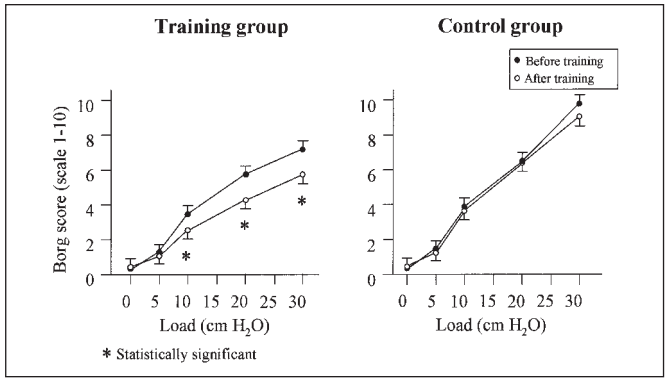

Figure 2: *The perception of dyspnea as was measured while the patient inspired against incremental load before and following training, in the training and in the control group.*

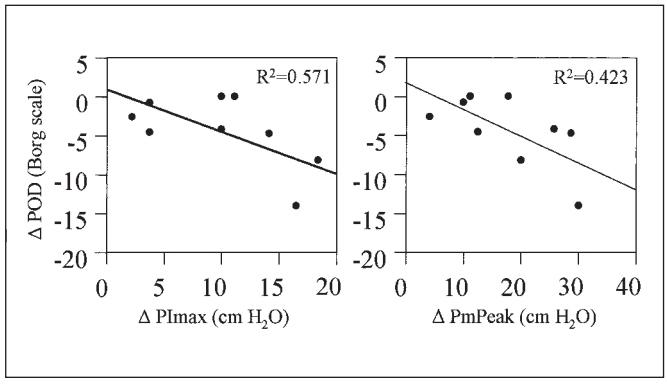

Figure 3: *The correlation between the increase in the inspiratory muscle strength (left) and endurance (right), and the decrease in the perception of dyspnea before and following training, in the training and in the control group.*

inspiratory muscle strength and endurance, and the decrease in the dyspnea index in the training group (R^2=0.571 and R^2=0.423, p<0.001, respectively) (Figure 3).

Quality of life. There was no significant change in the QOL as was assessed by the questionnaire in either group.

Discussion

We have showed that, in patients with PD, the inspiratory muscle strength and endurance may be improved by SIMT. This improvement in the inspiratory muscle performance is associated with a significant decrease in their POD.

The effects of PD on respiration are still debated. Most reports of pulmonary function abnormalities in PD predate the era of L-dopa therapy which revolutionized the treatment of this disorder. Many investigators emphasized the presence of a restrictive pattern of impairment in PD,[3,27] and reported improvement of the impairment following treatment with L-dopa. In a previous study we have shown that treatment with L-dopa results in a decrease in the POD, although it remains higher than in normal subjects. Since pulmonary function and performance was not altered by treatment, L-dopa may improve POD by correcting either central drive or thoracic and abdominal muscle coordination. Others have reported that a high percentage of PD patients present either upper or lower airway obstruction.[7] In all, mean airway resistance was in the normal range.[2]

Although respiratory abnormalities are common in PD, dyspnea is not a frequent complaint suggesting that PD patients have a decreased perception of dyspnea. Alternatively, it may be that most patients probably do not report dyspnea, because their physical disability does not lead to activities where such problems can manifest themselves. Most of our patients had a mild restrictive pattern of pulmonary function with no significant inspiratory or expiratory flow limitation.

