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Physical Activity Recommendations in Patients with Chronic Obstructive Pulmonary Disease

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Key Words
Cycle ergometry · Health benefits · Lung disease · Physical activity

Abstract
Background: Physical activity recommendations are hardly studied in patients with chronic obstructive pulmonary disease (COPD), and specifically recommendations that are individualized to a patient's aerobic fitness level are not studied. ***Objectives:*** To compare individualized (relative) and nonindividualized (absolute) physical activity recommendations in patients with COPD and to assess whether there are differences between patients with mild to moderate and (very) severe COPD. ***Methods:*** We compared 7 different physical activity recommendations that were described in the literature. Four recommendations were individualized based on the patient's aerobic fitness level measured by a maximal cycle ergometer test. Three recommendations were nonindividualized. The recommendations were measured with an accelerometer, pedometer or questionnaire in 115 patients with mild to very severe COPD (68% male, mean age 65 years, mean FEV_1 58% predicted). ***Results:*** The percentage of patients that met the different recommendations ranged from 22 to 86% and only 8 patients met all 7 recommendations. The agreement between the different recommendations was poor (intraclass correlation coefficient, 0.28). Individualizing the recommendations resulted in a higher number of patients with severe or very severe COPD meeting the individualized recommendations compared to the nonindividualized recommendations. In contrast, patients with mild to moderate COPD less frequently met the individualized recommendations. ***Conclusions:*** Our study showed that applying various physical activity recommendations with small differences in frequency, intensity or time led to large differences in the classification of patients with COPD into being sufficiently physically active or not. Consequently, the used recommendation will highly affect the proposed physical activity advice to the patient.

Introduction

Regular physical activity is known to have important health benefits and may limit the development and progression of chronic disease [1]. In patients with chronic obstructive pulmonary disease (COPD), physical inactivity has been shown to be a predictor of cardiac distress, hospitalization and mortality [2–4]. As disability increases over the years and a sedentary lifestyle is frequently present in all severity stages of COPD, increasing physical activity has become an important treatment target in

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these patients [5, 6]. However, once adopting the fact that physical activity should be enhanced in sedentary patients with COPD, the question arises how much physical activity is needed to obtain health benefits, in order to be able to give a tailored advice to the patient.

Approximately 40 years ago, the first physical activity recommendation guideline for the general population was published [7]. Currently, the physical activity recommendations of the American College of Sports Medicine (ACSM) for adults, which are in line with the recommendations of the World Health Organization (WHO), are often used [8–10]. The ACSM guidelines recommend that adults should engage in moderate-intensity aerobic physical activity for a minimum of 30 min on 5 days each week or vigorous-intensity aerobic physical activity for a minimum of 20 min on 3 days each week or an equivalent combination of both [8, 9].

In general, physical activity recommendations are mainly based on healthy adults, while recommendations for adults with a chronic illness are less clear. For example, the WHO states that adults who cannot reach the general recommendations due to health problems should be 'as physically active as their abilities and conditions allow' [10]. Furthermore, the ACSM advocates that elderly with a chronic illness should adjust the intensity of physical activity to one's aerobic fitness level, instead of using absolute measures of intensity that do not take into account the individual determinants of physical activity like fitness level [11]. Therefore, the latest ACSM guidelines also describe how to individualize physical activity recommendations, based on objective measurements like maximum oxygen uptake or heart rate (HR) [8]. These relative or individualized physical activity recommendations could be more appropriate compared to the absolute or nonindividualized recommendations, particularly for elderly and deconditioned persons [11].

So far, COPD-specific physical activity recommendations are not available and general physical activity recommendations are hardly studied in patients with COPD. Two studies examined physical activity recommendations in COPD, but only investigated absolute physical activity recommendations and did not individualize the recommendations to the aerobic fitness level of the individual patient [12, 13].

We hypothesize that individualized physical activity recommendations will be more suitable for patients with COPD; however, it is questionable whether this is true for all severity stages of COPD. The aim of this study is to compare individualized (relative) and nonindividualized (absolute) physical activity recommendations in patients with COPD, as well as to assess whether there are differences in meeting the different physical activity recommendations between patients with mild to moderate and (very) severe COPD.

