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European Journal of Cardio-thoracic Surgery 39 (2011) 756—762

EUROPEAN JOURNAL OF CARDIO-THORACIC SURGERY

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Value of the average basal daily walked distance measured using a pedometer to predict maximum oxygen consumption per minute in patients undergoing lung resection☆,☆☆

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Received 25 May 2010; received in revised form 29 July 2010; accepted 5 August 2010; Available online 10 December 2010

Abstract

Objectives: Maximum oxygen consumption per min (VO_{2max}) is currently considered the most accurate test for the preoperative risk assessment in patients scheduled for pulmonary resection. Due to its high-technology requirements and cost, VO_{2max} is performed less frequently than is desired. The objective of this investigation is to determine if the measurement of the basal daily ambulatory activity of the patients, with a pedometer, can be used to predict VO_{2max} values. **Methods:** This is a prospective study on 38 patients referred for scheduled lobectomy or pneumonectomy. Daily basal preoperative activity of the patients was measured 3 weeks before surgery by means of an OMROM HJ-720IT-E2 pedometer. Before surgery, VO_{2max} (dependent variable) was calculated using a Master Screen CPX module of Jaeger-Vyasis-Healthcare. The following independent variables were studied: age, sex, preoperative forced expiratory volume in 1 s percentage (FEV1%) and carbon monoxide diffusing capacity percentage (DLCO%), mean number of steps per day (aerobic and non-aerobic), mean daily time of aerobic activity (in min) and mean daily walked distance (in km). Two linear regression models with bootstrap robust estimation of the standard error of the coefficients were adjusted and the estimated values of VO_{2max} were kept as a new variable for comparison. To avoid collinearity problems, only one of the pedometer records entered the regression model. **Results:** Data of the series (mean ± SD): age 62.8 ± 10.14 years; FEV1% 90.1 ± 21.8; DLCO% 82.8 ± 20.1. After collinearity analysis, mean daily walked distance was chosen as the most representative variable. In the first regression model, 'Distance' ($p = 0.000$) was highly correlated to the dependent variable (adjusted R^2: 0.812). The second model improved the predictive value of the first one adding DLCO% to the model. In this model, DLCO% ($p = 0.000$) and 'Distance' ($p = 0.002$) were correlated to the dependent variable. The adjusted R^2 of the second lineal model was 0.935. **Conclusion:** These preliminary data show that a combination of the measured daily ambulatory activity using a pedometer, especially the mean daily walked distance in km, and the DLCO% of the patient could predict the VO_{2max} value. Larger data series are needed for conclusive results.

Keywords: Pedometer; Major lung resection; Daily ambulatory walked distance; $VO_{2\ max}$; CPET

1. Introduction

High-technology cardiopulmonary exercise test (CPET) with calculation of the maximum oxygen consumption per minute (VO_{2max}) is currently considered the most accurate test to predict complications after lung resection in patients with forced expiratory volume in 1 s percentage (FEV1%) or carbon monoxide diffusing capacity percentage (DLCO%) below normal values [1,2]. Thus, VO_{2max} remains the gold standard to compare new technologies in risk-estimation analysis. Unfortunately, VO_{2max} is performed less frequently than desired due to its high-technology requirements and costs. Besides, it could be hypothesized that a maximum exercise test performed in the laboratory could not be a perfect surrogate of the actual patient's fitness necessary for daily living, and more specifically, for the physical activity necessary the following weeks after being discharged after lung resection. Furthermore, for the conditions a test of this type imposes upon the patient, there may be a considerable number of subjects performing sub-optimally. Measuring physical activity in real-life conditions using pedometers, which have been validated as accurate sensors for ambulatory activity measurement [3], could be more objective and, perhaps, equally valid to estimate the exercise capacity before lung resection. Nevertheless, physical activity of daily living has not been studied as a variable predicting the outcome after lung resection.

☆ Presented at the 18th European Conference on General Thoracic Surgery, Valladolid, Spain, May 30—June 2, 2010. Winner of the ESTS Brompton Prize.

☆☆ Study supported by a grant of the Spanish Society of Respiratory Pathology (SEPAR) and by a grant of the Consejeria de Salud de Castilla y León (Sacyl).

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1010-7940/$ — see front matter
doi:10.1016/j.ejcts.2010.08.025

The main objective of this investigation is to determine if the measurement of the basal daily activity of the patients with a pedometer correlates with VO_{2max} values measured at the pulmonary function laboratory. As a secondary objective, we investigate if the addition of DLCO% to basal daily activity improves the accuracy of VO_{2max} prediction.

