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Research Article

Stable COPD Picture through Exhaled Breath Condensate, Questionnaires and Tests. A Proof of Concept Study

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Abstract

Background: Changes in lung structures persist in stable Chronic Obstructive Pulmonary Disease (COPD), but their correlation with the clinical picture remains unclear. The purpose of this study was to assess the stable COPD picture via the relationship between exhaled breath condensate (EBC) particle concentration and the Saint George Respiratory Questionnaire (SGRQ), COPD Assessment Test (CAT), and six-minute walking test (6 MWT).

Methods: 12 stable COPD and 12 healthy subjects participated in the study. The EBC was collected with Rtube and analyzed using the Accusizer FxNano. Particle concentration was measured and correlated with the findings of the tools used to assess the health status and functional profile of COPD. The results' analysis was performed with the Spearman's test and the Mann-Whitney U - test.

Results: The COPD group presented a worse picture of health status and functional profile compared to the healthy group. Correlations were observed between components of the SGRQ and CAT. The two groups presented similar levels of EBC particle concentrations, but the number of small particles was higher in COPD subjects. A correlation of the EBC particle concentration with the activity and total score of the SGRQ was only observed in the healthy group.

Conclusion: The total particle number was similar in the COPD and healthy groups. A few correlations between the EBC particles and tools used were also observed. The use of EBC particle concentration to monitor COPD status cannot be claimed with confidence because of the small sample size. Further research is necessary, particularly in large-scale groups.

More Information

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Keywords: Exhaled breath condensate; Saint george respiratory questionnaire; COPD assessment test; Six-minute walking test; Stable COPD; Particles

Introduction

Chronic obstructive pulmonary disease (COPD) is a heterogeneous disease with many different phenotypes [1]. Various causes have been blamed for its development and all of them lead to inflammation in the lungs. Inflammation leads to impairment in function and structural abnormalities in the lungs and the appearance of breathing symptoms with most characteristic dyspnea, cough, and mucous production [2]. The progress of the disease leads to changes and eventually disabilities affecting the lifestyle and quality of life of the patients [3]. This happens due to the engagement of other systems as well. As a result, assessment and monitoring of COPD require tools able to provide the whole dimension of its impact on the life of the patients. The Saint George Respiratory Questionnaire (SGRQ), the COPD assessment test (CAT), and the six-minute walking test (6 MWT) are the ones extensively applied in clinical practice and provide information on both the symptoms and the function-activity of the patients [4,5]. They are disease-specific and structured tools [6], based on the patient's perception to describe their condition and the results seem to be unclear regarding their connection between the clinical face of COPD and the mechanism of development of the inflammation [7,8].

A human specimen that seems to provide information on the pathophysiological processes of the lungs in COPD is exhaled breath condensate (EBC). It is a fluid sample that can be obtained non-invasively by freezing the exhaled air. Although water is its main component, the rest is characterized as a very rich biofluid with a great number of volatile and non-volatile compounds [9]. The entire content of EBC travels in the airways in droplets that contain particles. It is believed that the origin of the particles in the airway lining fluid (ALF) is based on the airway reopening hypothesis [10]. Their analysis may provide information on ALF changes due to inflammation in the airways [11]. Studies have shown a correlation between changes in the concentration of specific markers of inflammation in EBC (such as Hydrogen peroxide – H_2O_2 and 8-isoprostane) and the clinical picture of COPD patients as well as the severity of the condition [12]. However, the number and concentration of EBC particles in COPD is an issue without a definite answer. The study of Schwarz, et al. [13] showed no differences in the number of exhaled particles between COPD patients and healthy subjects, while Lastard, et al. [14] noticed a reduction in the particles emitted between COPD and healthy groups. Bake, et al. [10] in their review embrace the findings of Lastard, et al. work [14] and the explanation for that is the morphological and functional changes in the lungs of COPD patients. The ambiguity remains, considering that there is no standardization in the EBC collection and analysis processes [15] and that COPD is a disease with many faces [16].

