



Characterization and Triggers of Dyspnea in Patients with Chronic Obstructive Pulmonary Disease or Chronic Heart Failure: Effects of Weather and Environment

Ayham Daher¹ · Michael Matthes¹ · András Keszei² · Vincent Brandenburg³ · Tobias Müller¹ · Christian Cornelissen¹ · Michael Dreher¹ 

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Abstract

Background and Objectives Dyspnea is one of the most disturbing symptoms for patients with chronic obstructive pulmonary disease (COPD) or heart failure (HF). This study investigated dyspnea triggers and factors associated with worsening dyspnea in patients with COPD or HF.

Methods COPD support group members and HF patients with reduced ejection fraction (HF_{rEF}) and no airway obstruction answered a questionnaire describing different weather conditions (rising/falling air pressure, sunny, foggy, rainy, windy, snowy, hazy, high ozone levels, and airborne pollen) and environmental circumstances (cooking, grilling, perfumes, cigarette smoke, gasoline odor, and flower scents) and were asked to estimate the occurrence and severity of dyspnea under these conditions using predefined scales.

Results 230 patients with COPD and 90 with HF_{rEF} (left ventricular ejection fraction $34 \pm 10\%$, Tiffeneau index $> 70\%$) were analyzed. COPD patients reported dyspnea more often than HF patients in almost all weather and environmental conditions ($p = 0.004$ to $p < 0.001$), with the exception of outdoor floral scents and cigarette smoke. Severe to very severe dyspnea was reported more in COPD versus HF in all weather and environmental conditions except sunny weather ($p = 0.01$ to $p < 0.001$). COPD was associated with more severe dyspnea than HF in all conditions (all $p < 0.001$).

Conclusions Dyspnea was triggered by a variety of weather and other environmental triggers in patients with COPD and occurred more often than in HF patients under the same conditions. Foggy weather and exposure to perfumes were associated with severe dyspnea in the majority of COPD patients, but only a minority of HF patients.

Keywords Chronic obstructive pulmonary disease · Dyspnea · Environment · Heart failure · Weather

✉ Michael Dreher
mdreher@ukaachen.de

Ayham Daher
adaher@ukaachen.de

Michael Matthes
mmatthes@ukaachen.de

András Keszei
akeszei@mi.rwth-aachen.de

Vincent Brandenburg
vincent.brandenburg@post.rwth-aachen.de

Tobias Müller
tobmueller@ukaachen.de

Christian Cornelissen
ccornelissen@ukaachen.de

¹ Department of Pneumology and Intensive Care Medicine, University Hospital Aachen, Aachen, Germany

² Department of Medical Informatics, University Hospital Aachen, Aachen, Germany

³ Department of Cardiology, Angiology and Intensive Care Medicine, University Hospital Aachen, Aachen, Germany

Introduction

Dyspnea is a serious health issue and a leading cause of exercise limitation and reduced quality of life for patients with chronic obstructive pulmonary disease (COPD) [1, 2] and those with heart failure (HF) [3]. However, dyspnea is subjective and depends on several factors. In addition, it is often difficult to identify a specific cause for dyspnea given that there are several co-morbidities that can trigger dyspnea [4–6]. Furthermore, patient perception of dyspnea can vary widely from the results obtained using standard tools to assess dyspnea in clinical practice [7, 8], such as the Borg Scale [9] which only assesses dyspnea severity.

Knowing the precise triggers or aggravating factors for dyspnea might help to improve the patient quality of life or even reduce medication requirements. This should be the case for both COPD and HF.

Many studies have shown differences in COPD exacerbation rates between northern, southern, and tropical communities [10–13], which raises the question, whether there is a correlation between clinical course of the disease and its symptoms on one hand and differences in weather characteristics and lifestyle between the different communities on the other hand. To the best of our knowledge, only cold weather and air pollution have been defined as potential risk factors for exacerbations and worsening dyspnea in COPD patients [14–17].

Many patients, especially those who take a high level of responsibility for managing their own disease and are, for example, members of support groups, can describe specific circumstances that they try to avoid because these have a negative influence on their health, but there is a lack of scientific research on this topic.

