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The Impact of a High-Fat, Low-Carbohydrate Enteral Formula on Metabolic and Respiratory Function in Chronic Obstructive Pulmonary Disease Patients

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A B S T R A C T

Background: Malnutrition in participants with chronic obstructive pulmonary disease (COPD) is linked to conditions like cachexia, sarcopenia, and weight loss. This malnutrition can contribute to deteriorated pulmonary function, reduced exercise capacity, and an increased risk of exacerbations.

Objective: To assess the effectiveness of providing a high-fat diet, low-carbohydrate nutrition as compared to a high-carbohydrate (high-CH) carbohydrate diet concerning respiratory variables in participants with chronic obstructive pulmonary disease (COPD).

Methodology: The study was conducted at District Headquarter Hospital, Charsadda, from January 2020 to January 2021. Total of 70 COPD participants, characterized by low body weight [less than 92% of optimal body weight (IBW)], were randomly assigned to either the control class, 'which received dietary counseling' for a high-carbohydrate (CH) diet (20% proteins, 25% to 35% fats, and 65% to 75% CH), or the experiment class, which received three to four bottles a high-fat, low-CH supplement (17 % proteins, 54.9% fats, and 27.9% CH) in the evening as part of their diet.

Results: A total of 70 people were enlisted in the study, with 35 individuals in each class, dispersed equally. The classes did not differ statistically significantly in terms of baseline weight or mean age. Data on nutritional consumption showed that subjects in the experimental class ingested high fats and proteins and low carbohydrates (CH) than those in the control class, even if their overall calorie intake stayed the same. After four weeks, though, PaCO2 was much lower in both classes. Interestingly, PaO2 rose noticeably in the experimental class alone after four weeks, suggesting a general improvement in ventilatory status.

Conclusion: This research concludes that the 'pulmonary function of COPD participants' can be markedly enhanced with the incorporation of a high-fat, low-carbohydrate (low-CH) 'oral supplement compared' to the conventional high-CH diet.

Keywords: Chronic Obstructive Pulmonary Disease; Breathing Quotients; Pulmonary Function; Bloodstream Gases

Introduction

Chronic obstructive pulmonary disease is characterized by limitation in progressive airflow and respiratory symptoms. It poses a significant burden on health worldwide.[1] It is responsible for considerable morbidity and mortality rates despite of enhancement in therapeutic strategies.[2] Development of dietary interventions play an important role in management of COPD with modifications in diet showing an improved result both in metabolic and respiratory outcomes.[3]

COPD cause severe malnutrition, characterized by significant weight loss, stems from various factors such as the "pulmonary cachexia syndrome," heightened metabolic rate, increased calories requirements, loss of hunger, and low calories intake.[4] The increased effort required for breathing and the increased expense of oxygen in ventilation result in a raised metabolic rate.[5] In addition to impairing breathing due to the weakening of the respiratory muscles, malnutrition also increases the risk of pulmonary infections, lowers the amount of germs removed from the lungs, and eventually raises mortality.[6]

Considering that advanced COPD participants frequently suffer from malnutrition and that this condition is correlated with both functional and anatomical problems, treating nutrition should be a key element of the entire therapy strategy.[7] It might be difficult to incorporate dietary support,though, since eating can raise the respiratory quotient (RQ) and make breathing harder.The RQ, or carbon dioxide production to oxygen consumption, varies depending on how protein, fat, and carbs are metabolized.[8]

Metabolic alterations are induced by consuming high-fat, low-carbohydrate diets which includes enhancement in fat oxidation and ketogenesis, which may be beneficial in conditions characterized by systemic inflammation and metabolic dysregulation, such as COPD.[9] Furthermore, evolving evidence suggests that dietary fat intake may influence pulmonary function and airway inflammation through various mechanisms, including modulation of oxidative stress, inflammation, and mitochondrial function.[10]

The study's primary goals were to correct malnutrition without raising the RQ and to decrease overall carbon dioxide production, taking into account the fact that low O2 level and CO2 retention are common in COPD participants. Particularly in participants with CO2 retention, careful dietary replacement is crucial since an excessive carbohydrate load may increase their condition and possibly cause failure of respiration. The specific goal of the study was to evaluate the impact on lungs parameters in participants with COPD of giving a high-fat, low-carbohydrate (low-CH) oral nutritional supplement as opposed to a high-CH carbohydrate meal.

Objective

To assess the effectiveness of providing a high-fat diet, low-carbohydrate nutrition as compared to a high-carbohydrate (high-CH) carbohydrate diet concerning respiratory variables in participants with chronic obstructive pulmonary disease (COPD).

