ISSN 1413-3555
Rev Bras Fisioter, São Carlos, v. 14, n. 6, p. 470-6, Nov./Dec. 2010

Relationship between cough strength and functional level in elderly

Relação entre força de tosse e nível funcional em um grupo de idosos

Fábia S. Freitas[1], Cássio C. Ibiapina[2], Cristina G. Alvim[2], Raquel R. Britto[3], Verônica F. Parreira[3]

Abstract

Background: Respiratory muscle strength is influenced by aging. **Objectives:** To assess, in a healthy elderly population, the influence of physical activity and functional performance on the pulmonary function parameters, on respiratory muscle strength and on coughing. **Methods:** Observation study that sixty one elderly with age equal or more than 60 years (72.3±7.2 years), with normal spirometry were included. Maximal Inspiratory Pressure (MIP), Maximal Expiratory Pressure (MEP), Peak Expiratory Flow (PEF), Peak Cough Flow (PCF) and Human Activity Profile (HAP) were evaluated. The elderly were separated in two groups (active and moderately active) according to HAP. Student`s test was used for univariate analysis and regression analysis models was used for multivariate analysis. **Results:** Elderly participants who were classified as active presented on average 13.5 cmH_2O higher MEP (88±21.4 cmH_2O), and 16.2 cmH_2O higher MIP (76±17.7 cmH_2O). Maximal respiratory pressure decreases 1 cmH_2O per year. The PEF and PCF were higher for male ($p<0.001$) and active elderly ($p=0.046$ e $p=0.004$ respectively). A positive correlation was observed between HAP and the following variables: MEP MIP and PCF ($r=0.527$, $p<0.001$; $r=0.498$, $p<0.001$ and $r=0.365$, $p=0.004$, respectively). **Conclusions:** The active life style can positively affect the respiratory muscle strength and PCF values. Aging is associated to respiratory muscle strength reduction (both inspiratory and expiratory). Women showed lower PEmax.

Key words: aging; physiopathology; cough; muscle strength; physiology; elderly.

Resumo

Contextualização: A força muscular respiratória é influenciada pelo envelhecimento. **Objetivos:** Avaliar, em uma população de idosos saudáveis, a influência da atividade física e do nível funcional sobre parâmetros da função pulmonar, sobre a força da musculatura respiratória e sobre a tosse. **Métodos:** Estudo observacional em que foram incluídos 61 idosos com idade igual ou superior a 60 anos (72,3±7,2 anos), com espirometria normal. Foram avaliados: pressão inspiratória máxima (PImax), pressão expiratória máxima (PEmax), pico de fluxo expiratório (PFE), pico de fluxo da tosse (PFT) e perfil de atividade humana (PAH). Os idosos foram divididos em dois grupos (ativo e moderadamente ativo) classificados conforme o PAH. Utilizou-se o teste *t de Student* nas análises univariadas e foram desenvolvidos modelos de regressão linear nas análises multivariadas. **Resultados:** Os idosos ativos apresentaram, em média, 13,5 cmH_2O a mais no valor da PEmax (88±21,4 cmH_2O) e 16,2 cmH_2O na PImax (76±17,7 cmH_2O), ocorrendo queda, em média, de 1 cmH_2O a cada ano nessas variáveis. O PFE e o PFT foram maiores nos idosos do sexo masculino ($p<0,001$ para ambos) e nos ativos ($p=0,046$ e $p=0,004$; respectivamente). Observou-se correlação positiva entre PAH e as seguintes variáveis: PEmax, PImax e PFT ($r=0,527$, $p<0,001$; $r=0,498$, $p<0,001$ e $r=0,365$, $p=0,004$ respectivamente). **Conclusões:** O estilo de vida mais ativo pode influenciar de forma positiva, relacionando-se com maior força da musculatura respiratória e valores do PFT. O aumento da idade está relacionado com a redução da força muscular inspiratória e expiratória. As mulheres apresentaram menor PEmax.

