Comprehensive nutritional assessment with phase angle for early undernutrition detection in colorectal cancer patients

Evaluación nutricional integral con ángulo de fase para la detección temprana de desnutrición en pacientes con cáncer colorrectal

Avaliação nutricional abrangente com ângulo de fase para detecção precoce de desnutrição em pacientes com câncer colorretal

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Abstract

Introduction: early assessment of the nutritional status of the patient with colorectal cancer (CRC) has an important role because of its relationship with treatment success and prognosis.

Objective: to evaluate the use of a comprehensive nutritional assessment with phase angle (PA) for early detection of undernutrition in patients with CRC.

Methods: 14 patients with a recent diagnosis of CRC and 14 individuals without cancer were included in a descriptive cross-sectional study. Weight and height were measured. Bioelectrical impedance was performed, and PA was obtained. In addition, hand-held dynamometry, biochemical indicators, and dietary intake were evaluated. The Shapiro-Wilk test was applied to evaluate normality. Pearson correlation was used to determine the confounding variables. Analysis of covariance was performed for quantitative variables, adjusting anthropometric indicators for age and sex and biochemical parameters for socioeconomic level.

Results: more than 70.00 % of patients had a diagnosis of undernutrition based on patient-generated subjective global assessment (PG-SGA) and PA. Also, 91.70 % of patients had low handgrip strength. The prevalence of sarcopenia was high in

Resumen

Introducción: la evaluación temprana del estado nutricional del paciente con cáncer colorrectal (CCR) tiene un papel importante debido a su relación con el éxito del tratamiento y el pronóstico.

Objetivo: evaluar el uso de una evaluación nutricional integral con ángulo de fase (AF) para la detección temprana de desnutrición en pacientes con CCR.

Métodos: se incluyeron 14 pacientes con diagnóstico reciente de CCR y 14 individuos sin cáncer en un estudio descriptivo transversal. Se midieron peso y estatura. Se realizó impedancia bioeléctrica y se obtuvo el AF. Además, se evaluó la dinamometría manual, los indicadores bioquímicos y la ingesta dietética. Se aplicó la prueba de Shapiro-Wilk para evaluar la normalidad. Se usó la correlación de Pearson para determinar las variables confusoras. Se utilizó el análisis de covarianza para las variables cuantitativas, ajustando los indicadores antropométricos por edad y sexo. Los parámetros bioquímicos se ajustaron por nivel socioeconómico.

Resultados: más del 70,00 % de los pacientes tenía un diagnóstico de desnutrición según la valoración global subjetiva generada por el paciente (VGS-GP) y el AF. Además, el 91,70 % presentó baja fuerza de prensión. La prevalencia de sarcopenia

Resumo

Introdução: a avaliação precoce do estado nutricional do paciente com câncer colorretal (CCR) desempenha um papel importante devido à sua relação com o sucesso do tratamento e o prognóstico.

Objetivo: avaliar o uso de uma avaliação nutricional abrangente com ângulo de fase (AF) para a detecção precoce de desnutrição em pacientes com CCR.

Métodos: quatorze pacientes com diagnóstico recente de CCR e catorze indivíduos saudáveis foram incluídos em um estudo comparativo transversal. Peso e altura foram medidos. Foi realizada impedância bioelétrica e o AF foi obtido. Além disso, foram avaliadas a dinamometria manual, os indicadores bioquímicos e a ingestão dietética. O teste de Shapiro-Wilk foi aplicado para avaliar a normalidade. A correlação de Pearson foi utilizada para determinar as variáveis confundidoras. Foi utilizado análise de covariância para as variáveis quantitativas, ajustando os indicadores antropométricos por idade e sexo. Os parâmetros bioquímicos foram ajustados por nível socioeconômico.

Resultados: mais de 70,00 % dos pacientes receberam o diagnóstico de desnutrição com base em avaliação global subjetiva gerada pelo doente (AGS-GP) e AF. Além disso, 91,70 % dos pacientes

the CRC group (58.00 %) as well as in the non-cancer group (46.00 %). In addition, cholesterol, total protein, and albumin were significantly lower in patients with CRC. The protein-energy intake of patients with CRC was lower compared to their requirements.

Conclusions: 75.00 % of patients presented undernutrition at the time of CRC diagnosis according to the PA. Comprehensive nutritional assessment, which includes PA, is crucial for the timely diagnosis of malnourished oncology patients.

Keywords: electric impedance; undernutrition; hand-held dynamometry; sarcopenia.

fue alta en el grupo de CCR (58,00 %) y en los controles (46,00 %). El colesterol, la proteína total y la albúmina fueron significativamente más bajos en los pacientes con CCR. La ingesta de energía y proteínas de los pacientes con CCR fue inferior a sus requerimientos.

