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SHORT COMMUNICATION

Relationship between pulmonary function and physical activity in daily life in patients with COPD

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Summary
Background: It remains unclear how closely the physical inactivity observed in patients with Chronic Obstructive Pulmonary Disease (COPD) relates to the severity of their airflow limitation. Furthermore, it is unknown whether spirometric variables such as maximal voluntary ventilation (MVV) and inspiratory capacity (IC) reflect the level of physical activity in daily life better than the forced expiratory volume in the first second (FEV_1), the main spirometric variable used to determine the severity of COPD. The objective of the present study was to investigate the relationship between physical activity in daily life and the severity of COPD assessed by different spirometric variables: MVV, IC and FEV_1.
Methods: Forty patients with COPD (21 men; 68 ± 7 years; FEV_1 $41 \pm 14\%$ predicted) were performed spirometry and assessment of the physical activity level in daily life using an accelerometer (SenseWear® Armband).
Results: MVV was significantly correlated to total energy expenditure per day, energy expenditure per day in activities demanding more than 3 metabolic equivalents (METs), number of steps per day and time spent per day in moderate and vigorous activities ($0.42 \leq r \leq 0.52$; $p < 0.01$ for all). Correlation of these variables with IC and especially FEV_1 was more modest, borderline or not statistically significant. There was no difference in time spent in vigorous activities among patients classified according to the FEV_1-based GOLD stages II, III and IV,

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differently than that observed when patients were classified in groups according to their MVV.
Conclusion: In COPD patients, MVV better reflects the physical activity level in daily life than FEV_1 and IC.

Introduction

A reduction in the forced expiratory volume in the first second (FEV_1) is the most common outcome used to graduate the severity of Chronic Obstructive Pulmonary Disease (COPD).[1] However, literature is controversial concerning whether the reduction in the level of physical activity observed in patients with COPD is directly linked to the degree of airflow limitation severity or whether other factors interfere, leading inactivity to occur independently of the airflow limitation severity as measured by the FEV_1. Furthermore, it is unknown whether other spirometric variables such as maximal voluntary ventilation (MVV) and inspiratory capacity (IC) are more closely linked than the FEV_1 to the level of physical activity in daily life as well as to important outcomes in COPD such as functional exercise capacity and respiratory muscle force. The main objective of the present study was to investigate the relationship between physical activity in daily life and spirometric impairment assessed by different variables (FEV_1, MVV and IC) in patients with COPD. A secondary objective was to investigate the relationship of these 3 spirometric variables with functional exercise capacity and respiratory muscle force.

Methods

Forty consecutive patients in screening process for admission in a pulmonary rehabilitation program were included. Data were collected from June 2006 until June 2007. Admission of patients to the study was done throughout the whole year to avoid seasonal bias in the assessment of physical activity in daily life. The diagnosis of COPD was established based on internationally accepted criteria.[1] Inclusion criteria were: clinical stability (absence of exacerbations) for at least 3 months before inclusion in the study; and absence of osteo-neuro-muscular co-morbidities that might interfere in the assessments. Patients would be excluded if not able to finalize the proposed assessments by physical or cognitive reasons or if not willing to continue in the study for any reason. The study was approved by the institution's Committee for Ethics in Research, and all patients gave formal written consent to participate.

Spirometric assessment was performed using the Pony Cosmed® spirometer (Cosmed, Italy) according to the guidelines of the ATS/ERS.[2] Concerning the MVV testing, after 3 breaths at tidal volume, the patient performed the manoeuvre breathing as deeply and rapidly as possible for 12 s. The technician enthusiastically coached the subjects throughout the test, and suggested faster or slower breathing if necessary to achieve an ideal rate of 90–110 breaths/min in order to obtain an acceptable manoeuvre. Three valid and reproducible manoeuvres were obtained, and the best was used for the analysis. Relative relationship of MVV with the FEV_1 ($MVV/(FEV_1 \times 40)$) was 0.94, demonstrating that the MVV manoeuvre was properly performed and did not lack appropriate effort from the patients.[2] IC was obtained through the formula: VC–ERV (''slow'' vital capacity–expiratory reserve volume). All values used for analysis were obtained after bronchodilation. Reference values were those from Knudson et al.[3]

Maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) assessments were performed with an analogic manovacuometer Gerar (Gerar, Brazil) according to the technique described by Black and Hyatt,[4] with reference values from Neder et al.[5] The 6-min walking test (6MWT) was performed according to the guidelines of the American Thoracic Society.[6] Reference values were those from Troosters et al.[7]

