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Impact of direct substitution of arm span length for current standing height in elderly COPD

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Background: Arm span length is related to standing height and has been studied as a substitute for current standing height for predicting lung function parameters. However, it has never been studied in elderly COPD patients.

Purpose: To evaluate the accuracy of substituting arm span length for current standing height in the evaluation of pulmonary function parameters and severity classification in elderly Thai COPD patients.

Materials and methods: Current standing height and arm span length were measured in COPD patients aged >60 years. Postbronchodilator spirometric parameters, forced vital capacity (FVC), forced expiratory volume in first second (FEV_1), and ratio of FEV_1/FVC (FEV_1%), were used to classify disease severity according to global initiative for chronic obstructive lung disease criteria. Predicted values for each parameter were also calculated separately utilizing current standing height or arm span length measurements. Student's *t*-tests and chi-squared tests were used to compare differences between the groups. Statistical significance was set at $P<0.05$.

Results: A total of 106 COPD patients with a mean age of 72.1±7.8 years, mean body mass index of 20.6±3.8 kg/m^2, and mean standing height of 156.4±8.3 cm were enrolled. The mean arm span length exceeded mean standing height by 7.7±4.6 cm (164.0±9.0 vs 156.4±8.3 cm, $P<0.001$), at a ratio of 1.05±0.03. Percentages of both predicted FVC and FEV_1 values based on arm span length were significantly lower than those using current standing height (76.6±25.4 vs 61.6±16.8, $P<0.001$ and 50.8±25.4 vs 41.1±15.3, $P<0.001$). Disease severity increased in 39.6% (42/106) of subjects using arm span length over current standing height for predicted lung function.

Conclusion: Direct substitution of arm span length for current standing height in elderly Thai COPD patients should not be recommended in cases where arm span length exceeds standing height by more than 4 cm.

Keywords: chronic obstructive pulmonary disease, arm span, standing height, spirometry, severity

Introduction

Pulmonary function tests use standardized reference values based on ethnic and anthropometric characteristics, including age, sex, and height.[1] It has become increasingly necessary to measure pulmonary function in patients who are unable to stand, as their current standing height cannot be accurately measured.[2,3] The American Thoracic Society (ATS) and the European Respiratory Society (ERS) jointly recommend other options, including stated height or estimating from arm span when height cannot be measured.[4]

Substitution of standing height measurements can be estimated from arm span measurements using the appropriate regression equations and might be an alternative method to use for subjects in whom current standing height cannot be measured

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(eg, subjects with skeletal deformities or standing inability).[5,6] Substitution of arm span for standing height is important for assessment of predicted value of lung volume in elderly people with osteoporosis.[7] One study suggested that standing height estimated using arm span could be directly substituted for actual height in adults for whom height could not be measured reliably.[8] Other studies also suggested that arm span could be used for predicting lung function instead of height for elderly women[9,10] and that FEV_1 values using height and arm span were not statistically different in elderly individuals.[11,12]

However, estimating height from arm span is controversial because the relationship between height and arm span varies with age and ethnicity.[13–15] Although estimated height from arm span is highly correlated with standing height in general populations, there is very poor agreement with standing height in acutely ill elderly populations.[16] A longitudinal study showed that actual standing height is lost from age 30 to 80 years,[17] but arm span is still closely correlated to maximal standing height.[18] Elderly COPD patients may lose their standing height more rapidly than normal aging populations due to direct effects of the disease like osteoporosis, irrespective of corticosteroid use, age, and sex.[19–21] Therefore, substituting arm span measurement for actual height in estimating pulmonary function parameters should be investigated in COPD patients with advanced age. This study aimed to evaluate the use of arm span length as an alternative measure for the estimation of height and in the prediction of spirometry in elderly Thai COPD patients.