Conclusiones: 75,00 % de los pacientes presentó desnutrición al momento del diagnóstico de CCR de acuerdo con el AF. La evaluación nutricional completa, con la inclusión del AF, es crucial para un diagnóstico oportuno de los pacientes oncológicos desnutridos.

Palabras clave: impedancia eléctrica; desnutrición; dinamometría manual; sarcopenia.

apresentaram baixa força de dinamometria manual. A prevalência de sarcopenia foi alta no grupo de CCR (58,00 %) e nos controles (46,00 %). Além disso, o colesterol, a proteína total e a albumina foram significativamente mais baixos nos pacientes com CCR. A ingestão de proteínas e energia dos pacientes com CCR foi menor em comparação com suas necessidades.

Conclusões: 75,00% dos pacientes apresentaram desnutrição no momento do diagnóstico de CCR de acordo com o AF. A avaliação nutricional completa, com a inclusão do AF é crucial para um diagnóstico oportuno de pacientes oncológicos desnutridos.

Palavras-chave: impedância elétrica; desnutrição; dinamometria manual; sarcopenia.

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INTRODUCTION

Colorectal cancer (CRC) is a global public health problem, with both its incidence and mortality rates on the rise. According to the World Health Organization (WHO)[1], CRC is the third most diagnosed malignant tumor worldwide, representing the second leading cause of cancer mortality. In Mexico, it ranks as the fourth most diagnosed malignant neoplasm, with an incidence of 10.60 cases per 100,000 inhabitants and a mortality rate of 5.40 per 100,000 inhabitants[2].

The management of patients with CRC should be multidimensional, including surgical interventions, chemotherapy, radiotherapy, and nutritional therapy, among others[3]. To develop the appropriate nutritional therapy, it is essential to conduct an early assessment of the patient's nutritional status. Early assessment of the nutritional status of CRC patients plays an important role because it is related to treatment success, quality of life, and overall prognosis. Cancer patients are at high risk of developing undernutrition due to the tumor itself, medical and surgical treatment, as well as metabolic changes associated with the neoplastic process [4, 5].

The prevalence and incidence of undernutrition in CRC patients are high, which can increase the risk of morbidity, mortality, and treatment-related complications, whether surgical, chemo-, or radiotherapeutic[6]. According to Vitaloni *et al.*[3], around 87.00 % of oncology patients suffer from undernutrition, with 15.00 % to 40.00 % already experiencing weight loss at diagnosis. Undernutrition has been associated with 30.00 % of deaths in oncology[7, 8]. Additionally, it is important to identify nutritional deficiencies at early stages to develop personalized nutritional support strategies that improve treatment outcomes and the patient's quality of life[3].

Early nutritional intervention in patients with CRC, parallel to medical treatment, provides significant benefits. Nutritional therapy can improve the patient's weight, activity level, and energy and protein intake, as well as reduce the impact of symptoms that put at risk their nutritional status[3, 9]. In most CRC patients, surgery is the first step in treatment[6]. Treating undernutrition during the preoperative period (seven days before surgery) improves patient outcomes and reduces surgery-related complications[7]. Treatment side effects can be reduced while patient survival and recovery improve[3,9]. Additionally, adequate nutritional status is essential for proper functioning of the immune system, tissue repair promotion, and maintenance of muscle mass, all of which are important during cancer treatment[10].

According to the recommendations of the practical guideline "Clinical Nutrition in Cancer" by the European Society for Clinical Nutrition and Metabolism (ESPEN) and the clinical guideline of the American Society for Parenteral and Enteral Nutrition (ASPEN), nutritional screening should be performed at the time of cancer diagnosis[4, 11]. The Patient-Generated Subjective Global Assessment (PG-SGA) is among the validated screening tools in cancer patients, allowing for the detection of nutritional risk in this population at the time of diagnosis[11]. In addition to using the PG-SGA, in recent years, it has been suggested that the phase angle (PA) could be a reliable indicator of nutritional status, as well as a good prognostic marker for cancer patients. This can be used from the first contact with the patient and during treatment to monitor their progress[12].

Zhang *et al.*[12] observed that the PA had higher sensitivity and thus helped to detect more cases of undernutrition in cancer patients compared to using body mass index (BMI) alone. Furthermore, a systematic review conducted by Almeida *et al.*[13] found that the PA was correlated with other indicators of nutritional status in patients with different types of cancer. Despite clinical practice guidelines[4] emphasizing the importance of nutritional assessment in cancer patients at the time of diagnosis, this continues to be overlooked in many hospital centers[5]. Nutritional treatment is usually requested when the patient presents a higher degree of undernutrition, which prolongs the recovery time, affects the response to oncological treatment, increases morbidity, and raises the mortality rate[5].

Therefore, the aim of the present study was to analyze the use of a comprehensive assessment, including PG-SGA, anthropometry, PA, handgrip strength, biochemical analysis, and diet, for the early detection of undernutrition in patients with a recent diagnosis of CRC compared to a group of individuals without cancer.

