นิพนธ์ต้นฉบับ ▪ Original Article

สมการทำนายการไหลของอากาศสูงสุดในการไอในผู้สูงอายุสุขภาพดี

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Predictive Equations for Peak Cough Flow in Healthy Senior Persons

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หลักการและวัตถุประสงค์: การวัดค่าการไหลสูงสุดของอากาศขณะไอ (peak cough flow; PCF) เป็นวิธีการที่วัดง่าย สะดวก และเป็นวิธีแบบไม่รุกรานเพื่อประเมินประสิทธิภาพการไอ อย่างไรนั้น ตัวแปรปัจจัยด้านกายภาพที่มีผลต่อการไหลของอากาศสูงสุดขณะไอยังไม่ได้มีคำอธิบายผลไว้ชัดเจน วัตถุประสงค์การศึกษาคือ เพื่อประเมินปัจจัยที่ส่งผลต่อการไหลของอากาศสูงสุดขณะไอ เพื่อนำไปสร้างสมการทำนายการไหลสูงสุดของอากาศในขณะไอในผู้สูงอายุสุขภาพดี

วิธีการศึกษา: ทำการศึกษาในผู้ที่มีสุขภาพดีจำนวน 130 ราย ประกอบด้วย เพศชาย 65 ราย และ เพศหญิง 65 ราย ประเมินการไหลสูงสุดของอากาศขณะไอโดยอาสาสมัครหายใจเข้าเต็มที่แล้วไอออกเร็ว แรงมากที่สุดผ่านเครื่อง peak flow meter ทำการวัดสามครั้ง แล้วเลือกค่าที่สูงที่สุด

ผลการศึกษา: เพศหญิงมีค่า PCF น้อยกว่าเพศชาย นอกจากนี้ค่า PCF มีความสัมพันธ์กับอายุ ส่วนสูง เส้นรอบเอว และน้ำหนักในทั้งสองเพศ สมการทำนายค่าการไหลของอากาศสูงสุดขณะไอ คือ $PCF_{ทั้งหมด}$ = 364.996 + [91.577 เพศ] – 3.772 อายุ] + [3.190 น้ำหนัก]. $PCF_{เพศชาย}$ = 440.178 - 4.060 x (อายุ) + 3.830 x (น้ำหนัก) (R^2=0.357, p=0.005) และ $PCF_{เพศหญิง}$ = 398.268 - 3.428 x (อายุ) + 2.127 x (น้ำหนัก) (R^2=0.231, p=0.006)

สรุป: ตัวแปรอายุและน้ำหนักเป็นปัจจัยร่วมมีผลต่อค่า PCF ซึ่งค่าที่ได้จากสมการอาจจะช่วยในการทำนายค่า PCF ในทางคลินิกสำหรับผู้สูงอายุสุขภาพดี

คำสำคัญ: การไอ, ค่าการไหลสูงสุดของอากาศในขณะไอ, ผู้สูงอายุ

Objective and objectives: Measurement of peak cough flow (PCF) is a simple, convenient and noninvasive method providing the indices of cough efficiency. However, physical factors that affecting PCF are not clearly determined. Therefore, the aim of this study was to analyze the factors contributing to PCF for establishing a set of regression equations for community-dwelling senior adults.

Method: One hundred and thirty healthy participants including 65 men and 65 women were recruited in this study. The PCF was performed by a quick, short, and most vigorous possible cough after a maximal inspiration on the peak flow meter. The highest values of those three measurements were recorded, individually.

Results: The PCF values were lower in women than in men. Moreover, the PCF was correlated with age, height, waist circumference, and weight in both genders. The predictive equations in men and women were as follow: $PCF_{(all\ subjects)}$ = 364.996 + [91.577 Gender] – 3.772 Age (year)] + [3.190 Weight (kg)], PCF_{men} = 440.178 - 4.060 x (age) + 3.830 x (weight) (R^2=0.357, P=0.005) and PCF_{women} = 398.268 - 3.428 x (age) + 2.127 x (weight) (R^2=0.231, p=0.006).