Methods

Patients with mild to very severe COPD were recruited from general practitioners and outpatient clinics of general hospitals to participate in a cross-sectional study on physical activity in COPD [14]. Patients with a diagnosis of COPD according to the GOLD criteria [15] were included (post-bronchodilator FEV_1/FVC ratio <0.7). Comorbidity was allowed, but patients were excluded if they had a serious active disease that needed medical treatment (e.g. carcinoma, recent myocardial infarction) or had been treated for a COPD exacerbation in the past 2 months. All patients gave written informed consent, and the study was approved by the local ethics committee.

We compared 7 different types of physical activity recommendations described in the literature, and assessed whether a patient met or failed the different recommendations (table 1). Three physical activity recommendations were absolute and nonindividualized and 4 physical activity recommendations were relative and individualized. The absolute recommendations assume that all patients have normal aerobic fitness levels and these recommendations are not based on the individual's aerobic fitness level. In contrast, the relative individualized recommendations do base the intensity of physical activity that is required to meet the recommendation on the patient's individual aerobic fitness level. The recommendations evaluated in this study were measured with 3 different instruments (see measures of physical activity).

Absolute, Nonindividualized Recommendations

Absolute Metabolic Equivalent of Task Recommendation

This recommendation described in the ACSM guideline was met if patients engaged in at least 30 min of moderate-intensity physical activity [metabolic equivalent of task score (MET) ≥3] on ≥5 days per week or at least 20 min of vigorous-intensity physical activity (MET ≥6) ≥3 days per week or a combination of both [8]. Resting energy expenditure (EE) was estimated with the Mifflin-St. Jeor equation [16]. Furthermore, physical activity had to be accumulated in bouts of at least 10 min, with maximal 2-min interruption time within the bout [17].

Step-Based Recommendation

The step-based recommendation was met if patients took on average at least 7,000 steps per day during the week. Although the evidence for step-based recommendations is less extensive, a recent review and the ACSM have set this threshold measured with a pedometer for older adults [8, 18]. Because this recommendation is based on the number of steps measured with a pedometer, we used pedometer results instead of accelerometer results.

Questionnaire-Based Recommendation

The recommendation according to the questionnaire was met if patients engaged in at least 30 min of moderate-intensity physical activity (MET ≥3) on ≥5 days per week. The intensity of activities was based on the compendium of physical activities [19].

Table 1. Overview of the different recommendations

Recommendation		Frequency, days	Intensity		Aerobic physical activity, min	Volume
Absolute						
Absolute MET		≥5	MET ≥3	moderate	≥30	
	or	≥3	MET ≥6	vigorous	≥20	
Questionnaire-based		≥5	MET ≥3	moderate	≥30	
Step-based		no instructions on frequency, intensity or time				mean ≥7,000 step/day
Individualized						
VO_2 reserve		≥5	≥40%	moderate	≥30	
	or	≥3	≥60%	vigorous	≥20	
VO_{2max}		≥5	≥46%	moderate	≥30	
	or	≥3	≥64%	vigorous	≥20	
HR reserve		≥5	≥40%	moderate	≥30	
	or	≥3	≥60%	vigorous	≥20	
HR_{max}		≥5	≥64%	moderate	≥30	
	or	≥3	≥77%	vigorous	≥20	

The duration of aerobic physical activity was measured in minutes. Physical activity had to be accumulated in bouts of at least 10 min, except for the questionnaire-based recommendation, with maximal 2-min interruption time within the bout. Absolute MET, VO_2 reserve, VO_{2max}, HR reserve and HR_{max} were measured by an accelerometer, the questionnaire-based recommendation by the SQUASH questionnaire, and the step-based recommendation by a pedometer.

Individualized Recommendations

These recommendations are described in the ACSM guideline and have the same instructions on frequency and time as the absolute MET recommendation. To distinguish moderate and vigorous intensity we used the lowest thresholds described by the ACSM [8] based on: oxygen uptake (VO_2) reserve, VO_{2max}, HR reserve, and HR_{max}. The intensity thresholds are shown in table 1.

Measurements

Physical Activity

Accelerometer. The Dynaport (McRoberts, The Netherlands) is a validated triaxial accelerometer, which is worn around the waist and detects postures, measures steps, and estimates EE [20–22]. Patients were instructed to wear the accelerometer day and night for 1 week.

