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Measuring habitual physical activity in adults with cystic fibrosis

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KEYWORDS
Cystic fibrosis;
Physical activity;
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Summary
Background: The aim of the present study was to determine whether different methods of recording physical activity (PA), i.e., accelerometers vs questionnaires, provided similar information in adults with cystic fibrosis (CF).
Methods: 20 CF (age 33 ± 8SD yrs, FEV_1 68 ± 16% predicted) and 11 age-matched healthy controls completed the Habitual Activity Estimation Scale (HAES) questionnaire and wore a biaxial accelerometer (SenseWear Pro3 Armband). Exercise tolerance was measured in CF.
Results: Patients had similar values in PA compared with controls. None of PA categories estimated by HAES questionnaire correlated with PA categories measured by the accelerometer; in CF the HAES questionnaire overestimated the effective levels of PA measured by the accelerometer. There were no differences between weekdays and weekend days PA levels provided by the accelerometer. In CF the questionnaire detected different time reported during the "somewhat inactive" and "somewhat active" categories ($z = 2.651$; $p = 0.008$; $z = -2.651$; $p = 0.008$), weekdays vs weekend; patients reported more time spent in activity (somewhat active & very active) during the weekend ($z = -2.203$; $p = 0.02$). Peak oxygen uptake correlated with accelerometer activities of "moderate" (>4.8 metabolic equivalents (METS)) and "vigorous" (>7.2 METS) intensity ($r = 0.503$, $p = 0.02$; $r = 0.545$, $p = 0.01$).
Conclusions: In adults with cystic fibrosis PA levels are better evaluated by the accelerometer and are similar to the controls. PA measured by the accelerometer is similar during the week and correlates with exercise tolerance.

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Introduction

In healthy individuals, exercise tolerance and the level of daily physical activity are important determinants of health status and mortality [1]. In patients with cystic fibrosis (CF) exercise tolerance is usually reduced [2]. Importantly, research studies have shown that peak oxygen uptake ($VO_{2\ peak}$), maximal work rate ($Work_{max}$) and ventilatory equivalents for oxygen uptake (V_E/VO_2) measured during incremental cardiopulmonary exercise predict patients' survival in CF [3]. Data obtained in young adults with CF suggest that the level of daily physical activity (PA) may have a positive impact on exercise tolerance, on nutritional status [4] and on the rate of decline of FEV_1 [5]. There is also evidence that in CF patients improving physical activity increases sputum clearance, improves respiratory muscle strength and ultimately leads to better quality of life [2,6,7]. Therefore exercise training programs have been developed for CF to increase the patients' ability to undertake daily activities and to change their lifestyle to maintain the positive effects of rehabilitation. Recently, Troosters et al. showed in adults with CF that compared with age-matched controls, mild intensity physical activity was preserved while activity above moderate intensity was significant reduced [8].

However, translating this growing interest in activity into clinical practice has proven difficult, especially in adult CF patients. Although recommendations on the use of exercise testing in respiratory diseases are available [9], laboratory exercise testing remains relatively underutilized in the clinical setting of CF, probably because of its expense and the lack of adequately trained staff [10]. Some workers have used either $VO_{2\ peak}$ during incremental exercise or a 6 min walking test as surrogate assessment of PA [4,11] but how well these relate to objectively measured daily activity in CF patients is unclear. To date there is relatively little information about objectively measured PA in CF. Accelerometers can be used to accurately measure habitual PA levels but they are more expensive than using one of the questionnaires that have been developed. Although questionnaires have been utilized in chronic respiratory diseases, such as COPD and CF, as an alternative to accelerometers, their validity and reliability is debatable. In small cohorts of CF patients, Wells et al. [12] and Ruf et al. [13] found a significant correlation between levels of PA, estimated by the Habitual Activity Estimation Scale (HAES) questionnaire, and activity levels measured by the use of accelerometers. However in these studies the proportion of adult participants was relatively small. A recent larger study in adult CF population using a validated questionnaire was conducted by Rasekaba et al., but the results observed were not supported by objective measures of activity levels [14].