Palavras-chave: envelhecimento; fisiopatologia; tosse; força muscular; fisiologia; idoso.

Received: 08/06/2009 – **Revised:** 03/12/2009 – **Accepted:** 22/06/2010

[1] Physical Therapy Department, Pontifícia Universidade Católica de Minas Gerais (PUC Minas), Belo Horizonte (MG), Brazil
[2] Department of Pediatrics, Faculty of Medicine, Universidade Federal de Minas Gerais (UFMG), Belo Horizonte (MG), Brazil
[3] Physical Therapy Department, School of Physical Education, Physical Therapy and Occupational Therapy, UFMG
Correspondence to: Verônica Franco Parreira, Departamento de Fisioterapia, EEFFTO, Av. Presidente Antônio Carlos, 6627, Pampulha, CEP 31.270-901, Belo Horizonte (MG), Brasil,
e-mail: veronicaparreira@yahoo.com.br

Introduction

The aging process promotes a series of organism modifications, especially changes in the respiratory system[1] such as the reduction of the total lung capacity (TLC), the forced expiratory volume in one second (FEV_1) and the forced expiratory flow (FEF), as well as increases the functional residual capacity (FRC) and the expiratory reserve volume (ERV). These changes are related to decrease both lung elastic recoil and the thoracic complacency capacity[2,3]. Such alterations when associated with a reduction of muscle strength can lead to a reduced peak expiratory flow (PEF)[2,4]. On the other hand, Britto et al.[5] have found no significant differences in relation to the variables volume and timing of the breathing pattern when comparing adults with elderly.

In the musculoskeletal system, there is a reduction in respiratory muscle strength with the aging process[3,6-8]. Tolep et al.[9] observed a reduction of up to 25% of the diaphragm strength in elderly compared to young adults. Moreover, Caskey et al.[10] found a higher prevalence of diaphragm alterations in the elderly when assessing 120 chest and abdominal computed tomography scans.

Tolep et al.[11] described that there is skeletal muscle atrophy with aging, which affects mostly type II fibers (fast twitch fibers). Several factors are associated with this statement, such as a reduction of physical activity, alterations of neuromuscular function, nutritional state and hormonal factors[12]. The reduction of the respiratory muscle strength may affect its ventilatory and non-ventilatory functions, being the latter related to coughing, speeching and swallowing[13].

Cough is an important defense mechanism of the bronchial tree[14-16] that relies on the capacity to generate flow and speed in the airway[17] and it is directly related to respiratory muscle strength[18]. The muscle weakness and the alterations in the pulmonary parenchyma that are observed in the aging process can affect the ability to generate a satisfactory airflow for coughing, decreasing its efficacy and increasing the risk of developing acute respiratory tract infection. According to Salam et al.[18], peak cough flow (PCF) is the most reliable way to evaluate cough strength and recently it has been used frequently to assess patients with neuromuscular diseases. Smina et al.[19], observed that cough strength is a strong predictor of successful extubation outcome of patients without neuromuscular diseases, being also a good predictor of hospital mortality.

McConnell and Copestake[4] in 1999 and more recently Watsford et al.[8] attempted to determine the influence of physical activity on respiratory muscle strength and they found that physical activity has an important role for maintaining both inspiratory and expiratory muscle strength. Therefore, regular physical activity could indirectly improve the airway defense mechanisms since gaining strength could contribute to increase the effectiveness of cough.

The assessment of respiratory muscle strength measured by maximal respiratory pressures is an important tool in the daily routine of the respiratory physical therapist. The cough strength evaluation has been poorer explored in the assessment of patients. Therefore, the objective of this study was to assess the influence of physical activity and functional level on pulmonary function parameters, respiratory muscle strength and cough in a sample of healthy elderly.