Conclusion: Age and weight factors are considered as covariates for PCF measurement. Furthermore, these equations could be used to calculate the predictive values of PCF for the healthy senior persons in clinical practice.

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Introduction

Cough is an important defensive mechanism with two basic functions including to keep the airway free of foreign elements and to expel secretions that are produced in excess or under pathological conditions. Cough can be initiated by a reflex or by voluntary[1]. The mechanical events of a cough consist of inspiratory, compression and expiratory[2]. It is a forced expulsive maneuver, usually against a closed glottis, which is associated with a characteristic sound [3]. Therefore, effective coughing depends on respiratory muscles strength, airway caliber, and larynx[4]. However, the incident of aspiration from chest infections and other respiratory complications may affect cough efficiently[5]. For example, respiratory and neuromuscular diseases induce respiratory muscles weakness, resulting in accumulation of secretions in the airways, leading to development of pneumonia, where tracheal intubation and tracheostomy may be required to relieve the airway obstruction[6]. Therefore, evaluating the cough capacity and exploring factor-relating to cough efficiency is necessary for implementation in clinic.

Currently, peak cough flow (PCF) testing has provided clinical data to identify common variations in the respiratory muscles function in clinical practice and research. The test is a simple, quick and non-invasive procedure and widely used for measuring voluntary cough intensity[1]. In addition, it has been shown that the measurement from PCF is reliable and reproducible[1,2]. Moreover, the outcome of the test can be used as indicative to determine cough effectiveness[7].

There are several factors such as demographics and anthropometrics that influence cough capacity in healthy individuals, and in patients with neuromuscular disease. Previous studies found that cough strength decreased with age in both genders[8], but men had PCF higher than women[9,10]. In addition, Bianchi and Baiardi demonstrated that gender, height, and body mass surface were significantly correlated with PCF, ($p<0.001$) in both men and women[11]. Moreover, Yawata and colleagues have found that gender was a factor influences the voluntary cough intensity in community-dwelling adults[9]. However, there have been only few studied which have investigated the relationship between the characteristics of individuals, especially in senior people and PCF. Moreover, the equations to predict the PCF in adult persons have been reported in the Japanese[9]. However, the predictive equations in Thai population have not yet been established, particularly in elderly people where their respiratory function may be compromised. Therefore, this study aimed to identify factors contributing to PCF and to establish the predictive equations for Thai senior adults.

Methods

Participants

Community-dwelling individuals aged 55-85 years participated in this cross-sectional study. All participants recruited in the study were able to understand and follow verbal instruction and had peak expiratory flow rate (PEFR) greater than 80% of predicted values. Subjects who had history or clinical evidence of respiratory or cardiovascular, neurovascular disease or abnormal chest wall, and who were current smoker, or occupational exposure to environmental hazard, were excluded from this study. Sample size was determined using a power analysis program for statistical tests (G*Power 3.1.9.2); given an alpha of 0.05, power of test 0.95 and an effect size of 0.15, the desired sample size was 130. This study was approved by the Human Research Ethics Committee, University of Phayao (No.2/03/2016). The informed consent were obtained from all participants.

The eligible subjects were interviewed for their demographics including age, gender, height, weight, waist circumference, vital sign, underlying diseases and assessed for PEFR and PCF.

PEFR measurement

The PEFR was evaluated by using Mini–Wright Peak Flow Meter (Clement Clarke, Harlow, England). The testing was performed in sitting position on a chair with no armrest. The PEFR was measured as a rate of vigorous exhalation after a maximal inspiration, which was not accompanied by coughing or exhalation prolonged for more than two seconds. Three measurements were performed, with the highest value was used in analysis[12].

PCF measurement

The PCF, an indicator of cough capacity, was measured by Mini–Wright Peak Flow Meter (Clement Clarke, Harlow, England). The testing was performed in sitting position on a chair with no armrest. The participants were seated and asked to perform a voluntary cough by a quick, short and most vigorous cough using the peak flow meter. Measurements of cough were performed three times and the highest value was recorded [9, 10.]