Pedometer. The Yamax Digi-walker SW-200 is an accurate and reliable pedometer [23, 24]. Patients were instructed to wear the pedometer for 2 weeks. The patients also reported in a diary if they performed other nonambulatory activities, and these were translated into steps by using step equivalents based on the compendium of physical activities [19]. The accelerometer and pedometer were worn simultaneously during the first week.

Questionnaire. The short questionnaire to assess health-enhancing physical activity (SQUASH) was administrated by an interviewer [25].

Cycle Ergometry

Maximal and resting VO_2, HR, and EE were measured by a cycle ergometer test (bicycle ergometer, Jaeger ER900L, Oxygen Pro, CareFusion, Germany). A maximal incremental protocol was used with 3-min resting, 3-min unloaded cycling and approximately 10-min cycling with an individualized incremental load of 5–25 W per minute, in line with the American Thoracic Society/American College of Chest Physicians (ATS/ACCP) guidelines [26]. Cycle ergometry was used to derive the individualized intensity of physical activity (based on VO_2 reserve, VO_{2max}, HR reserve and HR_{max}). VO_2 reserve and HR reserve were calculated by subtracting the value at rest from the maximal obtained value [27].

Functional Capacity Measures. Functional exercise capacity was measured by a 6-min walk distance test according to the ATS guidelines [28]. Leg muscle function was measured by a 30-second chair stand test [29]. Forced expiratory volume in 1 s was measured using a spirometer (PFT, Masterscope; Viasus) according to the ERS/ATS guidelines [30].

Patient Perception

The SQUASH questionnaire also determines how many days per week the patients themselves reported to be physically active for ≥30 min at moderate intensity, which we used as an indication of the patients' perception whether they meet the general physical activity recommendation.

Table 2. Patient characteristics

Variable	Total group (n = 115)	GOLD I + II (n = 61)	GOLD III + IV (n = 54)
Male	78 (67.8%)	45 (73.8%)	33 (61.1%)
Age, years	65±8.7	66±7.8	64±9.5
COPD[a], A/B/C/D	54/5/19/37	54/5/0/2	0/0/19/35
FEV_1, % predicted	52 (14–119)	79 (50–119)	34.5 (14–49)
FEV_1/FVC, %	45 (17–69)	54 (32–69)	31 (17–55)
RV, % predicted	172±65	135±36	214±66
BMI, kg/m^2	25.1±4.0	25.5±3.4	24.6±4.6
6MWD, m	447 (6–646)	518 (344–646)	367 (60–600)
mMRC, score	2 (1–5)	2 (1–5)	3 (1–5)
Chair stand test, n	10.9±3.2	11.6±3.3	10.1±2.8
VO_{2max}, ml/kg	18.2 (5.7–37.7)	20.2 (13.0–37.7)	13.4 (5.7–22.8)
HR rest, beat/min	76 (56–121)	73 (56–97)	84 (58–121)
HR_{max}, beat/min	129 (89–166)	137 (93–166)	120 (89–161)
Steps[b], per day	5,552 (236–18,433)	7,388 (3,556–18,433)	3,376 (236–14,281)
Lying and sitting, % day	79.8±7.2	77.6±6.3	82.3±7.3
MET ≥3, min/day	103 (15–298)	130 (19–298)	70 (15–177)

Data are presented as numbers with percentages in parentheses, mean ± SD, medians with ranges in parentheses or number. RV = Residual volume; 6MWD = 6-min walk distance; mMRC = Modified Medical Research Council Dyspnea Index.

[a] Combined assessment of COPD with the use of the mMRC scale (GOLD guidelines 2011 [10]).

[b] Steps measured by an accelerometer.

Data Analyses

Patients were included in the accelerometer-based analyses if they had worn the accelerometer for at least 5 full days. If a patient had worn the accelerometer for 5 or 6 days, the patients were only included if they already reached 5 days of enough physical activity or if they certainly would not. A day was considered a valid measurement day if the device was worn for ≥94% of the day [31]. Resting and maximum values of VO_2, HR, and EE during the cycle ergometer test were obtained from the graphs in the ergometer software. The VO_2 and HR values were translated into EE measures by taking the corresponding EE value at that time point. The Wilcoxon signed-rank test was used to test the difference between the absolute nonindividualized recommendations and the individualized recommendations. To assess the agreement between the different recommendations we calculated intraclass correlation coefficients (ICC) with absolute agreement. Linear regression analyses were performed to assess if patients who met a specific recommendation had different scores on functional capacity tests than patients who failed the recommendation. Regression analyses were adjusted for FEV_1, age, sex, height and weight. p values <0.05 (tested two-sided) were considered statistically significant. All statistical analyses were performed using IBM-SPSS statistics version 20.

