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Relationship between daily physical activity and exercise capacity in patients with COPD

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Summary
Background: Exercise training programmes for patients with COPD are effective in improving exercise capacity. The few trials that have investigated the effects of exercise programmes on daily physical activity show contradictory results.
Aim: To investigate the relation between daily physical activity level and exercise capacity in patients with COPD using data of a randomised controlled trial in which the exercise intervention was aimed at improvement of both physical activity and exercise capacity (the COPE-II study).
Methods: These are secondary analyses of the COPE-II study, a randomised controlled trial in which a community-based physiotherapeutic exercise programme was evaluated. Daily physical activity was measured with a pedometer (steps/day). Exercise capacity was measured with an incremental maximal cycle ergometer test, the incremental (ISWT) and endurance shuttle walk test (ESWT). Pearson correlation coefficients were calculated.
Results: At baseline, correlations between steps/day and VO_{2peak}, ISWT (m), ESWT (m) and ESWT (s) were 0.54, 0.59, 0.44, and 0.34, respectively (all $p < 0.01$). In the intervention group, correlations between change in steps/day over 7 months and change in ISWT (m), ESWT (m) and ESWT (s) were 0.47, 0.41, and 0.38, respectively (all $p < 0.01$). In the control group, these same correlations were weak to non-existent.
Conclusions: A moderate to weak relationship was found between daily physical activity and exercise capacity. These results strengthen our beliefs that exercise interventions need to target not

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only exercise capacity but also behaviour change with regard to daily physical activity to achieve improvements in both parameters.

Background

Chronic obstructive pulmonary disease (COPD) is not only characterized by symptoms of dyspnoea, chronic cough, and sputum production, but also by a decreased exercise performance[1] and reduced physical activity level.[2–4] There is a large number of randomised controlled trials investigating the effects of exercise training programmes, whether part of a pulmonary rehabilitation programme or not, on exercise capacity in patients with COPD. A meta-analysis of Lacasse et al.[5] included 31 randomised trials and found that rehabilitation programmes including exercise therapy are effective in improving exercise capacity and quality of life. As a result, international guidelines recommend pulmonary rehabilitation for patients with chronic respiratory disease, and specifically for patients with COPD.[1]

Most exercise training programmes for patients with COPD focus on improvement of exercise capacity which is reflected in the outcome measures. The incremental maximal cycle ergometry test is the 'gold standard' for measuring exercise capacity.[6] However, this laboratory-based test requires specialised equipment and knowledge, which makes it a relatively expensive test. Frequently used alternatives test are the field-based walking tests: the internally paced six-minute walk test (6MWT)[7] and the externally paced incremental and endurance shuttle walk tests (ISWT and ESWT).[8,9]

A minimum of 30 min of physical activity at a moderate intensity, on at least 5 days per week, is recommended for elderly adults, and adults with a clinically significant chronic condition to improve and maintain health.[10] In the Netherlands, half of the patients with chronic respiratory diseases (asthma and COPD) do not meet this criterion.[11] This percentage will probably even be higher in a population of solely patients with COPD.[12] Compared to healthy subjects, patients with COPD spend significantly less time walking and standing, and more time sitting and lying.[2] Recent studies show that physical activity level gradually declines with severity of disease.[3,4] In COPD patients, regular physical activity leads to general health benefits such as a reduced risk for cardiovascular disease, stroke, and colon cancer,[13] but also to a lower risk for COPD-related hospitalisations and mortality.[14] Waschki and colleagues even state that the level of physical activity is the strongest predictor for all-cause mortality in patients with COPD.[15] On the shorter term, when participation in a rehabilitation programme leads to a permanent increase in daily physical activity, this might contribute to the maintenance of beneficial effects of the programme on exercise capacity. However, the latter is often not achieved with the current programmes.[16,17]