The aim of this study was to better understand the characteristics of dyspnea and to identify possible relationships between different weather and environmental factors and the occurrence and intensity of dyspnea. Patients with either COPD or HF were included because both groups experience both dyspnea and repeated exacerbations.

Methods

The protocol for this study was approved by the Institutional Review Board for Human Studies at RWTH University, Aachen, Germany, (EK 332/15) and all investigations were performed in accordance with the ethical standards laid down in the Declaration of Helsinki in its latest revision.

Patients

A monthly COPD support group newsletter was used to recruit COPD patients prepared to answer a questionnaire. Chronic HF patients with reduced ejection fraction (HFrEF)

were recruited from a HF outpatient clinic at the RWTH University Hospital in Aachen. COPD was excluded in all HF patients by full body plethysmography using GOLD criteria [1] (forced expiratory volume in 1 s [FEV₁]/vital capacity [VC] > 70%). All subjects in both patient groups were outpatients with stable disease and were not experiencing any exacerbation of symptoms. COPD and HF patients were asked to complete the study questionnaire.

Questionnaire

The questionnaire was designed by the head of the local COPD support group. Other members of the group brainstormed about different situations that triggered or worsened dyspnea. The final questionnaire included 30 items.

Participants were asked if they lived next to a busy street or are/were exposed to chemicals or dust in their place of work. All patients were also asked if they experienced shortness of breath when the weather changed, and specifically during increases or decreases in air pressure. A set of predefined external conditions was presented and each participant had to determine whether he/she was likely to experience dyspnea under each condition and the amount of that dyspnea based on a four-option grading system (1 = no breathlessness, 2 = moderate breathlessness, 3 = severe breathlessness, 4 = very severe breathlessness); weather conditions included were sunshine and warm weather, foggy weather, rainy weather, strong wind, frost and snow, high ozone levels in the summer, air pollution with fine dust in the summer, and airborne pollen of any sort. Patients were also asked to rate the severity of dyspnea under different environmental conditions using a 7-point scale (0 = no breathlessness, 1 = mild breathlessness, 2 = mild to moderate breathlessness, 3 = moderate breathlessness, 4 = moderate to severe breathlessness, 5 = severe breathlessness, 6 = very severe breathlessness); environmental conditions were while grilling, cooking, if somebody nearby is smoking, if someone nearby is heavily perfumed, if the patient is heavily perfumed, if gas fumes rise while refueling, if the patient is exposed to floral scents in nature, and if the patient is exposed to floral scents indoors.

Statistical Analysis

Standard summary statistics were used to describe the data. Relative frequencies were calculated based on the total number of subjects. For group comparisons, analyses were performed on subjects without missing data for the respective analysis. This approach assumes that data are missing completely at random. Proportions were compared between patient groups using Chi-squared test for independence. Nominal, uncorrected *p* values are presented. Between group differences in the occurrence and severity of dyspnea

were analyzed using logistic and linear regression models, respectively. Three models were considered: (1) unadjusted; (2) adjusted for age (years), sex (male/female), and smoking status (yes/no); and (3) as for model 2 but also adjusted for the occurrence of dyspnea in general (yes/no). In logistic models, Wald confidence intervals were calculated. For linear models the confidence intervals for differences were estimated using non-parametric bootstrap method with 1000 replications. The 95th percentile intervals are presented.

Results

A total of 230 COPD patients (age 59 ± 8 years) and 90 HF patients (age 72 ± 14 years, FEV₁/VC $80 \pm 8\%$, LVEF $34 \pm 10\%$) were included. The New York Heart Association (NYHA) Functional Classification of HF patients was as follows: NYHA-II (21% of HF patients), NYHA-III (65%) and NYHA-IV (14%). Demographic and environmental data for the two patient groups are shown in Table 1. The mean duration of smoking was 34 ± 11 years among COPD patients and 26 ± 11 among smokers in the HF group.