KEY POINTS

- The management of patients with CRC should be multidimensional, including surgical interventions, chemotherapy, radiotherapy, and nutritional therapy.
- Early assessment of the nutritional status of CRC patients plays an important role because it is related to treatment success, quality of life, and overall prognosis.
- In this study, 38.40 % of CRC patients were overweight or obese based on their BMI. Moreover, 75.00 % of CRC patients had a low PA compared to 28.60 % of individuals without cancer. Handgrip strength was also lower in CRC patients (91.70 %) compared to the non-cancer group (69.20 %).
- CRC patients had significantly lower concentrations of cholesterol ($p = 0.005$), total proteins ($p < 0.001$), and albumin ($p < 0.001$) compared to the individuals without cancer.
- Compared to the non-cancer group, the proportion of undernutrition was higher in patients with CRC at the time of diagnosis.

MATERIAL AND METHODS

Study design

A total of 14 patients with a recent diagnosis of CRC, aged ≥ 19 years, both sexes, participated in a comparative cross-sectional study (Figure 1), that was conducted from January to August 2023. Patients were excluded if they were undergoing chemotherapy or radiotherapy, receiving renal replacement therapy, had a personal history of oncological disease, or were using alternative cancer treatments. CRC patients were recruited on the surgical floor after tumor resection. For the non-cancer group, 14 individuals from the general population without a history or diagnosis of oncological diseases were included. The participants without cancer were matched to the patients with CRC based on age and sex variables.

Sample size was calculated estimating a prevalence of undernutrition of 6.00 % in individuals without cancer and 50.00 % in patients with CRC, according to Casagrande's formula[14] for comparing proportions, resulting in a total of 13 individuals per group. Both patients and participants received oral and written information about the study and signed an informed consent. The project was previously approved by the Bioethics Committees (registration numbers: 13174 and 396/05-09-2022). The study followed the ethical guidelines of the World Medical Association Declaration of Helsinki and General Health Law of Mexico [15, 16].

All participants answered a validated socioeconomic level questionnaire. The nutritional assessment included PG-SGA, anthropometric measurements, bioelectrical impedance analysis (BIA), and a dietary intake evaluation. Additionally, a fasting blood sample was taken from each participant for the determination of biochemical markers. Finally, handgrip strength measurements were taken from both CRC patients and non-cancer individuals.

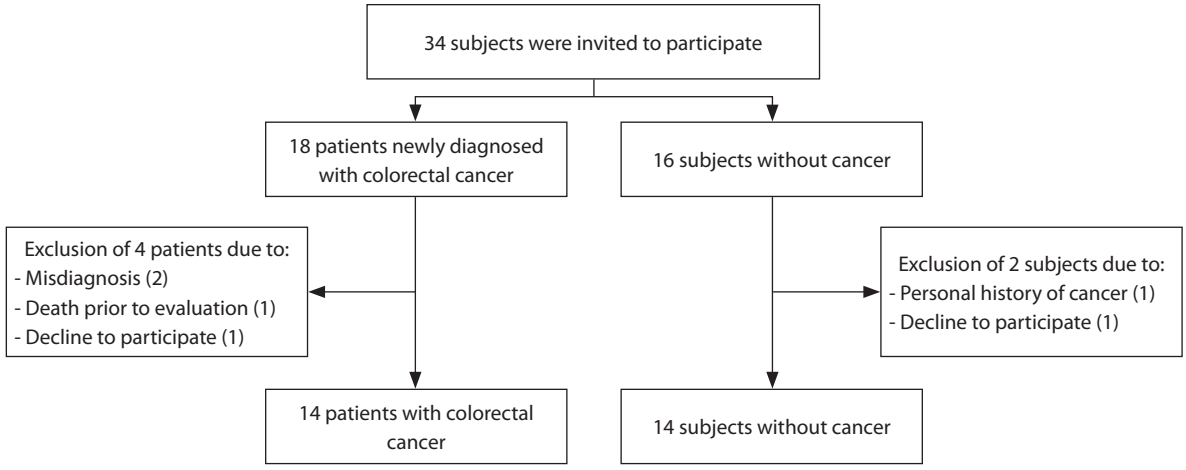

Figure 1. Flowchart of the patient recruitment process. Elaborated by the authors.

PG-SGA

The PG-SGA was used as a tool to estimate the nutritional status, which includes data such as unintentional weight change, evaluation of dietary intake, presence of gastrointestinal symptoms, functional capacity, and physical examination of the oncological patient[17]. Following the assessment, patients were classified into one of three categories according to the questionnaire: (A) well-nourished; (B) suspected undernutrition or moderately undernourished; or (C) severely undernourished[17, 18].