2. Methods

2.1. Population of the study

This is a prospective study performed on 38 consecutive patients referred to our unit for major lung resection for non-small-cell lung cancer (NSCLC) from May 2009 to December 2009. Patients were selected for operation according to the recommendations of the European Respiratory Society and the European Society of Thoracic Surgeons guidelines [2]. In chronic obstructive pulmonary disease (COPD) patients, bronchodilator therapy was optimized at the outpatient clinic before surgery. Patients physically unable to carry out the exercise test due to orthopedic problems or mentally limited to understand it were excluded from the study. In those cases with previous ischemic heart disease, cardiac consultation with evaluation of the cardiac functional status by ergometry or an equivalent test was considered mandatory before respiratory CPET.

Only patients already accepted for surgical resection were offered to enter the study and only those who accepted to participate were finally included in the study. All patients signed an informed consent for participation in the study, which was approved by the local Institutional Review Board.

2.2. Pedometer

Daily-living physical preoperative activity was measured using an OMROM Walking Style Pro® pedometer. The pedometer allows data acquisition up to 41 days and is capable to differentiate two types of ambulatory activity: the standard and the so-called aerobic mode. After 10 min of continuous walking at a rate of at least 60 steps per min, the aerobic mode is activated and it is deactivated after a 1-min break.

At the initial consultation, the patients were instructed on how to use the pedometer and it was adjusted for patients' weight and stride length. Subjects entering the study were also instructed to wear the pedometer on the belt or waistband from the moment they awoke until they went to bed except while bathing or swimming. The pedometer was firmly attached to their clothes at the waist with the aid of a clip and a secure band. Patients were not encouraged to increase their daily activity but counselling to quit smoking and training on the use of an incentive spirometer was provided. Daily basal activity was measured during the waiting time before surgery. Obtained data were downloaded at admission for surgery.

2.3. CPET and VO_{2max} acquisition

A MasterSreen CPX module of Jaeger-Vyasis-Healthcare was used for CPET developing and recording. This module is capable to measure and register all lung-ventilating parameters such as O_2 uptake (VO_2), CO_2 uptake (VCO_2), anaerobic threshold, respiratory exchange ratio (RER), HR, ventilatory equivalent for O_2 (EQO_2), ventilatory equivalent for CO_2 ($EQCO_2$) in an open mode 'breath by breath'. The module is also prepared for fast analysis of O_2, CO_2, and 12 electrocardiogram (ECG) leads. Ventilation was registered by a bidirectional sensor of high precision (Triple V), capable of in-breath flow and volume curve analysis. Before surgery, all patients underwent a standardized exercise test on a bicycle up to exhaustion or up to symptom limitation, according to the following protocol: after calibration of volumes and gases, a spirometry was performed to calculate minute ventilation (V_E) and analyze the intra-breath curve during exercise. Heart rate, blood pressure, arterial blood gas parameters and Borg dyspnea scale were recorded in basal conditions. Once the patient was connected to the pneumotachometer and gas analyzer, data acquisition at rest and 3 min of unloaded cycling followed. Then, an incremental exercise was initiated, according to Wassermann protocol [4], up to a maximal exercise within the estimated time of 10–12 min. After completion of the test, arterial blood gas parameters and modified Borg scale were recorded.

2.4. Variables included in the analysis

The following clinical variables were recorded: age, sex, body mass index (BMI), preoperative FEV1%, preoperative DLCO%, presence or absence of COPD according to the standard Global Initiative for Obstructive Lung Disease (GOLD) criteria and presence or absence of other comorbidities such as arterial hypertension, ischemic heart disease, valvular disease, diabetes mellitus, renal insufficiency, and peripheral arterial disease.

Data downloaded from the pedometer were: mean daily number of total steps ('Totalsteps'), preoperative mean daily aerobic steps ('Aerobsteps'), mean preoperative time of aerobic activity measured in min ('Time') and mean daily walked distance measured in km ('Distance').

From the CPET, VO_{2max} in absolute values (ml kg min^{-1}) and as a percentage of the individually estimated value for age, sex, and height was obtained.

2.5. Statistical methods

A linear relationship with each continuous clinical variable and VO_{2max} in absolute values was tested using the Pearson correlation coefficient. Then, linear relationships of the pedometer's downloaded variables with each other and with VO_{2max} in absolute values were similarly tested. To avoid collinearity problems, only the pedometer variable showing the higher correlation with VO_{2max} was selected for further analysis.

