

Comparative Assessment of CPET Versus Typical Work-related Activities in Women With and Without Mild COPD*

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Abstract. *Background: Prevalence of chronic obstructive pulmonary disease (COPD) is increasing in Germany. This study examined the work performance of healthy women compared to those with mild COPD. Patients and Methods: Nineteen women suffering from COPD Global Initiative for Chronic Obstructive Lung Diseases stage I and 41 healthy women underwent standardised cardiopulmonary exercise test (CPET) in comparison to 5 typical work-related tasks. Oxygen uptake, carbon dioxide output, ventilation volume, breathing frequency, heart rate and respiratory exchange ratio (RER) were measured. The activities were quantified. Wilcoxon test and ANOVA were calculated using the SPSS software. Results: Patients with COPD had a lower exercise capacity compared to healthy women and also showed lower performance during work-related activities. Patients with COPD had a lower oxygen uptake ($p < 0.001$), a higher breathing frequency was accompanied by a higher Borg scale. The heart rate and the ventilation volume as a percentage of maximum CPET were significantly higher in patients with COPD. Women suffering from progressive symptoms had lower oxygen uptakes and RER, whilst breathing frequency and Borg scale were elevated. Conclusion: Even at an early stage of the disease, patients with COPD exhibited limitations in work-related tasks.*

The number of women working has risen steadily in the EU and especially in Germany for the last ten years (1). There

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*Some of the results are included in the thesis of I. L. Giesser.

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Key Words: Women, COPD, work capacity, CPET, work-related tasks.

is a particular increase in those aged 60 to 65 years. Around 4 million women currently work in marginal employment. The majority are women over 65 years old, employed in the service sector, retail and gastronomy (2). Over time, it is expected that more and more elderly women will continue to have a working life. Their work performance will be an important issue in the labour market and ought to be evaluated.

Investigations which are tailored to examine typical workplace strain, especially for women, are hard to find. We are not aware of any study that examined the potential work performance of healthy women compared to women with chronic obstructive pulmonary disease (COPD). However, this is a relevant issue, as COPD is one of the leading causes of death worldwide (3).

In Europe, exact data on the prevalence of the disease are not available as there is no registry. According to Blanco *et al.*, the global prevalence of COPD arises to 12.4%. Europe has prevalence rates of 10.8% in Southern Europe (Spain, Portugal, Italy, Greece, Malta, Cyprus and Turkey) and up to 14.2% in Western Europe (the Netherlands, Belgium, Luxembourg, France, Ireland and England) (4). In Germany, smoking is one of the main causes of COPD (5). The proportion of the population with COPD over a period of 1 year in Germany is 5.8% for women, 5.7% for men, and increases with age (5).

In occupational and social medicine methods, which assess limitations of work, performance plays an important role. Statutory accident insurance assesses individuals for disability pension. Pension insurance assesses the remaining working capability of an individual and is relevant so as to estimate the degree of limitation in work performance. Such limitations usually manifest during physical stress. Exercise intolerance is a typical sign of COPD. Individual physical stress at the workplace is usually not measured. Thus, the determination of work-related limitations should be carried out in specifically designed field tests. These involve sitting, walking, restocking, cleaning the floor, and climbing stairs, thereby carrying weights up to 5 kg. Cardiopulmonary exercise capacity is age-dependent. The pensionable age has gradually risen to 67 years

in Germany. In particular, the chronically ill often cannot work until their pension age. The working capability of healthy, older adults as compared to those who suffer from even mild COPD should be standardised and validated in comparative, work-related tests, simulating typical job tasks.

Our target was to investigate the remaining work capacity through typical work activities in healthy women over 40 years of age and patients diagnosed with mild COPD. However, the physical strain during every day work activities ought to be examined in detail. An attempt was made to correlate these objective results with the perceived exertion of the Borg scale (6). By comparing typical work activities with the cardiopulmonary exercise test (CPET), we tried to find a reproducible and objective method for estimating the individual residual work capacity. This should allow a better allocation of patients to different referral activities.

Patients and Methods

Study population. In total, 60 women aged 40 years and older were included: 19 female patients with mild stable COPD (stage I), without exacerbation during the previous 6 weeks, and who had not participated in rehabilitation programs within the previous 6 months. As a control group, 41 normally active and healthy women without diseases which might affect their physical capacity in general were included.

All participants underwent a clinical examination by a physician. Competing left-sided heart failure potentially limiting CPET identified by coloured echocardiography including cw and pw, was an exclusion criterion. Informed consent was obtained from all participants. The study was approved by the Ethics Committee of the Justus-Liebig University in Giessen (Az.: 251/11) with an appendix dated March 5, 2014.

For body composition, the participants were weighed, measured, and their skinfold thickness was evaluated with a caliper in up to seven different regions of the body, using the Jackson/Pollock equations to assess the body density (7). Measurements were conducted by the same researcher to maintain reliability. Fat-free mass (FFM) and fat-free mass index (FFMI) were established using the equations according to Siri (8) and VanItallie *et al.* (9).