Dyspnea during Different Weather Conditions

The occurrence of dyspnea during weather changes was reported significantly more often by patients with COPD versus HF (62% vs 31%, $p < 0.001$). Dyspnea during both decreasing and increasing air pressure was also more frequent in COPD patients compared to those with HF (61% vs 22% and 57% vs 19%, respectively; both $p < 0.001$). Overall, COPD patients reported dyspnea more often than HF patients in all the investigated weather conditions (Table 2). In addition, more COPD patients reported severe to very severe dyspnea compared with HF patients, apart from when the weather was sunny and warm (Table 2).

The association between COPD and dyspnea across a range of weather conditions was stronger than that between HF and dyspnea under the same conditions (Fig. 1). This was the case in the unadjusted and adjusted models, and

estimates were similar across all three models in all conditions (Fig. 1).

Dyspnea in Different Environmental Conditions

COPD patients reported dyspnea more than HF patients apart from during exposure to floral scents in nature and in the presence of passive smoking (Table 3). In all circumstances, more COPD patients reported severe to very severe dyspnea compared with HF patients ($p = 0.01$ to $p < 0.001$) (Table 3). In addition, COPD patients experienced more severe dyspnea than HF patients in all environmental conditions (all $p < 0.001$) (Table 3).

Compared with HF, the presence of COPD was associated with much higher rates of dyspnea across all environmental conditions except for exposure to floral scents outdoors and passive smoking; this was seen in the unadjusted as well as adjusted models, and estimates were similar across the three models under all conditions (Fig. 2).

Dyspnea was much more severe in the COPD group compared with HF patients across all environmental conditions (Fig. 3). Again, this association was seen in the unadjusted and adjusted models, and estimates were similar across the three models (Fig. 3).

Discussion

The results of this study show that COPD patients are much more sensitive to different weather and environmental factors than HF patients, with significantly more COPD patients reporting any dyspnea and severe to very severe dyspnea in different weather and environmental conditions.

Cold weather has been previously shown to trigger bronchoconstriction and thereby worsen exercise-induced dyspnea in COPD patients [14]. Furthermore, polluted air with fine dust, so-called haze weather, has also been shown to worsen the course of COPD, from increasing symptoms and triggering acute exacerbations to emergency department visits, hospital admissions, and even mortality [15–17]. However, data about the effects of other weather conditions on

Table 1 Patient demographic and environment data

	COPD ($n = 230$)	HF ($n = 90$)	p Value
Age, years	59 ± 8	72 ± 14	< 0.001
Male, n (%)	89 (39)	60 (67)	< 0.001
Smoker, n (%)	222 (97)	50 (56)	< 0.001
Living next to a high-traffic street, n (%)	72 (31)	20 (22)	0.11
Exposure to chemicals in the professional medical history, n (%)	80 (35)	11 (12)	< 0.001
Exposure to dusts in the professional medical history, n (%)	98 (43)	21 (9)	0.002

Values are mean \pm standard deviation or number of patients
 COPD chronic obstructive pulmonary disease, HF heart failure