The purpose of this study was to assess the possible correlation between the particle concentration of EBC in stable COPD patients and their clinical picture and the burden on their quality of life. It focused on the measurement of the particle number, size, and concentration of EBC and their connection with the findings of the main tools that are used extensively in the assessment of the quality of life of COPD patients. An additional purpose was to assess the application for the first time in the analysis of the exhaled breath condensate with Accusizer FxNano which is a device with high resolution.

Materials and methods

Subjects

12 COPD patients and 12 healthy subjects were the participants of this research (18 males and 6 females, 3 in each group). Their demographic characteristics are presented in Table 1. The two sources of recruitment of COPD patients were the pulmonary clinic and the rehabilitation department of the General Hospital of Corfu. All the COPD patients were stable clinically and the inclusion criteria were no exacerbation and no change in their medication for six weeks. COPD patients were treated according to the guidelines of GOLD [17] (combination of LABA/LAMA/ICS). A healthy status and no change in any of their medication were also the inclusion criteria for the healthy group.

Table 1: Demographics characteristics of participants.

	Group			
	Control		COPD	
	Mean	SD	Mean	SD
Age (yrs)	68.92	6.22	72.50	9.24
Height (cm)	172.58	8.86	169.92	11.13
Weight (kg)	85.39	12.83	77.75	14.90
BMI	28.54	2.51	26.71	3.13
Sex male/female	9/3		9/3	

*yrs: years, cm: centimetre, kg: kilogram, BMI: body mass index, SD: standard deviation.

The majority of the participants were nonsmokers or had quit smoking and only eight were smokers (5 COPD patients and 3 healthy subjects). The main physical activity for all the participants was walking.

Ethics

The research was approved by the Research Ethics and Deontology Committee of the Ionian University (approval document number 781/12-04-2023) as well as by the Ethics Committee of the General Hospital of Corfu (approval document number 1187/27-09-2019). Written informed consent was given by all the participants of this research. Prior to that, information regarding the nature of the research was given to them as well as their rights.

Setting

The rehabilitation department of the General Hospital of Corfu was where the research was conducted to achieve a similar setting for each participant. Both the temperature and humidity of the room were recorded. The mean room temperature was 24,9375 (SD 3,40432) degrees Celsius and the mean air humidity was 46,3% (SD 7,1557%). The EBC was analyzed at the Bioinformatics and Human Electrophysiology Laboratory, at the Department of Informatics of the Ionian University.

Procedure

All the measurements of this study were performed in the morning, in order to avoid anything that could affect the EBC sample such as food consumption, medication, or exercise. The collection device for the EBC was an RTube (Figure 1). It is handheld and consists of 4 main parts: a tube – chamber made of copolymer polypropylene, a cooling sleeve made of aluminum, one insulating cover, and a plunger made of aluminum. There are also two one-way valves adjusted to the tube (chamber) to guide the exhaled air in one direction and a mouthpiece.

The process of collection of the EBC with the RTube followed the manufacturer's recommendations. A special fridge was used to freeze the cooling sleeve at -30 °C. All participants were shown a video of the collection process before performing it. They were instructed on how to breathe during the collection (tidal breathing) as well. Before starting, they used sterile water to rinse their mouth. During the collection process,

Figure 1: RTube (Respiratory Research, Austin, TX, USA). Right to left: Insulating cover, RTube – chamber, two endcaps, cooling sleeve and plunger.

their nose was closed with a nose clip to prevent them from breathing through it. The EBC collection lasted 15 minutes. Recommendations of the European Respiratory Society[15] regarding the technical standard for exhaled biomarkers were also followed. The participants' obligations in the morning on the day of the collection were to refrain from physical activities, consumption of food and drinks, smoking (for the smokers) as well and medication. Only one collection was performed for every participant and the volume of collected EBC was 2.2 (± 0,2) ml. Every sample of EBC was analyzed immediately.

The 6 MWT was also performed in this study, based on scientific recommendations [18]. The participants walked a 32-metre corridor which was flat and straight and was marked with two cones to indicate its length. Instructions were provided to the participants before they performed the walking test. A supervisor recorded the performance and data on its completion.