Pulmonary function testing. All pulmonary function tests were performed by trained technicians using a MasterScreen CPX (CareFusion Germany GmbH, Höchberg, Germany) according to the guidelines adjusted for body temperature and pressure-saturated with water vapour. Measurements in which the two best attempts fulfilled the American Thoracic Society (ATS) (10) criteria for reproducibility (an agreement within 5%) were included in the analysis. The flow volume curve was formed with the envelope method from curves obtained from at least three successive forced expiratory breathing manoeuvres using the standards of the ATS (10). Standard parameters were measured and forced expiratory volume in 1 s (FEV1) and the forced expiratory volume in 1 s (FEV1)/forced vital capacity (FVC) ratio (FEV1/FVC) were relevant for this study. Airway resistance (R_{aw}) was measured by body plethysmography (ML/MLpro-Body; CareFusion Germany GmbH). For grading of the pulmonary function, FEV1 was also expressed as a percentage of the predicted value in the reference

population as recommended by the guidelines (11). According to the airflow limitations all patients were classified as having mild COPD of Global Initiative for Chronic Obstructive Lung Diseases (GOLD) (12) stage I: FEV1/FVC ≤ 0.7 and FEV1 $\geq 80\%$ predicted. Because there is only a weak correlation between FEV1, symptoms and impairment of a patient's health status symptomatic assessment was considered to the refined ABCD combined assessment tool, according to the Global Initiative for Chronic Obstructive Lung Disease (12). Therefore, patients underwent assessment of either dyspnea using the Modified British Medical Research Council (mMRC) Questionnaire or symptoms using measures such as the COPD Assessment Test (CAT_{TM}) including exacerbation history [presented and cited in (12)]. According to these revised GOLD requirements, the patients with COPD were separated into group A with six patients, B with 11 patients, and D with two patients.

CPET. All participants performed an incremental maximal CPET, according to the criteria of the ATS (13). Seated individuals rode an electrically braked cycle ergometer (VIAsprint, type Ergoselect, Ergoline GmbH, Bitz, Germany) at a pedaling rate of 60 rotations per minute, breathing room air. After unloaded pedaling for 3 minutes, the workload was started at 25 W and increased by 25 W every 3 minutes. During exercise, ventilation volume (V'_E), oxygen uptake ($V'O_2$) and carbon dioxide output ($V'CO_2$) were collected with Oxycon (CareFusion, Höchberg, Germany) measured breath by breath. The breathing frequency (BF), the ventilated volume (V'_E) and the respiratory exchange ratio (RER) were determined. The main objectives were peak performance, maximal oxygen consumption, ventilated volume, breathing frequency and maximum heart rate. Respiratory gas exchanges indices were used for estimating the anaerobic threshold (AT) according to Solberg *et al.* (14). Twelve-lead electrocardiography was conducted and blood pressure was measured at rest, during exercise, and until 5 minutes into the recovery phase. Symptom-limited exercise testing was terminated when the participant reached exhaustion under maximal effort or if defined criteria for stopping according to the ATS were met (13).

Standardised work-related activities. The examinations during task-related activities were carried out with the Oxycon mobile (CareFusion Germany GmbH, Höchberg, Germany), a mobile gas exchange measurement system. Each participant carried out five standardised activities at usual speed under supervision, each lasting 6 minutes. Between the activities, the participants were allowed a break. The following work-related activities were performed over 6 minutes as follows:

- *Cashier work:* Sitting and horizontally moving 2x1 kg containers on a flat surface; the total distance the weights were horizontally transported was calculated.
- *6-Minute Walk:* Walking in the corridor on an even floor; the total distance covered was measured.
- *Restocking merchandise in shelves:* vertical transport by repeatedly lifting a 3.5 kg container onto a shelf; the frequency of lifting was counted and the total height the weight was lifted was calculated.
- *Cleaning the floor:* Wiping an even floor with a mop from one end to the other; the frequency of the sweeps and the total length cleaned were recorded.
- *Climbing stairs with parcels:* Carrying 2x2.5 kg heavy parcels on both sides, the time taken for the climb and the number of steps taken were recorded, the height of steps was measured and total weight (body weight + weight load) in metresxkg/s was calculated.

Table I. Anthropometric data and lung function analysis at rest in healthy women and female patients suffering from mild chronic obstructive pulmonary disease (COPD stage I). Mean values and the standard deviation are given. Significant results are printed in bold.

Parameter	Aged 40-60 years			Aged >60 years		
	Healthy (n=29)	COPD (n=6)	<i>p</i> -Value	Healthy (n=12)	COPD (n=13)	<i>p</i> -Value
Age (years)	50.5±5.5	50±5.2	0.630	69±7.4	68±5.4	0.870
Weight (kg)	69.9±14.6	80±17.8	0.136	64±9.8	69±10.8	0.141
Body mass index (kg/m ²)	24.9±4.3	27.9±7.2	0.381	23.9±3.2	26.5±4.4	0.128
FFM (kg)	48.6±6.6	55.7±7.4	0.040	47.1±4.9	48.2±4.8	0.479
FFMI (kg/m ²)	14.5±1.5	16.4±2.3	0.044	14.4±1.1	14.9±1.6	0.480
Tobacco consumption, pack-years	6±10.1	12.3±15.9	0.207	0.6±2.0	25.5±28.7	0.001
FEV1 (l)	2.9±0.5	2.2±0.5	0.024	2.4±0.8	1.8±0.5	0.026
FEV1/FVC (%)	82±5.6	67±12	0.001	81±5.5	68±9	0.001
FEV1 % predicted	127±14.8	91±26.4	<0.001	141±14.2	112±31.6	0.005
R _{aw} (kPa/l/s)	0.23±0.07	0.53±0.2	0.001	0.26±0.07	0.38±0.2	0.05
MEF50 (l/s)	3.4±0.8	1.8±1.0	0.001	2.7±1.0	1.3±0.8	0.002
mMRC dyspnea scale	-	1±0.6	-	-	2±0.9	-
CAT _{TM} assessment score	-	11±7	-	-	13±4.5	-
GOLD group (n)	-	-	-	-	-	-
A	-	2	-	-	4	-
B	-	3	-	-	8	-
D	-	1	-	-	1	-