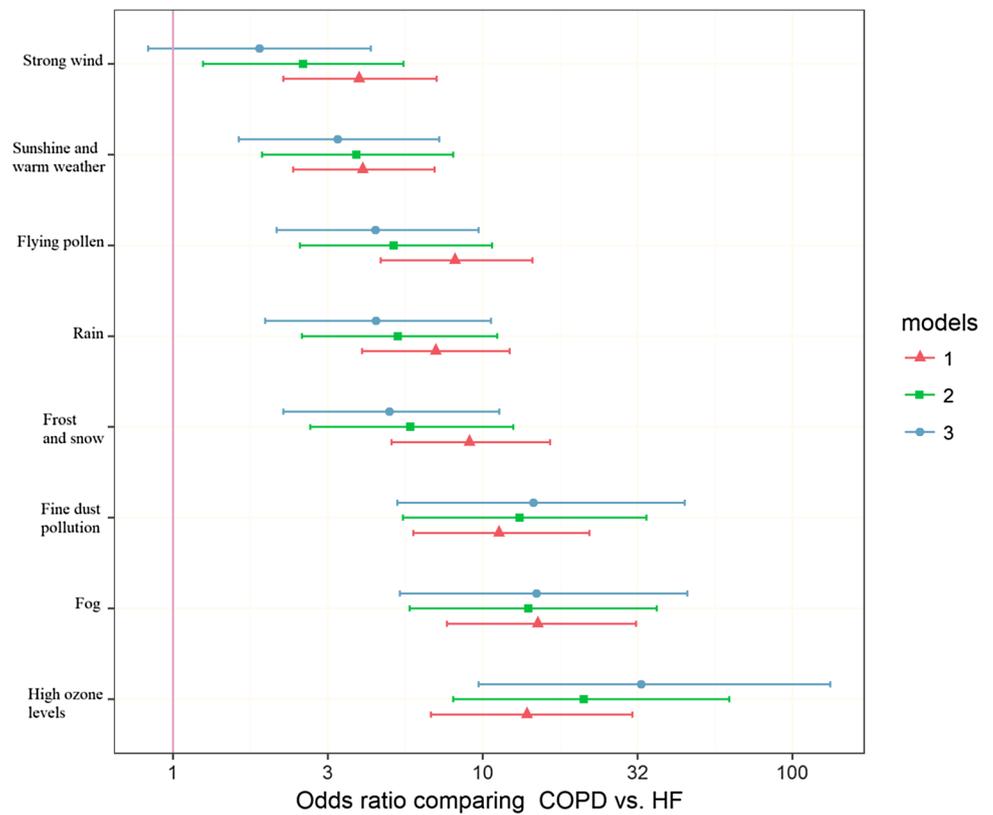
Table 2 Dyspnea in different weather conditions

	COPD (<i>n</i> =230)	HF (<i>n</i> =90)	<i>p</i> Value
Any dyspnea, <i>n</i> (%)			
Sunshine and warm weather	165 (72)	41 (46)	<0.001
Flying pollen regardless of the species	159 (69)	24 (27)	<0.001
Rain	173 (75)	34 (38)	<0.001
Frost and snow	187 (81)	39 (43)	<0.001
Strong wind	181 (79)	51 (57)	<0.001
Fine dust pollution in the summer	196 (85)	43 (48)	<0.001
High ozone levels in the summer	202 (88)	49 (54)	<0.001
Fog	200 (87)	45 (50)	<0.001
Severe to very severe dyspnea, <i>n</i> (%)			
Sunshine and warm weather	45 (20)	12 (13)	0.11
Flying pollen regardless of the species	59 (26)	6 (7)	<0.001
Rain	64 (28)	5 (6)	<0.001
Frost and snow	101 (44)	12 (13)	<0.001
Strong wind	110 (48)	15 (17)	<0.001
Fine dust pollution in the summer	115 (50)	11 (12)	<0.001
High ozone levels in the summer	125 (54)	15 (17)	<0.001
Fog	141 (61)	19 (21)	<0.001

Values are number of patients

COPD chronic obstructive pulmonary disease, HF heart failure

Fig. 1 Association between different weather conditions and the occurrence of dyspnea in patients with chronic obstructive pulmonary disease or heart failure, estimated from logistic models. Ranges represent 95% confidence intervals. Model 1: unadjusted; model 2: adjusted for age (years), sex and smoking status; model 3: adjusted for age (years), sex, smoking status, and occurrence of dyspnea in general



COPD are scarce, and a detailed comparison of triggering and characteristics of dyspnea in HF patients under these weather conditions is not yet available.

To the best of our knowledge, our study shows for the first time that weather affects COPD patients much more than it does HF patients. In all the tested weather conditions, COPD