Two linear regression models with bootstrap robust estimation (1000 iterations) of the standard error of the regression coefficients were tested. In both of them, VO_{2max} in absolute values was the dependent variable. In the first one, the mean daily walked distance measured in km ('Distance') was the independent variable. In the second model, besides 'Distance', DLCO% was also introduced. The estimated values of VO_{2max} by both models ('Est_distance'

and 'Est_Dist_DLCO') were considered as new variables and their correlation with actual VO_{2max} values were graphically presented.

To evaluate whether the difference between the measurements by the two methods is related to the magnitude of the measurement itself, we have plotted and calculated the correlation index between the difference of the estimated VO_{2max} value and the measured VO_{2max} against the average value of the measurement for each case, according to the Bland and Altman method [5]. Statistical analysis was done using Stata 10.1 software (Stata Corp, TX, USA).

3. Results

A total of 51 patients were included in the study but 13 of them were excluded because they were unable to carry out the exercise test, the most frequent reasons being cardiac comorbidity and joint pathology at the level of the knee. Of the 38 left, most patients (37 cases) were scheduled for lobectomy and only one for pneumonectomy. Mortality of the series was nil and seven patients (18.4%) developed postoperative cardiorespiratory complications. General characteristics of the patients are shown in Table 1.

Recorded ambulatory activity and global VO_{2max} data are presented in Table 2.

As anticipated, a high collinearity was found between all the parameters downloaded from the pedometer. In the correlation analysis between all pedometer variables and VO_{2max}, 'Distance' showed the highest correlation index ($r = 0.440$) and was chosen as the variable to enter the regression model (Table 3).

No correlation was found between VO_{2max} and FEV1% ($r = 0.026$) nor BMI ($r = -0.057$). However, age ($r = -0.550$) and DLCO% ($r = 0.214$) were correlated to VO_{2max} and both variables were correlated to each other ($r = -0.245$) (Table 4).

At the first linear regression model, adjusted R^2 was 0.81. The model accounted for most of the variance of VO_{2max} (analysis of variance (ANOVA), $p = 0.000$). In the second model, DLCO ($p = 0.000$) and 'Distance' ($p = 0.002$) predicted actual VO_{2max} value with an adjusted R^2 of 0.93. Again, the model accounted for most of the variance of VO_{2max} (ANOVA, $p = 0.000$, Table 5). Lastly, plotted VO_{2max} values (real vs linear model prediction) are shown in Fig. 1.

Table 1. Descriptive statistics of categorical and continuous clinical variables.

	N	%
Categorical variables		
Male	30	79
COPD	17	43.6
Coronary artery disease	4	10.5
Systemic hypertension	7	18.4
Diabetes mellitus	5	13.2

	Mean	±SD	Range
Continuous variables			
Age	62.8	10.1	38–80
BMI	26.1	6.8	19.29–45.9
FEV1%	90.1	21.8	39–137.8
DLCO	82.8	20.1	41.1–118

Table 2. Descriptive statistics of data downloaded from pedometers and preoperatively measured VO_{2max}.

	Mean	±SD	Range
Mean number of days wearing the pedometer	26.2	9.3	7–41
Mean daily total number of steps	8653.6	4578.3	821.6–20471.4
Mean daily aerobic number of steps	3441.7	2945.5	0–10173.5
Mean daily time of aerobic activity (min)	32.6	26.9	0–103.5
Mean daily distance walked (km)	5.5	3.17	0.37–12.6
VO_{2max} (ml kg min^{-1})	20.3	4.6	11.9–31.2
VO_2%	83.7	15.3	60–114

Table 3. Correlation between pedometer variables and VO_{2max}.

	Totalsteps[a]	Aerobsteps[b]	Time[c]	Distance[d]	VO_{2max}
Totalsteps[a]	1.00				
Aerobsteps[b]	0.75	1.00			
Time[c]	0.73	0.99	1.00		
Distance[d]	0.92	0.79	0.78	1.00	
VO_{2max}	0.40	0.16	0.11	0.44	1.00

[a] Mean daily total steps.
[b] Mean daily aerobic steps.
[c] Mean daily time of aerobic activity.
[d] Mean daily distance walked.

Finally, no difference between the two methods to find a VO_{2max} value depending on the magnitude of the measurement itself was found ($r = 0.067$) as shown in Fig. 2.

Nine patients showed an actual VO_{2max} of 15 ml kg min^{-1} or below (range 11.9–15.9 ml kg min^{-1}). In this subgroup, there were four females. In this subgroup, mean age was 70.5 years (range: 60–77 years), mean BMI was 28.6 kg m^{-2}(range: 21.3–32.8 kg m^{-2}) and mean DLCO% 78.1 (range 41.1–111). Three of them were on current treatment for hypertension, two for diabetes mellitus and one for cardiac ischemia. All of them underwent lobectomy and only one (patient number 3, see

Table 4. Correlation data between clinical and functional parameters and VO_{2max}.