Methods

Sample

The study sample consisted of 61 elderly (14 males and 47 females) aged equal to or greater than 60 years (mean age = 72±7.2 years) who were recruited in community centers. This study was approved by the Research Ethics Committe of the Instituto de Previdência dos Servidores do Estado de Minas Gerais (IPSEMG)/Hospital Governador Israel Pinheiro, Belo Horizonte (MG), Brazil (CEP 257/07), and all participants gave written informed consent.

The inclusion criterion was age equal to or greater than 60 years. The exclusion criteria were: recent thoracic or abdominal surgery; thoracic pain of surgical origin; pulmonary disease reported by the participant and/or obstructive, restrictive or mixed ventilatory disturbance observed by spirometry; neurological diseases that would undermine the accomplishment of the tests, and difficulty to understand and/or to perform the tests.

Study protocol

Subjects initially responded to a questionnaire adapted from the American Thoracic Society (ATS)[20] to evaluate the presence of chronic obstructive pulmonary disease (COPD), asthma or other pulmonary diseases, and those without pulmonary symptoms performed spirometry. Later, the participants responded the Human Activity Profile (HAP) that is a questionnaire used to assess the level of physical activity[21], and performed tests for respiratory muscle strength, peak expiratory flow (PEF) and peak cough flow (PCF). A minimum rest time of one minute was given between the tests, being the rest longer if needed by the participants.

Procedure

- **Spirometry:** The protocol to perform the test followed the 2002 Guidelines for Pulmonary Function Tests[2]. The SBG- SDI Diagnostics Spirometer (Easton, Missouri-USA) was the selected instrument.
- **Assessment of regular physical activity:** According to the Brazilian Society of Cardiology, subjects who informed that they performed physical activity (i.e. swimming, walking, jogging, aerobics, cycling) for at least 30 minutes three times a week were classified as "physically active (PA)", and those who performed physical activity with a lower duration and frequency were classified as "physically inactive" (PI)[23].
- **Assessment of functional level:** Functional level was assessed using the HAP questionnaire, which is recommended to evaluate the level of functional ability in both healthy individuals and those with some degree of impairment, at any age group. This questionnaire was translated and validated for the Brazilian population in a study that evaluated 230 functionally independent elderly[24]. The HAP investigates the ability to perform routine activities, ranging from low to high functional level. The adjusted activity score (AAS) can be used in a qualitative way, by classifying the individual as inactive (AAS<53), moderately active (AAS 53 –74) and active (AAS>74)[24].
- **Assessment of respiratory muscle strength:** The measurement of the maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) were used to assess the inspiratory and expiratory muscle strength respectively. The measurements were obtained through a portable manometer device (Wika - São Paulo, SP, Brazil), with operating range from -300 to +300 cmH_2O.

The MIP was performed from the residual volume, and the MEP was performed from the total lung capacity. Participants were in a sitting position with feet supported, using a nose clip and exerting pressure on the lips to prevent air leakage around the mouthpiece. They were instructed to breathe through the mouthpiece, inhaling (MIP) or exhaling (MEP) with as much effort and as fast as possible for at least one second. They performed each measure at least five times until three acceptable and reproducible ones were obtained, that is, with no leakage and with a difference between the measures of less than 10%[25]. All measures were taken by the same examiner.

- **Assessment of peak expiratory flow and peak cough flow:** The Mini-Wright Peak Expiratory Flow Meter (*Clement Clarke, Harlow, England*), with a scale ranging from zero to 900 L/min, was used for these measurements.

Subjects performed at least three measures that, when necessary, were repeated until three values with a maximum difference between them of 20 L/min were obtained[22]. The highest value was recorded. The PEF was obtained from a maximal inspiration followed by a rapid and vigorous exhalation, which could not be accompanied by coughing or exhalation prolonged for more than two seconds[22]. The PCF was obtained from a maximum inspiration followed by the most vigorous cough possible for the subject[26].