FFM: Fat-free mass, FFMI: fat-free mass index; FEV1: forced expiratory volume in 1 s; R_{aw}: airways resistance; MEF50: maximal expiratory flow at 50% of vital flow capacity; mMRC: modified British Medical Research Council questionnaire [presented and cited in (12)]; CAT_{TM}: COPD assessment test (presented and cited in 12).

For each task, the perceived exertion was determined with the Borg scale (category scale with ratio properties) with numbers from 0 (no exertion) to 10 (maximal exertion). The scale allows individuals to subjectively rate their level of exertion during exercise (6).

Blood pressure (BP), heart rate (HR), BF, V'O₂, V'CO₂, RER, as well as the ventilated volume (V'E) were measured. The measurements of the work-related activities were compared to the maximal values recorded during the incremental standard CPET. The field tests and the CPET were never carried out on the same day.

Statistical analysis. Data were analysed using SPSS 20.0 (SPSS Inc, Chicago, IL, USA). The Shapiro–Wilk test was used to analyze the distribution of the lung function parameters. Since a non-normal distribution was found for all groups, the statistical comparisons between the groups were carried out using the non-parametric Wilcoxon test. All *p*-values were obtained using a two-sided test. A comprehensive multifactorial analysis of variance (ANOVA) with repeated measures was calculated. The variables were within-subject factors, and the groups were the between-subject factors. For differences, *post-hoc* tests were performed with Bonferroni as well as Games–Howell. A *p*-value of less than 0.05 was considered statistically significant.

Results

All examined patients suffered from mild COPD, stage I, with a combined COPD assessment predominantly labelled GOLD group A or B. Due to the age-dependency of physical activities, the patients were assigned to groups of 40-60 years

or >60 years. The anthropometric data are presented in Table I and show mean age of the respective groups did not differ significantly. Younger patients with COPD tended to have a higher body weight, with a significantly higher FFM and FFMI (*p*<0.05). The group of healthy individuals consisted of more non-smokers than smokers. The mean number of pack years for (ex)-smokers varied widely and was significantly greater in the older group (*p*<0.001).

In patients with COPD, those aged 40-60 years achieved a maximum power of 104 W, and those >60 years 85 W, whereas data for healthy subjects were 129 W in the younger group and 106 W in older women (Table II). The younger individuals reached the predicted maximal value by Wasserman *et al.* (15), women over 60 years of age achieved only 2/3 of the reference values. The computerised determination of the anaerobic threshold was lower in patients suffering from COPD. The difference was significant for the weight-related exercise capacity (*p*<0.05). In particular, these >60 years suffering from COPD had significantly lower physical capacity during the typical work-related activities cashier work (285 m vs. 393 m) and climbing stairs with parcels of 5 kg (2,172 m×kg vs. 3,139 m×kg). The RER did not significantly differ between groups. However, climbing stairs with parcels was perceived as being more exhausting on the Borg scale, especially by the older patients suffering from COPD (8.4 vs. 5.8).

The variables HR, BF, V'E, and V'O₂ were measured during work-related tasks and compared with the

Table II. Pulmonary function data during cardiopulmonary exercise test (CPET) and work-related tasks in healthy women and female patients suffering from mild chronic obstructive pulmonary disease (COPD). Mean values and the standard deviation are given. Significant results are printed in bold.