Methodology

The majority of COPD participants with increased carbon dioxide tension in arteries and a current weight below 85% of their optimal body weight were the focus of this randomized controlled trial investigation. The study was conducted DHQ Hospital, Charsadd from January 2020 to January 2021. Each subject provided informed permission.

Table 1 gives information on the number of exacerbations encountered annually, the tenure of COPD of each participant and their stage. According to Kane et al. the experimental class in this investigation was directed to ingest three to four bottles of a 'high-fat', low-carbohydrate (CH) 'oral supplement' every evening.[11] The oral supplement made up half of their estimated basal caloric requirements, which were determined by utilizing the basal energy expenditure formula for Harris-Benedict.[12] Table 2 shows that its calorie distribution was 17% protein, 54.9% fat, and 27.9% carbohydrate.

The control class, on the other hand, received nutritional therapy for a high-CH diet, with a composition of 20% protein, 25% to 35% fat, and 65% to 75% CHO. With food intake diaries, dietary intake was tracked. The

Table 1. History of Chronic Obstructive Pulmonary Disease

Characteristics	Experiment class	Control class	P-value
Length	11.3 ± 6.3	8.6 ± 5.9	Not significant
Grade	Grades II-III	Grades II-III	Not significant
Exacerbation	4.9 ± 3.1	4.7 ± 3.6	Not significant

Table 2. Dietary formulation of oral supplementation

Dietary	Per 7 fluid oz (240mL)
Calorie intake	360
Proteins	15
Fats	24
Carbohydrates	26
Water	190
L-carnitine	42
Taurine	38
Vitamin A	2900
Vitamin D	150
Vitamin K	30
Vitamin C	60
Folic-acid	240
B1	0.60
B2	0.70
B6	1.5
B12	3.5
Niacin	9
Choline	130
Biotin	135
Pantothenic acid	5.0
Sodium	290
Potassium	450
Chloride	420
Calcium	300
Phosphorus	220

Magnesium	90
Iodine	35
Manganese	1.4
Copper	0.47
Zinc	5.5
Iron	4.3
Selenium	17
Chromium	35
Molybdenum	34

participants persisted in taking their regular medications, and the exclusion criteria included renal insufficiency, liver disease, 'suspicion of other illnesses' affecting 'nutrition support', and 'intolerance' to any component in the experimental formula as indicated by symptoms such as nausea, vomiting, diarrhoea, or stomach aches. The analysis did not include participants who withdrew from the study or were incapable or unwilling to follow research protocols.

Multiple measurements were recorded prior to the study and four weeks following the nutritional intervention, including blood stream compounds ('potassium, sodium, chloride, liver function, cholesterol, triglycerides, and albumin'), pulmonary variables i.e. 'Forced Expiration in 1 s or volume of air breathed out in 1 s of maximum expiration, minutes of ventilation, consumption of oxygen, 'carbon dioxide production, and respiratory proportion' (RQ), and bloodstream gases (pH, PaCO2, PaO2). Consistent bloodstream gas values were made when fasting. The severity, onset time, and tenure of adverse events were documented.

Statistical analysis utilized the 't-test', and results were presented as 'mean ± standard deviation', with significance set at $P \leq 0.05$.

Results

A total of 70 people were enlisted in the study, with 35 individuals in each class, dispersed equally. The classes did not differ statistically significantly in terms of baseline mean age or weight between experimental and control class (Table 3).

Table 4 shows data on dietary consumption showed that participants in the experimental class ingested high fats and proteins and low carbohydrates (CH) than those in the control class, even if their overall calorie intake stayed the same. The mean bloodstream chemistries of each class did not differ significantly from one another. For both the experimental and control class, albumin levels were relatable and within the normal values at baseline and four weeks ('3.7 ± 0.9 g/dL' and '3.3 ± 0.2g/dL', respectively;

Table 3. Demographic features of control class and experimental oral supplement

Variables	Experimental class	Control class
Men	17	18
Women	18	17
Age	63 ± 7	65 ± 5
Weight	54.8 ± 7	56.2 ± 6.1
Optimal weight	87	86

Table 4. Mean Intake of Nutrients in Control Class Experimental and

Nutrition	Experimental Class			Control class	p- value
	Diet	Oral Supplement	Total	Diet	
Total Daily Energy Intake (Kcal/Kg)	17.4 ± 4.4	18.3 ± 3.7	34.6 ± 7	33.6 ± 7.6	0.6493
Fat energy (kcal/kg)	5.4 ± 2	8.4 ± 3	14.7± 4	9.5 ± 2.5	0.04
Carbohydrate energy (kcal/kg)	12.3 ± 3.3	6 ± 2	17.4 ± 4.3	23.9 ± 4.9	0.02
Protein (g/kg)	0.57 ± 0.9	0.89 ± 0.15	1.36 ± 0.94	0.84 ± 0.3	0.0844

'3.5 ± 0.9g/dL' and '4.5 ± 0.8 g/dL', respectively).