Table 3 Dyspnea in different environmental conditions

	COPD (<i>n</i> = 230)	HF (<i>n</i> = 90)	<i>p</i> Value
Any dyspnea, <i>n</i> (%)			
If the patient is exposed to floral scents in nature	32 (14)	15 (17)	0.701
Cooking	99 (43)	17 (19)	<0.001
If the patient is exposed to floral scents indoors	87 (38)	21 (23)	0.004
Grilling	110 (48)	15 (17)	<0.001
If gas fumes rise while refueling	119 (52)	30 (33)	<0.001
If the patient is heavily perfumed	139 (60)	17 (19)	<0.001
Passive smoking	132 (57)	50 (56)	0.276
If someone nearby is heavily perfumed	172 (75)	37 (41)	<0.001
Severe to very severe dyspnea, <i>n</i> (%)			
If the patient is exposed to floral scents in nature	15 (7)	0 (0)	0.010
Cooking	32 (14)	2 (2)	0.001
If the patient is exposed to floral scents indoors	41 (18)	2 (2)	<0.001
Grilling	51 (22)	2 (2)	<0.001
If gas fumes rise while refueling	60 (26)	3 (3)	<0.001
If the patient is heavily perfumed	80 (35)	3 (3)	<0.001
Passive smoking	88 (38)	6 (7)	<0.001
If someone nearby is heavily perfumed	110 (48)	3 (3)	<0.001
Dyspnea severity ^a			
If the patient is exposed to floral scents in nature	4 (3, 5)	1 (1, 3)	<0.001
Cooking	4 (3, 5)	2 (1, 3)	<0.001
If the patient is exposed to floral scents indoors	4 (4, 5.8)	2 (1, 3)	<0.001
Grilling	4 (3, 5)	2 (1.5, 4)	<0.001
If gas fumes rise while refueling	4 (4, 5)	1.5 (1, 3)	<0.001
If the patient is heavily perfumed	5 (4, 6)	3 (2, 4)	<0.001
Passive smoking	5 (4, 6)	3 (1, 3)	<0.001
If someone nearby is heavily perfumed	5 (4, 6)	1 (1, 3)	<0.001

Values are number of patients, or median (quartile 1, quartile 3)

COPD chronic obstructive pulmonary disease, HF heart failure

^aOn a scale from 1 to 6 (patients without dyspnea were not considered)

patients had a higher rate of dyspnea than HF patients. This was true in the unadjusted model and after adjusting for age, sex, smoking status, and the occurrence of dyspnea in general. Furthermore, the difference between the two patient groups in different weather conditions was even more marked when only severe to very severe dyspnea was considered. The negative impact of “bad” weather on COPD patients was most obvious for foggy weather. In this case, the majority of COPD patients reported dyspnea, and this dyspnea was usually severe to very severe. Conversely, only a minority of patients with severe HF reported severe to very severe dyspnea in this weather condition.

The findings of this study regarding the influence of weather on dyspnea should be of clinical importance given that the majority of COPD patients reported weather-related dyspnea and more than half of all COPD patients reported severe to very severe dyspnea during each of the following: in foggy weather, in the summer with high ozone levels and due to fine dust pollution in the summer. Taking this

into consideration, along with the fact that dyspnea is a key symptom of COPD exacerbations [1], it remains to be determined whether the last-mentioned weather conditions trigger COPD exacerbations with a decline in lung function. This is an important issue, especially because frequent exacerbators are predisposed to impaired quality of life, a poor prognosis and a high mortality rate [18, 19].

In the light of our findings, there is a clear need to undertake preventive procedures during these weather conditions in COPD patients. Such recommendations relate specifically to patients with COPD because only a minority of HF patients reported severe to very severe dyspnea during the specific weather conditions assessed.

Triggering of acute dyspnea in COPD patients after exposure to non-infective environmental factors has been investigated in only a few previous studies [20]. For example, although the majority of COPD exacerbations are triggered by respiratory viral infections, airway pollutants have also been shown to precipitate exacerbations and

Fig. 2 Association between different environmental conditions and the occurrence of dyspnea in patients with chronic obstructive pulmonary disease or heart failure, estimated from logistic models. Ranges represent 95% confidence intervals. Model 1: unadjusted; model 2: adjusted for age (years), sex and smoking status; model 3: adjusted for age (years), sex and smoking status and occurrence of dyspnea in general

