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Original Article

The impact of nutritional status on centenarians' physical, mental, and functional health

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SUMMARY

Background & Aims: Nutrition has been described as a lifestyle factor strongly associated with health phenotypes in extreme longevity. However, little is known about its relationship with health-related outcomes in centenarians.**Methods:** A cross-sectional study was conducted from the COOL-CEN cohort. The Mini Nutritional Assessment (MNA) and the Prognostic Nutritional Index (PNI) were used to determine nutritional status, which were correlated with clinical, health status, and biochemical variables.**Results:** The sample included 139 centenarians, 74% (n=103) were female. Centenarians at risk of malnutrition (47%; n=66) and those with an absolute PNI value < 38.8 (54%) represented the most significant proportion. MNA was positively correlated with functional independence ($r^2 = 0.734$, $P < 0.05$), cognitive assessment ($r^2 = 0.650$, $P < 0.05$), and functional performance ($r^2 = 0.619$, $P < 0.05$). Inadequate physical performance, frailty, sarcopenia, severe dementia, some degree of dependency, low PNI, and avoiding the use of dental prosthesis were significantly associated with nutritional vulnerability ($P < 0.05$).

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Conclusions: This study identified that nutritional status in centenarians is associated with functional and cognitive status, physical performance, use of dental prostheses, and specific biochemical and anthropometric variables. These findings are relevant for decision-making in general and specialized healthcare and for public health policymakers to build evidence-based strategies to promote healthy aging.

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Introduction

Extreme longevity has become a topic of increasing interest due to global life expectancy, which has led to a significant rise in the proportion of octogenarians, nonagenarians, and centenarians [1,2]. Much has been hypothesized regarding the factors associated with successful aging and extreme longevity [3–5]. However, evidence suggests that aging is a multidimensional, multilevel, and multidirectional process [6], in which proximal and distal influences contribute to the aging phenotype in diverse ways, depending on the characteristics of the population and the environment in which the life cycle unfolds [7].

Nutrition is perhaps the most debated factor regarding its potential influence on the aging phenotype [8,9]. Some claim that the Mediterranean diet, characterized by high fish consumption, reduced red meat intake, and moderate alcohol consumption, is associated with successful aging and extreme longevity [8,9], as previously sought to be demonstrated in centenarians [10], representing the extreme phenotype of longevity. However, the evidence remains too heterogeneous and fragmented to conclusively support such claims [11].

From a clinical perspective, nutrition is a key determinant of health that, in theory, should be associated with other health outcomes essential for strengthening extreme longevity [8,9,12,13]. These outcomes help ensure functional independence, autonomy, and dignity, which are important predictors of healthy lifespan and survival in centenarians [13]. In Colombia, aging is one of the most significant demographics changes the country is facing in terms of healthcare, social security and pension system [14]. Therefore, identifying specific protective or risk factors related to nutritional status—factors that can be modified to maintain adequate nutrition and promote positive health outcomes—is crucial for evidence-based health decision-making and developing healthcare strategies for extreme longevity. This study explored the association between nutritional status and health-related outcomes in Colombian centenarians.

This study was reported according to STROBE guidelines [15].

Methods

Study design

Cross-sectional study derived from the Colombian Centenarian Cohort Study (COOLCEN Cohort) [14].

Setting and participants

Participant data came from the COOLCEN cohort study. The COOLCEN study is a nationwide longitudinal study involving centenarians in Colombia, starting in September 2023. This study applied simple random sampling to select subjects aged 100 years and older, whose ages were verified by identification documents or state records, and who provided written informed consent. No exclusion

criteria were determined. The centenarians were assessed at their home or at a geriatric outpatient and were included in five provinces of Colombia (Atlántico, Bogotá D.C., Bolívar, Sucre, and Valle del Cauca).

Variables

The outcomes, whether categorical or quantitative, were the results of the Mini Nutritional Assessment (MNA) score [16] and Prognosis Nutritional Index (PNI) [17,18] used to determine the nutritional status of centenarians. Independent variables were sociodemographic, economic, functional, cognitive, and clinical characteristics.