Parameter	Aged 40-60 years			Aged >60 years		
	Healthy (n=29)	COPD (n=6)	p-Value	Healthy (n=12)	COPD (n=13)	p-Value
Maximal power (W)	129±34	104±19	0.056	106±22	85±19	0.020
Predicted maximal power (%)*	104±15	114±20	0.137	66±14	70±12	0.328
Weight related power, (W/kg)	1.89±0.47	1.37±0.45	0.040	1.70±0.46	1.24±0.32	0.019
Power at AT (W)	102±30.6	85±13.7	0.181	90±24.9	73±23.6	0.096
Maximal achieved results for work-related tasks						
Cashier work with 2x1 kg (m)	360±100	419±145	0.294	393±106	285±78	0.007
6-Minute walk (m)	610±76.6	588±84.9	0.441	607±63.2	549±65.5	0.055
Restocking with 3.5 kg (m×kg)	80±34.2	61±14.8	0.175	70±20.6	62±25.7	0.174
Cleaning (m)	726±178.4	727±165.2	0.759	686±147.3	617±139.5	0.301
Climbing stairs with 5 kg (m×kg)	3460±956	3007±660	0.197	3139±868.5	2172±931	0.019
Climbing stairs with 5 kg (m×kg/s)	16.6±4.5	15.8±4.2	0.759	14.8±4.5	11.1±4.3	0.050
RER during						
CPET at max.	1.12±0.06	1.06±0.89	0.188	1.12±0.52	1.07±0.61	0.054
Cashier work with 2x1 kg	0.89±0.07	0.84±0.04	0.880	0.89±0.06	0.88±0.05	0.568
6-Minute walk	0.86±0.05	0.85±0.05	0.599	0.86±0.06	0.88±0.08	0.605
Restocking with 3.5 kg	0.89±0.06	0.86±0.04	0.246	0.89±0.06	0.88±0.05	0.430
Cleaning	0.85±0.05	0.82±0.02	0.196	0.83±0.04	0.85±0.06	0.479
Climbing stairs with 5 kg	1.05±0.08	1.00±0.10	0.381	1.02±0.11	1.00±0.10	0.253
Borg scale (points) during						
CPET at max.	7.2±1.9	6.2±1.5	0.169	6.4±2.4	6.5±1.5	0.912
CPET at AT	5.1±2.2	4.2±1.3	0.301	4.4±2.0	5.1±2.6	0.418
Cashier work with 2x1 kg	1.8±1.4	0.8±0.8	0.080	1.9±1.0	1.9±1.4	0.694
6-Minute walk	2.3±0.8	2.2±1.0	0.852	1.9±1.3	3.2±1.9	0.089
Restocking with 3.5 kg	4.6±1.4	3.8±1.0	0.221	4.3±1.8	5.2±1.3	0.071
Cleaning	2.8±1.5	2.7±0.8	0.891	2.8±0.9	3.2±1.3	0.307
Climbing stairs with 5 kg	7.1±1.9	8.2±1.3	0.183	5.8±1.5	8.4±1.6	0.001
Oxygen uptake (ml/min) during						
CPET at max.	1658±422	1538±266	0.237	1392±244	1193±286	0.073
CPET at AT	1307±383	1201±221	0.576	1192±295	1012±267	0.074
Cashier work with 2x1 kg	486±127	603±121	0.255	483±106	463±87	0.744
6-Minute walk	1049±268	1280±179	0.137	1011±172	1099±232	0.870
Restocking with 3.5 kg	1067±293	1233±264	0.457	943±122	1020±156	0.301
Cleaning	885±327	1024±250	0.431	784±107	824±152	0.913
Climbing stairs with 5 kg	1726±386	1703±325	0.662	1537±239	1376±343	0.039
Breathing frequency (/min) during						
CPET at max.	29.8±6.3	30.2±2.3	0.809	31.1±6.0	29.1±6.2	0.549
CPET at AT	23.8±4.9	23.3±4.3	0.942	24.3±3.7	25.3±6.1	0.926
Cashier work with 2x1 kg	22.8±5.0	23.7±2.0	0.264	22.3±2.6	22.7±4.0	0.624
6-Minute walk	22.9±4.5	25.5±1.7	0.072	25.1±4.1	25.9±5.3	0.496
Restocking with 3.5 kg	27.2±5.8	27.9±3.7	0.569	26.9±4.9	27.6±4.6	0.683
Cleaning	27.0±5.1	27.8±4.3	0.759	25.8±3.6	26.5±5.5	0.242
Climbing stairs with 5 kg	31.1±5.5	32.7±2.7	0.743	30.3±4.7	32.4±4.3	0.301
Heart rate (/min) during						
CPET at max.	159.8±14.2	152.8±14.3	0.105	150.1±13.2	129.9±19.8	0.013
CPET at AT	137.5±19.8	133.0±7.4	0.368	130.3±16.6	118.6±23.1	0.218
Cashier work with 2x1 kg	94.2±11.4	94.7±11.7	0.983	89.1±8.9	83.0±8.5	0.242
6-Minute walk	111.5±11.4	126.9±28.4	0.584	106.4±10.6	107.8±8.2	0.870
Restocking with 3.5 kg	121.0±15.7	135.8±31.7	0.599	111.6±11.1	110.8±10.1	0.807
Cleaning	107.5±14.4	126.4±30.1	0.060	99.3±10.6	100.4±10.3	0.870
Climbing stairs with 5 kg	148.8±14.7	157.36±22.9	0.896	137.73±9.5	131.0±13.9	0.050
Ventilation (l/min) during						
CPET at max.	57.1±15.5	53.2±6.9	0.324	50.0±9.6	47.2±12.6	0.221
CPET at AT	39.8±11.2	37.0±4.8	0.395	37.0±7.8	36.8±12.3	0.406
Cashier work with 2x1 kg	17.2±3.9	20.1±2.9	0.204	16.9±2.6	17.9±3.4	0.265
6-Minute walk	29.1±7.8	35.7±4.0	0.073	29.2±7.6	35.4±6.4	0.057
Restocking with 3.5 kg	33.1±11.2	36.7±5.5	0.220	29.4±4.6	34.8±5.2	0.039
Cleaning	27.8±10.6	31.1±5.0	0.381	24.5±4.1	28.7±4.7	0.050
Climbing stairs with 5 kg	54.0±14.6	55.8±8.8	0.793	47.4±12.4	50.1±8.6	0.913