Therefore, the primary aim of the present study was to determine whether different methods of recording habitual daily physical activity, i.e., accelerometers vs questionnaires, provide similar information in adults with CF. The secondary aims were to detect possible differences in the levels of PA during the week, i.e., weekdays vs weekend days and to assess the relationships between pulmonary function, exercise capacity, and physical activity. Specifically, we were interested to evaluate whether accelerometer or questionnaire data related to the prognostically important variables derived from cardiopulmonary exercise testing.

Material and methods

Subjects

Twenty clinically stable adult CF patients (33 ± 8SD years) were recruited from the CF outpatient clinic at Policlinico Umberto I Hospital (Sapienza University of Rome, Italy) and 11 age-matched healthy control subjects (30 ± 4SD years) were recruited from staff and colleagues of the same hospital. Patients were excluded if they had unstable medical conditions that could cause or contribute to breathlessness (i.e., cardiovascular, metabolic, or other respiratory diseases) or other disorders that could interfere with exercise testing, such as neuromuscular diseases or musculoskeletal problems. Patients with an exacerbation in the 4 weeks prior to the study, patients on the waiting list for lung transplantation and those who had undergone lung transplantation were excluded from the study.

To be eligible for inclusion, the healthy control subjects needed to be at least 18 years of age and free of cardiorespiratory diseases; specifically, five of them were students of the faculty of Medicine (Sapienza University of Rome), four were physiotherapists and two were employed.

Study design

All subjects signed written informed consent at the time of their first assessment and were familiarized with all procedures, questionnaire and symptom rating scale before these were evaluated in the study. The ethical approval was received from the Policlinico Umberto I Hospital (Sapienza University of Rome, Italy). On the first visit, after informed consent and appropriate screening of medical history, all subjects underwent pulmonary function testing but only the CF patients performed the 6 min walking test (6MWT) and a symptom-limited incremental cardiopulmonary exercise test (CPET). Finally, patients and healthy controls wore an accelerometer to assess daily habitual PA and they were studied over four consecutive typical days (including 2 weekdays and 2 weekend days). On the second visit all subjects returned the accelerometer and completed the HAES questionnaire.

Methods

Measurement of spirometry (COSMED PFT, Pavona Italy) was performed according with recommended standards [15]. In the patient group, spirometry was repeated 20 min post-bronchodilator (albuterol 400 μg) and these data were expressed as a percent of predicted [16].

CF patients performed the 6MWT in accordance with ATS recommendations [17] with two additional practice walks at the initial assessment. Perceived breathlessness was scored immediately before and at peak exercise, using the modified Borg scale [18]. A maximal incremental exercise test was conducted on an electronically-braked cycle ergometer according to recommended guidelines [19]. CPET consisted of a 2-min rest period, then 2 min of unloaded pedaling followed by a stepwise work rate increments of 10–20 Watt/min, depending on patient's height. The test was continued until exhaustion and subjects stated their main reason for stopping exercise, i.e., breathlessness, leg discomfort or both. Arterial oxygen saturation (SpO_2), heart rate (HR), and blood pressure (BP) were measured during CPET. Tidal volume V_T, breathing frequency (f) and O_2 and CO_2 expired gases were measured breath-by-breath (COSMED Quark B^2, Pavona, Italy) having the subjects breathing through a turbine attached to a low dead space face mask. A dedicated software calculated minute ventilation (V'_E), oxygen uptake ($V'O_2$) and carbon dioxide production ($V'CO_2$).

Activity measurement

All patients and all healthy volunteers completed the HAES questionnaire [20] for a typical weekday (either Tuesday or Thursday) and Saturday within the past week. Percentage of awake time was documented in each of four activity categories: inactive, somewhat inactive, somewhat active, and very active. Subjects referred to these descriptions when completing their estimates: "inactive" (I) like lying down, sleeping, resting; "somewhat inactive" (SI) like sitting, reading, watching television; "somewhat active" (SA) as walking, shopping, light household chores; "very active" (VA) like running, jumping, skating, skipping. The use of wakeup, bed, and meal times allowed the calculation of the total number of hours per day spent in each of the four activity categories. Total activity (TA) was calculated as "somewhat active" + "very active" and total inactivity (TI) was calculated as "inactive" + "somewhat inactive" for each day. This questionnaire has already been used in children with CF [21]. The test-retest reliability of the HAES questionnaire was analyzed in CF by Wells et al. who found a highly significant intra-class correlation coefficient ICC = 0, 72 [12].