Anthropometric assessment

Weight and height were measured by previously standardized personnel according to the methodology proposed by the International Society for the Advancement of Kinanthropometry (ISAK). Weight was measured using a digital scale (SECA model 813, Hamburg, Germany) with a capacity of 200 kg and a variation of 0.10 kg. Height was measured in all patients using a portable stadiometer (SECA model 213, Hamburg, Germany) with a height of 205 cm and a precision of 0.10 cm. BMI was calculated by dividing weight by height in square meters. Adults over 60 years old were classified as *underweight* if they had a BMI <23 kg/m^2; *normal weight* if BMI was >23 and <28; *overweight* if BMI was >28 and <32; and *obese* if BMI was >32; according to Torres Castañón *et al.*[19].

BIA

Using a body composition analyzer at a frequency of 50 kHz (SECA MBCA model 525, Hamburg, Germany), the following parameters were obtained: fat-free mass index (FFMI), fat mass index (FMI), and skeletal muscle mass (SMM). Reference values for patient diagnosis of undernutrition are shown in Table 1. Additionally, the PA was obtained, for which a cutoff point of PA <5.57 ° was used to classify CRC in both sexes with nutritional deficiency[20]. For the individuals without cancer, the reference values considered appropriate were a PA ranging from 5.36 °-7.36 ° in women and from 6.43 °-8.23 ° in men, according to the study on the Mexican population conducted by Espinosa-Cuevas *et al.*[21].

Handgrip strength

Muscle function was assessed in the dominant hand using a hand-held dynamometer Takei T.K.K.5401 GRIP-D (Takei Scientific Instruments Co., Ltd., Tokyo, Japan), with a maximum capacity of 100 kg, which measures the patient's handgrip strength. Cut-off points for low handgrip strength were values <16 kg for women and <27 kg for men[23]. The diagnosis of sarcopenia considered both handgrip strength and SMM evaluated by BIA following the updated European Working Group on Sarcopenia in Older People (EWGSOP2) recommendations[23].

Biochemical evaluation

A complete blood count was performed using a hematology analyzer (Sysmex XP-300, Kobe, Japan), obtaining values for hemoglobin, hematocrit, platelets, and total lymphocyte count. Additionally, a blood chemistry panel was conducted using an automated clinical chemistry analyzer (Spin 120, Spinreact, Girona,

Spain), which provided values for glucose, urea, blood urea nitrogen (BUN), creatinine, triglycerides, total cholesterol, total proteins, and albumin.

Table 1. Cutoff points for body composition assessment

Variable	Gender	BMI (kg/m²)	p5	p50	p95
FFMI (kg/m²)	Females	<25	14.11	15.63	17.14
		≥ 25, <30	15.35	16.88	18.41
		≥ 30	16.39	18.48	20.57
	Males	<25	17.11	18.81	20.51
		≥ 25, <30	18.40	20.08	21.77
		≥ 30	20.05	22.09	24.12
FMI (kg/m²)	Females	<25	4.27	6.55	8.84
		≥ 25, <30	8.09	10.30	12.50
		≥ 30	10.68	15.04	19.41
	Males	<25	2.21	4.23	6.24
		≥ 25, <30	4.97	7.08	9.19
		≥ 30	7.52	10.79	14.06
SMM (kg)	Females	<25	6.29	7.11	8.11
		≥ 25, <30	7.02	7.89	8.93
		≥ 30	7.70	8.82	10.18
	Males	<25	8.38	9.20	10.19
		≥ 25, <30	9.10	9.97	11.02
		≥ 30	9.99	11.06	12.35

Abbreviatures: BMI: body mass index; FFMI: fat-free mass index; FMI: fat mass index; p: percentile; SMM: skeletal muscle mass. Adapted from: Peine S, et al. Int J Body Composition Res. 2013;11(3):67–76 (22).

Dietary intake assessment

Trained nutritionists conducted three 24 hour recalls to all participants on non-consecutive and random days. The recalls were applied with an interval of three to four days. Two 24 hour recalls were applied on weekdays and one during the weekend[24].

The recalls collected data related to food preparation and portion sizes. To calculate energy and protein intake, the tables from the Mexican Equivalent Food System were used[25]. Energy and protein intake were calculated, and individualized requirement calculations were conducted following the recommendations of the ESPEN practical guidelines for clinical nutrition in cancer[4].

Socioeconomic questionnaire

The socioeconomic levels index of the Mexican Association of Market Intelligence and Opinion Agencies (AMAI) was used. The households of the evaluated individuals were categorized into one of seven levels according to their capacity to meet the needs using the "NSE 2022 Rule." The socioeconomic levels indicated by AMAI are as follows: A/B and C+: upper class; C: upper middle class; C-: middle class; D+: lower middle class; D: lower class; E: very low class[26].

Artificial intelligence

The authors declare the use of ChatGPT in the translation of the manuscript.