Statistical analysis

The descriptive statistics were applied to describe demographics data and findings of the study. The comparisons of characteristics of subjects and PCF between men and women were performed by student's t test. The correlation between PCF and participant characteristics was performed by Pearson's correlation. Stepwise multiple linear regression was used to identify significant determinants for PCF. Various independent determinants including age, height, weight, and waist circumference were included in the models for multiple regression. All statistical analyses were performed using SPSS version 23. A p-value less than 0.05 was considered as statistically significant.

Results

Physical characteristics, PEFR and PCF values of the participants

A summary of the physical characteristics of participants are shown in Table 1. The mean height, PEFR and PCF in men were significantly higher than women (p<0.001). However, means of age, body weight, BMI and waist circumference were not significantly different between men and women.

The correlation between PCF and participant characteristics

The results in Table 2 shown the univariate analysis of PCF and participant characteristics. There were significant correlation between PCF and all parameters including age, height and weight in men and women, excepting BMI and waist circumference in women (Table 2). It was noted that there were inverse correlations between PCF and age in both men and women, (r = -0.419 and -0.398, respectively). The strongest correlation were observed between PCF and weight in men and PCF and age in women.

Multiple linear regression analysis for the predictors of PCF

To examine determinants affecting PCF, gender, age, body weight, height and waist circumference were used in the initial multiple linear regression model. In the final model, the significant independent variables included gender, age and weight. Results of analysis and regression equation for the full final model are shown in Table 3 and Table 4. The measure of how well fit of data to the regression equation, R^2, in the final model was 0.475. The analysis was also carried out separately in men and women. The final models of men and women included age and weight. Analysis of the multiple regression and regression equations are shown in Table 3 and Table 4, where the R^2 were 0.336 and 0.206, respectively.

Discussion

PCF is the maximum expiratory flow measured during a cough maneuver and allowed to measure

Table 1 Physical characteristics, PCF and PEFR of participants.

Characteristics	All participants (n=130)	Men (n=65)	Women (n=65)	p-value
Age (years)	68.45 ± 6.71	69.58 ± 7.15	67.32 ± 6.10	0.072
Height (cm)	155.09 ± 8.10	157.92 ± 7.08	152.26 ± 8.12	<0.001*
Weight (kg)	54.99 ± 9.80	56.88 ± 10.76	53.11 ± 8.40	0.097
BMI (kg/m^2)	22.85 ± 3.53	22.78 ± 3.78	22.92 ± 3.29	0.825
Waist circumference (cm)	85.37 ± 11.03	84.06 ± 10.89	86.67 ± 11.10	0.179
PCF (L/min)	328.00 ± 93.17	375.54 ± 93.77	280.46 ± 64.14	<0.001*
PEFR (L/min)	345.39 ± 98.78	392.77 ± 97.54	298.00 ± 74.78	<0.001*

All data are presented as mean ± S.D. *p-values indicate significant gender difference. BMI=body mass index, PCF= peak cough flow, PEFR = peak expiratory flow rate.

Table 2 Univariate analysis of PCF and participant characteristics.

Variables	All participants (n=130)		Men (n=65)		Women (n=65)	
	r	p-value	r	p-value	r	p-value
Age	-0.260	0.003	-0.419	0.001	-0.398	0.001
Height	0.398	<0.001	0.284	0.022	0.275	0.027
Weight	0.489	<0.001	0.517	<0.001	0.364	0.003
Body mass index	0.287	0.001	0.427	<0.001	0.216	0.084
Waist circumference	0.172	0.050	0.324	0.008	0.212	0.090

All data are presented as correlation (r). P<0.05. Significant difference with the parameter measurements. PCF= peak cough flow

Table 3 Stepwise regression analysis of the predictors of PCF in all subjects.