Materials and methods

Participants and study design

We conducted a cross-sectional study enrolling Thai COPD patients who were more than 60 years of age and who were managed by pulmonologists at the chest clinic of Chiang Mai University Hospital, Chiang Mai, Thailand, between October 1, 2012 and September 30, 2013. Patients who were unable to stand, or had structural or neuromuscular defects, as well as subjects with chest or upper limb deformities were excluded. Accurate measurements of both standing height and arm span length in the same subjects were performed after the enrollment. Standing height was measured on barefooted subjects using a wall-mounted stadiometer (Zepper ZT160, China) while the subject was standing as tall as possible with buttocks, back, and head against the wall and looking straight ahead. Arm span was measured from tip-to-tip of middle fingers with hands maximally outstretched while standing against a wall, using a flexible calibrated steel tape measure (Butterfly brand tape measure, China). Both measurements were taken to the nearest centimeter, and the mean values recorded. Arm span: standing height ratios were calculated separately for all subjects. All subjects underwent spirometric evaluation using a spirometer (Vmax series 22, Sensor Medics, Bilthoven, Holland). Postbronchodilator (400 µg of salbutamol), forced vital capacity (FVC), forced expiratory volume in first second (FEV_1), and ratio of FEV_1/FVC were measured for all subjects using ATS/ERS standard guidelines.[1] Values were calculated using National Health and Nutrition Examination Survey (NHANES) III reference equations.[22] However, for Asians, a correction factor of 0.88 was applied to predicted FVC and FEV_1.[23] COPD was classified according to global initiative for chronic obstructive lung disease (GOLD) severity classification[24] using both current standing height and arm span length measurements for each subject. We considered results clinically significant if the percentage of predicted FEV_1 based on arm span differed by 5% or more from standing height calculations.[20] The study protocol was approved by the Institutional Ethics Committee of the Faculty of Medicine, Chiang Mai University.

Sample size calculation

A standard deviation (SD) of 22 cm between arm span length and standing height in patients was previously estimated as significant.[2] In the same study, the maximum acceptable difference between standing height and arm span length was set at 8 cm. Our sample size calculation was based on the 95% confidence interval (CI), thus, keeping the type I error rate at 0.05 and probability (power) at 0.95. A total of 100 patients was the minimum required sample size considered necessary to provide valid results.

Statistical analysis

Results for numerical values are expressed as mean ± SD, and those for categorical data are expressed as absolute frequencies and percentages. Categorical variables were analyzed using chi-square tests, whereas continuous variables were compared using Student's *t*-tests. Statistical significance was set at $P<0.05$. All analyses were carried out using the SPSS statistical package, version 16 for Windows (SPSS, Inc, Chicago, IL, USA).

Results

The baseline characteristics of all 106 enrolled COPD patients according to sex are shown in Table 1. Mean age of subjects was 72.1±7.8 years, with a mean body mass index of 20.6±3.8 kg/m^2, and a mean standing height of 156.4±8.3 cm.

Table 1 Baseline characteristics according to sex and all patients

Variables	Male	Female	COPD
n (%)	69 (65.1)	37 (34.9)	106 (100)
Age (years)	72.5±7.2	71.2±8.8	72.1±7.8
BMI (kg/m^2)	20.3±3.7	21.1±4.0	20.6±3.8
Height (cm)	159.9±6.9	149.8±6.6	156.4±8.3
Arm span length (cm)	168.0±7.2	156.7±7.3	164.0±9.0
Ratio of arm span/height	1.05±0.03	1.05±0.03	1.05±0.03
Arm span length minus height (cm)	8.1±4.8	6.9±4.2	7.7±4.6
Pulmonary function test (based on current standing height)			
FVC (L)	2.07±0.48	1.44±0.52	1.85±0.57
% predicted FVC	84.8±25.9	61.4±15.9	76.6±25.4
FEV_1 (L)	1.06±0.35	0.77±0.29	0.96±0.36
% predicted FEV_1	55.8±23.5	41.4±13.1	50.8±25.4
Ratio of FEV_1/FVC (%)	50.5±11.5	54.3±9.9	51.8±11.0

Note: Data are presented in number (%), or mean ± SD.
Abbreviations: BMI, body mass index; FVC, forced vital capacity; FEV_1, forced expiratory volume in first second; SD, standard deviation.

Mean standing height and arm span lengths were 156.4±8.3 and 164.0±8.3 cm, respectively. Mean ratio of arm span length to current standing height was 1.05±0.03. Arm span length exceeded current standing height by a mean length of 7.7±4.6 cm. Mean percentage of predicted FEV_1 was 50.8±25.4 and mean ratio of FEV_1 to FVC was 51.8±11.0 based on current standing heights. Arm span measurements exceeded current standing height in 101 (95.3%) patients, without significant difference between sexes (Table 2), and was categorized into four groups: <2.0, 2.0–3.9, 4.0–5.9, and >5.9 cm comprising 6 (5.7%), 10 (9.4%), 19 (17.9%), and 71 (67.0%) patients, respectively (Figure 1).

Table 3 shows spirometric data and GOLD classification based on current standing height and arm span length. Both percentage of predicted FVC and percentage of FEV_1 were significantly lower when based on arm span length compared to current standing height in both sexes. The variation between GOLD classification based on current standing height compared to arm span length was statistically significant ($P<0.001$). Disease severity based on GOLD stage classification was 39.6% (42/106) higher when standing height was used compared to arm span length, especially in males (52.2% vs 16.2% in females, $P<0.001$) (Table 4). When using arm span length, 41 cases (97.6%) were one GOLD classification lower, and 1 case (2.4%) was two GOLD classifications lower. In all, 69 subjects out of 90 had arm span lengths exceeding their respective standing heights by at least 4 cm, resulting in decreased predicted FEV_1 values ≥5%, without significant differences between sexes (Table 5).