CPET: Cardiopulmonary exercise test; AT: anaerobic threshold; RER: respiratory exchange ratio. *According to Wasserman (15).

standardised CPET at the anaerobic threshold and at maximum power. Using ANOVA for repeated measurements and *post-hoc* analysis according to Bonferroni as well as Games–Howell, no significant differences were found between the four groups with regard to $\dot{V}O_2$, BF, and \dot{V}_E . In CPET and climbing stairs, the HR of patients with COPD aged >60 years was 130/min and thus significantly lower ($p=0.013$) in comparison to healthy individuals of the same age with 153/min. Comparing the four groups over all activities, the HR was significantly lower in those aged over 60 years than in those aged 40 to 60 years ($p<0.01$), irrespective of being healthy or suffering from mild COPD. On the other hand, women suffering from COPD and over 60 years of age, had a significantly ($p<0.05$) higher \dot{V}_E whilst restocking merchandise in shelves (35 l/min vs. 29 l/min) and cleaning the floor (29 l/min vs. 25 l/min).

In comparison to their maximum CPET, patients with COPD often suffered from a higher intensity in work-related tasks than healthy individuals. Patients with mild COPD reached a higher percentage of their achieved maximal value of $\dot{V}O_2$ ($p<0.001$) than healthy women in work-related tasks (Figure 1A). For the HR, these differences were only found between younger healthy women and women aged >60 years suffering from COPD ($p=0.019$) (Figure 1B). No differences were detected when comparing the BF (Figure 1C). The \dot{V}_E in work-related tasks as a percentage of the maximum CPET was significantly higher ($p=0.046$) for women over 60 years of age in comparison to healthy individuals (Figure 1D). No significant differences were found between groups regarding the Borg scale as a percentage of maximum CPET (Figure 1E).

Regarding the GOLD assessment score (GOLD group A, B, or D), women were not only restricted in maximum $\dot{V}O_2$ during CPET, but also during all work-related tasks (Figure 2A). The same applies for GOLD group D concerning the RER (Figure 2B). The patients of GOLD group D differed significantly ($p<0.05$) from groups A and B, both in the maximally achieved RER during CPET and during the 6-minute walk, restocking, and cleaning. Contrary to the $\dot{V}O_2$ and the RER, the BF was elevated in all but one task (Figure 2C). The perceived exertion determined with the Borg scale was also elevated (Figure 2D). Due to the relatively small number of patients and the range of the measured parameters, the differences with respect to GOLD groups were not significant.

Discussion

Determination of functional impairment in individuals with COPD is necessary before an invalidity pension based on the degree of disability can be rendered. According to the recommendations (16), eligibility for invalidity pension in patients with COPD patients means that moderate or severe physical work is no longer possible. Patients suffering from

moderate, severe or very severe COPD according to GOLD classification of airflow limitations stage II, III or IV mostly are retired or unable to work, whilst patients with mild GOLD stage I mainly continue to work. Therefore, our goal was to investigate women with COPD suffering from mild COPD (GOLD stage I).

CPET is used in surveys to determine the remaining working capacity concerning the degree of disability and thus the disability benefit payment after rehabilitation in patients with COPD. The COPD assessment test correlates with health status impairment in COPD (12). The future risk of exacerbation is described by symptoms, exacerbation history and airflow limitations. Because there is only a weak correlation between FEV1, symptoms and impairment of a patient's health status, symptomatic assessment was considered additionally to the refined ABCD assessment tool. In our study, this assessment tool identified mostly COPD of GOLD group A or B.

Exercise intolerance is a typical sign of COPD. The standardised CPET plays an important role in social and occupational medicine, when an impairment of the cardio-pulmonary capacity needs to be quantified. The 6-minute walk reflects limitations expected in activities of daily life (ADL) (17). A significant relationship between walking distance and FEV1 and FVC was reported (17). The estimated exercise performance at peak work capacity (18–20) or peak oxygen uptake (21–24) either on a treadmill or cycle ergometer, were shown to be reduced in patients with moderate and severe COPD. In these studies, the predicted FEV1 was reported to be between 37% (23) and 52% (18). This was also described for the maximal values of oxygen uptake (24, 25), carbon dioxide output (26), oxygen saturation and minute ventilation, as well as for voluntary volume. In our study, we analyzed all relevant parameters in patients with mild COPD stage I (FEV1 predicted >80%) in comparison to healthy persons matching by age. It was our goal to determine these parameters essential for an evaluation not only by a standardised CPET, but also with regard to work-related tasks.

