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Insufficient intake of energy and protein is related to physical functional capacity among COPD patients referred to municipality based pulmonary rehabilitation

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SUMMARY

Background: Malnutrition is frequent in COPD. Malnourished patients participating in pulmonary rehabilitation (PR) may benefit less and even worsen prognosis. The aim of this study was to investigate energy and protein intake in outpatients with COPD referred to municipality based PR and to investigate the relation to functional capacity.

Methods: COPD patients referred to PR at five Danish municipals were assessed for energy and protein intake by self-reported intake record and 24-hour recall by a dietician. Nutritional status was assessed by BMI, weight loss, and eating validation scheme, functional status by 30-seconds chair stand (30s-CST), and 6-minutes walking test (6MWT), and severity of disease by FEV1 and mMRC.

Results: We included 79 patients (41% male and 73% above 65 + y). Ninety-six% had a FEV1 below 80%, 59% had a mMRC-score of 3 + and 14% had a BMI below 20 kg/m2. Fifty-one % and 41% of the patients had insufficient intake of protein and energy, respectively, defined as an average intake below the 75% of the recommended. Kruskal Wallis test showed a significant positive association between protein intake and 30s-CST ($p = 0.012$) and 6MWT ($p = 0.024$) but no association with energy intake.

Conclusions: Among patients with COPD referred for PR, there is a high prevalence of insufficient intake of energy and protein. This causes concern, as the physical training, which is the main component of PR, is likely to be futile unless the patients obtain a sufficient intake of energy and protein during the pulmonary; rehabilitation program.

1. Introduction

Chronic obstructive pulmonary disease (COPD) is an increasing health problem and has been predicted to become the third most common cause of mortality worldwide in 2020 [1]. In Denmark approximately 300,000 individuals suffer from COPD, and it is estimated that COPD is the fourth most frequent cause of death [2,3]. Patients with COPD present progressive and irreversible obstruction of the airflow, fibrosis and emphysema. The diagnosis is made by spirometry (FEV1) combined with assessment of symptoms and relevant exposures. Diagnostic workup includes evaluation of breathlessness, most often using the MRC dyspnoea score and optimally evaluation of physical capacity by a walking test, among which the six minute walking test is most widely used [4,5]. It is estimated, that approximately 50,000 Danish patients have severe and very severe COPD, defined by a reduction of forced expiratory volume in one second (FEV1) below 50% of the predicted value. Of annual hospitalizations, approximately 25,000 admissions each year are caused by COPD as main diagnosis, and many Danish patients with severe COPD have more than one hospitalization every year due to exacerbations [1,2,6,7].

Malnutrition is common in COPD, and is associated with significantly increased mortality and impaired quality of life [8–11]. Studies of body composition in COPD show, that both fat mass and fat-free mass are lost [12]. Muscle wasting is common, and wasting may be of great importance as muscle fatigue may predispose to respiratory failure and further functional decrease [13–21].

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Systematic reviews have demonstrated that nutritional interventions in COPD patients have a positive impact on several outcomes, including energy and protein intake, length of stay (LOS) and hospital readmissions as well as other nutritional and patient-centered outcomes [22,23]. This beneficial effect seems to be further improved when combined with exercise [8,22].

Rehabilitation programs are recommended for COPD patients with a dyspnea score corresponding to mMRC 2 or higher (inability to keep track of peers in even terrain). Physical exercise has shown useful for patients in all stages of COPD, aiming to improve physical function and reduce shortness of breath as is a main component of rehabilitation programs [24,25]. Annually 4,500 COPD patients participate in rehabilitation programs throughout Denmark. In order to achieve the highest benefit of the exercise rehabilitation, the participants need to be in energy and protein balance; otherwise they may risk a (further) loss of weight and muscle mass [22]. A sufficient intake of protein seems of utmost significance in this context [26]. However, little is known about the energy and protein intakes of COPD patients referred to pulmonary rehabilitation and its association with functional capacity.