Outcome measurements

Saint George Respiratory Questionnaire (SGRQ): The Greek version of the SGRQ was used to collect information on the health impairment in the lives of the patients due to COPD (permission for use was obtained from St. George's, University of London). This is a self-report tool. The SGRQ consists of two parts (three components): Part I deals with symptoms (frequency and severity) (component 1) and Part II deals with activity (physical) (component 2) and impact (psychosocial effect) (component 3), and a total of 50 items. The items in Part I are on several scales, while those in Part II are on a true/false scale, and only the last question is on a 4-point Likert scale. The score can range from 0 minimum to 100 maximum [19].

COPD Assessment Test (CAT): The second tool used in this research was CAT (permission for use was obtained from ePROVIDE). It can provide information on disease severity as well as the impact of the symptoms of the condition in patients. It is an 8-item questionnaire on symptoms, activity, and energy. The total score ranges from 0 to 40, and each item can be scored from 0 to 5. Three groups of patients are formed according to the results: low impact group (0-10), medium impact group (10-20), and high impact group (20-40) [20].

Exhaled breath condensate analysis: The analysis of the collected exhaled breath condensate was performed with the Accusizer FxNano device (Particle Sizing Systems Inc., Port Richey, FL, USA) as shown in Figure 2. The Accusizer FxNano device is used for liquid analysis. It uses single-particle optical sizing (SPOS) technology and can provide a quick analysis of the number and size of particles in liquids, one at a time. It has a sensor with a focused laser beam and with the extinction and the scattering, it provides an analysis between 0.15 to 10+ μm (microns). The FxNano sensor can be used in conjunction with the LE-400-05 sensor leading to an increase in the range of analysis of particles (the analysis range of the LE-400-05 sensor is 0.5 μm – 400 μm). The EBC analysis was performed according to the manufacturer's recommendations. The collected EBC was mixed with sterile water in a calibrated test tube to form a mixture of 40 ml. The Accusizer FxNano analyzer performed three cycles of analysis for each mixture and the fluid volume sampled was set to 6 ml. The analysis was performed twice: once with the EBC and the sterile water together and once with the sterile water only. The concentration and size of the particles in the EBC were the result of the subtraction of the two analyses. Analysis of the exhaled breath condensate was performed once after collection.

Other recorded tests: Spirometry was also performed in the present study. It was performed at the pulmonary department of the General Hospital of Corfu by specialized staff who used a dry spirometer to record the results of FEV_1, FVC, and FEV_1/FVC (Jaeger, MasterScreen, MS-Diffusion, Hochberg, Germany). The American Thoracic Society's criteria for the standardization of spirometry were followed [21].

Statistical Analysis

Statistical analyses were performed using SPSS software. Participants' characteristics were expressed using means and standard deviations. Correlations between the EBC and

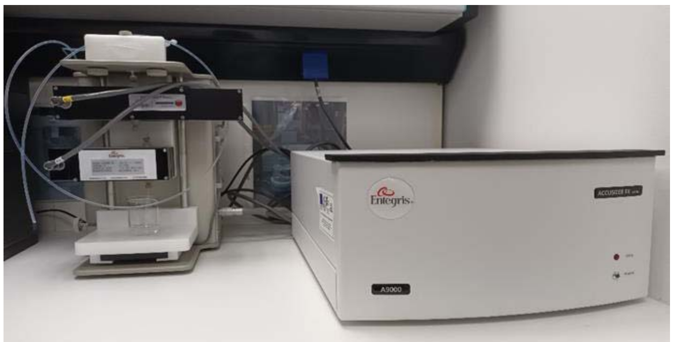

Figure 2: Accusizer FxNano (Particle Sizing Systems Inc., Port Richey, FL, USA). The syringe with the tubes to pump the sample and the sensors (black squares) are on the left side of the figure and the counter is on the right.

all indices were assessed using Spearman's rho coefficient. Differences in EBC levels were examined using the Mann-Whitney *U* - test. The significance level was set at 0.05.