	Age	BMI	FEV1%	DLCO%	VO_{2max}
Age	1.000				
BMI	−0.056	1.000			
FEV1%	−0.025	−0.014	1.000		
DLCO%	−0.245	0.476	0.179	1.000	
VO_{2max}	−0.550	−0.057	0.026	0.214	1.000

Table 5. Predictive models.

	Observed coefficient	Bootstrap SE	95% CI	p
Model 1: independent variable: mean daily distance[a]				
Distance	2.993	0.231	2.539–3.446	0.000
Model 2: independent variable: mean daily distance and DLCO%[b]				
Distance	0.922	0.303	0.327–1.516	0.002
DLCO%	0.175	0.019	0.137–0.213	0.000

Dependent variable: VO_{2max}. $p = 0.000$.
[a] $R^2 = 0.812$.
[b] $R^2 = 0.935$.

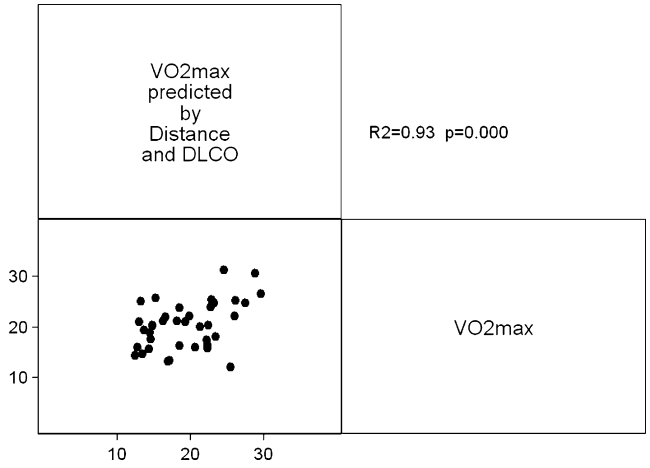

Fig. 1. Graphical plot of the actual versus estimated VO_{2max} in model 2 that includes distance and DLCO%.

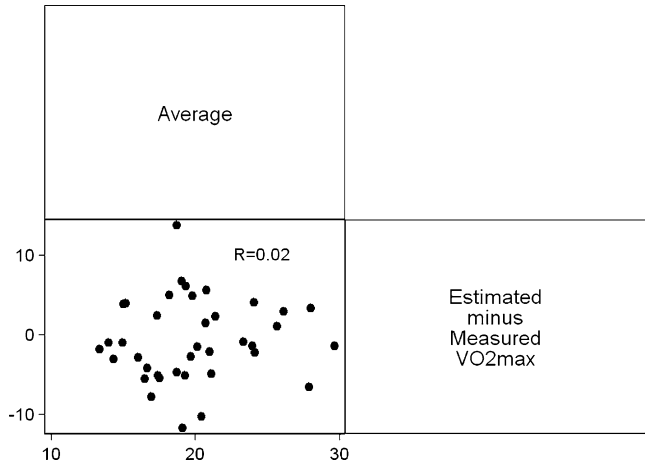

Fig. 2. The graph represents the difference of the estimated VO_{2max} value and the measured VO_{2max} against the average value of both types of measurement for each case according to the Bland and Altman method [5].

Table 6) had a postoperative complication (prolonged air leak). The acquired data from the pedometer for this subgroup in mean ± SD for each variable were: daily total number of steps: 6786.38 ± 1566.31; daily aerobic number of steps: 3130.24 ± 1164.07; daily time of aerobic activity (min): 30.13 ± 10.81; daily distance walked (km): 3.95 ± 1.02; and the estimated VO_{2max} with model 2 are: 17.32 ± 1.54 ml kg min^{-1} (range 12.46–25.57 ml kg min^{-1}). There were five cases where the estimated VO_{2max} was higher than the actual and four cases where the actual VO_{2max} was higher than the estimated. In these latter cases, the differences between the actual and the estimated values were smaller than the differences found within the first group (Table 6).

4. Discussion

Surgical risk estimation is an obligatory step in the preoperative workout of every patient undergoing lung resection. Although a temporal trend toward a decrease in postoperative morbidity was recently reported [6], post-operative cardiorespiratory complications are still frequent. Moreover, some patients are denied surgery because of a high probability of severe complications and operative death. In this context, developing feasible and accurate methods for preoperative assessment of surgical risk is necessary.