1.1. Aim of study

The *aims* of this study were to investigate energy and protein intake in COPD outpatients referred to municipality based pulmonary rehabilitation (PR) and to investigate the association to physical functional capacity.

2. Materials and methods

2.1. Sampling

In 2016, a questionnaire-based investigation regarding the structure of pulmonary rehabilitation in Danish municipalities was performed. In relation to this, the municipalities were asked whether they wanted to participate in the present study focusing on nutritional aspects. Eight municipality centers were positive and received additional information. Of these, six municipality centers agreed to participate, however due to organizational changes, only five participated.

The centers included consecutive COPD patients referred to PR. In each municipality center, all patients enrolled in PR during a specified time-period were approached and invited to participate in the study, by the local contact person (a nurse with nutritional expertise or a registered dietician). Exclusion criteria were alcohol abuse, severe psychiatric disorders or non-willingness to participate.

2.2. Background information

After inclusion, and before the start of the PR, the following background information was collected: Age, gender, physical activity level, weight loss during the recent three months, use of home care, home nursing and meals-on-wheels, smoking and alcohol status, co-morbidities (e.g. ischemic heart disease, diabetes, musculoskeletal and rheumatic diseases, cancer), prednisolone maintenance treatment and recent hospital admissions for COPD.

Lung Function was measured by mean forced expiratory volume in 1 second (FEV1), and breathlessness was assessed using mMRC in order to evaluate disease severity.

2.3. Weight, height and BMI

After inclusion, and before the start of the PR, body weight and height were either measured by the local contact person or self-reported. Based on this information, BMI was calculated.

2.4. Nutritional risk

The Eating Validation Scheme (EVS) is a Danish nutritional assessment chart used to assess nutritional risk factors and target the old adults who will benefit from a nutritional intervention [27]. The screening tool contains information about eating habits, recent unintended weight loss and presence of nutritional risk factors (eating dependency, chewing and swallowing problems, acute disease or acute change in chronic disease). This information was gathered by the local contact person after inclusion, and before the start of PR. The information was combined to calculate a score: 0 (no nutritional risk); 1 (at nutritional risk), and 2 (would benefit from nutritional intervention).

2.5. Nutritional impact symptoms and weighing

After inclusion, and before the start of the PR, participants were asked to rate the following on a 3-point scale (from ''completely agree'' to ''completely disagree''); appetite, strength to eat, shortness of breath when eating large meals, difficulties eating due to e.g. coughing, enjoyment of meals, weekly weighing, and can eat without problems. Patients were furthermore asked to answer if they were able to eat what they found necessary.

2.6. Nutritional intake and requirement (energy and protein)

Regarding the nutrient intake and requirement, the focus was on protein and energy.

To get valid data about the intake of protein and energy a total of four days of dietary registration is needed [28].

The participants were therefore provided with a 3-days dietary record and instructed by the local contact person on how to fill it in at home. An appointment in the home of the patient or in the municipality center was made to collect the dietary record and perform an additional 24-h dietary recall. In addition to the 24-h recall, the local contact person also went through the patient registered dietary record together with the patient, to check for missing information (e.g. regarding fat content of milk, cheese and meat, and use of in-between meals).

The dietary records and 24-h dietary recalls form all the participants were entered in “Vitakost.dk” dietary data program by a research dietician. The program allows detailed calculation of the content of the food distribution of nutrients according to estimated portion size. The system is supported by a huge image catalogue, where the patient can visualize more in detail the specific food items (i.e. half slice of rye bread, thin layer of butter, with a slice of cheese). The system contains over 100,000 foods and includes recipes of consumer food, which extends the number of nutritional values. The resulting data about average energy and protein intake for a total of 4 days was used to assess whether the intake was above or below 75% of the estimated requirements [29,30].