Results

Particle concentration of EBC

The levels of the recorded EBC values did not differ between the two groups according to the Mann-Whitney U test (M-W = 81; $p = 0.630$). The descriptive characteristics of the EBC particle concentrations are shown in Table 2.

SGRQ, CAT, Spirometry and 6MWT Distance

The answers to the SGRQ and CAT questionnaires from both groups are shown in Table 3. The COPD group presented higher scores (mean and standard deviation) on both questionnaires compared to those in the control group. The results of spirometry and the 6 MWT are shown in Table 4. The COPD group walked a shorter distance than the healthy group.

EBC and CAT, SGRQ, FEV_1 and 6MWT distance correlation

Spearman's correlation coefficient that was examined for the relationship between EBC and the outcomes of interest, specifically, FEV_1, CAT, 6 MWT distance, and the four dimensions of the SGRQ for each of the two groups are shown in Table 5.

The analysis showed a statistically significant and positive correlation between EBC and activity score in the control group (Rho = 0.632; $p = 0.027$), while no statistically significant correlation was observed in the COPD group ($p = 0.366$). Similarly, a statistically significant and positive correlation was observed between EBC and the total score in the control group (Rho = 0.577; $p = 0.049$), but not in the COPD group ($p = 0.318$).

Additional analysis of the particle concentration of the EBC according to their size (Table 6) and their relationship with the results of the SGRQ and CAT questionnaires through the application of Spearman's test was also performed (Tables 7,8). Four groups were chosen for inclusion in the additional statistical analysis, and their size ranges were 0.1 μm – 0291 μm, 0.309 μm – 0669 μm, 071 μm – 247 μm, and 2.621 μm – 188.468 μm, respectively. That was because of the combination of a) the ability of the sensors of Accusizer FxNano to perform the EBC analysis (LE400-05 sensor dynamic range 0,5 μm – 400 μm and FxNano sensor dynamic range 0,15 μm – 150 μm) and b) the classification of the particles according to their size which includes three modes: coarse (10 μm – 2.5 μm), fine (0.1 μm – 2.5 μm) and ultrafine (lower than 0.1 μm). Studies have shown that particles of different sizes have different penetrations and effects on the human body.

Table 2: Differences in the total number of EBC particles between the two groups.

		Group		
		Control	COPD	*p*
Exhaled breath condensate	Mean	13.451.472,92	14.092.109,67	0.630
	SD	4.022.827,63	4.865.205,06	
	Median	13.892.075,50	14.917.269,50	
	Minimum	6.822.268,00	4.291.654,00	
	Maximum	19.131.233,00	19.643.677,00	

*SD: Standard Deviation.

Table 3: Mean, SD, Max and Min of the scores of SGRQ and CAT questionnaires.

	Groups							
	vCOPD				Control			
	Mean	SD	Max	Min	Mean	SD	Max	Min
SGRQ Symptoms score	38.06	20.7198	76.82	8.92	2.04	4.3886	13.83	0.00
SGRQ Activity score	62.00	21.6629	93.86	29.49	4.31	6.5292	17.14	0.00
SGRQ Impacts score	34.94	17.5831	60.21	5.60	1.11	2.3810	7.77	0.00
SGRQ Total score	43.70	16.9112	69.59	17.94	2.27	3.7359	11.56	0.00
CAT	11.83	5.63807	22.00	3.00	2.25	2.0504	6.00	0.00

*Max: Maximum; Min: Minimum; SGRQ: Saint George Respiratory Questionnaire; CAT: COPD Assessment Test.

Table 4: Spirometry and 6 MWT distance results (mean and SD).

	Group			
	Control		COPD	
	Mean	SD	Mean	SD
FEV_1 (L)	107.1583	11.44770	58.9833	25.13812
FEV_1/FVC (%)	74.0883	8.00257	52.4167	14.57765
6MWT dist.(m)	460.75	53.136	401.25	78.006

*FEV_1: Forced Expiratory Volume in One Second; L: Liters; FVC: Forced Vital Capacity; %: Percentage; 6 MWT dist.: Six-Minute Walking Test Distance; m: meters.