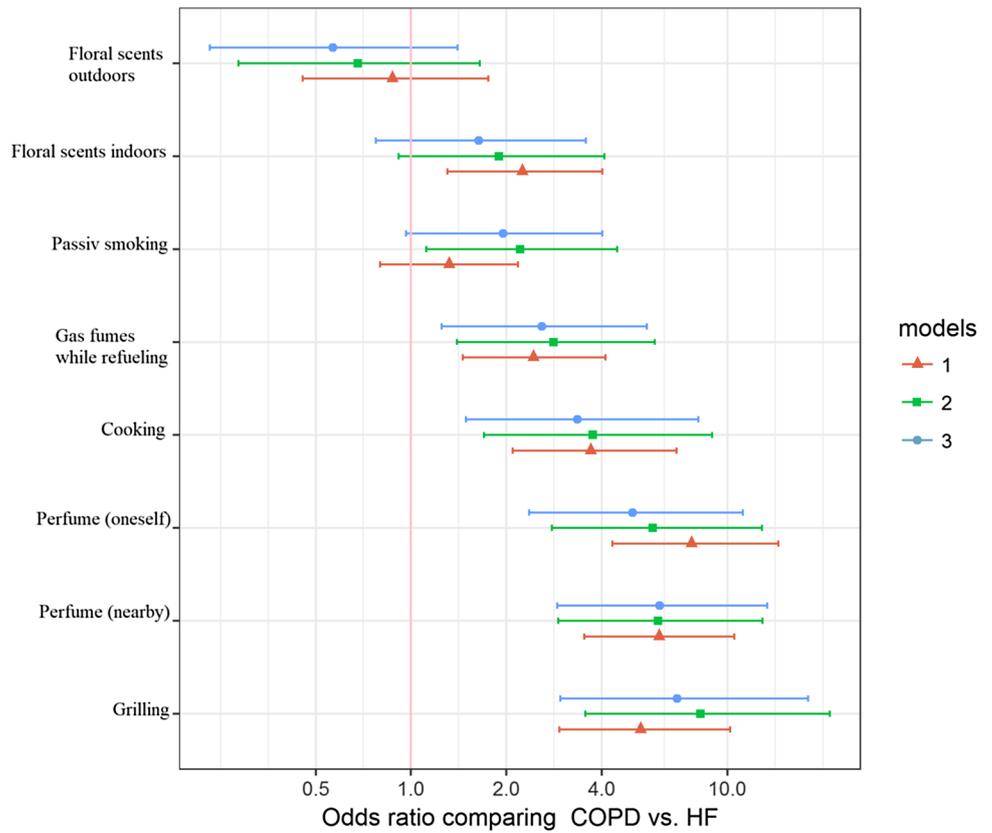
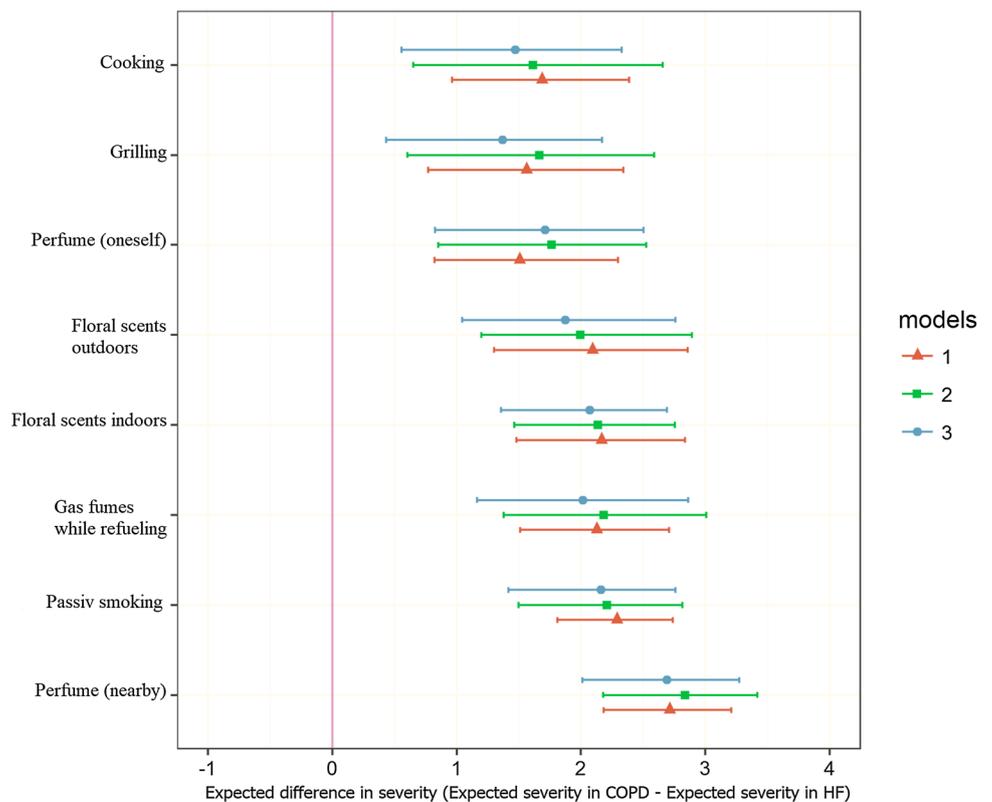