Statistical analysis

The Student's t test was used to compare the outcome variables and the categorical covariates, which met the criteria for normality and homocedasticity. The Pearson Correlation Coefficient (r) was calculated to compare the outcome variables with the quantitative covariates[27]. The level of significance adopted for the analysis was of 5%.

The AAS variable was analyzed using both quantitative and qualitative methods. Linear regression models were developed for each quantitative outcome variables of the study. Initially, all variables that presented at least a trend for statistical significance (p≤0.25) in the univariate analysis was included in the multivariate model. Then, the variables were excluded from the model by stepwise elimination until the final model presented only the variables that achieved statistical significance (p≤0.05), but also considering their clinical relevance. Further, all interactions between variables that were present in the final regression model were tested. Only the models that had at least one of the variables at a significance level of 5% were adjusted.

Results

Eighty-seven elderly were included in the study. According to the inclusion criterion, those who were aged 60 years or older were selected for the study. According to the exclusion criteria, 26 subjects were excluded (16 for presenting changes in the pulmonary function on spirometry, eight for being unable to understand and/or to perform the pulmonary function test and two for presenting thoracic pain during the tests). Therefore, 61 elderly were assessed (30 active and 31 moderately active). Among them, 35 subjects were classified as PA and 26 as PI. A total of 88.5% of participants reported that have never smoked and 7% were former smokers. Only one subject was illiterate, 31% had complete elementary education, 39% were high school graduates and 11.5% had a university degree.

Table 1 shows data related to age, body mass index (BMI) and FVC, FEV_1, $FEF_{25-75\%}$ values for the final sample of 61 elderly.

Maximum expiratory pressure and maximum inspiratory pressure

Table 2 shows the comparisons between MEP and MIP mean values and the variables gender, AAS and physical activity. In relation to MEP, there was a significant difference between men and women (90.0 and 74.9 cmH_2O respectively, p=0.001), being men having a higher MEP than women. Subjects who were considered active by the AAS also showed higher MEP (p=0.025). For MIP, the only statistically significant difference was that the active subjects showed higher MIP than the moderately active ones (p<0.001). Regarding the reporting of participants on whether they were physically active or not, no significantly between-group difference was found for MEP or MIP (p=0.175 and p=0.990, respectively).

A moderate and positive correlation was observed between MEP and quantitative AAS (r=0.527, p<0.001). A weak and negative correlation was found between MIP and age (r=-0.359, p=0.005), and the correlation found between MIP and AAS was moderate and positive (r=0.498, p<0.001).

Table 3 shows data related to the regression analysis that demonstrated that MEP is, on average, 17.2 cmH_2O higher in men than in women, and 13.5 cmH_2O higher in participants who were classified as active by the AAS. MIP was on average 16.2 cmH_2O higher in active participants. The regression coefficients found for age were -1 and -0,8 for MEP and MIP, respectively, demonstrating a reduction of approximately 1 cmH_2O for both MEP and MIP in each year.

Peak expiratory flow and peak cough flow

PEF was higher in active than in moderately active elderly, and higher in men than in women (Table 2, p=0.046 and p=0.001, respectively). The linear regression model demonstrated that men showed, on average, 139.5 L/min higher than women.

When comparing PCF with the other variables, a statistically significant difference was found for gender and AAS, with a higher PCF for males (P<0.001) as well as for active participants (p=0.004, Table 2). The correlation coefficient demonstrated a weak and positive correlation between PCF and AAS (r=0.365 and p=0.004). The linear regression analysis demonstrated that men showed on average 113 L/min higher than women, and that active elderly showed on average 43 L/min higher than in moderately active participants (Table 3).

No statistically significant difference was found between PA and PI groups for PEF and PCF values (p=0.175 and p=0.117, respectively).

Table 1. Characteristics of 61 elderly participants.