Total body activity measurement

Habitual daily activity was assessed for four consecutive typical days. We used the SenseWear Pro3 Armband (BodyMedia Inc., Pittsburgh, PA, USA) positioned on the upper right arm (on the triceps point), as recommended by the manufacturer. The sensor contains a biaxial accelerometer (longitudinal and transverse), a galvanic skin response sensor, a heat flux sensor, a skin temperature sensor and a near-body ambient temperature sensor from which the data were stored minute by minute. Using specific software these variables, as well as body weight, height, handedness and smoking status (smoker or non-smoker) were used to estimate the intensity of PA, expressed in metabolic equivalents (METS), total energy expenditure, total physical activity duration, time lying down and sleep duration. All subjects wore the armband day and night only removing it for bathing or showering. The outcome obtained from the armband was the time spent in PA at different intensities and the definitions for activity levels based on METS were those used by Troosters et al. [8]. The time (in min) spent with an energy expenditure of >3 METS was considered "mild" activity (e.g., walking at normal walking speed, carrying out light household work), time spent at >4.8 METS was considered "moderate" activity (e.g., brisk walking or cycling) and activities with an energy expenditure of >7.2 METS were considered "vigorous" (e.g., activity with training effects when applied for a sufficient length of time and at an appropriate training frequency) [22]. Finally, the number of steps was measured.

Statistical analysis

Descriptive data are reported as mean, standard deviation (SD), minimum and maximum values. Data from the accelerometer and HAES questionnaire were compared for the same day (weekday or weekend). Data from the two weekdays and the two weekend days activity levels measured by the accelerometer were averaged to give a single weekday and weekend value so as to match with the weekday and weekend day reported by the HAES questionnaire.

We used a Kruskall–Wallis test to compare the scores of the questionnaire and the accelerometer between patients and controls. The association between measures collected during weekdays and weekend days both for the accelerometer and the questionnaire was tested with the sign-rank non parametric test (Z) for matched data. The correlation between the exercise physiological variables, and both the items of the questionnaire and the measures collected by the accelerometer, was evaluated by the Spearman correlation coefficient, a non-parametric measure of statistical dependence between two variables. The level of significance was set at $p < 0.05$. As these analyses were exploratory in nature no correction for multiple testing was carried out.

Results

The baseline characteristics and pulmonary function data for both groups are shown in Table 1. Most CF patients were male, well nourished despite their pancreatic insufficiency, chronically colonized by *Pseudomonas aeruginosa* and with mild to moderate lung obstruction (80% > FEV_1 > 40% predicted). Control subjects were characterized by normal values in all these outcomes.

The results of exercise testing (6MWT and CPET) performed by CF patients are presented in Table 2. Aerobic fitness, measured by $V'O_2$ peak and expressed either as absolute value or as function of body mass, as well the maximal workload achieved, was reduced compared to our laboratory normal values. By contrast, the 6 MW distance was normal [17].

Habitual daily activities of the patients and of the age-matched controls included in the study group are shown in the Online supplement (Table E1). Compared with control subjects, patients with CF had similar values in daily life physical activities whether measured over four typical consecutive days by the SW accelerometer or estimated by the questionnaire.

As illustrated in Table 3, no significant differences between weekdays and weekend days activity levels, measured objectively by the SW accelerometer were seen

Table 1 Characteristics of patients with cystic fibrosis (CF) and controls.