Data measurement

A semi-structured questionnaire collected data during a medical interview with the centenarian and their caregiver. We used the MNA score and PNI to measure the nutritional status. To be eligible for the application of this questionnaire, participants did not need to be fully cognitively intact but able to reliably respond to questions about themselves. In some cases, caregivers or relatives helped them comprehend and respond to the questions. If the participants were unable to sign the informed consent, their legal representatives did so.

We used the full MNA scale [16] and recorded quantitative and qualitative results of this scale. The MNA consists of 18 items with a range of 0–30 points and determines three nutritional status categories: 1) Normal nutritional status (24–30 points); 2) At-risk of malnutrition (17–23.5 points); and 3) Malnourished (less than 17 points).

The PNI is an indicator of nutritional status and inflammation [17,18], used as a predictor of morbidity or mortality in older persons, especially in acute care scenarios. However, it is hypothesized that it may serve as a valuable predictor of health-related outcomes in organically stable long-lived individuals, as it is directly related to nutritional status. The PNI is calculated using serum albumin and blood lymphocyte count [$10 \times \text{Albumin (g/dL)} + [0.005 \times \text{blood lymphocyte (cells/mm}^3)]$]. We used an absolute cut-off score of 38.8 based on previous studies [17,18]. Therefore, a value ≥ 38.8 was considered high, while a value < 38.8 was considered low.

We measured frailty by using the Fried scale and sarcopenia using the SARC-F scale [19]. To determine functional status, we used the Barthel Index [20], Lawton and Brody [20], Downton [21] and Short Physical Performance Battery (SPPB) scales [22]. The Mini-Mental Status Exam (MMSE) [23], the Montreal Cognitive Assessment (MoCA) [24], and the Clinical Dementia Rating (CDR) [25] evaluated the cognitive status. Yesavage scale [26] computed depression, and GAI-SF (Geriatric Anxiety Inventory – Short Form) [27] assessed anxiety. The Insomnia Severity Index (ISI) scale [28] measured the sleep quality. We evaluated the quality of life and well-being using the World Health Organization Quality of Life (WHOQOL) and The Satisfaction With Life Scales (SWLS) scales [29], respectively. Prosociality was examined, focusing on perceptions of caregiving, feelings of loneliness, social interactions, contact, and experiences with any form of violence. We also explored biochemical parameters of interest in the health status of extreme longevity related to lipid metabolism, renal profile, thyroid profile, and inflammatory markers, among others [30].

Statistical methods

Kolmogorov–Smirnov test showed the normality of quantitative variables. Data are presented as median (interquartile, IQR) for skewed variables. Qualitative variables were summarized using frequency and percentages.

We conducted comparative analysis using Pearson's Chi-square test or Fisher's exact test for qualitative variables and Mann-Whitney U test or Student's t-test for quantitative variables.

Multiple regression analyses and Pearson's or Spearman's correlation coefficient tests evaluated associations and correlations between MNA, PNI, and the other outcomes. Due to multiple statistical comparisons and to avoid the risk of type I error, *P*-values were adjusted by the Bonferroni correction. A *P*-value < 0.05 was considered statistically significant. All analyses were performed using the R statistical package (Version 4.3.1) (<https://www.r-project.org/>).

Ethical statement

This study complied with Act 008430/1993 of the Ministry of Health of the Republic of Colombia, which classified it as minimal-risk research. The institutional review board approved the study design.

Results

A total of 139 centenarians were included, with a median age of 101 years. Of these, 74% (n=103) were female, and 80% lived in urban areas. Eighty percent (n=111/138) belonged to a low or very low socioeconomic level, 87% (n=119/137) had one or less minimum wage as household economic income, and only 4% (n=5/133) had completed at least secondary school (Table 1).