Table 5: Correlation matrix between EBC and FEV_1, CAT, 6 MWT distance, and the four dimensions of the SGRQ by group.

		EBC		
		Spearman's Rho	*p*	*N*
FEV_1 (L)	Control	-0.021	0.948	12
	COPD	0.007	0.983	12
CAT	Control	-0.135	0.675	12
	COPD	-0.386	0.215	12
6MWT dist.(m)	Control	-0.056	0.863	12
	COPD	-0.510	0.090	12
Symptoms score	Control	0.340	0.280	12
	COPD	-0.210	0.513	12
Activity score	Control	0.632	0.027*	12
	COPD	-0.287	0.366	12
Impacts score	Control	0.386	0.216	12
	COPD	-0.392	0.208	12
Total score	Control	0.577	0.049*	12
	COPD	-0.315	0.318	12

*$p < 0.05$, N: Population Size; p: *p* - value.

Table 6: Results and ranges of analysis of EBC particles.

	Group			
	COPD		Health	
EBC particle size range:	Mean	SD	Mean	SD
0.100 - 0.309 (μm)	14.211.180,42	4.757.137,475	13.519.185,00	3.901.645,15
0.328 - 0.710 (μm)	35.976,33	19.672,34951	32.235,58	9.427,72
0.753 - 2.470 (μm)	9.206,25	4.961,313043	9.084,00	4.291,86
2.621 - 188.468 (μm)	912,75	768,6458133	701,33	802,44

μm: microns.

Table 7: Spearman's test analysis between the range of the EBC particle size analysis and CAT and SGRQ (healthy group).

Healthy Group			CAT	Symptoms score	Activity score	Impacts score	Total score
Spearman's rho	0.100 - 0.309 (μm)	Correlation Coefficient	-0.153	0.330	0.607	0.376	0.569
		Sig. (2-tailed)	0.635	0.294	0.036	0.228	0.053
		N	12	12	12	12	12
	0.328 - 0.710 (μm)	Correlation Coefficient	-0.160	-0.055	0.146	-0.009	0.125
		Sig. (2-tailed)	0.619	0.865	0.652	0.977	0.699
		N	12	12	12	12	12
	0.753 - 2.470 (μm)	Correlation Coefficient	0.384	0.266	0.474	0.587	0.421
		Sig. (2-tailed)	0.217	0.403	0.119	0.045	0.173
		N	12	12	12	12	12
	2.621 - 188.468 (μm)	Correlation Coefficient	-0.306	-0.229	-0.037	-0.046	-0.156
		Sig. (2-tailed)	0.333	0.473	0.908	0.887	0.628
		N	12	12	12	12	12

Table 8: Spearman's test analysis between the range of the EBC particle size analysis and CAT and SGRQ (COPD group).

COPD Group			CAT	Symptoms score	Activity score	Impacts score	Total score
Spearman's rho	0.100 - 0.309 (μm)	Correlation Coefficient	-0.432	-0.266	-0.322	-0.448	-0.375
		Sig. (2-tailed)	0.161	0.404	0.308	0.145	0.230
		N	12	12	12	12	12
	0.328 - 0.710 (μm)	Correlation Coefficient	-0.084	-0.161	-0.231	-0.280	-0.137
		Sig. (2-tailed)	0.795	0.618	0.471	0.379	0.672
		N	12	12	12	12	12
	0.753 - 2.470 (μm)	Correlation Coefficient	0.046	-0.007	-0.063	0.014	0.004
		Sig. (2-tailed)	0.888	0.983	0.846	0.966	0.991
		N	12	12	12	12	12
	2.621 - 188.468 (μm)	Correlation Coefficient	-0.049	0.042	-0.119	-0.063	-0.109
		Sig. (2-tailed)	0.879	0.897	0.713	0.846	0.737
		N	12	12	12	12	12

Statistical significance and positive correlations were found only for the following

- SGRQ activity score and range of particle size 0.100 μm – 0.309 μm of the control group and the (p = 0.036, Rho = 0.607).
- SGRQ impacts score and the control group and range of particle size 0.753 μm - 2.470 μm of the control group (p = 0.045, Rho = 0.587).