At baseline, bloodstream gas tests did not show any discernible differences between the classes. (Table 5) After four weeks, though, PaCO2 was much lower in both classes. Interestingly, PaO2 rose noticeably in the experimental class alone after four weeks, suggesting a general improvement in ventilatory status (Table 5).

Upon analyzing between-class results, a significant decrease was observed in respiratory proportion, carbon dioxide production, oxygen consumption, and minute ventilation in the experimental class compared to the control class. Airway resistance decreased in both classes. Forced expiration volume in 1 second increased in both classes, with statistical significance achieved only in the experimental class.

Importantly, no individuals withdrew from the study because of intolerance of the oral supplementations. However, two individuals reported distention, and one reported dryness of oral cavity as adverse events.

Discussion

Patients with hypercapnia and hypoxemia are common in severe COPD patients.[13] High-CHO feedings worsen the current situation of affairs by raising CO_2 and RQ. Although nasal oxygen can lessen hypoxia, it cannot treat hypercapnia and may even make it worse by removing hypoxic drive. Reducing the VCO2 will lessen this since it will need fewer breaths per minute (VE) and less carbon dioxide to be expelled, which will reduce the respiratory quotient (RQ). As a result, breathing requires lesser effort and oxygenation is enhanced.

A study conducted by Bradshaw et al 20 revealed that nighttime feedings of a high-fat, low-CHO formula reduce VCO2, RQ, and VE in individuals with cystic fibrosis compared to high-CHO feedings.[14] In those who have COPD, respiratory strength of muscles becomes crucial. These muscles may become exhausted from the additional effort of breathing, which would increase CO2 retention.

A study by Schols A has shown that in undernourished COPD patients, diet modification has enhanced the respiratory function and overall well-being.[15] A previous research shown that a high-fat, low-CHO enteral feeding decreases the amount of time patients needed to be on mechanical ventilation.[16] Lack of nutrition results in weakened respiratory muscles in addition to lower hand strength.

The present investigation showed that VCO2 is influenced by the composition of diet in terms of macronutrients. The respiratory quotient, VCO2, and VO2 of COPD patients who followed a high-fat, low-CHO diet with 50% of their calories arriving from the experimental formula were considerably lower than those who followed a high-CHO

Table 5. Outcomes of gases of blood

Gases	Experimental Class		Control Class	
	Baseline	4 weeks	Baseline	4 weeks
pH	8.48 ± 0.37	7.49 ± 0.22	7.46 ± 0.35	7.48 ± 0.32
$PaCO_2$ (mm Hg)	56± 6	44 ± 5	55 ± 5	46 ± 4
PaO_2 (mm Hg)	69 ± 4	80 ± 5	71 ± 6	72 ±7

diet. Compared to protein or fat, the RQ for carbohydrates is higher. A mixed dinner is said to have an RQ of 0.75.[17] The present study indicates that the mean relative Q-values at baseline for the control and experimental classes were 0.82 and 0.8 respectively, suggesting that patients either like to consume more CHO than one would anticipate, or that this number is excessively low.

Lowering the PaCO2 is another objective in the treatment of COPD. This study demonstrates that a low-CHO high-fat diet can effectively lower VCO_2 and eventually, PaCO2. This is especially helpful for patients on mechanical ventilation who have trouble removing carbon dioxide due to high PaCO2 and VCO2 levels, making them difficult to wean. When individuals who have stable chronic obstructive airway disease transition from standard enteral feeding to a high-fat formula, such as the experimental formula employed in this research, CO2 production, RQ, and PaCO2 are reduced, according to a study by Angelillo Va et al.[18]

Following four weeks of oral dietary supplements, the experimental class minute ventilation (VE) was considerably lower than the baseline data. This shift was probably brought about by the supplement's lower RQ, which raised VO2 and VCO2 levels and reduced the need for breathing. In the control class, these characteristics did not significantly alter from the baseline. The patients continued on their regular treatment plans, and both classes' FEV1 increased as compared to baseline, perhaps indicating better adherence. The advancement in FEV1 only for the experimental class was significant statistically (P=0.05), indicating a considerable reduction in airway blockage. Rather than a change in the actual airway obstruction, this could be the result of an enhancement in their dietary status leading to an increase in respiratory and auxiliary muscle strength, tolerance, and total effort.[19,20]

Conclusion

The oral supplement utilized in our study for COPD participants with its low-CH, high-fat composition, proved clinically were effective in enhancing respiratory and metabolic function when used as an evening supplement over a 4-week period in individuals with chronic COPD.

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