Many mathematical models and algorithms have been developed for risk-estimation purposes [7], but even using these mathematical tools, individual risk estimation is frequently inaccurate due to non-controllable variables and to case selection bias [8]. Models not including CPET values are usually not accurate as measured VO_{2max} is currently the best predictor of early postoperative cardiorespiratory morbidity [1,2]. It is well known that VO_{2max} values are dependent, amongst other factors, on the age and gender of the patient [9,10], previous respiratory disease [11], genetic background [12], and previous patient's fitness, the last being daily activity-dependent [9,13]. It has been demonstrated that more physically active COPD patients have better functional status, including higher VO_{2max} peak [14]. The amount and intensity of daily physical activity is also closely related to health and mortality [15,16].

Both lung cancer and COPD are associated with smoking, which, by generating reactive oxidant species, induces a chronic inflammatory state in the lung [17]. Due to this association, many NSCLC patients referred for surgery also have COPD. It is also known that patients with COPD are markedly inactive in daily life [18,19] and that, in this population, higher values of systemic inflammation and left cardiac dysfunction are associated with reduced physical activity independently of GOLD stages or body mass index, airflow obstruction, dyspnea and exercise (BODE) score. These previous data, associated with the fact that few individuals with COPD are willing to exercise to maximal symptom intensity [20] suggest that walking, instead of cycling, is a more useful test for evaluating functional

Table 6. Data from the nine cases with the lowest actual VO_{2max} value in the series.

Case	Age	Sex[a]	DLCO%	Distance (km)	Actual VO_{2max} (ml kg min^{-1})	Estimated VO_{2max} (model 2) (ml kg min^{-1})
1	65	2	90	10.63	11.9	25.5
2	60	2	83	2.63	13.1	16.9
3	77	1	96	.365	13.3	17.1
4	75	1	41.1	5.71	14.3	12.4
5	63	2	67	1.91	14.5	13.5
6	75	1	70.4	2.25	15.5	14.4
7	76	1	111	3.2	15.7	22.4
8	77	2	86	6.1	15.8	20.6
9	67	1	58	2.83	15.9	12.7

[a] Sex: 1: male.

capacity in COPD cases [18,20]. Unfortunately, neither the 6 min walking test nor the 20 m shuttle run test has shown a high accuracy to predict postoperative outcome [2].

The idea of correlating VO_{2max} and daily physical activity is not new and daily steps counts have been found to be predictive of VO_{2max} in previous reports using accelerometers [21] or pedometers [22–24]. Accelerometers have become important as activity assessment tools in research [21]. Although accelerometers can measure all kinds of physical activity beside walking, they are more expensive and require supporting hardware and software due to the frequent need of calibration to maintain their precision. Pedometers are generally considered the more practical alternative for recording daily-living activity. They are unobtrusive body-worn instruments, simple to use, affordable, and the output is extremely user friendly [25]. The type of pedometer used in this study has been validated previously showing a high correlation index with the 6 min walking test and treadmill [3,25]. Previously published non-exercise test in a healthy population reported varying success in predicting VO_{2max} values, R^2 ranging from 0.72 to 0.82 [22,23].

Approaching the development of the regression model, the first limitation was the small sample size ($n = 38$) that only allowed the introduction of one or, at most, two independent variables in the model. Therefore, the first variable chosen was 'Distance', the pedometer record showing the highest correlation index with VO_{2max} ($r = 0.448$) in the preliminary analysis. Seeking to achieve an improvement in the prediction value, DLCO% was included in the model. In other studies [21–24], some physical variables such as age or BMI have been added to the model, but, to our knowledge, never functional parameters. The rationale for introducing DLCO% in the linear regression model was twofold: first, this parameter has shown a correlation with the patient's age ($r = 0.245$), a constant variable in all the previously published models [21–23] due to the well-known relationship between age and VO_{2max}; and second, this parameter is frequently quoted as the best predictor of the cardiorespiratory adverse effects of lung resection when VO_{2max} is not calculated [2]. The improvement of the prediction in the second model is moderate and its usefulness should be tested in larger series of cases.

As was pointed out in Section 3, when analyzing the nine patients with the lowest measured VO_{2max}, we found discrepancies between the data in all cases; however, these differences were less important when the estimated VO_{2max} were lower than the measured VO_{2max}. This finding should be considered with caution because when the whole data series is analyzed using the Bland and Almand method [5], the correlation indicates no differences in the results obtained depending on the magnitude of the measurement itself.