Characteristics	CF	Control
Subjects *n*	20	11
Male:Female	15:5	7:4
Age, yr	33 ± 8	30 ± 4
BMI, Kg/m^2	22 ± 2	22 ± 3
FEV_1, L	2.6 ± 0.6	4.2 ± 0.7
FEV_1, % predicted	68 ± 16	108 ± 11
FVC, L	3.9 ± 0.8	5.2 ± 0.9
FVC, %predicted	88 ± 13	110 ± 10
PI:PS	15:5	
Pseudomonas aeruginosa positive:negative	13:7	
ΔF508 homozygous:heterozygous	6:12	

Data are presented as mean ± SD, unless otherwise stated. ***BMI***: body mass index; ***PI***: pancreas insufficiency; ***PS***: pancreas sufficiency; ***FEV_1***: forced expiratory volume in 1 s; **% pred**: % predicted; ***FVC***: forced vital capacity.

in both groups, except for "vigorous intensity activities" ($z = 2.396$; $p = 0.016$) performed by CF patients which were more likely during the weekday period and for "lying time" ($z = -2.215$; $p = 0.02$) which was higher during the weekend in healthy subjects (more data available in Table E2 of the online supplement). However the questionnaire identified significantly different activity measures during the course of the week in the CF patients, specifically at the "somewhat inactive" and "somewhat active" categories ($z = 2.651$; $p = 0.008$; $z = -2.651$; $p = 0.008$). The CF participants reported more time spent in activity (somewhat active & very active) during the weekend ($z = -2.203$; $p = 0.02$) and more inactivity time (somewhat inactive & inactive) on weekdays ($z = 2.464$; $p = 0.01$). Finally, the age-matched control group reported more "somewhat inactive" time during the weekend ($z = 2.224$; $p = 0.02$).

Table 2 Results of 6MWT and CPET in patients with cystic fibrosis (CF).

Variable	CF
6MWT, m	642 ± 49
6MWT, % pred	106 ± 8
W max, W	158 ± 47
$V'O_2$ peak, ml/min	1855 ± 512
$V'O_2$ peak, ml/min/kg	28.2 ± 5.2
$V'O_2$ peak % pred	69 ± 11
HR max, beats min^{-1}	154 ± 13
HR max, % pred	82 ± 8
V'_E max, l/min	70.0 ± 19.2
$V'_E/V'CO_2$	32 ± 4

Data are presented as mean ± SD, unless otherwise stated. ***6MWT***: 6-min walking distance; **W max**: maximal work rate; **$V'O_2$ peak**: peak oxygen uptake; **HR max**: maximal heart rate; **V'_E max**: maximal minute ventilation.

None of HAES questionnaire activity categories showed significant correlations with PA categories determined by accelerometer (data are given in the Online supplement Table E3). The only significant correlation between physical activity, measured by accelerometer, and the individual's activity level, estimated by the HAES questionnaire, was found in patients with CF for the questionnaire category "total inactivity" vs accelerometer category "lying time" ($r = 0.559$; $p = 0.01$) when assessed during the weekend.

Peak exercise tolerance measured at CPET, i.e., $V'O_2$ peak and Watt max, did not correlate with weekdays and weekend activity categories detected by the HAES questionnaire. $V'O_2$ peak, expressed relative to body weight, correlated significantly with the average daily accelerometer activities of "moderate" intensity ($r = 0.503$, $p = 0.02$); particularly during the weekday recordings ($r = 0.588$, $p = 0.006$). $V'O_2$ peak, expressed as absolute, also correlated significantly with the average daily accelerometer activities of "moderate" intensity ($r = 0.503$, $p = 0.02$) and with physical activities above the threshold of moderate (>4.8 METS) and vigorous (>7.2 METS) ($r = 0.515$, $p = 0.02$) (Fig.1). $V'O_2$ peak expressed as percentage of predicted was significantly related only with the "moderate" activities performed during the weekdays ($r = 0.508$, $p = 0.02$). The same weekdays data were related to the Watt max ($r = 0.459$, $p = 0.04$). The average time spent in vigorous physical activity related with $V'O_2$ peak ($r = 0.545$, $p = 0.01$) and with Watt max ($r = 0.547$, $p = 0.01$).

Interestingly, the maximal V'_E measured at CPET correlated with the total energy expenditure ($r = 0.757$, $p = 0.0001$), with the time spent in "moderate" activities both during the weekdays and the weekend ($r = 0.436$, $p = 0.05$; $r = 0.435$, $p = 0.05$) and during the weekdays with the time spent in "vigorous" activities ($r = 0.568$, $p = 0.008$).