Statistical analysis

Descriptive statistics included percentages, medians, and confidence intervals. Normality analysis was conducted on quantitative variables using the Shapiro-Wilk test. The association between study groups was assessed using the chi-square test for qualitative variables. For quantitative variables, analysis of covariance was performed, adjusting anthropometric indicators for age and sex, and biochemical parameters for socioeconomic level. Pearson correlation was used to determine the confounding variables. The comparison of dietary intake and requirements between groups was conducted using the independent t-test for independent variables, and the paired t-test was used to compare intake and energy and protein requirements within the same group. A significance level of p <0.05 was used. Statistical analysis was performed using SPSS version 29 (IBM Corp., Armonk, NY, USA).

RESULTS

As part of the general characteristics, 50.00 % of the population with CRC were women, with the same characteristics maintained in the individuals without cancer. The average age in the CRC group was 59.50 years, and in the non-cancer group was 60 years. Significant differences were observed in occupation between both groups. Patients with CRC were mainly dedicated to housework (42.90 %), engaged in agriculture (21.40 %), or were unemployed (21.40 %); whereas the majority of individuals without cancer were dedicated to housework (28.60 %), were retired (21.40 %), were office employees (14.30 %) or teachers (14.30 %). In the patients with CRC, the tumor was located in the colon in most patients (64.30 %), and 64.30 % required a colostomy after tumor resection. Almost 60.00 % of the patients with CRC were diagnosed at late stages (16.70 % in stage III and 41.70 % in stage IV).

According to the PG-SGA, 78.60 % of the patients with CRC had some degree of undernutrition (42.90 % moderate, 35.70 % severe), compared to the non-cancer group, where only 7.10 % of the population was detected with altered nutritional status (p <0.001). As shown in Table 2, 38.40 % of CRC patients were overweight or obese based on their BMI. Moreover, 75.00 % of CRC patients had a low PA compared to 28.60 % of the individuals without cancer (p = 0.001). Handgrip strength was also lower (p = 0.031) in CRC patients (91.70 %) compared to the non-cancer group (69.20 %). However, body composition indicators did not show significant differences between groups. The prevalence of sarcopenia was 58.00 % in CRC patients and 46.00 % in individuals without cancer, but they were not significantly different (p = 0.666).

More than half of the patients with CRC had anemia (Table 3), compared with the non-cancer group where no cases were found (p <0.001). Also, CRC patients had significantly lower concentrations of cholesterol (p = 0.005), total proteins (p <0.001), and albumin (p <0.001) compared to the individuals without cancer.

Table 2. Comparison of body composition indicators between CRC patients and individuals without cancer

Characteristic	CRC patients Median (95 %CI) or % (n)	Individuals without cancer Median (95 %CI) or % (n)	*p**
BMI (kg/m²)	25.00 (23.84-28.25)	26.85 (23.85-28.09)	0.961
Underweight (%)	15.40 (13.00)	14.30 (14.00)	
Normal weight (%)	46.20 (13.00)	57.10 (14.00)	
Overweight/obese (%)	38.40 (13.00)	28.60 (14.00)	
FFMI (kg/m²)	16.94 (16.27-18.42)	16.68 (16.39-18.21)	0.952
Low FFMI (%)	40.00 (10.00)	42.90 (14.00)	
Average FFMI (%)	50.00 (10.00)	57.10 (14.00)	
High FFMI (%)	10.00 (10.00)	-	
FMI (kg/m²)	10.15 (6.87-11.58)	8.86 (6.83-10.79)	0.782
Low FMI (%)	30.00 (10.00)	28.60 (14.00)	
Average FMI (%)	30.00 (10.00)	42.90 (14.00)	
High FMI (%)	40.00 (10.00)	28.60 (14.00)	
SMM (m²)	7.27 (6.67-8.03)	7.72 (7.44-8.58)	0.140
Depleted SMM (%)	70.00 (10.00)	71.40 (14.00)	
Average SMM (%)	30.00 (10.00)	28.60 (14.00)	
PA (°)	4.95 (4.15-5.16)	5.85 (5.59-6.53)	<0.001
Low (%)	75.00 (12.00)	28.60 (14.00)	
Adequate (%)	25.00 (12.00)	71.40 (14.00)	
HGS	21.20 (19,68-26,98)	29.60 (25.46-32.48)	0.031
Low (%)	91.70 (12.00)	69.20 (13.00)	
Adequate (%)	8.30 (12.00)	30.80 (13.00)	

Abbreviatures: BMI: body mass index; CI: Confidence interval; CRC: colorectal cancer patients; FFMI: fat-free mass index; FMI: fat mass index; HGS: handgrip strength; PA: phase angle; SMM: skeletal muscle mass. *Analysis of covariance adjusted for age and sex. Elaborated by the authors.