Significant limitations of the (body-weight-related) exercise capacity even in patients with mild COPD in comparison to healthy adults are confirmed in the present study. Investigations concerning limitations in exercise capacities for women suffering from COPD mostly investigated domestic ADL (27, 28). Task-related studies, especially those which estimate the metabolic equivalent (MET), are mostly restricted to male healthy individuals below 60 years of age. Therefore, we also examined women older than 60 years. Herein a wide range of physical activities was analysed, including activities performed whilst sitting and moving weights (cashier work), vertically lifting weights (restocking merchandise in shelves), ascertaining the possible walking distance (6-minute walk), wiping an even floor (cleaning the floor), and climbing stairs with light

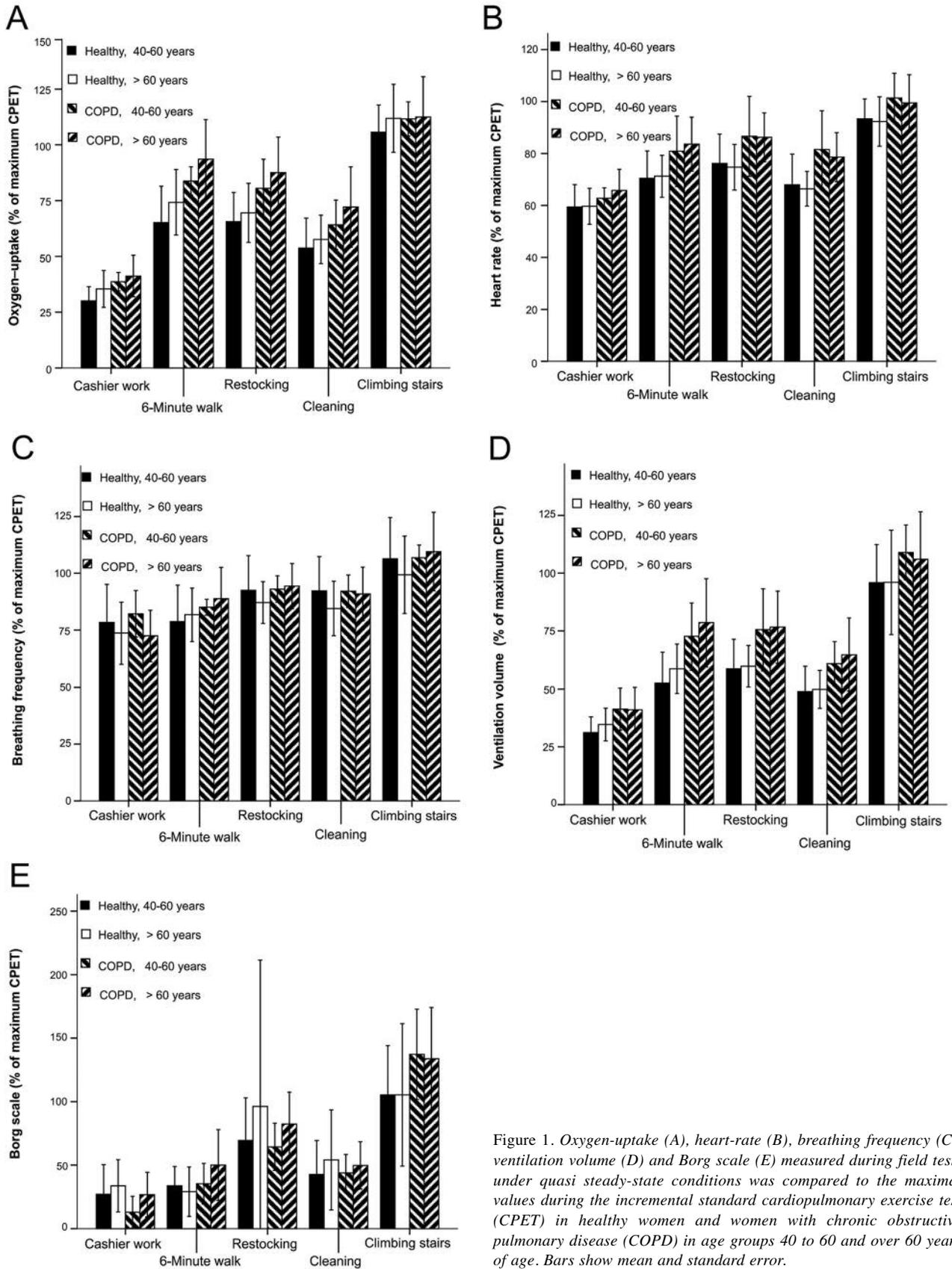


Figure 1. Oxygen-uptake (A), heart-rate (B), breathing frequency (C), ventilation volume (D) and Borg scale (E) measured during field tests under quasi steady-state conditions was compared to the maximal values during the incremental standard cardiopulmonary exercise test (CPET) in healthy women and women with chronic obstructive pulmonary disease (COPD) in age groups 40 to 60 and over 60 years of age. Bars show mean and standard error.