Discussion

A total of 24 subjects participated in our study (12 patients with COPD and 12 healthy subjects). Our aim was to assess the picture of stable COPD via the EBC and its particle concentration, which is a medium proposed for the assessment of the pathophysiological processes within the airways of the lungs and its correlation with the most applicable tools of health status assessment. Statistical analysis of the results showed a worse status of the COPD group compared with the healthy group in almost all the tools used, as well as some extent of correlation among them.

EBC is a matrix of potential biomarkers for COPD because it is believed to provide information regarding inflammation in the airways [12]. Although the number of compounds observed in exhaled breath condensate is large [22], previous studies have mainly focused on specific markers of pathological processes taking place in the airways, such as H_2O_2 and 8-isoprostane. Their elevated levels in the exhaled breath condensate seem to correlate with the severity of COPD assessed by CAT [23] and BODE [24]. The concentration of H^+ in the airways is also important because it shows their acidity, which plays a significant role in inflammation. However, it is not reliable due to the ambiguous results in COPD. On the other hand, the number of exhaled particles is thought to be involved in the information obtained regarding inflammation [25]. In our study, the analysis of the EBC showed the presence of a number of particles in both groups, a fact that was expected, as research has shown their existence in healthy subjects as well as in respiratory diseases [26]. It is still unclear if there is a change in the number of particles that are exhaled between the two conditions. We found that the total particle concentration was almost similar in both groups (Mean Whitney U - test = 81, p = 0,630) (Table 2). That may be because COPD is a disease of the small airways, and studies have shown that the particles of the EBC originate from the whole respiratory tract, including the small airways and alveoli [27]. However, Bake, et al. [10] in their review suggest that the changes in both the structures and function of the lungs due to the disease are likely to lead to the production of fewer particles in COPD patients compared to healthy subjects. A possible explanation is the different equipment used to collect and analyze the EBC, as well as the variety of the structure of the studies [28].

According to the results of the SGRQ and CAT questionnaire, it seems that there is a substantial impact of the disease on the health status of the COPD group compared to the healthy group. The majority of the COPD group scored higher than 10 in the CAT tool (Table 3), a result that indicates a significant degree of COPD effect in the participants' lives [20]. A similar picture of the quality of life in the COPD group was obtained from the SGRQ scores. All its components presented higher values compared to the results of the healthy group, especially activity one (Table 3). Patients with COPD seem to be less active than healthy people of similar age due to symptoms, especially dyspnea [29]. Impairment of the functional performance capacity of the COPD group was also observed based on the results of the 6 MWT. Patients with COPD walked less distance on the completion of the test compared to healthy subjects (Table 4). Indeed, according to the results of the work of Cazzoletti, et al. [30], the average distance that healthy people walk on the completion of the 6 MWT is longer than that of COPD patients. The above results are consistent with the high degree of airway obstruction in the COPD group, which was assessed using spirometry (FEV_1). Some correlation was also found among the tools used above. We found a significant statistical correlation between the CAT and the symptom score, impact score, and total SGRQ score in COPD subjects but not in healthy subjects. According to Morishita-Katsu, et al. [4], these two questionnaires present correlations and slight differences. Moreover, FEV_1 was correlated with the 6 MWT distance in the COPD group only. A similar result was observed in a study by Krishna, et al. [31] who indicated that both provided information on the assessment of COPD severity.