Physical activity in daily life was assessed by the SenseWear® Armband (Bodymedia, United States), a physiologic activity monitor which records continuous data about energy expenditure and physical activity habits in subjects during their daily life. The device is light, portable, worn in the upper posterior part of the arm and was previously validated in patients with COPD.[8] Assessment was performed for 2 days, during 12 h per day (from the moment the patient wakes up until 12 h after that), and the average of the 2 days was used for analysis. Results were obtained through the analysis of the data by the specific software provided by Bodymedia (InnerView, Bodymedia, United States).

Statistical analysis was performed with the software GraphPad Prism 3.01. Distribution of the data was assessed using the Kolmogorov–Smirnov test. Since the variables from the physical activity assessment were non-normally distributed, correlations were performed using the Spearman correlation coefficient. Comparison among the groups classified according to the values of FEV_1 and MVV was performed using Kruskal–Wallis test, with the Dunn's post-test when applicable. The level of significance was determined as $p < 0.05$.

Results

No patient refused to perform the assessments or was not capable of performing them, and therefore no patient was excluded from the study. The general characteristics of the group of patients included in the study are shown in Table 1 ($n = 40$; 21 male; 1 patient GOLD stage I, 11 GOLD II, 19 GOLD III, 9 GOLD IV). In this group of patients, BMI was not significantly correlated to FEV_1 ($r = 0.19$; $p = 0.25$) and IC ($r = 0.11$; $p = 0.51$), whereas its correlation with MVV tended to be slightly higher, although not reaching statistical significance ($r = 0.29$; $p = 0.09$).

Table 2 shows that there were significant correlations between MVV, IC and FEV_1 in one hand and MIP and MEP in the other ($p < 0.05$ for all). In general, MVV had higher

Table 1 General characteristics of the group of patients with COPD included in the study ($n = 40$, except when otherwise indicated)

	Mean (SD)
Age (years)	68 (7)
BMI (kg/m^2)	24 (6)
FVC (% pred)	66 (19)
FEV_1 (l)	0.90 (0.26)
FEV_1 (% pred)	41 (14)
MVV (l) ($n = 39$)	34 (13)
MVV (% pred) ($n = 39$)	37 (15)
IC (l)	1.44 (0.52)
MIP (% pred) ($n = 30$)	71 (29)
MEP (% pred) ($n = 30$)	111 (34)
6MWT (%pred)	75 (17)
TEE (kcal/day)	1235 (547)
EEA > 3 METs (kcal/day)	412 (499)
Steps/day	4178 (3007)
TSA > 3 METs (min/day)	79 (72)

Results are shown as mean (standard deviation). COPD = Chronic Obstructive Pulmonary Disease; BMI = body mass index; FVC = forced vital capacity; FEV_1 = forced expiratory volume in the first second; MVV = maximal voluntary ventilation; IC = inspiratory capacity; TEE = total energy expenditure per day; EEA > 3 METs = energy expenditure per day in physical activities demanding more than 3 metabolic equivalents; steps/day = number of steps per day; TSA > 3 METs = time spent per day in activities with energy expenditure above 3 metabolic equivalents; MIP = maximal inspiratory pressure; MEP = maximal expiratory pressure; 6MWT = 6-min walking test.

correlations with MIP and MEP than IC and FEV_1. MVV and IC also showed significant correlation with the 6MWT ($r = 0.50$ and 0.51, respectively; $p < 0.005$ for both), whereas the same was not observed for the correlation between FEV_1 and 6MWT ($r = 0.29$; $p = 0.07$).

Table 2 also shows that MVV was significantly correlated with all variables concerning physical activity in daily life ($0.42 \leq r \leq 0.52$; $p < 0.01$ for all). Correlations of these same variables with IC and especially FEV_1 were more modest, borderline or not statistically significant (Table 2). If total energy expenditure per day and energy expenditure per day in physical activities demanding more than 3 metabolic equivalents (METs) were corrected for body weight, the results were rigorously maintained, with MVV showing better correlation with these variables in comparison to IC and especially to FEV_1.