Results

In total 118 patients with COPD were included in this study between February 2009 and February 2012 and provided informed consent. Three participants dropped out during the study due to lack of time or health problems. Therefore, 115 patients with COPD were included in the analyses (68% male, mean age 65 years, mean FEV_1 58% predicted) (table 2). None of the patients participated in a pulmonary rehabilitation program during the study or during 6 months before study participation. All patients wore the pedometer and completed the SQUASH questionnaire, and 111 patients wore the accelerometer for at least 5 days.

Estimates of Intensity

The calculated estimates of intensity, based on the absolute and individualized estimates of intensities, are shown in online supplementary table 1 (for all online suppl. material, see www.karger.com/doi/10.1159/000360298). In the total group, the mean value of the individualized estimate of moderate intensity was not significantly different from the absolute measure (p = 0.08). The mean value of the individualized estimates of moderate intensity was significantly higher in GOLD stage I and II patients than the absolute measure of moderate intensity (p < 0.001). In patients with GOLD stage III and IV, the mean value of the individualized estimates of moderate intensity was significantly lower than the absolute measure of intensity (p < 0.001).

Table 3. Minutes per day that patients met the recommendations and the proportion of patients that met the recommendations

	Total group		GOLD I + II		GOLD III + IV	
	min/day	number (%)	min/day	number (%)	min/day	number (%)
Absolute						
Absolute MET						
≥3	28.0 (0–201)	39 (35.1)	51.7 (9–201)	33 (55.9)	5.9 (0–144)	6 (11.5)
≥6	0.0 (0–50)	7 (6.3)	0.0 (0–50)	6 (10.2)	0.0 (0–12)	1 (1.9)
Total		40 (36.0)		33 (55.9)		7 (13.5)
Questionnaire-based		97 (84.3)		55 (90.2)		42 (77.8)
Step-based		25 (21.7)		22 (36.1)		3 (5.6)
Step-based incl. step equivalents		40 (34.8)		32 (52.5)		8 (14.8)
Individualized						
VO_2 reserve						
≥40%	26.5 (0–656)	26 (25.2)	36.9 (0–198)	20 (34.6)	10.8 (0–656)	6 (13.3)
≥60%	5.4 (0–78)	25 (24.0)	3.6 (0–78)	15 (25.4)	7.2 (0–62)	10 (22.2)
Total		36 (34.3)		23 (39.0)		13 (28.3)
VO_{2max}						
≥46%	35.2 (0–1,380)	35 (34.3)	42.0 (0–201)	22 (38.6)	24.1 (0–1,380)	13 (28.9)
≥64%	7.4 (0–643)	31 (30.1)	7.4 (0–98)	17 (29.3)	7.3 (0–643)	14 (31.1)
Total		46 (45.1)		26 (45.6)		20 (44.4)
HR reserve						
≥40%	30.4 (0–1,440)	35 (34.7)	34.5 (0–201)	20 (34.5)	24.9 (0–1,440)	15 (34.9)
≥60%	4.7 (0–643)	22 (21.8)	3.4 (0–108)	11 (19.0)	5.9 (0–643)	11 (25.6)
Total		42 (41.2)		22 (37.3)		20 (46.5)
HR_{max}						
≥64%	55.8 (0–1,343)	31 (55.4)	56.1 (0–1,343)	25 (55.6)	46.3 (7–1,250)	6 (54.5)
≥77%	12.6 (0–195)	30 (41.1)	11.0 (0–195)	22 (39.3)	14.4 (3–89)	8 (47.1)
Total		41 (58.6)		32 (59.3)		9 (56.3)
Patient perception		81 (70.4)		49 (80.3)		32 (59.3)

In this table, the minutes per day that patients met the different recommendations are shown, and furthermore the proportion of patients that met the recommendations. Data are presented as median minutes per day with ranges in parentheses or number of patients that met the recommendation with percentages in parentheses. 'Total' represents the number of patients that met either the moderate- or vigorous-intensity recommendation.