2.7. Nutritional requirements (energy and protein)

Requirements were set for the individual based on information of weight, height and gender as a pragmatic cut-off of energy 25 kcal/kg/d and protein 1.1 g/kg/d [18,21,31–33], according to the recommendations from the Danish National Board of Health, assuming that all participants were outpatients. Requirements were regulated for obese (BMI> 30) and underweight patients (BMI< 18.5) by the clinical dietician, according to the same recommendations [34].

2.8. Assessment of physical capacity

To measure the physical status, the patients performed the 30-second chair-stand test (30-s CST), and six-minute walking test (6MWT) before the start of the PR. The tests were part of the standard assessments and supervised by a local physiotherapist.

With regard to 30-s CST, participants were asked to fold their arms across their chest and to stand up and sit down on a chair, as many times as possible for 30 seconds [35]. The seat should be a height of at least 43 cm. The score was the total number of times the person managed to stand within the 30 seconds. Initially, the physiotherapist showed the participant the test in a slow tempo (stand-sit), to demonstrate the technique. Number of stand ups were recorded and divided according to the prevalence below 9, 9 to 11 and above 11 repetitions using the criteria developed for the healthy oldest old [35–37].

The 6MWT was performed at sight according to standards from the Pulmonary Rehabilitation Toolkit, and evaluated for walking distance <350 meters, between 350 and 450 meters and >450 meter [37,38].

2.9. Statistical analysis

Demographic data were analyzed using Student's t test and the χ 2 test. Energy- and protein intake was divided according to the covering of 75% of requirements and compared to functional parameters by Kruskal Wallis test. Putative associations between functional parameters (30-s-CST and 6 MWT) as the dependent variable and energy- and protein intake, sex, age, FEV1 and BMI as risk factors were analyzed using univariate regression analysis. Backward stepwise multivariate regression analysis was performed to evaluate independent predictors of low energy- and protein intake. Missing data were excluded from the analysis; thus, data were treated numerically. If all participants did not reply to the given question, the number of replies is given in brackets in the results. All reported P -values were two-tailed, and values less than 0.05 were considered statistically significant. Data were analyzed using the software package STATA version 14.1 (StataCorp LP, College Station, TX, USA).

2.10. Ethical considerations

Prior to inclusion, the patients were given written and oral information about the aim, content and practicalities of the study. The participants were informed that they could withdraw from participation at any time before or during the study. The study was conducted according to the rules of the Helsinki Declaration of 2002. The study was not within claim of notification with the local ethical committee due to law number 593 of 14/6/2011, committee law § 14.2. The project was reported to the data Protection Agency through the Region North Umbrella Review number 2008-58-0028.

3. Results

3.1. Patient characteristics

The study included 79 patients from a total of five different municipalities, of whom 41% were male. Seventy three percent of the participants were above 65 years of age. Of the population, 63 patients (80%) suffered from concomitant diseases such as cardiovascular diseases, diabetes mellitus, musculoskeletal or rheumatoid diseases, cancers or others. Only few of the participants had never smoked, but and almost 60% were ex-smokers.

Community help around the house was present in four of the participants, while only two participants had home care nurse. None of the participants received Meals on Wheels. Table 1 shows participant characteristics.

Most of the participants (65%) reported that they were able to eat what they found necessary. Of those with eating obstacles, the most profound Nutrition Impact Symptoms are shown in Table 2 and were: Feeling reduced appetite, not having the strength to eat very much, large meals evoking shortness of breath and dysphagia.

Pulmonary Function (FEV1) was widely distributed in the patients, but almost all patients had a FEV1 below 80% of the predicted value. mMRC $\geq$3 was found in 59% of the patients. Only few of the participants received permanent treatment with Prednisolone. Hospitalizations due to COPD exacerbation within the past year was seen in 18 patients (14%). Table 1 shows the details about the demographic features.