Discussion

Our study aimed to evaluate the use of arm span length as an alternative to standing height in the prediction of spirometry in elderly Thai COPD patients. The results revealed that the percentages of predicted FVC and FEV_1 based on arm span length were significantly lower than current standing height in elderly Thai COPD patients. Both measures of percentages of predicted FVC and FEV_1 were significantly underestimated when using arm span length compared to standing height (mean percent difference: 15.1±13.5 and 9.7±9.9, respectively). A clinical underestimation of at least 5% of the predicted FEV_1 values was revealed in all subjects whose arm span length exceeded standing heights of at least 4 cm. Underestimation of percentages of predicted FVC and FEV_1 based on arm span length in this study resulted in significant reclassification (~40%) into a higher GOLD severity category. Treatment implications are different for patients classified into incorrect GOLD cateogies.[24] Because the absolute mean difference between height and arm span in any

Table 2 Comparison of standing height and arm span length (n=106)

Categories	Male (n=69)	Female (n=37)	COPD (n=106)	*P*-value
Arm span length exceeded standing height	66 (95.7)	35 (64.6)	101 (95.3)	0.902
Arm span length equaled standing height	1 (1.4)	1 (2.7)	2 (1.9)	
Arm span length less than standing height	2 (2.9)	1 (2.7)	3 (2.7)	

Notes: Data are presented in number (%); *P*-value compared between sex groups using chi-square test.

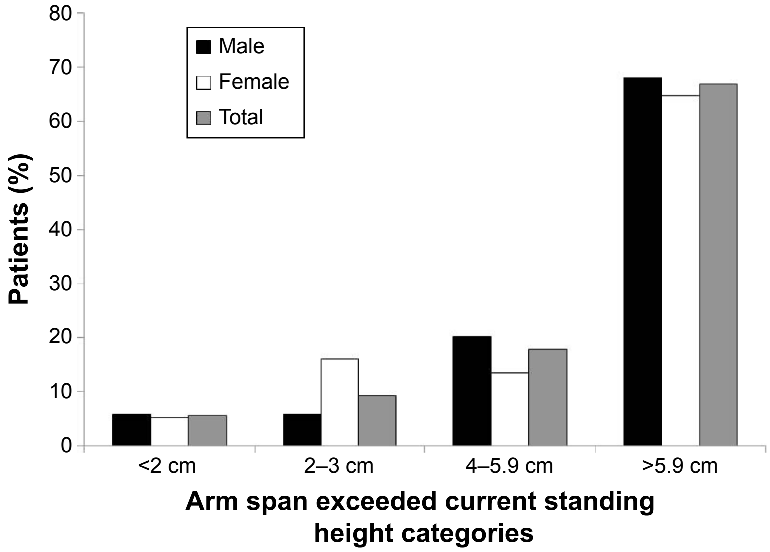

Figure 1 Percentage of patients whose arm span length exceeded standing height according to sex and all patients.
Note: $P=0.330$ compared between sex groups using chi-square test.

Table 3 Spirometric data and GOLD classification based on standing height and arm span length

Variables	Male (n=69)		Female (n=37)		COPD (n=106)	
	Base on standing height	Base on arm span length	Base on standing height	Base on arm span length	Base on standing height	Base on arm span length
Height used to predict pulmonary function	159.9±86.9	168.0±7.2[a]	149.8±6.6	156±7.3[a]	156.4±8.3	164.0±9.0[a]
Pulmonary function test						
% predicted FVC	84.8±25.9	65.4±17.3[a]	61.4±15.9	54.4±13.1[a]	76.6±25.4	61.6±16.8[a]
% predicted FEV_1	55.8±23.5	43.2±16.6[a]	41.4±13.1	37.3±11.7[a]	50.8±25.4	41.1±15.3[a]
GOLD classification[b]						
I	8 (11.06)	2 (2.9)	1 (2.7)	0 (0.0)	9 (8.5)	2 (1.9)
II	33 (47.8)	18 (26.1)	7 (18.9)	6 (16.2)	40 (37.7)	24 (22.6)
III	21 (30.4)	32 (46.4)	22 (59.5)	21 (56.8)	43 (40.6)	53 (50.0)
IV	7 (10.1)	17 (24.6)	7 (18.9)	10 (27.0)	14 (13.2)	27 (25.5)

Notes: Data are presented in number (%), mean ± SD; [a]$P<0.001$ compared between data based on standing height and arm span length, [b]the severity classification were significantly different based on arm span length compared to standing height ($P<0.05$).
Abbreviations: FVC, forced vital capacity; FEV_1, forced expiratory volume in first second; GOLD, Global initiative for chronic Obstructive Lung Disease; SD, standard deviation.