Apart from that subgroup, there were three cases with a significant discrepancy between actual and predicted data using both regression models; in all the cases, the estimated VO_{2max} value was much higher than the actual. It could be hypothesized that an inaccurate use of the pedometer may have played a role, and/or that other physical conditions not taken into account in the model may have hampered the exercise capacities of some patients. Motivational reasons may also account, in part, for a discrepancy between physical capacities and the amount of exercise. These factors should be taken into consideration in future studies on this topic.

Due to the aforementioned discrepancies, a higher number of cases and future studies are mandatory to distinguish the causes leading to under- or overestimating VO_{2max} values and how to avoid the risk that an operable patient could be denied surgery or the contrary. Currently, the measurement of the daily activity cannot considered as a substitute of formal CPET as the latter provides an array of information and parameters on the ventilatory and cardiovascular systems helping the physicians to identify and treat the deficits in the oxygen transportation system. Hopefully, after the information presented in this article will be confirmed in larger studies and more functionally compromised patients, the daily basal activity could be useful to screen those subjects in whom formal CPET cannot be replaced by low-technology exercise tests before lung resection.

To conclude, in the present report on a representative sample of the clinical population undergoing anatomical resection for lung cancer, we have found that VO_{2max} can be significantly predicted by the mean daily walked distance recorded by a pedometer. The strength of the prediction is slightly increased by adding the measured preoperative DLCO% in the dregression model. These preliminary data have to be confirmed on a larger population of patients.

References

[1] Brunelli A, Charloux A, Bolliger CT, Rocco G, Sculier JP, Varela G, Licker M, Ferguson MK, Faivre-Finn C, Huber RM, Clini EM, Win T, De Ruysscher D, Goldman L, European Respiratory Society; European Society of Thoracic Surgeons Joint Task Force on Fitness For Radical Therapy. The European Respiratory Society and European Society of Thoracic Surgeons clinical guidelines for evaluating fitness for radical treatment (surgery and chemoradiotherapy) in patients with lung cancer. Eur J Cardiothorac Surg 2009;36:181–4.

[2] Benzo R, Kelley GA, Recchi L, Hofman A, Sciurba F. Complications of lung resection and exercise capacity: a meta-analysis. Respir Med 2007;101:1790–7.

[3] Tudor-Locke C, Williams JE, Reis JP, Pluto D. Utility of pedometers for assessing physical activity. Convergent validity. Sports Med 2002;32:795–808.

[4] Wasserman K, Hansen JE, Sue DY, Stringer WW, Whipp BJ. Principles of exercise testing and interpretation. Including pathophysiology and clinical applications, 4 edition, Philadelphia: Lippincott Williams & Wilkins; 2005.

[5] Bland JM, Altman DG. Comparing methods of measurement: why plotting difference against standard method is misleading. Lancet 1995;346:1085–7.

[6] Licker MJ, Widdiker I, Robert J, Frey JG, Spiliopoulos A, Ellenberger C, Schweizer A, Tschopp JM. Operative mortality and respiratory complications after lung resection for cancer: impact of chronic obstructive pulmonary disease and time trends. Ann Thorac Surg 2006;81(5):1837–8.

[7] Varela G, Novoa N. Future Trends in preoperative evaluation. Thorac Surg Clin 2008;18:31–7.

[8] Utley M, Treasure T. The use of scoring systems in selecting patients for lung cancer resection: work-up bias come full-circle. Thorac Surg Clin 2008;18:107–13.

[9] Woo JS, Derleth C, Stratton JR, Levy WC. The influence of age, gender, and training on exercise efficiency. J Am Coll Cardiol 2006;47:1049–57.

[10] Johnson BD. Respiratory system responses to exercise in ageing. In: Weisman IM, Zeballos RJ, editors. Clinical exercise testing Prog Respir Res, vol. 32. Basel: Kerger; 2002. p. 159–72.

[11] O'Donell DE. Exercise limitation and clinical exercise testing in chronic obstructive pulmonary disease. In: Weisman IM, Zeballos RJ, editors.