Changes in EBC content (molecules) in COPD seem to reflect the severity of the disease and provide information on inflammation [22]. Even the number of particles seems to play an informative role in the pathological procedures that happen in the airways, especially small ones [12,13]. However, the connection between the particle concentration of the EBC that carries these molecules and the picture of COPD obtained by other assessment tools still presents ambiguity. In this study, no correlation was detected between the EBC particle concentration and the assessment tests used (SGRQ, CAT, 6 MWT, and FEV_1) in the COPD group. Instead, a significant positive correlation between the total concentration of EBC and the total score as well as the activity score of the SGRQ was observed in the healthy group (Table 5). This may be related to respiratory functional characteristics, breathing activities, age, and lung size [32]. Moreover, the performance of EBC analysis of a range between 0.1 μm and 200 μm and for four different groups based on the size of the particles led to a similar result (Tables 7 & 8). The particle size range of EBC is 0,3 μm – 0,8 μm [33]. Studies have shown that the diameter of the exhaled particles ranges between 0.01 μm and 1000 μm and depends on the site of origin as well as the mechanism of their generation [10]. However, it was noticed that the patient group presented more particles of smaller size compared to the healthy group in all three clusters of size. This is in contrast to the work of Larstad, et al. [14] who found that COPD patients exhaled fewer particles than healthy subjects. According to the technical standards of exhaled biomarkers in lung diseases of ERS [15], it must be taken into account that the differences in the techniques used for the collection and analysis of EBC affect the results, and the lack of standardization is still an issue in the field of exhaled breath application. Consequently, direct comparison is not possible. Moreover, our study is proof of concept one, and the sample size was small. The fact that we observed only a correlation between the EBC particle concentration and SGRQ in the healthy group does not allow us to claim that EBC particle concentration can be used to monitor COPD status.

Regarding the device used for the analysis of the EBC, it seems that it is feasible to fulfil this purpose. It uses the single-particle optical technique, which is commonly used for fluid analysis, and it provides high resolution owing to its sensors and its ability to measure one particle at a time. Moreover, its range of analysis can provide information on particles of small size, which is important for the study of inflammation of medium and small airways [28]. Although this is the first time that this device has been used for the analysis of EBC, there is a study on cell secretome [34], which can support our choice of application.

This study had some limitations. The COVID pandemic affected participation, and only a relatively small number of participants were involved. Moreover, the COPD participants were of different COPD stages. Every COPD stage has different characteristics related to the clinical picture, which might influence both the particles and the content of EBC [12]. The healthy group showed some differences from the baseline values as well. Healthy subjects also present differences in the EBC too [35].

The picture of stable COPD via the study of EBC particle concentration and the most common assessment tests of health quality of COPD was worse than that of healthy subjects, and some correlations were observed. However, considering the possibilities that EBC provides and the open issues that still exist regarding its performance as a method, further research is necessary for its in-depth study, establishment as a tool, and interpretation of the obtained results. Larger studies are needed to confirm these relationships in a statistically significant manner as well.

Conclusion

The health status and functional profile of patients with stable COPD were worse than those of healthy subjects. The EBC particle concentration appeared to be similar in both groups, but the range of the particles was different. Due to the small sample size, our results do not allow us to claim that the EBC particle concentration can be used to reliably monitor COPD status. Therefore, further studies are required.

Credit (Contribution Roles Taxonomy)

Stephanos Patsiris: Conceptualization, Data Curation, Investigation, Methodology, Project Administration &

Writing (original draft preparation & editing) (leader); Andreas Afthinos: Resources (equal); Ligeri Auguste: Resources (equal); Katerina Valsami: Resources (equal); Andonis Dimitras: Resources (equal); Themistoklis Exarchos: Conceptualization, Methodology & Writing (review & editing) (leader); Panagiotis Vlamos: Conceptualization, Methodology & Writing (review & editing) (leader).

Summary

The subject of this research was the assessment of stable COPD pictures via the study of the number and size of the exhaled breath condensate (EBC) particles and their relationship with quality of life and functional tests. EBC particle measurement, Saint George Respiratory Questionnaire (SGRQ), COPD Assessment Test (CAT), and six-minute walking test (6 MWT) were used. It was noticed that the total particle number was almost similar in the COPD group and the healthy one. Moreover, a few correlations between the EBC particles and the quality of life tools used were also observed. Further research is necessary, especially for large-scale group studies.

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