According to the Barthel index, 44% (n=61/138) had total independence or mild dependence, while the prevalence of frailty and sarcopenia was 75% (n=99/132) and 73%, respectively, and cognitive impairment was present in 73% (n=86/118). Seventy-nine percent (n=108/137) of centenarians had no upper teeth, while 64% (n=88/138) had no lower teeth. Only half of the population used dental prostheses (Table 1).

When evaluating nutritional characteristics, the centenarians predominantly had not decreased food intake in the last three months (58%), 56% had a body mass index (BMI) less than 19 kg/m², and the

Table 1
Demographic and clinical characteristics of the population studied (N=139)

Variable	N	%
Age (years), median, (IQR)	101 (3)	-
Sex		
Female	103	74
Residence area		
Urban	109/137	80
Educational Level		
Without education	89/133	67
Primary education	39/133	29
Upper secondary education or higher	5/133	4
Household Economic Income		
<1 MMW	96/137	70
1 MMW	23/137	17
1–2 MMW	13/137	9
> 2 MMW	5/137	4
Socioeconomic level		
Very low	68/138	49
Low	43/138	31
Lower-middle and higher	27/138	20
Functionality		
Independence	18/138	13
Mild dependence	43/138	31
Moderate dependence	15/138	11
Severe dependency	19/138	14
Total dependency	43/138	31
No Upper teeth	108/137	79
No Lower teeth	88/138	64
Use of dental prosthesis	70	50
Frailty	99/132	75
Sarcopenia	101	73
Favorable physical performance	19/137	14
Depression	20/130	15
Anxiety	1/131	1
Cognitive impairment^a	86/118	73
Insomnia	26/137	19
Favorable life satisfaction	108/130	86

^a MMSE ≤ 24. MMW: Minimum monthly wage (\$303,10 for the year 2024).

majority consumed three meals a day (87%). Protein intake was adequate in 49%, 61% fed themselves without difficulty, and 63% considered themselves free of nutritional problems. The most representative proportion was that of centenarians at risk of malnutrition (47%; n=66) and those with an absolute PNI value less than 38.8 (54%) (Table 2).

Correlations were found between the MNA and PNI and health-related outcomes. The MNA demonstrated a strong positive correlation with functional independence (Barthel Index; $r^2 = 0.734$, $P < 0.05$), cognitive assessment (MoCA; $r^2 = 0.650$, $P < 0.05$), and functional performance (SPPB; $r^2 = 0.619$, $P < 0.05$). Additionally, it showed a strong negative correlation with clinical dementia rating (CDR; $r^2 = -0.671$, $P < 0.05$). Similarly, the PNI was positively correlated with cognitive assessment (MoCA; $r^2 = 0.417$, $P < 0.05$), functional independence (Barthel Index; $r^2 = 0.364$, $P < 0.05$), and functional performance (SPPB; $r^2 = 0.364$, $P < 0.05$) (Table 3).

When discriminating by gender, we identified that both the positive and negative correlations between the MNA and functional independence (Barthel Index; $r^2 = 0.712$ vs. 0.675), cognitive assessment (MoCA; $r^2 = 0.643$ vs. 0.421), clinical dementia rating (CDR; $r^2 = -0.651$ vs. -0.599), and other health-related outcomes were stronger for women compared to men (Table 4).

By establishing two nutritional status phenotypes—nutritional vulnerability (malnourished + at risk of malnutrition) and good nutritional status— nutritional vulnerability was linked to inadequate physical performance ($P < 0.001$), frailty ($P = 0.002$), sarcopenia ($P < 0.001$), severe dementia ($P <$

Table 2
Nutritional characteristics of the population studied (N=139)