Meeting the Recommendation

Table 3 shows the minutes per day that patients met the lower threshold of the recommendations and the proportion of patients that met the different recommendations (fig. 1). The number of eligible patients per recommendation is presented in online supplementary table 2. Remarkably, the recommendations based on HR_{max} were not applicable to a large proportion of the patients (49%) due to reaching very low HR_{max} values during the cycle ergometer test (online suppl. table 1).

The proportion of patients that met the different recommendations ranged from 22 to 84% in the total group, in GOLD stage I and II patients from 36 to 90%, and in GOLD stage III and IV from 6 to 78%. Only 8 patients (7%) met all 7 recommendations. The agreement between all recommendations in the total group was poor (ICC, 0.28, HR_{max}-based recommendations left out).

The absolute nonindividualized recommendations showed poor agreement (ICC, 0.17). Thirty-six percent of the patients met the absolute MET recommendation, 22% the step-based recommendation, and 84% the questionnaire-based recommendation. By including step equivalents, 35% of the patients met the step-based recommendation. Although the step-based recommendation including step equivalents seems similar to the absolute MET recommendation, the agreement between the two recommendations was moderate (ICC, 0.49), indicating that different patients met the two different recommendations.

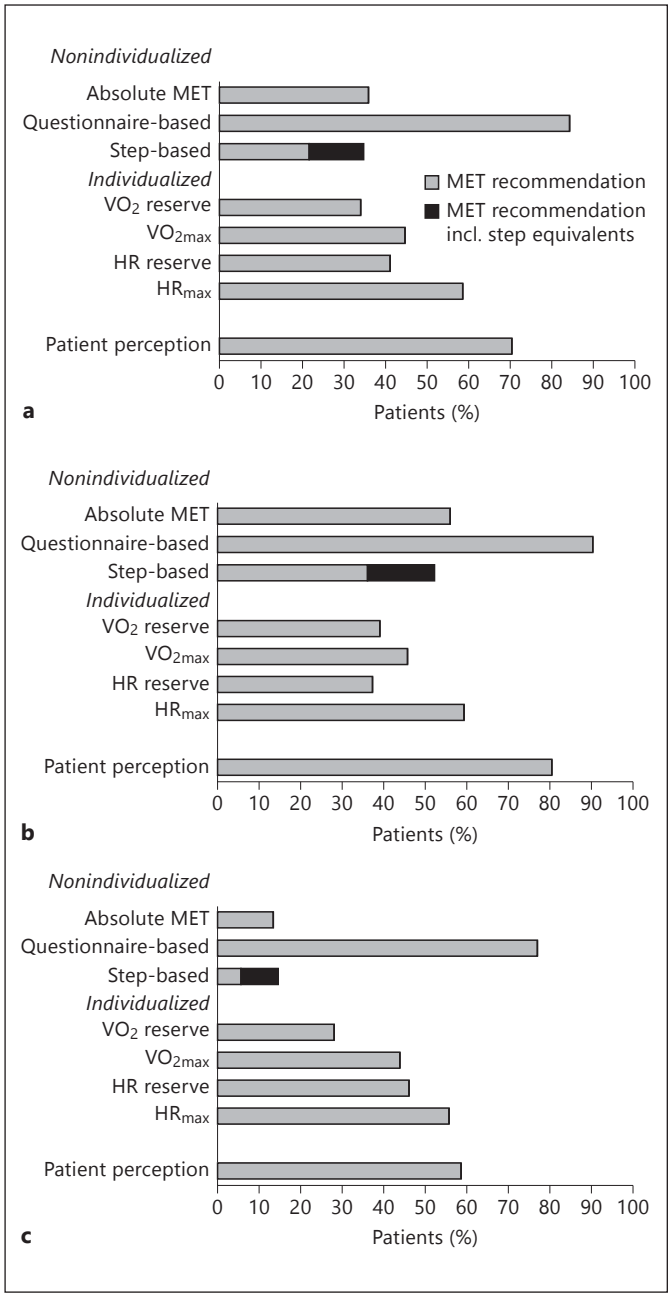

Fig. 1. Proportion of patients that met the different recommendations. **a** Total group. **b** Patients with GOLD stage I and II. **c** Patients with GOLD stage III and IV.

In patients with GOLD stage I and II, more patients met the absolute nonindividualized recommendations than the individualized recommendations. In contrast, in GOLD stage III and IV, more patients met the individualized recommendations than the absolute nonindividualized recommendations.