3.2. Nutritional status, nutritional intake and physical functional capacity

Of the included patients, 10% had a self-reported unplanned weight loss within the past month and 20% had lost weight since the time of diagnosis. Despite that, the majority were overweight or obese according to their BMI.

Insufficient intake of protein was seen in 51% of the participants, while 41% of the participants had reduced intake of energy, defined as an average intake below 75% of the recommended requirements. In contrast, however, 24 participants had an intake of >100% of the measured requirement of energy and 15 had more than 100% of protein requirements covered. Fig. 1. Shows the distribution of energy- and protein intake respectively, in percentage of individually measured requirements.

Table 1
Demographic features.

Study population	Characteristics
Gender (female), %	59
Age, mean (SD)	69.1 (7.4)
Actual smokers (n = 30), mean pack years (SD)	36.6 (16.9)
Former smokers	58
Never smokers, %	4
Never drink alcohol, %	35
Units per week for those who report drinking alcohol (N = 51), mean (SD)	9.3 (9.3)
Comorbidity	
Cardiovascular disease, %	37
Diabetes, %	11
Musculoskeletal and rheumatic diseases	29
Cancer, %	10
Others, %	33
None, %	20
Prednisone	
Continuous treatment, %	3
Short treatment within the last year, %	35
None, %	59
Lung function FEV1 mean L/s (SD)	44.3 (24.0)
<30, %	22
30–49, %	23
50–80, %	39
>80%	4
Medical Research council (MRC) dyspnoea scale	
1. Breathless with strenuous exercise (Mild), %	10
2. Short of breath when hurrying on the level of walking of a slight hill (Moderate), %	30
3. Walks slower than people of the same age on the level or stops for breath while walking at own pace on the level (Moderate), %	33
4. Stops for breath after walking 100 meters (Severe), %	22
5. Too breathless to leave the house or breathless when dressing (Severe), %	4

Table 2
Nutrient intake, BMI and physical functional capacity.

Variables	Value
Nutritional parameters	
Protein intake, g/d mean (SD)	73 (22)
Energy intake, kcal/d, mean (SD)	1814 (567)
Coverage protein requirement	
At or above 75%, %	49
Coverage of energy requirement	
At or above 75%, %	59
Nutrition Impact Symptoms	
Reduced appetite, %	34
Large meals evoke shortness of breath, %	31
Not strength to eat very much, %	17
Dysphagia, %	9
BMI kg/m^2, mean (SD)	26.9 (6.2)
Below 20, %	14
20–24.9, %	23
25–29.9, %	30
30–34.9, %	22
At or above 35, %	10
Functional parameters	
30-seconds chair stand (N = 76), mean (SD)	11.5 (3.9)
Less than 9 repetitions, %	18
9-11 repetitions, %	34
Above 11 repetitions, %	44
Six-minute walking test (N = 75), mean (SD)	364 (114.7)
Less than 350 meters, %	43
350–450 meters, %	30
Above 450 meters, %	22

The 30-second chair-stand test revealed that 18% of the participants could do less than nine repetitions and the six-minute walking test showed that 43% could walk less than 350 meters (Table 2).

A significant positive association was found between protein intake and 30s-CST ($p = 0.012$) and 6MWT ($p = 0.024$). Excessive collinearity was observed between energy- and protein intake. Consequently, two separate multivariate models were developed with inclusion of these separately.

Logistic regression showed that decreased energy intake below 75% of requirements was an significantly related to 30s-CST (Table 3a,b), but only a tendency was shown towards a decreased protein intake, while 6MWT ($p = 0.024$) was positively associated with decreased protein intake, but not with energy intake (Table 3a,b). Age also had a significant impact on both physical functional capacity measures.

The covering of less than 75% of requirements of protein also showed a positive significant association with a poorer performance for both 30-s-C and 6MSWT, as shown in Table 4.