Variable	n	%
Food intake over the past 3 months		
Severe decrease in food intake	23	17
Moderate decrease in food intake	35	25
No decrease in food intake	81	58
Weight loss during the last 3 months		
Weight loss greater than 3 kg	27	19
Does not know	33	24
Weight loss between 1 and 3 kg	26	19
No weight loss	53	38
Body Mass Index		
BMI less than 19	75	56
BMI 19 to less than 21	19	14
BMI 21 to less than 23	25	19
BMI 23 or greater	16	12
Full meals consumed by the patient eat daily		
1 meal	5	4
2 meals	13	9
3 meals	121	87
At least one serving of dairy products per day	76	55
Two or more servings of legumes or eggs per week	125	90
Meat, fish or poultry every day	129	93
MAC		
MAC less than 21	41	29
MAC 21 to 22	18	13
MAC greater than 22	80	58
CC		
CC less than 31	106	76
CC 31 or greater	33	24
Nutritional status		
Malnourished	50	36
At-risk of malnutrition	66	47
Normal nutritional status	23	17
Nutritional supplement intake	54	41
PNI		
High	46/99	46
Low	53/99	54

CC: Calf circumference; MAC: Mid-arm circumference.

Table 3
Correlations between nutritional status and main clinical, functional, and biochemical variables in centenarians (N=139)

Variable	MNA	PNI
QoL (WHOQOL-AGE)	0.491 ^a	0.217
Functional performance (SPPB)	0.619 ^a	0.364 ^a
Cognitive assessment (MoCA)	0.650 ^a	0.417 ^a
Mini mental status (MMSE)	0.552 ^a	0.321
Clinical Dementia Rating (CDR)	-0.671 ^a	-0.311
Depression (GDS-15)	-0.411 ^a	-0.058
Frailty (Fried scale)	-0.434 ^a	-0.210
Functional independence (Barthel Index)	0.734 ^a	0.364 ^a
BMI	0.498 ^a	0.106
Calf circumference	0.537 ^a	0.093
Mid-arm circumference	0.494 ^a	0.025
Deltoid circumference	0.539 ^a	-0.028
Grip strength	0.488 ^a	0.294
Hematocrit	0.078	0.347 ^a
Albumin	0.285	0.998 ^a
Albumin fraction	0.302	0.521 ^a
BUN	0.174	0.399 ^a
Testosterone	0.349 ^a	0.344

BMI: Body Mass Index; BUN: Blood Urea Nitrogen.

^a <0.05 after Bonferroni's correction.

Table 4
Correlations between nutritional status and main clinical, functional, and biochemical variables by gender in centenarians (N=139)

Variable	MNA		PNI	
	Men	Women	Men	Women
Cognitive assessment (MoCA)	0.421	0.643 ^a	0.356	0.275
Mini mental status (MMSE)	0.410	0.470 ^a	0.395	0.216
Clinical Dementia Rating (CDR)	-0.599 ^a	-0.651 ^a	-0.417	-0.225
Depression (GDS-15)	-0.401	-0.434 ^a	-0.030	-0.048
Functional independence (Barthel Index)	0.675 ^a	0.712 ^a	0.414	0.301
BMI	0.479	0.474 ^a	0.167	0.099
Heel-to-knee height	0.360	0.423 ^a	0.333	0.236
Mid-arm circumference	0.554 ^a	0.442	0.277	0.052
Deltoid circumference	0.562 ^a	0.503 ^a	0.070	0.042
Grip strength	0.487 ^a	0.580 ^a	-0.073	-0.000
Hematocrit	0.075	0.084	0.131	0.439 ^a
Albumin	0.351	0.257	0.996 ^a	0.998 ^a
Testosterone	-0.296	0.354	-0.076	0.268 ^a

BMI: Body Mass Index.

^a $P < 0.05$, after Bonferroni's correction.

0.001), some degree of dependency ($P < 0.001$), low PNI ($P = 0.004$), and not using dental prostheses ($P = 0.0016$). Additionally, severe dementia was found to be significantly associated with a low PNI value ($P = 0.0112$) (Table 5).

The complete and detailed description of the evaluated domains can be found in the tables of the supplementary material (Tables S1–S5).