Patient Perception

Seventy percent of all patients reported that they were physically active for at least 30 min at moderate intensity on at least 5 days per week and thus met the recommendation. In GOLD stage I and II patients, this was reported by 80% of the patients and in GOLD stage III and IV patients by 59%.

Association with Functional Capacity Measures

Table 4 shows the differences in functional capacity outcomes between patients that met or failed the different recommendations with adjustment for FEV_1, age, sex, height and weight. Patients who met the absolute nonindividualized recommendations (absolute MET, questionnaire-based and step-based) had significantly higher functional capacity scores than patients who failed the recommendations. Contrary, patients who met or failed the individualized recommendations did not differ in functional capacity outcomes. Absolute values without adjustment are shown in online supplementary table 3.

Discussion

Our results showed that the percentage of patients with COPD that met the different physical activity recommendations ranged from 22 to 86%, and that the agreement between the recommendations was poor. Individualizing the recommendations by adapting the intensity to a patient's aerobic fitness level resulted in more patients with GOLD stage III and IV meeting the individualized recommendations than the absolute nonindividualized recommendations. In contrast, GOLD stage I and II patients less frequently met the individualized recommendations.

Several factors might contribute to the low agreement between the different physical activity recommendations. Firstly, it is well known that subjective methods to measure physical activity are less accurate than performance-based methods [32]; usually patients overestimate their physical activity level [33]. Secondly, the pedometer and the accelerometer both mainly measure locomotion, and therefore could unjustly classify patients as inactive when they perform a lot of nonambulatory activities like cycling. Thirdly, recommendations measured by an accelerometer include a threshold on 'bout duration'; periods of physical activity only count when performed in bouts

Table 4. Differences in functional capacity measures between patients that met or failed the different recommendations

Recommendations	Chair stand test		6MWD		W_{max}		VO_{2max}	
	B	p value	B	p value	B	p value	B	p value
Absolute								
Absolute MET	–2.220	*0.001*	–82.799	*<0.001*	–21.257	*<0.001*	–185.255	*0.002*
Questionnaire-based	–2.492	*0.002*	–97.234	*<0.001*	–19.741	*0.004*	–195.906	*0.009*
Step-based	–3.155	*<0.001*	–79.884	*0.001*	–17.713	*0.005*	–144.321	*0.036*
Individualized								
VO_2 reserve	0.284	0.672	–37.309	0.061	–1.606	0.774	71.925	0.220
VO_{2max}	–0.583	0.383	–28.816	0.153	1.091	0.844	94.128	0.108
HR reserve	–1.002	0.130	–35.778	0.066	0.657	0.904	78.714	0.174
HR_{max}	–0.038	0.966	–12.325	0.550	0.280	0.967	62.278	0.418

Analyses were adjusted for forced expiratory volume in 1 s, age, sex, height and weight. Recommendations were coded as: 0 = met recommendation, 1 = failed recommendation. 6MWD = 6-min walk distance; W_{max} = maximum workload; VO_{2max}/kg = maximum oxygen uptake/kilogram. p values in italics are significant.

of at least 10 min. To illustrate the impact of bout duration, if we had allowed a 1-min interruption in the 10-min bout instead of 2 min, 23% of the patients would have met the recommendation instead of the current 36%. Contrary, in the step-based and questionnaire-based recommendation, every step or minute counts. Our results are in line with a study in healthy men, which also showed huge differences between various recommendations [34].

Only a few studies have investigated physical activity recommendations in COPD, and these studies differ importantly in the reported proportion of patients meeting the used recommendations (16–84% patients met the recommendation in the different studies) [12, 13, 35, 36]. Indeed, this broad range can easily be explained by differences in the study populations but certainly also by different methods used to assess if patients meet a recommendation. For example, two studies set 30 min of walking time as a threshold to meet the recommendation [13, 36], one study used a questionnaire on leisure time physical activity [35], and one study used EE estimated with an accelerometer [12]. The latter study of Donaire-Gonzalez et al. [12] is the most alike to our study. In line with our study, they showed that applying differences in bout duration or intensity levels changed the proportion of patients that were categorized as being sufficiently physically active [12]. Although the authors follow the same ACSM guideline, a few methodological differences should be noticed. First, they based the intensity of the MET cutoff point of moderate or vigorous intensity on the aerobic level of the *total* group instead of the *individual* patient. Secondly, they based the reaching of a certain intensity level on the median MET level during a period of time, which probably overestimated a patient's physical activity level. This shows that studies are difficult to compare and that more consensus is needed on the preferred method to assess if patients with COPD meet a physical activity recommendation.