4. Discussion

In this study we aimed to investigate energy and protein intake in a broad population of among outpatients referred to pulmonary rehabilitation, which has also been referred to as a tertiary prevention strategy for COPD patients [1]. Unfortunately, we have no data describing the total amount of patients approached and the numbers who were excluded due to alcohol abuse, severe psychiatric disorders or non-willingness to participate. No patients were excluded due to under- or over reporting. The study was based on the paradigm, that a sufficient nutrition intake, especially the intake of protein, is important for patients with COPD in relation to exercise and to maintain function and reduce mortality [13,15,19,27,34], [12,17,22]. We found that a high percentage of the participants had an insufficient intake of energy and protein before the start of PR and that this low intake, especially the intake of protein, had significant negative impact of the physical functional capacity. This indicates that the patients are at risk of not achieving the desired benefit of PR. In fact, participating in a rehabilitation program, while undernourished may result in further loss of weight and muscle mass. This problem is highlighted in the Cochrane review by Ferreira et al. which concludes that even if nutritional support does not significantly contribute to weight gain, adequate nutrition could prevent further weight loss by counteracting the impact of increased inflammation [22].

The low intake of protein among participants in our study has also been reported in previous studies among of older adults living independently [39,40]. Nutrition intake, again primarily focusing on protein, was decreased compared to that recommended for patients at nutritional risk, and those not at risk [17,29,30]. Other studies have found patients attending pulmonary rehabilitation and out-clinic patients having similar decreased intake [10,39–41].

The study revealed that obesity is also an element of concern in this population, in spite of the loss of weight reported. However, even though the study found many obese patients, these, had insufficient intake of energy and especially protein compared to their requirements. This was also seen in COPD patients with

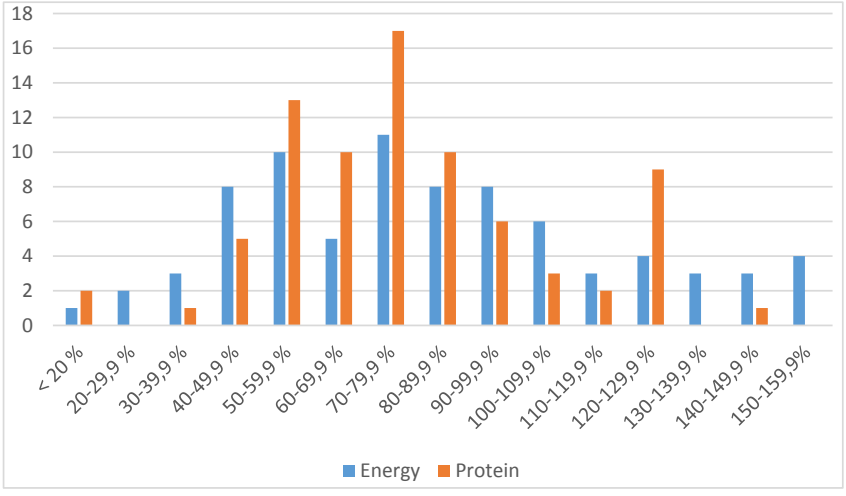

Fig. 1. The distribution of energy-and protein intake in percent of the individually recommended amount.

Table 3a
Linear regression model comparing walking test and chair stand as the dependent variable and energy intake (mean 4 days) as the non-dependent variable.

	6 min Walking test		30s-Chair Stand test	
	Unstandardized Coefficients B (Std Error)	p-value	Unstandardized Coefficients B (Std Error)	p-value
Energy intake <75% of requirements	40.4 (28.3)	0.12	2.6 (1.02)	0.01
Sex	−18.4 (25.8)	0.48	−0.02 (0.9)	0.98
Age	−7.1 (1.7)	0.00	−0.18 (0.06)	0.00
FEV1	0.1 (0.5)	0.81	0.01 (0.02)	0.57
BMI	0.3 (2.2)	0.87	0.09 (0.08)	0.28

Table 3b
Linear regression model comparing, respectively walking test and chair-stand as the dependent variable and protein intake (mean 4 days) as the non-dependent variable.