The severity of the airflow obstruction, i.e., FEV_1, correlated with the total energy expenditure during both weekdays and the weekend ($r = 0.524$, $p = 0.01$ and $r = 0.511$, $p = 0.02$ respectively). During weekdays, FEV_1 was related to the active energy expenditure obtained from activities that require at least two consecutive minutes at 3.0 METS or higher ($r = 0.445$, $p = 0.04$). However, FEV_1 did not explain the variance in $V'O_2$ peak ($r = 0.419$, $p = 0.06$) and was a poor determinant of functional exercise tolerance, as assessed by the 6MWD ($r = 0.344$, $p = 0.13$).

The 6MWT did not correlate with any physical activity outcome measurements, assessed by both accelerometer and questionnaire, but there was a relationship with the number of steps per day registered during the week ($r = 0.488$, $p = 0.02$).

Discussion

The most important findings of the present study on daily PA of adult CF patients with mild to moderate lung function impairment, were: 1) the levels of PA, measured objectively by means of an accelerometer, are similar through the week (i.e., weekdays vs weekend days) and to those in

Table 3 Time spent in different physical activity categories as measured by the accelerometer and obtained from HAES questionnaire during the week in patients with cystic fibrosis (CF) and controls.

Instrument	Variable		Weekdays	Weekend	*p* Value*
Accelerometer	Lying time (min/day)	CF	444.2 ± 112.8	479.9 ± 85.3	$z = -0.952; p = 0.341$
		Control	455 ± 75.2	523 ± 81	**$z = -2.215; p = 0.02$**
	Duration physical activity (min/day)	CF	224.8 ± 105.1	236.7 ± 139.3	$z = -0.280; p = 0.779$
		Control	217 ± 135.3	208.5 ± 112.3	$z = -0.323; p = 0.746$
	Mild intensity activities (min/day)	CF	195.6 ± 93.7	207.3 ± 128.1	$z = -0.168; p = 0.866$
		Control	188.8 ± 118.4	187.4 ± 107.4	$z = -0.265; p = 0.791$
	Moderate intensity activities (min/day)	CF	26.1 ± 22.6	27.9 ± 29.3	$z = -0.224; p = 0.822$
		Control	24.9 ± 19.7	18.9 ± 17.3	$z = 0.441; p = 0.65$
	Vigorous intensity activities (min/day)	CF	3.65 ± 5.8	1.7 ± 3.5	$z = 1.790; p = 0.07$
		Control	3.4 ± 8.8	2.4 ± 3.9	**$z = 2.396; p = 0.016$**
HAES questionnaire	Inactive (min/day)	CF	43.6 ± 77.2	53.1 ± 85.5	$z = -0.263; p = 0.79$
		Control	58.6 ± 61.2	70.9 ± 89.7	$z = -0.426; p = 0.67$
	Somewhat inactive (min/day)	CF	363.5 ± 167.6	262.6 ± 131.6	**$z = 2.651; p = 0.008$**
		Control	306 ± 163.5	317.5 ± 114.5	**$z = 2.224; p = 0.02$**
	Somewhat active (min/day)	CF	352.2 ± 165.4	460.3 ± 147.1	**$z = -2.651; p = 0.008$**
		Control	475.5 ± 141,6	364.1 ± 100.6	$z = -0.941; p = 0.34$
	Very active (min/day)	CF	147.5 ± 152.4	114.9 ± 143.2	$z = 1.876; p = 0.06$
		Control	82.4 ± 65.8	91.4 ± 90	$z = 1.248; p = 0.21$
	Total inactivity (Inactive + Somewhat inactive, min/day)	CF	407.1 ± 154.7	315.7 ± 141.4	**$z = 2.464; p = 0.01$**
		Control	364.7 ± 135.2	388.4 ± 88.4	$z = 1.842; p = 0.06$
	Total activity (Somewhat active + very active, min/day)	CF	499.8 ± 168.7	575.3 ± 175.9	**$z = -2.203; p = 0.02$**
		Control	558 ± 138.8	455.6 ± 103.3	$z = -657; p = 0.51$

Data are presented as mean ± SD, unless otherwise stated. **p* Values are differences between weekdays and weekend days data; sign-rank non parametric test ($p < 0.05$).
Bold values are statistically significant.

healthy age-matched subjects. In contrast levels of PA estimated by the HAES questionnaire differ between the weekdays and the weekend days; 2) accelerometer and self-report method provide different information, in particular self-reported questionnaire overestimates the levels of PA and likely reflects what CF patients recall rather than what they actually did; 3) exercise tolerance and levels of PA above moderate intensity are closely related.