Clinical Exercise Testing Prog Respir Res, vol. 32. Basel: Kerger; 2002. p. 138–58.
[12] Ingelsson E, Larson MG, Vasan RS, O'Donnell CJ, Yin X, Hirschhorn JN, Newton-Cheh C, Drake JA, Musone SL, Heard-Costa NL, Benjamin EJ, Levy D, Atwood LD, Wang TJ, Kathiresan S. Heritability, linkage, and genetic associations of exercise treadmill test responses. Circulation 2007;115:2917–24.
[13] Zhang JG, Ohta T, Ishikawa-Takata K, Tabata I, Miyashita M. Effects of daily activity recorded by pedometer on peak oxygen consumption (VO_2 peak), ventilatory threshold and leg extension power in 30- to 69-year-old Japanese without exercise habit. Eur J Appl Physiol 2003;90:109–13.
[14] Garcia-Aymerich J, Serra I, Gómez FP, Farrero E, Balcells E, Rodríguez DA, de Batlle J, Gimeno E, Donaire-Gonzalez D, Orozco-Levi M, Sauleda J, Gea J, Rodriguez-Roisin R, Roca J, Agustí AG, Antó JM, Phenotype and Course of COPD Study Group. Physical activity and clinical and functional status in COPD. Chest 2009;136:62–70.
[15] Myers J, Prakash M, Froelicher V, Do D, Partington S, Atwood JE. Exercise capacity and mortality among men referred for exercise testing. N Engl J Med 2002;346:793–801.
[16] Garcia-Aymerich J, Lange P, Benet M, Schnohr P, Antó JM. Regular physical activity reduces hospital admission and mortality in chronic obstructive pulmonary disease: a population based cohort study. Thorax 2006;61:772–8.
[17] Brody JS, Spira A. State of the art. Chronic obstructive pulmonary disease, inflammation, and lung cancer. Proc Am Thorac Soc 2006;3:535–7.
[18] Pitta F, Troosters T, Spruit MA, Probst VS, Decramer M, Gosselink R. Characteristics of physical activities in daily life in chronic obstructive pulmonary disease. Am J Respir Crit Care Med 2005;171:972–7.
[19] Watz H, Waschki B, Boehme C, Claussen M, Meyer T, Magnussen H. Extrapulmonary effects of chronic obstructive pulmonary disease on physical activity: a cross-sectional study. Am J Respir Crit Care Med 2008;177:743–51.
[20] Turner SE, Eastwood PR, Cecins NM, Hillman DR, Jenkins SC. Physiologic responses to incremental and self-paced exercise in COPD: a comparison of three tests. Chest 2004;126:766–73.
[21] Guy P, Westerterp KR. Accelerometry and heart rate as a measure of physical fitness: proof of concept. Med Sci Sports Exerc 2005;37:872–6.
[22] Cao ZB, Miyatake N, Hihuchi M, Ishikawa-Takata K, Miyachi M, Tabata I. Prediction of VO_{2max} with daily step counts for Japanese adult women. Eur J Appl Physiol 2009;105:289–96.
[23] Wier LT, Jackson AS, Ayers GW, Arenare B. Nonexercise models for estimating VO_{2max} with waist girth, percent fat, or BMI. Med Sci Sports Exerc 2006;38:555–61.
[24] Schönhofer B, Ardes P, Geibel M, Köhler D, Jones PW. Evaluation of a movement detector to measure daily activity in patients with chronic lung disease. Eur Respir J 1997;10:2814–9.
[25] Tudor-Locke C, Williams JE, Reis JP, Pluto D. Utility of pedometers for assessing physical activity. Construct validity. Sports Med 2004;34:281–91.

Appendix A. Conference discussion

Dr G. Rocco (*Naples, Italy*): Firstly, what are your future expectations when the series becomes larger? Secondly, this pedometer is not recording cardiac rate, which I think is a relevant variable for evaluating the type of exercise the patient is doing. Maybe a more sophisticated model with a heart rate reading could be of help in the future. Also, accelerometers have been used in COPD. Their utility has not been discussed at great length during this presentation. Is the price and complexity of these accelerometers worth the information they can possibly give us?

Lastly, would a predictive model with distance and age, instead of DLCO, which has shown high collinearity, be better indicated, in your opinion?

Dr Novoa: Measuring heart rate is quite important in the estimation of VO_{2max}. At the beginning of this study when we were considering how to do it, we were thinking about something very simple, because when we considered the measurement of heart rate, we knew we had to use another device, and we knew it had to be properly placed. Otherwise the accuracy of the registry cannot be guaranteed. So we were looking for something very simple, because the type of patients we have are not allowed to have many things. Therefore in the end, we decided not to measure heart rate.

But there was a second reason for not measuring it. This pedometer has the capability of distinguishing two types of linear activity. One is the basal, the normal activity, the total number of steps you can walk in one day, and the other is what is called the aerobic mode. In the aerobic mode, when the person starts walking at a speed of more than 60 steps per minute for more than 10 minutes, this aerobic mode activates. And we know from the lab studies that were previously published that when a person is capable of maintaining this exercise, their heart rate was going up to 80–85% of their maximum heart rate. So that is how we knew such a patient was doing at least a submaximal exercise.