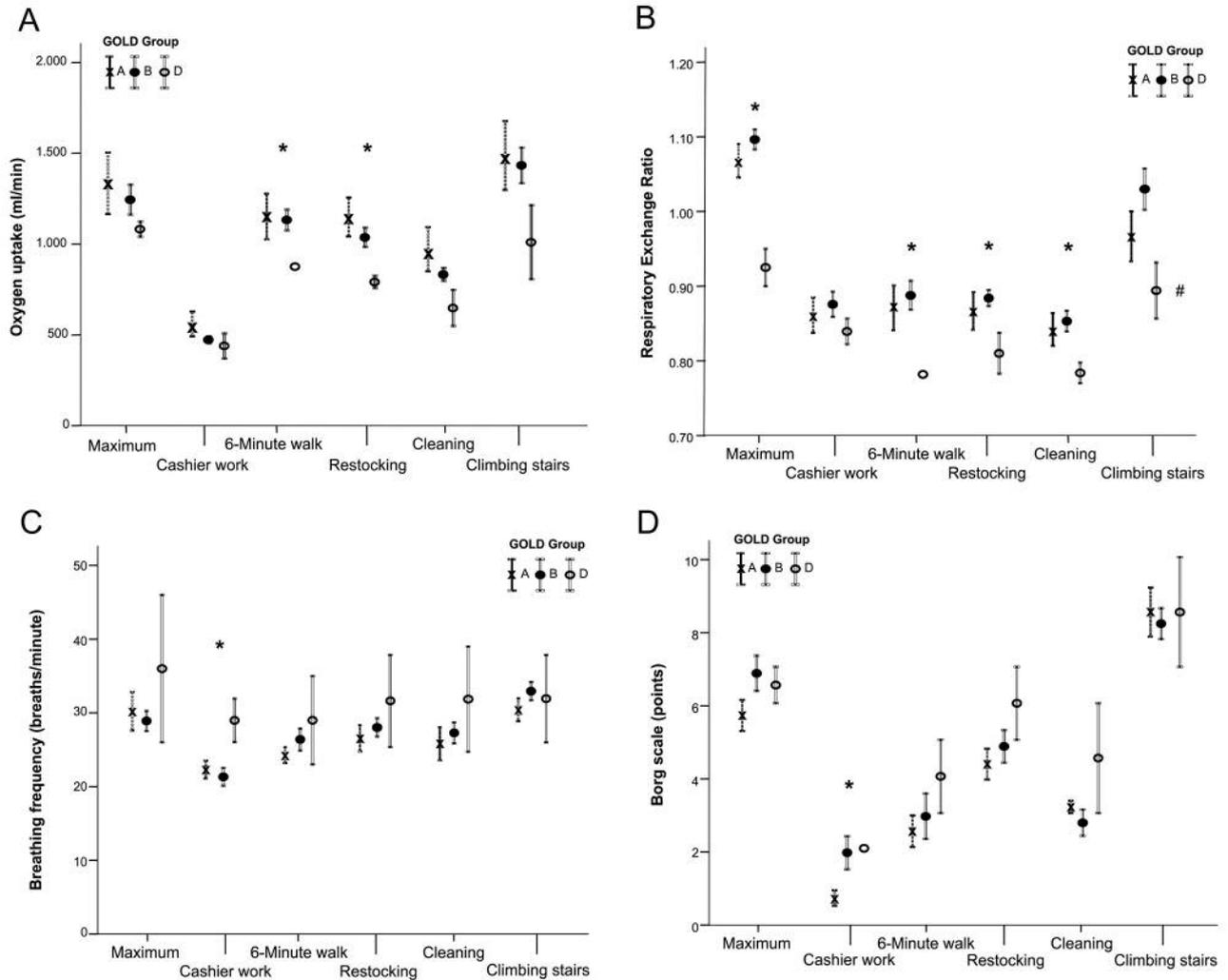


Figure 2. Group dependence of chronic obstructive pulmonary disease (COPD) in women during maximum cardiopulmonary exercise test (CPET) and during work-related tasks. Whiskers show mean \pm standard error for oxygen-uptake (A), respiratory exchange ratio (B), breathing frequency (C), Borg scale (D). Significantly different at $p < 0.05$ for *difference between GOLD group A or B and D, and #difference between all GOLD groups.

weights (climbing stairs with parcels). Merely Kozey *et al.* examined general physical activities such as climbing stairs, walking, and transporting a box of 6 kg weight. In this regard, hardly any studies are found for women at all (29). Accordingly, our study explores these issues. With respect to the influence of age dependence of nearly all physical activities, we examined 40- to 60-year-old women and over 60-year-old subjects with and without COPD. Subsequently they carried out the five above mentioned field tests and quasi steady condition.

The collective showed that those aged 40-60 years with COPD had a higher body weight, increased FFM and FFMI. Even mild COPD results in significant impairment in daily activities (17, 30). In our study patients with mild COPD,

even in GOLD group A or B, achieved lower physical results in the 6-minute walk, restocking and climbing stairs. According to van Helvoort *et al.* (31), and Schneider and Funk (32) however, patients with COPD had a lower power during CPET. Patients with COPD stage II and higher were reported to be usually less physically active than healthy subjects of the same age group (17). The older patients with COPD also showed significantly lower exercise capacity compared to healthy people of the same age (>60 years) when climbing stairs with weights and in the cashier task (Table II).

With age, HR at rest and under maximum load decreases (33). In our study, the HR was lower among the older participants than the younger ones. Significant differences

between the patients and the age-matched control groups were found for maximal CPET and climbing stairs with weights (Table II). Resting BF increases significantly with the severity of COPD (33). We were also able to confirm this observation with work-related activities for women suffering from mild COPD GOLD group A and B.