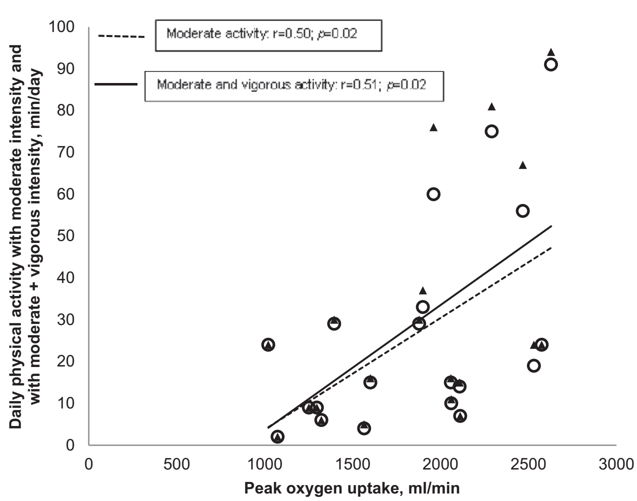

Figure 1 ○ Relationship between peak oxygen uptake ($V'O_{2\ peak}$) and physical activities above the threshold of moderate activity (>4.8 METS); ▲ Relationship between peak oxygen uptake ($V'O_{2\ peak}$) and physical activities above the threshold of moderate (>4.8 METS) and vigorous (>7.2 METS) activity.

PA is defined as any bodily movement produced by skeletal muscles that result in energy expenditure [23]. Therefore, daily PA can be considered the totality of voluntary movement produced by skeletal muscles during every day functioning [24]. Habitual PA can be quantified by direct observation, assessment of energy expenditure and with self-report questionnaire and motion sensor [25,26]. Quantifying PA in daily life through questionnaires and diaries has the advantage of being inexpensive and easy to apply. However there is now general agreement that in COPD self-reported physical activity is subject to recall bias [26], correlates poorly with objectively measured physical activity [27,28] and does not provide an accurate estimate of free-living energy expenditure [25]. The main factors limiting the use of questionnaires in COPD are the accuracy of perception and recall of information by the subject as old patients, particularly when recalling light activities (slow walking, self-care, gardening, home management, *etc*) over long periods of time. Limited information is available on the use of questionnaires in CF population. Recently, a validated questionnaire was used to evaluate habitual PA levels among CF adult population compared with a healthy aged matched group. Despite the results showed that the CF group was comparable to the non-CF population for moderate and vigorous physical activity, the lack of objective measurements did not clarify if the perception and self rating of intensity may have been subjective [14].

Moreover, the few previous studies comparing the questionnaires against accelerometers were on adolescent and young adults with CF and thus the reliability and validity of questionnaire in CF adult population is still not established. Wells et al. [12], in a small group of adolescent CF showed that HAES questionnaire data was related to the activity levels obtained from the accelerometer, suggesting that this questionnaire was a reliable and valid instrument to assess different activity levels in CF. However Ruf et al. [13] found only a moderate correlation between these two methods of assessment and the results were from a combination of both adolescent and adult CF data. So, this relatively small proportion of adult participants might be insufficient to describe a CF adult 's activity behavior. Ours is the first study examining the levels of PA using both a validated HAES questionnaire [20,12] and an accurate accelerometer, as showed by Dwyer et al. [29] in a group of adult CF with a mean age of 33 years.