Our study is the first one in COPD that compared absolute nonindividualized physical activity recommendations versus individualized physical activity recommendations. Unexpectedly, patients with mild to moderate COPD met the absolute nonindividualized recommendations more often than the individualized recommendations. Therefore, it is questionable if individualizing the recommendations is already necessary in this patient population. In patients with severe to very severe COPD, a larger number of the patients met the individualized recommendations compared to the absolute nonindividualized recommendations. Furthermore, we found that patients who met the individualized recommendations did not have better functional capacity scores than patients who failed the recommendations. Consequently, the question arises whether low recommended intensities due to adjusting the intensity of physical activity to the individual level of aerobic capacity still lead to health benefits.

Which physical activity recommendation should be used in patients with COPD is quite speculative but we nevertheless comment on a few aspects. An absolute nonindividualized recommendation like the ACSM is easy to understand and results in a clear advice to the patient. However, relying on subjective measures whether such a

recommendation is met is not recommendable, as patient perception or filling in a questionnaire overestimates a patient's physical activity level. Additionally, absolute nonindividualized recommendations could be discouraging for patients with severe COPD, because most patients are physically not able to achieve these high physical activity levels. In patients with less severe COPD, who are less restricted by their pulmonary condition, the absolute nonindividualized recommendations might be more appropriate. Another absolute recommendation, the step-based recommendation, has the advantage that the goal is easy to understand and can be easily monitored by the patient. However, the evidence of the efficiency of the step-based recommendation is poor and dose-response studies in sedentary or old individuals are lacking.

We do agree with the ACSM guidelines that for older and deconditioned patients the individualized recommendations probably might be most suitable. An important advantage is that the dose of physical activity is individualized and patients do not get frustrated with too high targets. However, the use of individualized recommendations probably demands frequent monitoring of aerobic capacity and should therefore not be fixed at one time point. Aerobic capacity could increase because of exercise benefits but also decrease due to disease progression or aging. Using HR-based recommendations has the advantage that intensity goals are easy to measure by the patients, for example by a heart monitor watch. However, a problem with using HR is that it is not suitable for a lot of patients, because their HR goals are difficult to define due to very low exercise capacity, sometimes also partly due to medication like beta-blockers. A VO_2-based recommendation can only be applied in sophisticated exercise labs, but once a VO_{2max} has been measured, it is possible to define individual advises for ergometer programs. As discussed earlier, another problem of the individualized recommendations is that the recommended physical activity may be too low to lead to health benefits in highly deconditioned patients.

We included COPD patients with a broad range of COPD severity in this study. It is difficult to compare the physical activity level of COPD patients between various studies because many different devices have been used to measure physical activity. Therefore, there is a large difference in for example the used outcome variables and time period used to measure physical activity. However, three large studies that also measured physical activity in a broad range of COPD patients demonstrated a comparable number of steps per day in the 4 GOLD stages [31, 37] or in the total group [12, 14].

A limitation of the present study is the cross-sectional design. Due to this design we could not investigate how much physical activity is sufficient to obtain health benefits. A next step would therefore be to investigate physical activity, dose-response relationships and its health benefits longitudinally. Another limitation of the study is the conversion of cycle ergometer data into EE and the transformation of accelerometer data into EE. As shown by others, the estimation of EE by accelerometers is still not perfect [20]. However, currently the accelerometer is the most practical and patient-friendly tool to use, in contrast to for example measuring EE by doubly labeled water or indirect calorimetry. Furthermore, we believe that the conclusions of this study would not change if we had used other instruments.

Conclusions

In conclusion, we found that applying various physical activity recommendations with small differences in frequency, intensity or time led to large differences in classifying if patients with COPD are sufficiently physically active or not. This indicates the importance to precisely state which physical activity recommendation is being used and to be cautious with comparing results of recommendations. Future longitudinal studies on physical activity should determine how much physical activity should be recommended to patients to maintain or increase physical and mental health in the various stages of COPD.

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