	N	Mean	SD	Minimum	Maximum
Age (year)	61	72.3	7.2	60.0	90.0
AAS	61	73.5	9.7	53.0	90.0
BMI (Kg/m2)	61	24.9	4.2	14.3	38.9
FVC (% predicted)	61	94.9	8.2	56.1	116.8
FEV1 (% predicted)	61	98.7	9.3	85.8	139.7
FEF25-75% (% predicted)	61	99.3	22.7	74.6	165.9

SD=standard deviation; AAS=adjusted activity score; BMI=body mass index; FVC=forced vital capacity; FEV1=forced expiratory volume in one second; FEF25-75%=forced expiratory flow between 25 and 75% of FVC.

Table 2. Comparison among maximum respiratory pressures (MEP and MIP), peak expiratory flow and peak cough flow and qualitative co-variables.

Covariate		Gender		AAS		Physical Activity	
		Females	Males	Active	Moderately Active	PI	PA
MEP	Mean	74.9	90.0	88.0	69.0	73.9	81.7
	SD	18.9	29.1	21.4	19.2	19.4	24.0
	P	0.001*		0.025*		0.175	
MIP	Mean	66.0	70.0	76.0	58.1	66.9	66.9
	SD	18.1	24.5	17.7	17.4	17.8	21.1
	P	0.503		<0.001*		0.990	
PEF	Mean	323.4	462.9	377.3	334.2	331.2	373.4
	SD	45.7	110.8	94.6	76.8	60.4	101.1
	P	0,001*		0.046*		0.175	
PCF	Mean	309.2	434.3	371.3	305.5	316.5	353.7
	SD	61.3	111.1	101.6	67.4	69.9	102.8
	P	0.001*		0.004*		0.117	

SD=standard deviation; MEP=maximum expiratory pressure; MIP=maximum inspiratory pressure; PEF=peak expiratory flow; PCF=peak cough flow; AAS=adjusted activity score: PA=physically active; PI=physically inactive; *=Student's t test.

Table 3. Linear regression model for maximum respiratory pressures (MEP and MIP), peak expiratory flow and peak cough flow.

Co-variate		Constant	Gender		AAS		Age (years)
			Males	Females	Active	Moderately Active	
MEP	Coefficient	136.7	17.2		13.5		-1.0
	SE	27.9	6.6		5.2		0.4
	P	<0.001	0.012		0.013		0.016
MIP	Coefficient	117.7	---	---	16.2		-0.8
	SE	22.3	---	---	4.3		0.3
	P	<0.001	---	---	<0.001		0.010
PCF	Coefficient	290.9	112.8		42.8		---
	SE	13.4	22.8		19.2		---
	P	<0.001	<0.001		0.030		---
PEP	Coefficient	323,4	139.5		---	---	---
	SE	20	9.6		---	---	---
	P	<0.001	<0.001		---	---	---

MEP=maximum expiratory pressure; MIP=maximum inspiratory pressure; PEF=peak expiratory flow; PCF=peak cough flow; AAS=adjusted activity score; SE=standard error, p=significance level. ---:= no between-variable statistically significance differences.

Discussion

The present study evaluated the PCF, PEF, MIP and MEP in elderly classified as moderately active or active by the HAP, aiming to verify if the functional level is associated with those variables. Functional level can be defined as the ability of the individual to perform routine activities with varied levels of complexity and energy expenditure. Among this type of activity are the activities of daily living, leisure and sport[21]. To our knowledge, this is the first study that addressed this matter.

The main result of this study was the presence of a positive correlation between AAS, MEP and MIP (r=0.527, p<0.001, r=0.498, p<0.001, respectively). However, no statistically significant difference was observed for the respiratory muscle strength measurement between elderly who did and those who did not perform regular physical activity. These findings suggest that the ability to perform more complex activities of daily living that involve more energy requirement has an important role in respiratory muscle strength.

In relation to PEF and PCF, the highest values were found for males and for active elderly. This result can be related to the fact that contracting the expiratory muscle is an important phase for coughing, and in our sample male and active elderly showed greater values of expiratory muscle strength than women and moderately active elderly.