Fig. 3 Differences in dyspnea severity under different environmental conditions in patients with chronic obstructive pulmonary disease or heart failure, estimated from general linear models. Dyspnea severity was measured on a 6-point scale (from 1 to 6; patients without dyspnea were not considered). Ranges represent 95% confidence intervals. Model 1: unadjusted; model 2: adjusted for age (years), sex and smoking status; model 3: adjusted for age (years), sex and smoking status and occurrence of dyspnea in general



worsen disease symptoms, especially in association with respiratory viruses [19]. Furthermore, a large survey in Singapore reported that although trigger factors are more common in asthma patients, they also occur frequently in patients with COPD [21]. In the latter study, nearly half of the COPD patients had at least one trigger factor and, interestingly, non-infectious triggers were reported more frequently than infectious ones [21].

Our study confirms the sensitivity of COPD patients to many environmental factors. Compared with HF patients, more patients with COPD reported dyspnea during daily life situations such as cooking or grilling, and as a result of contact with fuel gas fumes or perfume. In addition, significantly more COPD patients reported severe to very severe dyspnea under all the tested environmental conditions compared with HF patients. Again, our findings are clinically relevant given the fact that 48% of COPD patients reported severe to very severe dyspnea when in contact with someone who was heavily perfumed. Again, this was specific to COPD patients because a similar response was only reported by 3% of HF patients. Across all situations tested, dyspnea severity was significantly higher in COPD versus HF patients, indicating that environmental factors have a significantly greater negative impact on patients with COPD versus severe HF.

The study has several limitations which need to be taken into account when interpreting the results. Firstly, we do not have comprehensive information on heart function in COPD patients. Therefore, it is unclear if a co-morbid HF has contributed to the severity of dyspnea in this group. The prevalence of ventricular dysfunction among COPD patients has been estimated to be 17% [22]. Taken this into account, some of the COPD patients in the current study also have a co-morbid HF and this impact on our results remains unclear. However, the prevalence of dyspnea and the severity of dyspnea under different weather and environmental conditions was remarkably lower in patients with isolated HF. In addition, we do not have spirometric data of our COPD patients, which makes it not possible to characterize the prevalence and severity of dyspnea under the various weather and environmental conditions in patients with mild, moderate, severe, and very severe COPD. Nevertheless, all COPD patients had been diagnosed with fixed obstructive pulmonary disease according to their medical history. The comparison group were patients with HFrEF who mostly have severe disease and experience limitation in daily activities due to breathlessness, making the comparison with COPD patients relevant regardless of disease severity. The HF cohort is well characterized to exclude any lung function limitations. Finally, the questionnaire was designed by a local COPD support group and was not validated which strongly impairs the reproducibility.

In conclusion, dyspnea in COPD patients is very sensitive to weather conditions and other environmental triggers, and these triggers play a more important role in COPD than in HF. Therefore, undertaking preventive actions in specific weather conditions and extrinsic environmental situations is likely to be very important for day-to-day management of dyspnea in patients with COPD but less so for those with HF.

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Compliance with Ethical Standards

Conflict of interest The authors state that they have no competing interests relating to this manuscript.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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