Although there is an extensive amount of research on the effects of exercise programmes on exercise capacity, only a few trials investigated the effects on daily physical activity in patients with COPD.[18–20] These studies showed contradictory results, which is probably due to the variation in length and content of the interventions. Whereas an increase in exercise capacity can be achieved with exercise programmes as short as 4 weeks,[1] an increase in daily physical activity is elicited by a change in habits and behaviours of the sedentary patient with COPD, and is thus more time-consuming.[17,19] Therefore, it is likely that there is a difference in concept between exercise capacity and daily physical activity.[21] Hence, we hypothesise that a positive change in exercise capacity does not necessarily lead to an increase in daily physical activity and vice versa. Several earlier studies have investigated daily physical activity in relation to exercise capacity. In the majority of the studies the latter was measured with the 6MWT.[2,15,22–28] The relationship between physical activity and the ESWT and ISWT is less thoroughly investigated.[26] Using the data of a previous published randomised controlled trial in patients with COPD,[20] in which the exercise intervention was aimed at change in both exercise capacity and daily physical activity, we further investigated the relationship between exercise capacity and daily physical activity. With these secondary analyses, we were among the first to investigate the relationship between change in exercise capacity and change in daily physical activity in patients who participated in the exercise programme and patients who received usual care. In addition, we have explored whether other patient characteristics were correlated with physical activity at baseline, and with change in physical activity.

Methods

Detailed methods of the COPE-II study have been published elsewhere.[20,29]

Subjects

Patients eligible for inclusion had a clinical diagnosis of COPD according to the GOLD criteria[30]; a post-bronchodilator FEV_1 between 25 and 80% of predicted; at least 3 exacerbations or one hospitalisation for respiratory problems in the two years preceding study entry. Patients were excluded when they had a serious other disease with a low survival rate; another disease that influenced bronchial symptoms and/or lung function; a need for regular oxygen therapy; a disorder or progressive disease that seriously influenced walking ability.

Study design

All patients included in the COPE-II study participated in four self-management sessions. The intention was to change the patient's disease behaviour by increasing their knowledge,

confronting them with consequences of specific behaviour, and helping patients acquire and practice skills to deal with different components of their disease. Subsequently, only the intervention group participated in a community-based physiotherapeutic exercise programme (COPE-active). This programme was divided in two parts: a 'compulsory' 6-month, and a subsequent optional but recommended 5-month training period. In the first period, patients trained three times per week, and in the second period patients trained two times per week. In both periods, one training session per week was performed at home to encourage the patients to exercise in their own environment. The training sessions consisted of cycling, walking, climbing stairs, and lifting weights. Besides improvement of physical condition, the main goal of COPE-active was a behaviour change towards exercise. The intensity of the programme was tailored to the individual patient's performance level by providing the physiotherapist with the baseline results of the incremental maximal cycle ergometry test, and the incremental shuttle walk test.[20]

Measurements

Exercise capacity

Incremental maximal cycle ergometer test

At baseline, patients in the COPE-active group performed an incremental maximal cycle ergometer test on an electronically braked cycle ergometer. The tests started with two minutes of seated rest followed by three minutes of unloaded cycling. After this, the workload was increased with 10, 15 or 20 W each minute depending on the patient's height, weight and age. The patients were instructed to cycle at a speed of 60–70 rpm, and were encouraged to continue cycling until exhaustion. During the test, patients breathed through a facemask connected to a calibrated metabolic cart. Expired gas passed through a flow metre, oxygen (O_2) analyser and a carbon dioxide (CO_2) analyser. The flow metre and gas analysers were connected to a computer, which calculated breath-by-breath minute ventilation (VE), oxygen uptake (VO_2), carbon dioxide output (VCO_2) and the respiratory exchange ratio (RER = VCO_2/VO_2) from conventional equations. Heart rate (HR) was measured continuously during the exercise test by electrocardiogram (ECG). Peak oxygen consumption (VO_{2peak}) was calculated as the average value over the last 30 s before subjective exhaustion.