	6 min Walking test		30s-Chair Stand test	
	Unstandardized Coefficients B (Std Error)	p-value	Unstandardized Coefficients B (Std Error)	p-value
Protein intake <75% of requirements	62.1 (27.4)	0.03	1.87 (1.04)	0.08
Sex	−26.3 (25.5)	0.31	−0.13 (0.97)	0.89
Age	−6.1 (1.7)	0.00	−0.14 (0.06)	0.03
FEV1	−0.3 (0.5)	0.56	−0.00 (0.02)	0.84
BMI	0.8 (2.1)	0.72	0.06 (0.08)	0.45

Table 4
Independent samples test for covering or not of 75% of energy- and protein requirements versus measured physical function.

	Measured activity	Covering of requirements	Mean (SD)	P-value
Energy	30 sec Chair Stand, repetitions	<75%	10.4 (2.4)	0.97
		≥75%	12.0 (4.5)	
	6 minutes Walking Test, Meters	<75%	346 (94)	0.388
		≥75%	370 (125)	
Protein	30 sec Chair Stand, repetitions	<75%	10.6 (3.8)	0.046
		≥75%	12.4 (3.9)	
	6 minutes Walking Test, Meters	<75%	332 (115)	0.023
		≥75%	393 (108)	

similar BMI in the study by Laudisio et al., who sampled patients in geriatric ambulatory care [41]. Often such nutritional problems might be overlooked when dealing with obese patients, resulting in a referral to clinical dieticians for weight loss instead of optimization of intake of protein.

Nutrition impact symptoms found in our study were primarily loss of appetite, large meals evoking shortness of breath, and lack of strength to eat very much. These seemed less severe than those described in an earlier qualitative study. However the latter found that although their participants were motivated to develop strategies to overcome food-related challenges, most participants did not achieve a healthier diet [42]. This should be taken into consideration when planning pulmonary rehabilitation programs in the future, with the focus on giving priority to dietician support, providing the ability to focus on protein intake. The dietician should be able to provide individual advice on intake related to the individual's body composition, preferences and nutrition impact symptoms, and set qualified goals together with the individual. Such interventions should be initiated before the start of PR, which may improve the outcome of rehabilitation and treatments also argued by others [43,44].

4.1. Strength and weaknesses

Within the five community rehabilitation centers recruiting participants in this study, we found a quite narrow population regarding age, however a very broad population looking at BMI, FEV1, mMCR, and physical function. Thus, we believe that this sample of patients is representative for patients with COPD included in rehabilitation programs in Denmark [3,44]. Although patients with MRC<1 are normally not referable to pulmonary rehabilitation, we found that 10 patients only had a low degree of disease when measured during the study. Thus, these patients were less suitable for rehabilitation, including being within the scope of this study. We chose to include them, since they may have been actually worse at the time of referral.

In our study, we unfortunately did not include bioimpedance, and thus we were not able to evaluate fat free mass, which would especially have been relevant in the focus of pulmonary rehabilitation and nutrition intake of which especially protein was associated to physical function.

5. Conclusion

Among patients with COPD referred for community rehabilitation, insufficient intake of energy and protein is highly prevalent, and weight loss is common, even though overweight often occurs. This causes concern, as the physical training, which is the main component of rehabilitation strategies is likely to be futile unless the patients obtain a sufficient intake of energy and protein during the PR program.

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Conflict of interest statement

The authors have no conflicts of interest to declare for this study.

CRediT authorship contribution statement

M. Holst: Conceptualization, Data curation, Formal analysis, Writing - original draft. **A.M. Beck:** Conceptualization, Data curation, Formal analysis, Writing - original draft. **H.H. Rasmussen:** Conceptualization, Data curation, Formal analysis, Supervision. **P. Lange** Conceptualization, Data curation, Formal analysis, Supervision.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clnesp.2019.02.009.

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