Several studies have demonstrated a negative correlation between respiratory muscle strength and variables that are modified by aging[3-6,9,25,28-31]. This study found a negative correlation between age and MIP (r=-0.359, p=0.005), and a reduction of approximately 1 cmH_2O per year on MEP and MIP (regression coefficient = -1 cmH_2O and -0.8 cmH_2O, respectively) in the study sample. Moreover, men also showed higher MEP and MIP than women (on average, 16.2 cmH_2O and 17.2 cmH_2O more, respectively). These findings were similar to the ones found in a multicenter study conducted by Enright et al.[29] in 1994, who assessed 4443 elderly aged 65 years and over and found a decrease in respiratory muscle strength from 0.8 to 2.7 cmH_2O per year, being this loss more important in women.

Some studies have evaluated the influence of physical activity or fitness in pulmonary function and respiratory muscle strength. Cook et al.[2] investigated the correlation between functional ability and physical activity, by means of the Katz scale and a specific questionnaire developed for the study, and PEF in 2250 subjects aged 65 years and over. They concluded that individuals who were capable of performing their activities of daily living had higher PEF rates (p<0.0001), in the same way as those who performed regular physical activity (p<0.0001).

In 1999, McConnell and Copestake[4] calculated the energy expended by elderly subjects during a four-week period based on a guided diary. The authors found significant correlation between physical activity and MEP and MIP (r=0.67; p=0.032 and r=0.87; p=0.001, respectively).

A sedentary lifestyle combined with the aging process may exacerbate the reduction in both inspiratory and expiratory muscle strength, leading to a reduction in intrathoracic pressure and expiratory flow during cough[32]. In 2005, Watsford et al.[8] evaluated 77 subjects aged over 64 years that were classified as active or inactive. Active participants showed MIP and MEP 14 and 25% higher than inactive participants, respectively. The authors also showed a positive correlation between respiratory muscle strength and maximal oxygen intake (VO_{2max}) in both men (MIP r=0.39: p<0.05 and MEP r=0.50; p<0.05) and women (MIP r=0.54; p<0.05 and MEP r=0.59; p<0.05). Vasconcellos et al.[33] also found that MIP and distance walked in the 6 minute walk test were correlated (r=0.44; p=0.005) in elderly women.

As for PCF, this variable is very similar to PEF, being the primary difference between them the closure of the glottis during PCF[34]. The investigation of PCF is a relatively recent measurement tool that has been used to assess the severity of cases, the risk of pulmonary complications and also as a predictor of successful extubation or decannulation, mainly of patients with neuromuscular diseases[18,26,34]. Those without neuromuscular diseases who presented respiratory muscle weakness also benefit from this assessment as they are more susceptible to pulmonary complications. Kim, Davenport and Sapienza[32] published a study in 2008 that investigated the effect of a four-week expiratory muscle strengthening program on parameters of capsaicin (an active component of pepper) on the induced cough reflex in sedentary elderly. The authors reported an increase on MEP and PEF rates of cough, which was measured by pneumotachograph ($p<0.001$ for both variables).

Importantly, the fact that the assessment of the physical activity level relied solo on the information given by the participants is a limitation of this study. The procedures used to assess respiratory muscle strength and PEF and PCF variables are effort-dependent and require full cooperation of the participant that underwent the evaluation[35]; therefore, using the Mini-mental state examination could have contributed to select the participants from those in which the cognitive aspect could affect the understanding. Also, the level of and individual maximal effort during the tests could justify the differences found in each study. Once cough is commonly a reflex event, the best way to determine the effect of the respiratory muscle strength on it would be measuring their strength from a reflex cough[34]. Another limitation of the present study is the difference between the number of males and females that could have contributed to the absence of difference on MIP between men and women, which would be considered a type II error. However, this study did not aim to assess the influence of gender on cough strength, but the influence of physical activity and functional level on it.