Table 3. Comparison of biochemical parameters related to nutritional status

Characteristic	CRC patients Median (95 %CI) or % (n)	Individuals without cancer Median (95 %CI) or % (n)	*p**
Hemoglobin (g/dL)	12.10 (11.56-13.04)	14.90 (13.93-15.35)	<0.001
Anemia (%)	57.10 (14.00)	-	
Non-anemia (%)	42.90 (14.00)	100.00 (14.00)	
Hematocrit (%)	35.80 (34.05-38.63)	43.90 (40.71-45.11)	<0.001
Low (%)	78.60 (14.00)	14.30 (14.00)	
Adequate (%)	21.40 (14.00)	85.70 (14.00)	
Platelets (10*3/u)	289.50 (247.55-374.45)	228.00 (196.80-323.70)	0.262
Low (%)	7.10 (14.00)	-	
Adequate (%)	78.60 (14.00)	92.30 (13.00)	
High (%)	14.30 (14.00)	7.70 (13.00)	
Total lymphocyte count (mm^3)	1494.07 (1125.47-1772.54)	1772.15 (1558.94-2181.47)	0.070
Adequate (%)	14.30 (14.00)	35.70 (14.00)	
Mild depletion (%)	50.00 (14.00)	57.10 (14.00)	
Moderate/severe depletion (%)	35.70 (14.00)	7.10 (14.00)	
Glucose (mg/dL)	99.50 (90.45-110.04)	103.05 (95.24-114.08)	0.518
Hypoglycemia (%)	7.10 (14.00)	-	
Normoglycemia (%)	42.90 (14.00)	42.90 (14.00)	
Hyperglycemia (%)	50.00 (14.00)	57.10 (14.00)	
Urea (mg/dL)	24.90 (19.89-33.13)	29.00 (23.00-35.74)	0.536
Low (%)	21.40 (14.00)	7.10 (14.00)	
Adequate (%)	71.40 (14.00)	85.70 (14.00)	
High (%)	7.10 (14.00)	7.10 (14.00)	
BUN (mg/dL)	11.50 (9.22-15.51)	13.50 (10.62-16.68)	0.559
Low (%)	7.10 (14.00)	-	
Adequate (%)	7.60 (14.00)	92.90 (14.00)	
High (%)	14.30 (14.00)	7.10 (14.00)	
Creatinine (mg/dL)	0.67 (0.64-0.93)	0.90 (0.81-1.09)	0.100
Adequate (%)	85.70 (14.00)	100.00 (14.00)	
High (%)	14.30 (14.00)	-	
Total cholesterol (mg/dL)	138.5 (101.44-152.67)	174.40 (158.01-202.97)	0.005
Low (%)	83.30 (12.00)	21.40 (14.00)	
Adequate (%)	8.30 (12.00)	50.00 (14.00)	
High (%)	8.30 (12.00)	28.60 (14.00)	
Triglycerides (mg/dL)	101.50 (67.26-143.28)	102.15 (82.96-149.68)	0.667
Low (%)	25.00 (12.00)	-	
Adequate (%)	58.30 (12.00)	71.40 (14.00)	
High (%)	16.70 (12.00)	28.60 (14.00)	
Total proteins (g/dL)	5.10 (4.41-5.58)	6.80 (6.27-7.14)	<0.001
Low (%)	88.90 (9.00)	7.10 (14.00)	
Adequate	11.10 (9.00)	92.90 (14.00)	
Albumin (g/dL)	2.60 (2.28-2.98)	4.25 (3.93-4.44)	<0.001
Normal	11.10 (9.00)	100.00 (14.00)	
Mild hypoalbuminemia	11.10 (9.00)	-	
Moderate/severe hypoalbuminemia	77.80 (9.00)	-	

Abbreviatures: CI: confidence interval; CRC: colorectal cancer. Reference values: hemoglobin: 12 g/dL (♀) and 13 g/dL (♂)[27]; hematocrit: 37%-47% (♀) and 42%-52% (♂)[27]. Platelets: >150-<450 × 10^3/mm^3 [27]; total lymphocyte count: adequate >2000 cells/mm^3, mild depletion 1200-2000 cells/mm^3 and moderate to severe depletion <1200 cells/mm^3[28]; glucose: <100 mg/dL[29]; urea: 14,90-40,00 mg/dL[29]; blood urea nitrogen (BUN): 6-20 mg/dL[29]; creatinine: 0,60-1,10 mg/dL[29]; total cholesterol: <200 mg/dL[30], hypocholesterolemia <160 mg/dL[31]; triglycerides: >50, <150 mg/dL[31]; total proteins: ≥ 6 g/dL[31]; albumin: adequate >3,50 g/dL, mild depletion de 3-3,40 g/dL and moderate to severe depletion <3 g/dL[32]. *Analysis of covariance adjusted for socioeconomic level. Elaborated by the authors.