Discussion

Nutrition is a key element in the regulation of health and disease in humans [31,32]. Studies in nutrigenomics identified nutrition's role in the complex regulation of metabolic processes and the microbiome, with direct implications for disease prevention [31,33,34]. These findings show that

Table 5

Associations between nutritional status, specific characteristics, and health-related outcomes

Variable	MNA (N=139)			PNI (N=99)		
	Nutritional vulnerability ^a	Good nutrition	P-value	Low	High	P-value
Functional performance (SPPB)						
Inadequate performance	106	12	<0.001 ^b	47	37	0.3898
Adequate performance	8	11		6	9	
Frailty						
Fit	1	2	0.002 ^b	1	2	0.0801
Pre-frail	19	10		9	15	
Frail	90	10		43	29	
Sarcopenia						
No	23	15	<0.001 ^b	13	17	0.2615
Yes	93	8		40	29	
Mini mental status (MMSE)						
Normal (26–30)	79	7	<0.001 ^b			0.0074
Cognitive impaired (≤24)	19	13		8	19	
	79	7		42	25	
CDR						
No dementia	7	6	<0.001 ^b	3	7	0.0112
Questionable dementia	9	9		4	12	
Mild dementia	7	2		5	3	
Moderate dementia	14	3		6	7	
Severe dementia	71	2		35	16	
PNI						
Low (<38.5)	49	4	0.004 ^b	–	–	–
High (≥38.5)	32	14		–	–	
Functional independence (Barthel Index)						
Independence	8	10	<0.001 ^b	5	10	0.1008
Some degree of dependence	107	13		48	36	
Downton						
Low	42	15	0.019	20	23	0.3056
High	73	8		33	23	
Use of dental prosthesis						
No	65	4	0.0016 ^b	31	23	0.4247
Yes	51	19		22	23	

CDR: Clinical Dementia Rating; MNA: Mini Nutritional Assessment; PNI: Prognostic Nutritional Index; SPPB: Short Physical Performance Battery.

^a Nutritional vulnerability [malnourished + at risk of malnutrition].

^b $P < 0.05$, after Bonferroni's correction.

nutrients, phytochemicals, and microRNAs are absorbed through diet and digestion, contributing to the development of the microbiome, which, in turn, influences epigenomic regulation and gene expression [33]. These processes regulate appetite, inflammation, immunity, and metabolism [33]. This intricate relationship between diet and biological factors is essential for shaping the aging phenotype, which is directly related to extreme longevity [34]. From a clinical perspective, it is crucial to understand the dietary characteristics and variables most strongly associated with the nutritional status of centenarians to establish valid and effective evidence-based interventions.

In this study, it was found that 47% of the population was at nutritional risk, followed by 36% experiencing malnutrition, despite 58% reporting no reduction in food intake, 62% reporting no weight loss or being unaware of it, 87% consuming three full meals a day, and 91% having an adequate or regular protein intake. However, it must be noted that 67% of the centenarians had no formal education, 87% lived in households with up to one minimum monthly wage, 80% belonged to a low or very low socioeconomic status, and 76% reported serious difficulties in meeting basic needs. This suggest that, despite no reduction in food intake, the quality of the diet may be poor due to a lack of food security and freedom [35]. Therefore, it would be important to identify the specific dietary characteristics to assess centenarians' nutritional intake.

Similarly, the missing teeth (64% vs. 79% for lower and upper teeth, respectively) and the fact that only 50% of those without teeth use dental prostheses likely have a significant impact on chewing

quality and, consequently, on overall eating behavior. More than 50% of centenarians have a body mass index of less than 19 kg/m²; however, the centenarians (or their families) perceive themselves as having no nutritional issues. This perception may be influenced by the widespread belief in the irreversible decline or deterioration of long-lived individuals and the lack of awareness about the potential for recovery of intrinsic capacity and functional capacity [36]. This could result in an overestimation of the centenarian's health status, while, in fact, they are in a nutritional vulnerability state that requires intervention by healthcare providers.

Nutritional variables we studied directly influence functional independence, physical performance, cognitive status, and quality of life. Nutritional status was negatively correlated with depression and frailty. These findings indicate that nutritional status is directly associated with the overall health phenotype of the centenarian and all related domains. Longitudinal studies have previously demonstrated this long-term association in centenarians. However, the specific nutritional variables that most significantly contribute to survival outcomes remain insufficiently understood [37].