It was previously reported that the inspiratory muscle strength, as well as the inspiratory muscle endurance, are decreased in patients with PD.[7,10] However, when the respiratory muscle strength was assessed with nonvolitional tests, it was clearly shown that both inspiratory and expiratory muscle strength were entirely normal.[28]

Dyspnea was recently defined by the Medical Section of the American Lung Association as "subjective experience of breathing discomfort that consists of qualitatively distinct sensations that vary in intensity".[17] The pathophysiology of dyspnea is not completely understood. An attractive theory is that dyspnea results from a mismatch between central respiratory motor activity and incoming afferent information from receptors in the airway, lungs, respiratory muscles and chest wall structures.[18,19] This phenomenon may be similar to the sensory-motor mismatch observed in the function of limb muscles in PD. The POD is an attribution process that incorporates the way in which an individual identifies and evaluates the symptoms and makes interpretations about their causes and consequences. The significant improvement in the POD in our patients following treatment with L-dopa cannot be explained by improvement of pulmonary function or respiratory muscles and is possibly due to a central effect.

It is well-documented that the inspiratory muscles can be successfully trained.[29-31] There is some evidence that SIMT leads to a decrease in the intensity of dyspnea. Harver and colleagues[32] and Kim and colleagues[33] showed a consistent improvement in dyspnea indices and fewer symptoms of dyspnea, in patients with chronic obstructive pulmonary disease, following SIMT.

It was previously shown that the inspiratory muscles can be successfully trained also in multiple sclerosis.[34] However, the present study is the first to report successful SIMT in patients with PD.

In conclusion, we have shown that in PD patients the inspiratory muscles can be successfully trained with an increase in the inspiratory muscle strength and endurance. This improvement is associated with a significant decrease in their POD. Whether this improvement in the POD will translate to improvement in exercise tolerance and daily activities should be investigated in the future.

Acknowledgements

There is no financial relationship between the authors and the producers of "POWERbreathe®".