Incremental shuttle walk test

The ISWT was conducted according to the protocol of Singh et al.[9] Patients were instructed to walk along a 10-m course, and to turn around at the cones at either end in time with the audio signal. The test started at a walking speed of 0.5 m/s, and each minute the speed increased with 0.17 m/s. The maximum duration of the test was 12 min. However, the test was terminated earlier when the patient indicated not to be able to continue due to fatigue or dyspnoea, or when the patient failed to reach the cone in the time allowed. The ISWT was performed at baseline, 7, and 12 months. At baseline, each patient performed a practice walk.[9]

Endurance shuttle walk test

The ESWT was also performed on a 10-m course.[8] After a warming up period of 120 s, walking speed increased and was constant during the test. Walking speed was set at 85% of the patient's maximum capacity as predicted from the distance walked during the ISWT. The maximal duration of the test was 20 min, and the criteria to stop the test were the same as described for the ISWT.[9] The ESWT was performed at baseline, 7, and 12 months.

Daily physical activity level

Pedometer

Daily physical activity was assessed by the number of steps per day measured with the Yamax Digi-Walker SW-200 (Tokyo, Japan). Patients were instructed to wear a pedometer for a 7-day period, and to note the number of steps in a daily diary, at baseline, 7, and 12 months. Daily physical activity was calculated by summing up the number of steps over 7 days, and then averaging it by that same number of days.[20]

Other measurements

At baseline, lung function was assessed using spirometry. The forced expiratory volume in one second (FEV_1) and vital capacity (VC) were measured. Also, the Medical Research Council (MRC) dyspnoea scale was administered,[31] and anthropometry and demographic variables were collected.

Statistical analysis

Baseline characteristics are reported as mean ± SD for continuous variables with a normal distribution, or as median and range when not normally distributed. Categorical variables are presented as number with percentage. The relationship between continuous variables was tested by calculating Pearson or Spearman correlation coefficients, depending on the normality of the distribution of the variables. Correlation coefficients were considered to be statistically significant when the p-value was smaller than 0.05. All analyses were performed using SPSS version 15.0.

Results

One hundred fifty nine patients were included in the COPE-II study, 80 patients were randomised to participation in the community-based physiotherapeutic exercise programme (COPE-active) and 79 patients were randomised to the control group. In both study groups, three patients dropped out between randomisation and baseline measurements. Table 1 shows the baseline characteristics of the remaining 153 patients.

Relationship between daily physical activity and exercise capacity at baseline

The Pearson correlation coefficients between steps/day and ISWT (m), ESWT (m), and ESWT (s) at baseline were calculated for the patients in both study groups together ($n = 125$), and were 0.59, 0.44, and 0.34, respectively ($p < 0.01$ for all). Pearson correlation coefficients between steps/day on the one hand and VO_{2peak} and W_{peak} on the other hand were only calculated for the COPE-active group ($n = 57$ and $n = 58$, respectively), and were 0.54 ($p < 0.001$) and 0.44 ($p = 0.001$) respectively.

Table 1 Baseline characteristics.

	Total	COPE-active ($n = 77$)	Control ($n = 76$)
Age (years)	63.6 ± 7.9	62.9 ± 8.1	63.9 ± 7.8
Male (%)	58.2	58.4	57.9
Smokers (%)	34.6	35.1	34.2
MRC dyspnoea scale	2.37 ± 1.11	2.25 ± 1.05	2.50 ± 1.15
FEV_1 (L)	1.41 ± 0.53	1.43 ± 0.54	1.40 ± 0.53
FEV_1% predicted value	50.2 ± 15.6	49.6 ± 14.2	50.5 ± 17.0
IVC (L)	3.63 ± 0.97	3.78 ± 1.05	3.47 ± 0.84
BMI (kg/m^2)	26.5 ± 4.72	26.1 ± 5.0	26.8 ± 4.4
Daily physical activity level (steps/day)[a]	4857 ± 3132	4472 ± 2716	5224 ± 3464
Incremental shuttle walk test (m)[b]	365.0 ± 159.9	387.7 ± 164.5	341.4 ± 152.4
Endurance shuttle walk test (m)[b]	654.7 ± 552.3	678.9 ± 553.1	629.5 ± 554.1
Endurance shuttle walk test (s)[b]	505.7 ± 370.3	503.7 ± 368.1	507.9 ± 375.1
VO_{2peak} (ml/kg/min)[c]	n.a.	18.05 ± 5.03	n.a.
W_{peak} (watt)[d]	n.a.	93.38 ± 47.67	n.a.