	Model	Coefficients	Significant	R^2	Adjust R^2
All subjects	(Constant)	364.996	0.000	0.487	0.475
	Gender	91.577	0.000		
	Age	-3.772	0.000		
	Weight	3.190	0.000		
Men	(Constant)	440.178	0.005	0.357	0.336
	Age	-4.060	0.001		
	Weight	3.830	0.000		
Women	(Constant)	398.268	0.006	0.231	0.206
	Age	-3.428	0.019		
	Weight	2.127	0.000		

PCF= peak cough flow.

Table 4 Multiple regression equations

PCF (all subjects) = 364.996 + [91.577 Gender x (0/1)] – 3.772 Age (year)] + [3.190 Weight (kg)] (when 1 = men, 0 = women)
PCF (men) = 440.178 - [4.060 Age (year)] + [3.830 Weight (kg)]
PCF (women) = 398.268 - [3.428 Age (year)] + [2.127 Weight (kg)]

the clearance of secretion in the airways[13]. The risk of aspiration and respiratory infections is increased in individuals with a coughing problem.This can occur when patients are unable to generate sufficient flow to cough out the debris[5]. The predicted PCF will be used as reference values for patients who perform PCF to predict risk of respiratory complications.

This study showed that the PCF value in men was higher than women ($p < 0.001$). The major factor influenced on PCF capacity was height of the participants, which have been reported to affect respiratory function and respiratory muscle strength[14-16]. Furthermore, the previous studies suggested that vital capacity was directly related to height because of increasing surface area of the lung[17,18]. In addition, the respiratory muscles strength built up by skeletal muscle mass is conceivable that men have respiratory muscle strength more than women[19]. Moreover, the maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) are also higher in men (33%) than women (23%) [20]. These result in men PCF value was significantly higher than women PCF.

For correlation between PCF and age, the present study found that age was a significantly negative predictor for PCF. This result similar to previous studies reports of the inverse relationship between PCF and age[9]. Generally, respiratory muscle strength is depending on age. Increase of age leads to decrease of maximal respiratory pressure 1 cm H_2O per year in elderly[10] resulting in reducing respiratory muscle strength. The respiratory muscle strength, which is crucial for ventilation and cough, is relating to PCF

capacity. Therefore, the decreasing of muscle strength leads to reduce intrathoracic pressure and expiratory flow during cough. Finally, the PCF capacity is also decreased [21,22].

The previous studies reported that small weight increases could improve lung function and respiratory muscle strength resulting in increasing respiratory muscle force[23]. In addition, weight could cause the enlarged muscle bulk, such as increasing the diaphragmatic muscle mass, leading to increase respiratory muscle strength[24]. Those studies support our finding that body weight was the positive predictor for PCF capacity.

The R^2 in our equations was quite low, 0.336 in men and 0.206 in women. Our R^2 value was similar to the previous study from Yawata and colleagues [9] that the R^2 in men and women were 0.31 and 0.28, although, the methodology in two studies are different. Therefore, the characteristic of subject, such as age and weight, should be considered and used in the equations. It is noted that, the equation which included gender into the model has high R^2 (0.475) value, suggesting this equation may be more suitable than the equation for separated gender.

PCF measurement is useful to assess cough capacity in neuromuscular patients, elderly, healthy children, and adolescents[2,7,9]. The prediction of PCF value using equation would be provided the information about the predictive value of individual cough capacity. If PCF value is less than predictive PCF, it mean that the subject could have a high risk of respiratory complication. Therefore, this information could be used for concerning the subject, who have the PCF value less than the prediction, to modify their behavior. For example, they should increase physical activity or aerobic exercise for improving the cough capacity[10].

However, this study also had some limitations. Firstly, we did not measure MIP and spirometry values that were more influence on cough ability. Therefore, MIP and spirometry need to be performed in future study for measuring the PCF capacity. Secondly, the measurement of PEFR and PCF is depend on participants practice of forced expulsive maneuver, as well as the participate in the procedure. Therefore, in clinical setting or research should use the Mini-mental state examination to measure cognitive aspect before PCF testing.

Conclusion

The PCF values were lower in women than in men. The PCF correlated with age, height, and body weight and waist circumference in both genders. The reference equations derived from this study are useful in assessing the strength of cough in Thai senior persons.

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