In summary, our results demonstrated that aging is associated with a reduction in inspiratory and expiratory muscle strength. Moreover, the routine activities of living performed by the elderly can have a positive influence on maximum respiratory pressures and PCF. Thus, it seems that as important as maintaining a regular physical activity, such as mentioned in previous studies, is to include more complex tasks in daily life routine. New studies aiming to assess the same variables in inactive elderly classified by the HAP may give us a better understanding of the influence of the functional level and the physical activity on pulmonary function. Furthermore, this study highlights the relevance of PCF as an assessment tool very useful for respiratory physical therapists, and for designing both rehabilitation and prevention of complications programs.

References

1. Oskvig RM. Special problems in the elderly. Chest. 1999;115(Suppl 2):158S-64.
2. Cook NR, Evans DA, Scherr PA, Speizer FE, Vedal S, Branch LG, et al. Peak expiratory flow rate in an elderly population. Am J Epidemiol. 1989;130(1):66-78.
3. Janssens JP, Pache JC, Nocod LP. Physiological changes in respiratory function associated with ageing. Eur Respir J. 1999;13(1):197-205.
4. McConnell AK, Copestake AJ. Maximum static respiratory pressure in healthy elderly men and women: issues of reproducibility and interpretation. Respiration. 1999;66(3):251-8.
5. Britto RR, Vieira DSR, Rodrigues JM, Prado LF, Parreira VF. Comparação do padrão respiratório de adultos e idosos saudáveis. Rev Bras Fisioter. 2005;9(3):281-7.
6. Polkey MI, Harris ML, Hughes PD, Hamnegärd CH, Lyons D, Green M, et al. The contractile properties of the elderly human diaphragm. Am J Respir Crit Care Med. 1997;155(5):1560-4.
7. Chaudri MB, Liu C, Hubbard R, Jefferson D, Kinnear WJ. Relationship between supramaximal flow during cough and mortality in motor neurone disease. Eur Repir J. 2002;19(3):434-8.
8. Watsford ML, Murphy AJ, Pine MJ, Coutts AJ. The effect of habitual exercise on respiratory-muscle function in older adults. J Aging Phys Act. 2005;13(1):34-44.
9. Tolep K, Higgins N, Muza S, Criner G, Kelsen SG. Comparison of diaphragm strength between healthy adult elderly and young men. Am J Respir Crit Care Med. 1995;152(2):677-82.
10. Caskey CI, Zerhouni EA, Fishman EK, Rahmouni AD. Aging of the diaphragm: a CT study. Radiology. 1989;171(2):385-9.
11. Tolep K, Kelsen SG. Effect of aging on respiratory skeletal muscles. Clin Chest Med. 1993;14(3):363-78.
12. Kim J, Sapienza CM. Implications of expiratory muscle strength training for rehabilitation of the elderly: Tutorial. J Rehabil Res Dev. 2005;42(2):211-24.
13. Mizuno M. Human respiratory muscles: fibre morphology and capillary supply. Eur Respir J. 1991;4(5):587-601.
14. Mahajan RP, Sing RP, Murty GE, Aitkenhead AR. Relationship between expired lung volume, peak flow rate and peak velocity time a voluntary cough manoeuvre. Br J Anaesth. 1994;72(3):298-301.
15. Sivasothy P, Brown L, Smith I, Shneerson J. Effect of manually assisted cough and mechanical insufflation on cough flow of normal subjects, patients with chronic obstructive pulmonary disease (COPD), and patients with respiratory muscle weakness. Thorax. 2001;56(6):438-44.
16. Suleman M, Abaza KT, Gornall C, Kinnear WJ, Willis JS, Mahajan RP. The effect of a mechanical glottis on peak expiratory flow rate and time to peak flow during a peak expiratory flow manoeuvre: a study in normal subjects and patients with motor neurone disease. Anaesthesia. 2004;59(9):872-5.
17. McCool FD, Leith DE. Pathophysiology of cough. Clin Chest Med. 1987;8(2):189-95.
18. Salam A, Tilluckdharry L, Amoateng-Adjepong Y, Manthous CA. Neurologic status, cough, secretions and extubation outcomes. Intensive Care Med. 2004;30(7):1334-9.
19. Smina M, Salam A, Khamiees M, Gada P, Amoateng-Adjepong Y, Manthous CA. Cough peak flows and extubation outcomes. Chest. 2003;124(1):262-8.
20. Ferris BG. Epidemiology Standardization Project. II. Recommended respiratory disease questionnaires for use with adults and children in epidemiologic research. Am Rev Respir Dis. 1978;118(6):7-52.
21. Souza AC. Human Activity profile: Adaptação transcultural e análise das propriedades psicométricas [dissertação]. Belo Horizonte: Universidade Federal de Minas Gerais; 2004.
22. Pereira CAC, Neder JA. Diretrizes para testes de função pulmonar. J Bras Pneumol. 2002;28(Supl 3):1-80.