Medical Research Council (MRC); Forced Expiratory Volume in 1 s (FEV_1); Inspiratory Vital Capacity (IVC); Body Mass Index (BMI); Peak oxygen uptake (VO_{2peak}); Peak wattage (W_{peak}).
[a] Based on 62 patients in the COPE-active group and 65 patients in the control group.
[b] Based on 77 patients in the COPE-active group and 74 patients in the control group.
[c] Based on 69 patients in the COPE-active group.
[d] Based on 71 patients in the COPE-active group.

Relationship between change in daily physical activity and change in exercise capacity at 7 and 12 months

The correlations between change in daily physical activity and change in the various measures of exercise capacity after 7 months of follow-up were moderate in the COPE-active group ($p < 0.01$ for all), and negligible and not statistically significant in the control group (Table 2). After 12 months, only the correlation between change in ISWT distance and change in steps/day in the COPE-active group was moderate and statistically significant (Table 2).

Table 2 Pearson correlation coefficients between change in daily physical activity and change in exercise capacity from baseline to 7 and 12 months for the COPE-active and control group.

Δ 0–7 months	Daily physical activity (steps/day) Δ 0–7 months			
	COPE-active ($n = 53$)		Control ($n = 48$)	
	r	p	r	p
Incremental shuttle walk test (m)	0.47	<0.001	−0.11	0.48
Endurance shuttle walk test (m)	0.41	0.003	−0.05	0.74
Endurance shuttle walk test (s)	0.38	0.006	−0.05	0.74
Δ 0–12 months	**Daily physical activity (steps/day) Δ 0–12 months**			
	COPE-active ($n = 54$)		Control ($n = 54$)	
	r	p	r	p
Incremental shuttle walk test (m)	0.40	0.003	0.09	0.54
Endurance shuttle walk test (m)	0.18	0.21	0.10	0.46
Endurance shuttle walk test (s)	0.17	0.22	0.17	0.23

Relationship between daily physical activity and patient characteristics at baseline

The Pearson correlation coefficients between steps/day on one hand and FEV_1, IVC, age and Body Mass Index (BMI) at baseline on the other hand were calculated for the patients in both study groups together ($n = 127$), and were 0.32 ($p < 0.001$), 0.17 ($p = 0.05$), −0.23 ($p = 0.01$), and −0.09 ($p = 0.29$) respectively.

Relationship between change in daily physical activity from baseline to 7 months and patients characteristics at baseline

In the COPE-active group as well as in the control group, none of the variables measured at baseline was significantly correlated to change in daily physical activity from baseline to 7 months (Table 3).

Discussion

The current study showed that daily physical activity and exercise capacity were only moderately correlated in patients with COPD. Additionally, in patients with COPD who participated in a physiotherapeutic exercise programme, the relationship between change in exercise capacity and change in daily physical activity was moderate to weak. In the control group, change in exercise capacity and change in daily physical activity were not correlated.

Table 3 Pearson correlation coefficients between change in daily physical activity from baseline to 7 months and patient characteristics at baseline for the COPE-active and control group.

	Δ Steps/day 0–7months			
	COPE-active		Control	
	r	*p*	*r*	*p*
VO_{2peak} (ml/kg/min)[a]	0.22	0.11	n.a.	n.a.
W_{peak} (watt)[b]	0.21	0.12	n.a.	n.a.
Incremental shuttle walk test (m)[c]	0.05	0.70	0.04	0.78
Endurance shuttle walk test (m)[c]	0.08	0.53	0.07	0.64
Endurance shuttle walk test (s)[c]	0.1	0.47	0.07	0.60
FEV_1 (L)[d]	0.08	0.55	0.13	0.94
IVC (L)[d]	0.00	0.98	−0.06	0.69
Age (years)[d]	0.06	0.63	0.09	0.55
BMI (kg/m^2)[d]	0.19	0.14	0.02	0.89

Peak oxygen uptake (VO_{2peak}); Peak wattage (W_{peak}); Forced Expiratory Volume in 1 s (FEV_1), Inspiratory Vital Capacity (IVC); Body Mass Index (BMI).