For the dietary analysis, a comparison was made between the energy and protein intake of each group and their corresponding requirements, as well as a comparison of energy and protein intake between cancer patients and individuals without cancer. These results are shown in Table 4. CRC patients exhibit a significantly lower intake of energy and protein compared to their corresponding requirements. Additionally, CRC patients had a significantly lower energy intake compared to patients without cancer.

DISCUSSION

In this study, patients with CRC had undernutrition at the time of their diagnosis, according to PG-SGA, PA, handgrip strength, and biochemical indicators. Additionally, a low intake of energy and protein was observed in this group. Patients with malignant tumors in the digestive tract are often particularly susceptible to undernutrition due to the symptoms associated with these neoplasms[6]. Therefore, an early comprehensive nutritional assessment, together with medical treatment, is crucial for these patients[4, 5].

The high prevalence of undernutrition, found in approximately 80.00 % of CRC patients according to the PG-SGA at the time of their diagnosis, contrasts significantly with the low prevalence observed in the non-cancer group, which was 7.00 %. These findings are higher than those reported in previous studies. For example, Souza *et al.*[35] reported that 31.20 % of CRC patients were identified with nutritional deficiencies according to the PG-SGA; however, the population studied by these researchers corresponded to patients in different stages of oncological treatment.

According to the anthropometric and body composition assessment, it was observed that 38.40 % of CRC patients were overweight or obese based on their BMI. This finding is consistent with previous studies reporting prevalence of obesity ranging from 41.00 %[6] to 62.00 %[35] among CRC patients[35]. According to Arends *et al.*[5], obesity is a prevalent condition in patients with various types of cancer, including CRC. In the present study, BMI only detected 15.40 % of patients with undernutrition. Gillis *et al.*[6] observed that, based solely on BMI, only 2.00 % of CRC patients were diagnosed with undernutrition. Therefore, since BMI does not account for the body composition of individuals, it is considered to be a tool for diagnosing undernutrition in cancer patients with low sensitivity. Hence, other assessment methods such as BIA, PA, or even handgrip strength have been proposed[5, 12].

No significant differences between CRC patients and individuals without cancer were observed in the body composition assessment by BIA. However, both groups had low values for FFMI, FMI, and SMM. Additionally, they showed low handgrip strength, resulting in a high prevalence of sarcopenia in both groups. Sarcopenia is a condition characterized by changes in skeletal muscle, primarily affecting strength, and also includes a decrease in muscle mass[23]. In the non-cancer group, the presence of sarcopenia could be related to the age of the individuals evaluated. It has been observed that handgrip strength significantly declines from the fifth decade of life onwards[36]. In the case of CRC patients,

Table 4. Comparison between energy and protein intake with the recommended requirements for each group

Group	Energy intake (kcal) Median (95 %CI)	Energy requirement (kcal) Median (95 %CI)	*p**	Protein intake (g/kg) Median (95 %CI)	Protein requirement (g/kg) Median (95 %CI)	*p**
CRC patients (n = 13)	1277.55 (905.69-1717.17)	1700.00 (1579.84-1881.69)	0.044	0.95 (0.59-1.13)	1.20 (1.15-1.34)	0.003
Individuals without cancer (n = 12)	1641.85 (1390.41-2337.39)	1580.00 (1471.99-1936.34)	0.275	1.10 (0.81-1.81)	1.15 (1.06-1.39)	0.568
p****	0.050	0.832		0.086	0.751	

Abbreviatures: CI: confidence interval; CRC: colorectal cancer; kcal: kilocalorie. Reference values: energy: cancer patients 25-30 kcal/kg[4], healthy adults <65 years 25 kcal/kg[33], older adults >65 years 30 kcal/kg[34]; protein: cancer patients 1.0-1.5 kcal/kg[4]; healthy adults <65 years 0.8-1.0 g/kg[33], older adults >65 years 1.0-1.2 g/kg[34]. *Paired t-test. Comparison of variables within the same group. **Independent t-test. Comparison between groups. Elaborated by the authors.

sarcopenia is likely secondary to the disease itself and the undernutrition they experience, in addition to age and a sedentary lifestyle[23]. Sarcopenia, in both groups, increases the risk of falls and a lower quality of life. In addition, it also represents a higher risk of treatment toxicity for the CRC patients[37].

To our knowledge, there are no established cut-off points to determine undernutrition in CRC patients using PA. Souza *et al.*[35] observed that the PA was useful as a predictor of muscle alterations, with good diagnostic accuracy for detecting decreased muscular function and low muscle mass. A low PA indicates poor cellular membrane status, alterations in muscle composition and function, and cellular death[38]. Additionally, a decrease in PA in patients with advanced cancer has been associated with decreased survival after adjusting for cancer type, weight loss, and inflammatory markers[39]. According to Gupta *et al.*[20], a PA ≤ 5.57 ° in CRC patients is equivalent to a median survival of 8.6 months, while patients with PA >5.57 ° have a median survival of 40.40 months.