Fig. 1 shows the comparison of time spent per day in vigorous activities (demanding 6–9 METs) among patients classified in 3 subgroups according to the FEV_1 (corresponding to GOLD stages II, III and IV; (A)) and according to the MVV in similar intervals as used for the FEV_1 (*i.e.*, 50–80% predicted, 30–49% predicted, and ≤29% predicted; (B)). Fig. 1A shows no significant difference among the groups classified by GOLD stages ($p = 0.65$). Furthermore, there was no correlation between the GOLD stages with any variable from physical activity in daily life, maximal respiratory pressures and 6MWT ($-0.25 < r < 0.16$; $p > 0.05$ for all). Fig. 1B shows statistically significant difference when comparing the subgroup MVV ≤ 29% predicted with the other 2 subgroups ($p = 0.02$; Dunn's post-test $p < 0.05$ for both analyses).

Table 2 Correlations of MVV, IC and FEV_1 with respiratory muscle force, functional exercise capacity and outcomes deriving from the assessment of physical activity in daily life ($n = 40$, except when otherwise indicated)

	MIP ($n = 30$)	MEP ($n = 30$)	6MWT	TEE	EEA > 3 METs	Steps/day	Sedentary activities	Moderate activities	Vigorous activities
MVV (l)	0.61***	0.55**	0.50**	0.52***	0.48**	0.49**	−0.41**	0.42**	0.49**
($n = 39$)	(0.30–0.81)	(0.22–0.77)	(0.21–0.71)	(0.24–0.72)	(0.18–0.69)	(0.20–0.70)	(−0.65–0.10)	(0.11–0.66)	(0.20–0.71)
IC (l)	0.39*	0.43*	0.51**	0.42**	0.30	0.35*	−0.27	0.25	0.33*
	(0.02–0.67)	(0.07–0.70)	(0.22–0.72)	(0.11–0.66)	(−0.03–0.57)	(0.02–0.60)	(−0.54–0.06)	(−0.08–0.53)	(0.01–0.59)
FEV_1 (l)	0.46*	0.52**	0.29	0.37*	0.31#	0.25	−0.26	0.29	0.31#
	(0.10–0.71)	(0.18–0.75)	(−0.03–0.56)	(0.05–0.61)	(−0.01–0.58)	(−0.08–0.53)	(−0.53–0.06)	(−0.04–0.56)	(−0.01–0.57)

Analysis performed with the Spearman correlation coefficient (95% confidence intervals). *$0.01 < p < 0.05$; **$0.001 < p < 0.01$; ***$p < 0.001$; #$p = 0.05$. MVV = maximal voluntary ventilation; IC = inspiratory capacity; FEV_1 = forced expiratory volume in the first second; l = liters; MIP = maximal inspiratory pressure (in cm H_2O); MEP = maximal expiratory pressure (in cm H_2O); 6MWT = 6-min walking test (in m); TEE = total energy expenditure per day (in kcal/day); EEA > 3 METs = energy expenditure per day in physical activities demanding more than 3 metabolic equivalents [METs] (in kcal/day); steps/day = number of steps per day; sedentary activities = time spent per day (in min) in sedentary activities (<3 METs); moderate activities = time spent per day (in min) in moderate activities (3–6 METs); vigorous activities = time spent per day (in min) in vigorous activities (6–9 METs).