[a] Based on 54 patients in the COPE-active group.

[b] Based on 55 patients in the COPE-active group.

[c] Based on 59 patients in the COPE-active group and 50 patients in the control group.

[d] Based on 59 patients in the COPE-active group and 52 patients in the control group.

Various earlier studies have investigated the relationship between daily physical activity and exercise capacity in patients with COPD. The studies that investigated the relationship between daily physical activity and VO_{2peak} show divergent results with correlations varying from weak to moderate.[2,24–26] This variety in correlations might be due to differences in patient characteristics and the method of measuring physical activity. Hill and colleagues were recently the first to investigate daily physical activity in relation to performance on the incremental shuttle walk test.[26] In this study, daily physical activity was measured in 26 subjects with bi-axial accelerometers and expressed as daily energy expenditure in kcal. They found a statistically significant correlation of 0.52 between distance walked on the incremental shuttle walk test and daily energy expenditure.[26] Whereas we have measured daily physical activity with pedometers, we have found a similar correlation of 0.59 between steps per day and distance walked on the incremental shuttle walk test. Pedometers are relatively simple and inexpensive compared to other activity monitors such as accelerometers. In our study we used the Yamax Digi-Walker SW-200. The mechanism of the SW-200 is the same as the mechanism of the SW-701 and this latter pedometer was considered to be among the most accurate ones in comparison with 9 other models.[32,33] In a more recent study, Turner et al. compared a pedometer to an activity monitor with an accelerometer and both devices underestimated step counts at slow walking speed.[34] In the original COPE-II study pedometers were used to measure the level of physical activity in the intervention and control group, in case of underestimation this would be expected in the same amount in both groups, and would thus have not affected difference between the groups.

To our knowledge, we are the first to investigate daily physical activity in relation to the endurance shuttle walk test. The relationship between physical activity and endurance time of the ESWT at baseline seems weaker than the relationship between activity and distance walked during the ISWT, and it seems also weaker than the relationship between daily physical activity and VO_{2peak}. This is contrary to what we expected to find. Patients with COPD perform their activities of daily living at a submaximal level of intensity.[26] The ESWT measures endurance capacity also at a submaximal level of intensity, and therefore we assumed that performance on the ESWT would better reflect the level of daily physical activity. However, a recent other study of Hill et al. gives more insight by indicating that peak rates of oxygen uptake and peak heart rates that patients with moderate COPD achieve during the ESWT are similar to rates achieved during the cycle ergometry test and the ISWT.[35]

Opposite to the limited research on the relationship between daily physical activity and the shuttle walking tests, the six-minute walk test (6MWT) has been investigated more thoroughly. In the majority of the studies, daily physical activity relates slightly better with the 6MWT than that it relates with the ISWT and ESWT in our study.[2,15,22–28] During the 6MWT patients are instructed to walk at their own pace, and cover as much ground as they can within 6 min, moreover, patients are allowed to stop and rest during the test.[7] This differs from the ISWT and the ESWT, in which patients are instructed to walk at a predetermined speed until they are not able to continue due to dypsnoea or fatigue.[8,9] Pepin et al. showed a significantly higher heart rate, respiratory rate, minute ventilation and dyspnoea after completing the ESWT than after completing the 6MWT in patients with COPD.[36] In contrast, Hill and colleagues found no differences between VO_{2peak} and heart rate after completion of the 6MWT, ESWT, ISWT and CPET in patients with COPD.[35] Patients in the latter study were functionally more impaired than the patients in the study of Pepin et al. This might explain why the 6MWT seems to relate better to exercise behaviour and the submaximal intensity of daily physical activity in patients with mild COPD.