To allow comparison between motion sensor and HAES questionnaire data we subdivided PA intensity into comparable categories [30]. As described earlier, the time in minutes spent with an energy expenditure of >3 METS was considered "mild" activity (i.e., walking at normal speed, carrying out light household work), time spent at >4.8 METS was considered "moderate" activity (i.e., brisk walking or cycling) and activities with an energy expenditure of >7.2 METS were considered "vigorous" (i.e., activity with training effects when applied for a sufficient length of time and at an appropriate training frequency). In the description of HAES questionnaire no METS values were mentioned for the corresponding activity levels and the examples given to the participants indicated "inactive" like lying down, sleeping, resting; "somewhat inactive" like sitting, reading, watching television; "somewhat active" as walking, shopping, light household chores and finally "very active" like running, jumping, skating, skipping. So when we have compared these two methods, we considered SW armband "mild" activity represented by the questionnaire category "somewhat active", SW armband "moderate" activity like questionnaire "very active", SW armband "lying time" as the questionnaire " total inactivity" (inactive + somewhat inactive) and finally SW armband "duration of physical activity" like the questionnaire "total activity" (somewhat active + very active"). None of the physical activity parameter obtained from the questionnaire used in this study was related to the activity levels measured by the accelerometer. Only the level of "total inactivity" was adequately estimated by the questionnaire when compared with data provided by the accelerometer.

Our results raise several issues. First, adults with cystic fibrosis have similar levels of activity at weekdays and weekend days, showing that the most sedentary patients during the working-day also showed the lowest activity in their free time. Second, an important finding of the present study is that these adult patients with mild to moderate pulmonary disease seem to engage in a relatively normal amount of daily activity, because no differences appear between them and healthy age-matched subjects in the objective time spent at different activity intensities. We speculate that encouraging exercise as part of their therapy should help to maintain an active lifestyle. However, our adult CF patients had some difficulty in remembering the exact time spent doing both low and moderate intensity activity; by contrast it seems easier for them to remember and report the time spent sitting or resting. This ability may reflect the fact that adult patients have a significantly longer life expectancy now and spent much of their weekday working.

Using the same motion sensor for PA monitoring and the same METS levels, our findings are comparable to those of Troosters et al. who investigated 20 stable CF adult patients [8] and to those of Ward et al. [31] who studied 24 adults at one month post-discharge, for the mean times spent in mild and vigorous PA. However, our sample recorded a mean of 27 min of moderate PA, greater than the 15 min reported by Troosters et al. [8] and lower than the 43 min reported by Ward et al. [31]. Whether this reflects cultural differences or is an issue of sampling error cannot be addressed here.

We found that $V'O_{2\ peak}$ and Watt max were strongly related to the levels of PA of moderate intensity or greater, as measured by the accelerometer, particularly during the weekdays. Moreover patients who spent 30 min per day performing daily PA above moderate intensity had better exercise tolerance, i.e., higher $V'O_2$ peak. These findings support the notion that moderate PA levels should be recommended to maintain physical fitness, as suggested by the American College of Sports Medicine [1]. This is in line with the recent literature that have demonstrated that habitual PA is a significant predictor of $V'O_2$ peak in CF patients [4,8].

The present study has some limitations. First, our adult CF patients had only mild/moderate spirometric impairment. In fact, we were interested at looking the PA behavior of adults CF patients in the early stage of the disease. Second, this study involved a relatively small number of participants which were predominantly male and thus it is possible that it did not fully represent PA in the female population. Thus, further research including a more heterogeneous adult CF population will be needed to highlight potential gender differences and to better characterize physical activity particularly in a more advanced disease.

In conclusion, this is the first study in adult CF to provide evidence that accelerometers should be preferred to questionnaires in evaluating habitual PA. Using the accelerometer we could demonstrate that the time spent in daily physical activity at different intensities was similar in adults with cystic fibrosis and in healthy controls and across the whole week. Questionnaire tends to overestimate the levels of PA in CF. Finally, the present study clearly showed in adult CF patients, that exercise tolerance and levels of PA above moderate intensity are closely related. Further studies are needed to confirm the results of this single center trial but if confirmed they indicate that daily activity need not be impaired in adults with CF and emphasize that treatment decisions should be informed by objective measurements of habitual activity as well as subjective patient reports which tend to be more positive than is really the case.

Conflict of interest statement

The authors declare no conflict of interest associated with this study.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.rmed.2013.09.012.

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