23. Sposito AC, Caramelli B, Fonseca FAH, Bertolami MC. IV Diretriz brasileira sobre dislipidemias e prevenção da aterosclerose Departamento de aterosclerose da Sociedade Brasileira de Cardiologia. Arq Bras Cardiol. 2007;88(Supl 1):2-19.

24. Souza AC, Magalhães LC, Teixeira-Salmela LF. Adaptação transcultural e análise das propriedades psicométricas da versão brasileira do Perfil de Atividade Humana. Cad Saúde Publ. 2006;22(12):2623-36.

25. Neder JA, Andreoni S, Lerario MC, Nery LE. Reference values for lung function tests. II. Maximal respiratory pressures and voluntary ventilation. Braz J Med Biol Res. 1999;32(6):719-27.

26. Bach JR, Gonçalves MR, Páez S, Winck JC, Leitão S, Abreu P. Expiratory flow maneuvers in patients with neuromuscular diseases. Am J Phys Med Rehabil. 2006;85(2):105-11.

27. Triola MF. Introdução à estatística. 9ª ed. Rio de Janeiro: LTC; 2005.

28. Chen HI, Kuo CS. Relationship between respiratory muscle function and age, sex, and other factors. J Appl Physiol. 1989;66(2):943-8.

29. Enright PL, Kronmal RA, Manolio TA, Schenker MB, Hyatt RE. Respiratory muscle strength in the elderly. Correlates and reference values. Cardiovascular Health Study Research Group. Am J Respir Crit Care Med. 1994;149(2 Pt 1):430-8.

30. Enright PL, Adams AB, Boyle PJ, Sherrill DL. Spirometry and maximal respiratory pressure references from healthy Minnesota 65- to 85-year-old women and men. Chest. 1995;108(3):663-9.

31. Watsford ML, Murphy AJ, Pine MJ. The effects of ageing on respiratory muscle function and performance in older adults. J Sci Med Sport. 2007;10(1):36-44.

32. Kim J, Davenport P, Sapienza C. Effect of expiratory muscle strength training on elderly cough function. Arch Gerontol Geriatr. 2009;48(3):361-6.

33. Vasconcellos JAC, Britto RR, Parreira VF, Cury AC, Ramiro SM. Pressões respiratórias máximas e capacidade funcional em idosas assintomáticas. Fisioter Mov. 2007;20(3):93-100.

34. Suárez AA, Pessolano FA, Monteiro SG, Ferreyra G, Capria ME, Mesa L, et al. Peak flow and peak cough flow in the evaluation of expiratory muscle weakness and bulbar impairment in patients with neuromuscular disease. Am J Phys Med Rehabil. 2002;81(7):506-11.

35. ATS/ERS. Statement on respiratory muscle testing. Am J Respir Crit Care Med. 2002;166(4):518-624.