The strongest, although moderate, relation between change in physical activity and change in exercise capacity was found in the intervention group over the first 7 months. In this period, the number of moments for goal setting and feedback were the most frequent (four self-management sessions, and subsequently two training session per week at the physiotherapy practice and one training session per week at home). We therefore expected, and also detected a mean improvement in both exercise capacity and daily physical activity. During the following five months, the intervention was less intense (one exercise sessions at home, and one supervised physiotherapy session). We anticipated that the less intense training approach, but still frequent feedback and reinforcement would be necessary to maintain exercise capacity and further facilitate a shift towards being more active at home. After this second period, we observed a slight decrease in exercise capacity,

this in contrast to a further increase in daily physical activity. Over 12 months, the relationship between activity and performance on the ISWT, and in particular the ESWT was weakened. The weakening of the relationship after including the period in which the intervention was primarily focused on improvement of daily physical activity, underlines the need to use interventions that target not only exercise capacity but also health behaviour regarding exercise in patients with COPD to achieve an increase in both parameters.

In the COPE-active group as well as in the control group, none of the patient characteristics measured at baseline were correlated with change in daily physical activity over 7 months. However, nearly all of these parameters were of a physiological nature, which are not the only variables influencing activities.[37] Daily activities are also influenced by environmental and personal factors.[37] Environmental factors make up the physical, social, and attitudinal environment in which people live and conduct their lives.[37] Personal factors are the particular background of an individual's life and living and contribute to features of the individual. These factors include sex, race, age, but also lifestyle, coping styles, social background, education, overall behaviour patterns and other characteristics.[37] One of the main objectives in the COPE-II study was to assess the efficacy of a self-management programme, including a community-based physiotherapeutic exercise programme in increasing exercise capacity and daily physical activity. With the exception of steps per day no further (process) measures of behavioural change were measured. In future research on daily physical activity in patients with COPD, more attention should be paid to the role of behavioural characteristics and psychosocial factors such as self-efficacy, emotional status, and social functioning. Another remark that can be made, is that by including patients with at least three exacerbations in the two years preceding study entry, we have included relatively severe COPD patients. The COPE-II study was also designed to investigate the effectiveness of self-treatment of exacerbations,[29] and the criterion of at least three exacerbations was used to ensure that a sufficient number of exacerbations could be detected during study follow-up. How this has affected the level of daily physical in our patients is hard to determine. Only few studies have assessed step count in patients with COPD using a pedometer, and the sample size of these studies was small. However, Hospes et al. also measured daily physical activity during 7 days with the Digi-Walker SW-200 in 39 Dutch patients with COPD. Compared to the patients in this study, the patients in our study reported on average fewer steps: 7087 $\pm$ 4058 steps versus 4857 $\pm$ 3132 steps, respectively.[38] This is probably due to the less restrictive inclusion criteria in the study of Hospes et al., which is also reflected in a higher mean FEV_1% of predicted of 67.4 $\pm$ 17.5% versus 50.2 $\pm$ 15.6% in our study. A consequence for the current analyses might be that the results cannot be generalised to the general COPD population, but only to the more severe patients.

Although we found statistically significant correlations between daily physical activity and different measures of exercise capacity, these correlations were at best moderate. What do these results mean for clinical practice? The primary goal of exercise programmes for patients with COPD, as part of a pulmonary rehabilitation programme or not, is improvement of exercise capacity.[1] Intuitively it is logical to assume that an increased exercise capacity will subsequently lead to an increased physical activity level. An increased exercise capacity in patients with COPD reduces symptoms of dyspnoea and fatigue during and after exercise and therefore removes a barrier to be active. However, during the years that the severity of COPD gradually progresses, the patient develops a sedentary lifestyle that needs more than an increase in exercise capacity to change.[21] Behavioural techniques such as motivational interviewing and cognitive behavioural therapy are probably helpful in achieving and maintaining an improved daily physical activity level. However, future research has to investigate which tools are most effective in increasing daily physical activity.

In this study, a moderate to weak relationship was found between daily physical activity and exercise capacity. These results strengthen our beliefs that exercise interventions need to target not only exercise capacity but also behaviour change with regard to daily physical activity, to achieve improvement in both parameters.

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Conflict of interest statement

There are no conflicts of interest.

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