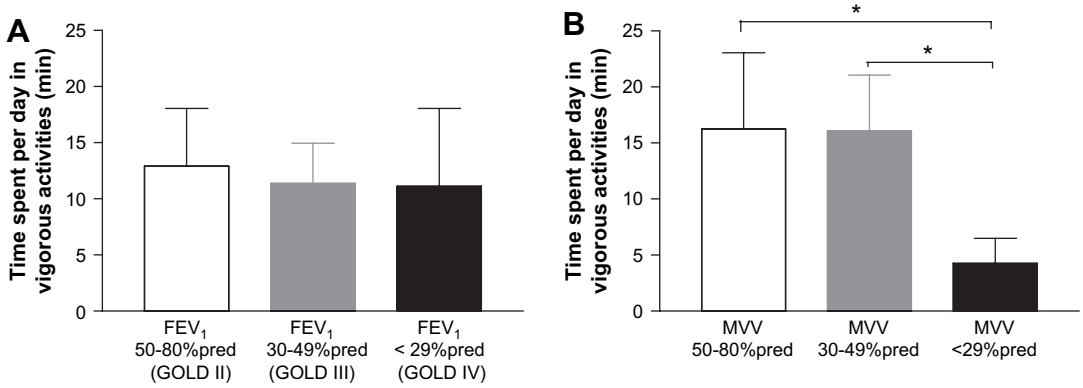

Figure 1 Comparison of time spent per day in vigorous activities (demanding 6—9 metabolic equivalents — METs) among patients classified according to: (A) forced expiratory volume in the first second (FEV_1) in 3 subgroups: left column (white): $50\% \leq FEV_1 < 80\%$ predicted — GOLD II ($n = 11$); middle column (grey): $30\% \leq FEV_1 \leq 49\%$ predicted — GOLD III ($n = 19$); right column (black): $FEV_1 \leq 29\%$ predicted — GOLD IV ($n = 9$); (B) maximal voluntary ventilation (MVV) in 3 subgroups: left column (white): $50\% \leq MVV < 80\%$ predicted ($n = 8$); middle column (grey): $30\% \leq MVV \leq 49\%$ predicted ($n = 16$); right column (black): $MVV \leq 29\%$ predicted ($n = 15$). Predicted values according to Knudson et al. GOLD = global initiative for obstructive lung disease. In (A) $n = 39$ since 1 patient was classified as GOLD I. Analysis performed with the Kruskal—Wallis test showed no statistically significant difference among the groups ($p = 0.65$). In (B) $n = 39$ since MVV was not obtained in 1 patient. Analysis performed with the Kruskal—Wallis test showed $p = 0.02$ (*$p < 0.05$ in the Dunn's post-test).

Discussion

The present study showed that, in patients with COPD, MVV is better correlated to different outcomes from physical activity in daily life than FEV_1 and IC. MVV, IC and FEV_1, although known to be correlated, are spirometric variables which reflect the different aspects of lung function. While FEV_1 reflects basically the airflow limitation, MVV additionally reflects the ventilatory reserve available to respond to the increased physiologic demand during exercise, and IC reflects lung hyperinflation. Specifically concerning MVV, although previous data indicated that the diaphragm has limited contribution to the generation of maximal levels of ventilation in patients with severe COPD,[9] in this study we observed a positive correlation between MVV and respiratory muscle force (Table 2). Furthermore, there is evidence that MVV may be responsive to general exercise training programs in COPD patients,[10] unlike what is commonly observed concerning the FEV_1. The present study also showed significant correlation between MVV and 6MWT, as previously described.[11] It is also known that the 6MWT is responsive to exercise training[12] and that there is good correlation between 6MWT and time spent actively in daily life.[13] Therefore, the fact that MVV is more responsive to exercise training suggests that this outcome has better predictive value to detect improvements in physical activity in daily life after pulmonary rehabilitation programs than the FEV_1. Therefore, we suggest that MVV should be incorporated to the routine of assessment in pulmonary rehabilitation programs, as well as it should be included in the methodology of studies concerning the influence of lung function impairment in the functional status of patients with COPD.

Current literature concerning the relationship between FEV_1 and the level of physical activity in daily life assessed by motion sensors is controversial, varying from weak and not statistically significant to strong and statistically significant correlations.[13—17] Differences observed between the present findings and other studies with relatively conflicting results [14,15,17] are possibly due to the differences in the populations' characteristics and differences in the tools used for the objective assessment of daily physical activity. However, it has been previously suggested that the GOLD stages do not properly differentiate which COPD patients are active or inactive in daily life, in contrast to a multi-factorial severity index capable of taking into account the disease's systemic characteristics, the BODE index.[18] In the present study, MVV correlated better than the FEV_1 with 6MWT and BMI, which are also components of the BODE index. This reinforces the message that MVV better reflects the disease severity as a whole, including physical inactivity and functional limitation. It is important to underline, however, that this study was performed with a sample characterized (by chance) by normal BMI as a group. Therefore care must be taken when generalizing these findings to patients with very low or very high BMI.

In conclusion, MVV is a better correlate of the level of physical activity in daily life, functional exercise capacity and respiratory muscle force than FEV_1 and IC in patients with COPD. Different stages of disease severity classified according to the FEV_1-based GOLD do not present differences regarding daily physical activity. This shows that the reduction in physical activity in daily life in patients with COPD does not depend on the disease severity determined solely based on the FEV_1. Therefore, the present study reinforces the idea that although FEV_1 might be an important outcome in order to indicate the severity of airflow limitation in COPD, it should not be used by itself as an indication of disease severity in a broader sense.

Conflict of interest statement

The authors have no conflicts of interest to declare.

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