In most domains, the correlations were stronger among female centenarians compared to males. However, there were some slight variations in the correlations between genders. Females predominated in this cohort so that this trend may reflect differences between the two groups. Some anthropometric measures, such as grip strength and deltoid circumference, showed consistent patterns regardless of gender distribution. This serves as a reference to infer that muscle mass is directly correlated with nutritional status [38] and with the overall health status of centenarians.

This trend is more pronounced with the MNA compared to the PNI. Although the PNI has been associated with inflammatory status, potentially linked to the nutritional state, it was found that hematocrit, albumin, and blood urea nitrogen had the strongest and most significant correlations. This contrasts with previous research, which suggested that ferritin and C-reactive protein could be blood markers of inflammation in centenarians [39]. Inflammaging could not be a predominant sub-phenotype in this Colombian cohort of centenarians.

In this context, centenarians with nutritional vulnerability are expected to experience negative impacts on their health phenotype, including reduced brain health, loss of functional independence and autonomy, diminished physical performance, and neuropsychiatric instability. Therefore, strengthening nutritional status should be considered a key target in the healthcare of centenarians. This should be accompanied by the implementation of interventions aimed at rehabilitating the nutritional status of centenarians to promote a healthy lifespan and functionality in this population. Dietary diversity [40] and the long-term association of nutritional status [41], as well as their medical intervention, represent significant gaps of interest for future research on the nutrition of this population.

Opportunities and limitations

This is a novel study from a geographic area characterized by racial and cultural mixing [42]. The identification and recruitment of centenarians present significant challenges including ageism and healthcare access [43,44]. According to the National Administrative Department of Statistics (DANE - <https://tinyurl.com/msn9wre3>), in 2023, it was estimated that there were 19,400 centenarians in Colombia. As part of an ongoing study on Colombian centenarians, 139 individuals were included in this analysis. We acknowledge that no sample size was previously defined. However, the study ensured that both the sample size was adequate, and the statistical methods were correctly applied allowing to produce reliable results, ultimately leading to accurate conclusions that can inform and suggest practice, policy, and further research.

The study indicates the effects of nutritional status of centenarians on health-related outcomes and clinical variables, providing valuable information for subsequent analyses. The shortcomings of this manuscript are acknowledged. It should be mentioned the bias from the non-specificity of existing diagnoses in the medical records derived from the centenarians' regular health care by their health insurance company, which could confound the actual prevalences of chronic diseases. The cross-sectional design and the lack of a full dietary assessment may be considered as a limitation. However, the MNA is an important tool in research on extreme longevity because of its ability to fully measure nutritional status, predictive validity for health outcomes, and usefulness in leading interventions to improve the quality of life for older persons.

Conclusion

This study identified that the nutritional status and phenotype in centenarians are associated with functional and cognitive status, physical performance, use of dental prostheses, and specific biochemical and anthropometric variables. Some of these associations tend to be stronger depending on the centenarian's gender. These findings are relevant for decision-making in general and specialized healthcare and for prescribing clinical interventions in centenarian populations.

Author contributions

IDLM and JMA contributed to the conception and design of the study. IDLM, SCT, JCS and JMA carried out data collection and data cleaning. IDLM, JCS and JMA performed the statistical analyses and were involved in data organization and presentation. IDLM, LVM, JCS, and JMA drafted the manuscript. IDLM, LVM, SCT, JCS and JMA critically reviewed the manuscript with suggestions for improvement and revision. All authors read and approved the final version.

Availability of data and materials

The dataset generated and analyzed is available and provided on request.

Ethics approval and consent to participate

This study was performed in compliance with Act 008430/1993 of the Ministry of Health of the Republic of Colombia, which classified it as minimal-risk research. The institutional review board of Universidad de la Costa approved the study design.

Consent for publication

Not applicable.

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Declaration of competing interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.nutos.2025.01.010>.

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