But I have to be sincere. At the beginning I thought that to measure the time the patient was doing aerobic activity, or the number of steps in the aerobic activity, was something important. That was the key to the whole study. If the patient is capable of doing exercise on a daily basis, a kind of exercise that counts for fitness, I thought it could somehow be relevant in the study, but we couldn't find it. It is not significant at all, even though we looked for it.

Regarding accelerometers, this is a very good question, a very good comment. Up to now, accelerometers were used more in clinical settings but not really for public health or in high numbers of people, because they are difficult to manage. They have to be calibrated frequently for an accurate registry. It is not the kind of device that you can give a patient and collect two or three weeks later on. So we decided not to use them.

And finally, about future expectations and a model with distance and age, these are very promising results, but they are preliminary. We are short in numbers of patients. But somehow I got the feeling it is going to work. So we introduced in this first model DLCO, because, as I said, it is the most quoted variable for risk prediction when not taking into account the VO_{2max}, but also because we were looking for something that was related to our professional daily activity. Of course, we are open to any results, and I think that maybe in the future distance and age could be also a very good model. We have to try.

Dr M. Ferguson (*Chicago, IL, USA*): I congratulate you on using some older technology for a new and very important application. In the rationale that you gave for performing the study, one of the considerations was the inability of patients to perform accurately an exercise test, particularly those who have COPD. I am wondering if a better rationale is to use very low cost testing, both in terms of expense for the technology but also in terms of human costs, to do the equivalent of measuring VO_{2max}, which is very intensive both from an equipment standpoint and personnel standpoint.

The second question I have is, in your manuscript you mention that there were three outliers of the 38 who were not correctly predicted. By inspecting your graph, it seems to me that at least two of those were high performers, not low performers. So I am wondering if the test is relatively inaccurate for people who are low risk but relatively accurate for people who would otherwise be considered high risk.

Dr Novoa: Regarding the discrepancies, those three cases, there were two patients that were very good on the pedometers but not on the exercise test. But we have to take a look, because the problem with this low-technology system, as you said, is that you need cooperation. So not all the patients cooperate in the same way. As I said, we gave the pedometer for two or three weeks to every patient, which is the time they were on the waiting list. So at that time we found that there were people that were wearing the pedometer on a daily basis, and most of them were very regular in taking their exercise. But there was another group of people that were not so regular; they were not cooperating as well. One of those discrepancy cases belonged to this group that were not really very cooperative patients. So results are so–so.

Dr S. Mattioli (*Bologna, Italy*): Practically speaking, we diagnose stage and operate on patients in 10–12 days now. This is good medical practice I think. It is a particularly peculiar period, because the patients undergo tests, they are anxious, etc. Do you think that this situation can influence your measurements, first question.

Second question. Go back to the future. The old test, the treadmill test, was the measurement of the basal and after strength gases. It sounds to me that it is quite close and if you think that surgery is a stress test, maybe you correlate better. So those are the two questions.

Dr Novoa: To summarize, I think that the high-technology test allows us to distinguish between a respiratory problem, a cardiological problem, or even a cardiovascular problem, but all those things you can see together with the low-technology test. So, I mean, a big workout cannot be needed. I don't know if this answer helped both of your questions.

Dr A. Turna (*Istanbul, Turkey*): The mean FEV1 value of your patients was 90%, but VO_{2max} is required in COPD patients mostly. Would you comment on the applicability of the pedometer in COPD patients and could you give the number of patients who fit GOLD COPD criteria?

Dr Novoa: As you saw in the data of the series, most of the patients were standard patients for a thoracic surgical unit. We have some patients with a VO_{2max} (or CPET) under 15. It was around 15 patients with COPD. So there were more people with very good respiratory functional results, but then they were performing sub-optimally in the high-technology test later on. But most of those patients were performing very well with the pedometer, and, as a result of that, mortality was low in the series and cardiorespiratory complications were also low. But as I said before, these are promising but preliminary results.

Dr A. Brunelli (*Ancona, Italy*): I have just two suggestions for future line of research. These are not questions. So the first is, I would suggest that you test the correlation between the pedometer variables and the VO_2 expressed as percentage of predicted; secondly, I noticed the average VO_2 is around 20, which is quite high. So I would suggest shifting the focus to those patients with lower values of VO_2, those with a VO_2 below 15 maybe. Those are the patients in whom we want to know whether there is a correlation between a pedometer and the VO_2.