Oxygen consumption is not only dependent on the basal metabolic rate, but in particular on the work performed and on age (34). The $\dot{V}O_2$ peak correlates significantly with the physical performance, quality of living, and everyday life (35).

According to van Helvoort *et al.* (31), as well as Schneider *et al.* (32), oxygen uptake at the same work load is comparable in healthy and ill patients. Whilst performing identical work rates at CPET, discrimination between patients with different GOLD stages and healthy individuals was not possible (32). In the present study, it is notable that the oxygen uptake during the task-related activities in patients with COPD was lower in a group-dependent manner confirming the patient-reported outcome in the revised COPD assessment tool (Figure 2A). Mild COPD resulted in significant impairment of oxygen uptake in daily activities (17, 30). According to Vaes *et al.* (27) patients with progressive GOLD classification had the lowest task-related oxygen uptake accompanied by higher perceived exertion during domestic ADL. This is consistent with other studies, in which patients with even mild COPD had decreased oxygen uptake in the CPET (36, 37) and in ADL (stair climbing, warehousing, vacuuming) (30).

We additionally analysed the oxygen uptake as a percentage of the maximum CPET. Patients suffering from mild COPD used a significantly higher proportion of the peak O₂ uptake during CPET in cashier work, restocking, the 6-minute walk and cleaning than the healthy women (Figure 1A), moreover the activities were accomplished at a lower intensity.

In regard to the ADL, Vaes *et al.* (28) and van Helvoort *et al.* (31) came to the same conclusion. Van Helvoort *et al.* described how in patients suffering from early-stage COPD, the relative oxygen consumption as a percentage of the peak was increased compared to healthy individuals in various ADL (climbing stairs 71% vs. 67%, vacuum cleaning 47% vs. 40%, restocking cupboard 69% vs. 62%) (31). This was accompanied by higher task-related Borg dyspnoea scale in the range of 3 to 6 (28).

Consistent with previously reported results, the maximum ventilated volume of patients with COPD was lower than that of healthy individuals, depending on the stage of the disease (32). At the same work rate, there were no significant differences between diseased and healthy women (32). For men, however, Schneider-Lauteren *et al.* demonstrated that climbing stairs significantly increased ventilation (38). When climbing stairs with weights, the ventilation was also

increased, however, not significantly. During restocking, cashier work, cleaning, and the 6-minute walk, the ventilation volume as a percentage of peak ventilation during CPET in patients with COPD was higher than those in healthy women (Table II).

During physical activities such as climbing stairs, vacuum cleaning and placing groceries into a cupboard, van Helvoort *et al.* confirmed a higher ventilation in patients with COPD in comparison to the healthy control group. A pathological dead-space ventilation proven under physical exercise is compensated by an increased ventilation (31). The increased (relative) ventilation leads to dyspnea. In dependence of the ADL, peak ventilation was reported to be between 40% and 80% (28). Results showed no sex-related differences. Correspondingly, our study also showed a significantly higher ventilated volume as a percentage of the peak ventilated volume during work-related activities in all patients with COPD when compared to healthy women (Figure 1D).

In patients with COPD, ventilatory capacity is limited. In the present study it is notable that the breathing frequency increased over all activities (Figure 2C) in a GOLD group-dependent manner. Ofir *et al.* also showed an increase in the breathing frequency of sick patients, thus requiring higher ventilation (36).

Regarding the RER, in all groups no significant differences were detected during work-related activities (Table II). In our study, the Borg scale was used to indicate perceived exertion. In patients with COPD, the severity of dyspnea plays a role in the quantification of fatigue.

Patients with COPD had task-related Borg dyspnea scores in the range of 3 to 6 and used up to 100% of their peak in CPET for different ADLs (28). In our study, climbing stairs was indicated by all participants as having the highest Borg scale (Figure 1E; Table II). Particularly static activities, such as lifting, cleaning, cash work, and restocking, were accompanied by higher Borg scales relatively to the peak CPET. Again, a group-dependence was found (Figure 2D). With increasing physical stress, Mador *et al.* showed that the Borg scale in patients suffering from COPD does not necessarily correlate with the physiological parameters of the strain, so that its value is limited (39). Even in studies performed on healthy volunteers, the correlation between objective intensity of exercise and subjective fatigue was low (40).

In conclusion, women with mild COPD had a lower performance in all physical tasks than women without COPD. In our study, we reproduced several typical work-related activities and demonstrated that limitations were not only detectable in CPET, but also in tasks at the workplace which are considered as light physical activities. Besides the classification of severity of airway obstruction (FEV1 in % predicted) patients health status and the risk of future events classified with GOLD group ABCD are also associated with functional disorders in a group-dependent manner. Particularly

static activities were associated with greater subjective exhaustion. Our results provide additional information for the patient's workplace, which has not been mapped with ADL. The activities represent a wide range of tasks. This will allow a more comprehensive assessment of possible work performance enabling a more suitable recommendation for referral professions in patients suffering from COPD.

Conflicts of Interest

All Authors declare no financial conflicts. There was no commercial funder. All Authors are employees of the Federal University in Gießen.

Acknowledgements

All Authors hereby thank all our study participants, without whom our research work would not have been possible.

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Received September 28, 2018

Revised October 23, 2018

Accepted October 26, 2018