Barao *et al.*[40] observed that a PA >5 ° in elderly patients with CRC was associated with a decreased mortality risk. In the present study, 75.00 % of CRC patients had a PA below the established ranges for the disease, indicating cell membrane damage and cell death. A low PA brings as consequences muscle damage, lower functional status, decreased quality of life, and increased postoperative infections, complications that contribute to an increase in hospitalization time, morbidity, and low survival rate[38, 41, 42]. Thus, PA may be considered an important indicator of nutritional status in patients with cancer that is more sensitive than BMI[12, 13]. In addition, measuring PA is a practical, minimally invasive, and easily transportable method that allows for the detection of at-risk patients and monitoring of their progress throughout nutritional treatment. More studies are needed to determine potential cut-off points using PA for undernutrition diagnosis. Also, considering that these results were obtained right after the diagnosis of CRC and before the start of chemotherapy, it is crucial to carry out nutritional intervention from the time of diagnosis, as indicated by the corresponding guidelines[4].

The prevalence of anemia among the CRC patients that participated in the present study was high. Similar to our results, Ristescu *et al.*[43] found anemia in the 82.30 % of patients with CRC post-operation. Anemia is common in these patients due to gastrointestinal bleeding and to the characteristics of the tumor itself[44]. The presence of anemia in CRC patients increases the risk of complications and mortality during the postoperative period and a higher risk of cancer recurrence, making its treatment vital from the moment of diagnosis[43].

The total lymphocyte count in blood has been used as a biomarker of nutritional status and as a prognostic factor in various clinical conditions, including cancer. Therefore, a decrease in the total lymphocyte count should be considered a risk factor in oncology[45]. In this study, 85.70 % of CRC patients had a low total lymphocyte count. According to a previous study in hospitalized patients with cardiovascular disease and several types of cancer, a low total lymphocyte count may signify a higher risk of complications related to nutritional status[45]. Additionally, this indicator is related to other biochemical parameters of nutritional status, such as plasma lipid concentration and hemoglobin, as well as inflammatory markers like albumin[45]. For instance, in the case of the patients evaluated in this study, more than 80.00 % had low levels of cholesterol and total proteins. Additionally, a meta-analysis by Zhang *et al.*[31] observed that blood markers such as hemoglobin, cholesterol, and total proteins are useful biochemical indicators of undernutrition, even in the presence of inflammation.

In the case of CRC patients, the prevalence of hypoalbuminemia was high. Albumin allows the assessment of underlying inflammation, and since inflammation is associated with an increase in basal metabolism, albumin could be considered an indicator of nutritional risk[46]. Therefore, analyzing different biochemical markers related to nutritional status increases the specificity and sensitivity when providing a nutritional diagnosis[31].

The energy and protein intake of CRC patients was found to be below their requirements. Furthermore, a low energy intake was observed in CRC patients when compared to healthy subjects. These results are similar to those observed in CRC patients in Portugal, where an approximate intake of 1335 kcal/day was reported[47]. The low energy and protein intake may partially explain the undernutrition observed in the population and the loss of muscle mass, leading to increased susceptibility to infections, treatment interruptions, and prolonged hospital stays[47]. Therefore, increasing energy and protein intake should be a priority for the successful medical treatment of these patients.

The present study has some limitations. First, the sample size is small, and due to the conditions of some patients, it was not possible to collect anthropome-

tric, body composition, and dietary data completely. However, significant differences were detected in most study variables, including PA, and it was possible to demonstrate that patients recently diagnosed with CRC have undernutrition compared to a non-cancer group, which will allow for specific recommendations to be made for their treatment. To the best of our knowledge, this is the first study in patients with newly diagnosed CRC that evaluates the use of PA as an indicator of nutritional status, together with anthropometric, biochemical, and dietary parameters.

CONCLUSIONS

Compared to individuals without cancer, the proportion of undernutrition was higher in patients with CRC at the time of diagnosis. Also, PA detected more cases of undernutrition compared to BMI. The PG-SGA, PA, handgrip strength, biochemical, and dietary markers allowed for the detection of more than 70.00 % of cases of undernutrition compared to using BMI alone and compared to individuals without cancer. Therefore, in oncology, complete nutrition interventions that include follow-up using PA, together with medical treatment, are crucial so that patients with nutritional deficiencies or those at risk can be identified early and receive medical-nutritional treatment according to their requirements.

Declaration of authorship

Conception and design of the research, B.MR., OP.G. and JL.R.; data acquisition, B.MR., KM.GN., and R.HO.; data analysis and interpretation, B.MR., KM.GN.,and MC.C.; funding acquisition, OP.G. and KM.GN.; drafted the manuscript, B.MR. and OP.G.

Conflict of interest

The authors declare no conflicts of interest.

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