https://doi.org/10.1017/S0317167100003991

References

1. Marsden CD. Parkinson's disease. J Neurol Neurosurg Psychiatry 1994; 57:672-681.
2. Obenour WH, Stevens PM, Cohen AA, et al. The causes of abnormal pulmonary function in Parkinson's disease. Am Rev Respir Dis 1972; 105:382-387.
3. Lilker ES, Woolf CR. Pulmonary function in Parkinson's syndrome: the effect of thalamotomy. Can Med Assoc J 1968; 99:752-757.
4. Vincken WG, Gauthier SG, Dollfuss RE, et al. Involvement of upper-airway muscles in extrapyramidal disorders: a cause of airflow limitation. N Engl J Med 1984; 311:438-442.
5. Sabate M, Rodriguez M, Mendez E, et al. Obstructive and restrictive pulmonary dysfunction increases disability in Parkinson's disease. Arch Phys Med Rehabil 1996; 77:29-34.
6. Tzelepis GE, McCool FD, Fridman JH, et al. Respiratory muscle dysfunction in Parkinson's disease. Am Rev Respir Dis 1988; 138:266-271.
7. Estenne M, Hubert M, DeTroyer A. Respiratory muscle involvement in Parkinson's disease. N Engl J Med 1984; 311:1516.
8. De Bruin FFC, De Bruin VMS, Lees AJ, et al. Effects of treatment on airway dynamics and respiratory muscle strength in Parkinson's disease. Am Rev Respir Dis 1993; 148:1576-1580.
9. Neu HC, Connolly JJ, Schwertley FW, et al. Obstructive respiratory dysfunction in parkinsonian patients. Am Rev Respir Dis 1967; 95:33-47.
10. Ebmeier KP, Calder SA, Crawford JR, et al. Mortality and causes of death in idiopathic Parkinson's disease: results from the Aberdeen whole population study. Scott Med J 1990; 35:173-175.
11. Saltin B, Landin S. Work capacity, muscle strength and SDH activity in both legs of hemiparetic patients and patients with Parkinson's disease. Scand J Clin Lab Invest 1975; 35:531-538.
12. Carter JH, Nutt JG, Woodward WR. The effect of exercise on levodopa absorption. Neurology 1992; 42:2042-2045.
13. Weiner P, Inzelberg R, Davidovich A, et al. Respiratory muscle performance and the perception of dyspnea in Parkinson's disease. Can J Neurol Sci 2002; 29:68-72.
14. Killian KG, Campbell EJM. Dyspnea and exercise. Ann Rev Physiol 1983; 445:465-479.
15. Killian KG, Jones NL. The use of exercise testing and other methods in the investigation of dyspnea. Clin Chest Med 1984; 5:99-108.
16. Killian KG, Gandevia SC, Summers E. Effect of increased lung volume on perception of breathlessness, effort, and tension. J Appl Physiol 1984; 57:686-691.
17. American Thoracic Society. Dyspnea. Mechanism, Assessment, and Management: A consensus statement. Am J Respir Crit Care Med 1999; 159:321-349.
18. Schwartzstein RM, Simon PM, Weiss JW, et al. Breathlessness induced by dissociation between ventilation and chemical drive. Am Rev Respir Dis 1989; 139:1231-1237.
19. Schwartzstein RM, Manning HL, Weiss JW, et al. Dyspnea: a sensory experience. Lung 1990; 168:185-199.
20. Flash T, Inzelberg R, Schechtman E, et al. Kinematic properties of upper limb trajectories in Parkinson's disease. Exp Neurol 1992; 118:215-226.
21. Hoehn MM, Yahr MD. Parkinsonism: onset, progression and mortality. Neurology 1967; 17:427-442.
22. Black LF, Hyatt RE. Maximal respiratory pressures: Normal values and relationship to age and sex. Am Rev Respir Dis 1969; 99:696-702.
23. Nickerson BG, Keens TG. Measuring ventilatory muscle endurance in humans as sustainable inspiratory pressure. J Appl Physiol 1982; 52:768-772.
24. Martyn JB, Moreno RH, Pare PD, et al. Measurement of inspiratory muscle performance with incremental threshold loading. Am Rev Respir Dis 1987; 135:919-923.
25. Kikuchi Y, Okabe S, Tamura G, et al. Chemosensitivity and perception of dyspnea in patients with a history of near-fatal asthma. N Engl J Med 1994;330:1329-1334.
26. el-Manshawi A, Killian KJ, Summers E, et al. Breathlessness during exercise with and without resistive load. J Appl Physiol 1986; 61:896-905.
27. Ware JEJr, Sherbourne CD. The MOS36-item short form healthysurvey (SF-36): 1Conceptual framework and item selection. Med Care 1992; 30:473-483
28. Paulson GD, Tarfrate RH. Some "minor" aspects of parkinsonism, especially pulmonary function. Neurology 1970; 20(2):14-19.
29. Lyall RA, Reuter I, Mills J, et al. Effects of acute subcutaneous apomorphine on respiratory muscle strength in Parkinson's disease. Move Disord 1998; 13(suppl 2):148.
30. Marin JM, De Oca MM, Rassulo J, et al. Ventilatory drive at rest and perception of exertional dyspnea in severe COPD. Chest 1999; 115:1293-1300.
31. Pardy RL, Leith DE. Ventilatory muscle training. Res Care 1984; 29:278-284.
32. Shaffer TH, Wolfson MR, Bhutani VK. Respiratory muscle function, assessment, and training. Phys Ther 1981; 61(12):1711-1723.
33. Harver A, Mahler DA, Daubenspeck J. Targeted inspiratory muscle training improves respiratory muscle function and reduces dyspnea in chronic obstructive pulmonary disease. Ann Intern Med 1989; 111:117-124.
34. Kim A, Larsen J, Covey M, et al. Inspiratory muscle training in patients with chronic obstructive pulmonary disease. Nurs Res 1993; 42:356-362.
35. Gosselnik R, Kovacs L, Ketelear P, et al. Respiratory muscle weakness and respiratory muscle training in severely disabled multiple sclerosis patients. Arch Phys Med Rehabil 2000; 81:741-751.