Table 4 GOLD classification changes based on substituting arm span length for standing height

Male GOLD classification based on		GOLD classification change	Female GOLD classification based on		GOLD classification change	Total GOLD classification based on		GOLD classification change
Standing height (n=69)	Arm span length (n=69)		Standing height (n=37)	Arm span length (n=37)		Standing height (n=106)	Arm span length (n=106)	
I 8	I 2 II 5 III 1	6/8 (75.0)	I 1	I 0 II 1 –	1/1 (100.0)	I 9	I 2 II 6 III 1	7/9 (77.8)
II 33	II 13 III 20	20/33 (60.6)	II 7	II 5 III 2	2/7 (28.6)	II 40	II 18 III 22	22/40 (55.0)
III 21	III 11 IV 10	10/21 (47.6)	III 22	III 19 IV 3	3/22 (13.6)	III 43	III 30 IV 13	13/43 (30.2)
IV 7	IV 7	–	IV 7	IV 7	–	IV 7	IV 7	–
		36/69 (52.2)			6/37 (16.2)[a]			42/106 (39.6)

Notes: Data are presented in number (%); [a]$P<0.001$ compared between sex groups using chi-square test.
Abbreviation: GOLD, Global initiative for chronic Obstructive Lung Disease.

Table 5 The proportion of COPD subjects within each arm span exceed height category where the difference in percent predicted FEV_1 exceed 5% point

Arm span exceed height category (cm)	Patients with % predicted FEV_1 reduction exceed 5% point			*P*-value
	Male (n=69)	Female (n=37)	Total (n=106)	
<2	–	–	–	0.196
2–3.9	–	–	–	
4–5.9	13/14 (92.9)	1/5 (20.0)	14 (73.7)	
>5.9	43/47 (91.5)	12/24 (50.0)	55 (77.5)	

Notes: Data are presented in number (%), *P*-value compared between sex groups using chi-square test.
Abbreviations: FEV_1, forced expiratory volume in first second; GOLD, Global initiative for chronic Obstructive Lung Disease.

individual is usually small (mean: 3.4–4.7 cm) in previous studies, arm span was proposed as a direct substitution for height in prediction equations.[8–10] Since this phenomenon is more marked in our elderly COPD patients, with an absolute mean difference between height and arm span almost twice higher (7.7 cm), a direct substitution of arm span length to current standing height incurred a significant underestimation of lung function and led to an almost 40% increase in GOLD severity classification. This should be considered as an incorrect interpretation of pulmonary function tests, misclassification of GOLD severity, and erroneous change in treatment regimen in elderly Thai COPD patients.

Our study should, therefore, draw attention to the potential discordance of arm span and height measurements in spirometric assessments of elderly COPD patients. Such a discrepancy may be related to ethnicity or may be due to extraordinary loss of current standing height as a result of COPD-related osteoporosis rather than the normal physiologic aging process.[9,10] A previous longitudinal study suggests that current measured height may underestimate the progression of COPD, and that the use of arm span to determine height will give a more accurate measure of COPD progression.[25] We disagree with this suggestion because arm span length significantly differed from current standing height in our study. Current standing height is one of the standard variables for pulmonary function measurement; therefore, we may not be able to reliably replace standing height with arm span. The potential clinical significance of the discrepancy between arm span and standing height, including underestimation of disease severity, should be taken into consideration. Once a method is chosen to estimate height, parameters required for arm span length or current standing height should be considered. When surrogate measures of height for elderly COPD patients are used in a clinical setting, data collection should not be mixed with the methods of height estimation.

Further investigation is needed for patients with osteoporosis, as they were not investigated in our study. Our study was limited because no height estimation regression equation using arm span length is available for Thai populations and because the study was conducted with a limited sample size of elderly COPD patients.

We suggest that until a regression equation correlating arm span length to standing height for Thai patients is developed, arm span length cannot be substituted for standing height when evaluating elderly Thai COPD patients.

Conclusion

Direct substitution of arm span length for current standing height in elderly Thai COPD patients cannot be recommended in cases where arm span length exceeds standing height by more than 4 cm.

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Author contributions

The first author, Chaicharn Pothirat, developed the study design and carried out acquisition and interpretation of data, statistical analysis, manuscript preparation, and critical revision of intellectual contents. The remaining authors contributed to acquisition and interpretation of data, revised the article for important intellectual content, and gave final approval of the version to be published.

Disclosure

The authors report no conflicts of interest in this work.

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