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Food consumption is associated with frailty in edentulous older adults: evidence from the ELSI-Brazil study

Consumo alimentar está associado à fragilidade em adultos mais velhos edêntulos: evidências do estudo ELSI-Brasil

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Abstract *This cross-sectional study aimed to evaluate the association between food consumption (meat, fish, and fruits and vegetables), anthropometric indicators (body mass index, waist circumference, and waist-to-height ratio), and frailty; and to verify whether these associations vary with edentulism. We used data from 8,629 participants of the Brazilian Longitudinal Study of Aging (ELSI-Brazil) (2015-16). Frailty was defined by unintentional weight loss, weakness, slow walking speed, exhaustion, and low physical activity. Statistical analyses included multinomial logistic regression. Of the participants, 9% were frail and 54% pre-frail. Non-regular meat consumption was positively associated with pre-frailty and frailty. Non-regular fish consumption, and underweight were associated only with frailty. Models with interactions reveled a marginal interaction between meat consumption and edentulism (p-value = 0.051). After stratification, non-regular meat consumption remained associated with frailty only in edentulous individuals (OR = 1.97; 95%CI 1.27-3.04). Our results highlight the importance of nutritional assessment, oral health, and public health-promoting policies to avoid, delay and/or reverse frailty in older adults.*

Key words *Anthropometry, Eating, Frailty*

Resumo *Este estudo transversal teve como objetivo avaliar a associação entre consumo alimentar (carnes, peixe e frutas e hortaliças), indicadores antropométricos (índice de massa corporal, circunferência da cintura e relação cintura/estatura) e fragilidade; e verificar se essas associações variam com o edentulismo. Usamos dados de 8.629 participantes do Estudo Longitudinal da Saúde dos Idosos Brasileiros (ELSI-Brasil) (2015-16). A fragilidade foi definida por perda de peso não intencional, fraqueza, baixa velocidade da marcha, exaustão e baixa atividade física. As análises estatísticas incluíram regressão logística multinomial. Dos participantes, 9% eram frágeis e 54% pré-frágeis. O consumo não regular de carnes foi positivamente associado à pré-fragilidade e fragilidade. O consumo não regular de peixe e o baixo peso foram associados apenas à fragilidade. Modelos com interações revelaram uma interação marginal entre consumo de carnes e edentulismo (p-valor = 0,051). Após estratificação, o consumo não regular de carnes permaneceu associado à fragilidade apenas em indivíduos edêntulos (OR = 1,97; IC95% 1,27-3,04). Nossos resultados destacam a importância da avaliação nutricional, saúde bucal e políticas públicas de promoção da saúde para evitar, retardar e/ou reverter a fragilidade em adultos mais velhos.*

Palavras-chave *Antropometria, Consumo alimentar, Fragilidade*

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Introduction

Frailty is defined as a biologic syndrome of decreased reserve and resistance to stressors derived from cumulative declines in physiologic systems that might increase adverse outcomes[1]. As a multidimensional biologic syndrome, frailty involves the interaction of physiological, nutritional, psychological, cognitive, and social factors[2]. However, it is commonly assessed through physical components named frailty phenotype, including unintentional weight loss, weakness, slow walking speed, self-reported exhaustion, and low physical activity[1]. Considering the nutritional status, the association with frailty is probably bidirectional, either deriving[3] or leading to inadequate food consumption. Indeed, food and nutritional intake depend on intrinsic and extrinsic factors. Within the intrinsic factors, we highlight the edentulism, i.e., the state of being without natural teeth, a high-prevalent oral health problem leading to a poorer eating ability that might cause frailty in older adults[4-6].

A balanced diet pattern is fundamental to delay frailty onset among older adults[7]. It includes adequate energy, protein, and other nutrient intakes, associated with a wide range of food groups and low fast-food consumption. Regarding protein intake, the beneficial effect on frailty might be linked to maintaining muscle mass and preventing sarcopenia during the aging process[8]. However, the literature reports contradictory results regarding the role of either energy or protein intake on frailty[9]. Recently published international works have suggested that total protein intake and protein source are crucial for preventing frailty[10,11]. Proteins from animal sources, such as meat, eggs, and dairy, have shown stronger associations with frailty[10] since they present a higher quantity of essential amino acids (i.e., leucine) linked to the muscle protein anabolism in older adults[11].

Findings from a previous study showed that dietary patterns with elevated protein intake, including higher fish consumption, were associated with a lower frailty prevalence[12]. Fish consumption has been recommending as part of a healthier dietary because it is a protein source, omega-3 Poly-unsaturated Fatty Acids (PUFAs), suggesting a protective effect on frailty[13]. Moreover, omega-3 PUFAs intake has the potential to prevent both muscle mass and strength losses, considering its anti-inflammatory effects[14].

A systematic review showed consistent evidence that a high-quality general dietary pattern is inversely associated with the frailty risk[15]. This effect might be mediated by an elevated fruit and vegetable intake, supported by recent results from cohort studies demonstrating a protective effect on frailty onset[16,17]. Fruit and vegetable intake might decrease frailty risk due to different mechanisms. They are important sources of dietary fibers, micronutrients, and antioxidants[18] negatively associated with frailty[17]. Moreover, fruit and vegetable intake stimulate the immunologic system[19] and decreases inflammatory response[20], both described as linked to frailty among older adults[21].

The nutritional status goes beyond the food consumption indicators and also includes the anthropometric indicators. The adequate anthropometric indicators have been described as protective against frailty due to their link with sarcopenia[22]. Cross-sectional studies have shown a U-shaped association of Body Mass Index (BMI) with frailty in older adults[23,24], in which both low and high BMI increases frailty risk. Even though suitable BMI varies across these studies, their findings highlight the importance of keeping adequate BMI to decrease frailty prevalence. Nevertheless, considering BMI limitations on sensitivity and distinction of body composition, other studies also investigated waist circumference and its association with frailty. These studies evidenced an association between frailty and elevated waist circumference[25,26].

In Brazil, a population-based study named Frailty in Brazilian Older People Study (in Portuguese, FIBRA) demonstrated a significantly higher prevalence of frailty among older adults with low BMI and elevated waist circumference[26]. Despite being a multicenter and representative study of the older adult population from seventeen cities, it is not nationally representative. Therefore, nationally representative studies are needed to a broader comprehension of nutritional status on frailty. According to data from the Brazilian Longitudinal Study of Aging (ELSI-Brazil), frailty prevalence was 9% in older adults and increased with age, summing nearly 21% among those aged 70 years and over[27].

Thus, the aims of the current study were: (1) to evaluate the association between the food consumption indicators (meat, fish, and fruits and vegetables consumption) and frailty; (2) to evaluate the association between anthropometric indicators (BMI, waist circumference, and waist-to-height ratio) and frailty; and (3) to assess whether the association of food consumption indicators with frailty vary with edentulism. For

these purposes, we used a nationally representative sample of older Brazilian adults derived from the ELSI-Brazil.

Methods

Study design and population

This cross-sectional study included baseline data of the ELSI-Brazil, conducted in 2015-16. ELSI-Brazil is a nationally representative, population-based longitudinal study of 9,412 community-dwelling older adults aged 50 years and over from 70 municipalities of the five great regions in Brazil. The ELSI-Brazil sampling used a design with selection stages, combining stratification of primary sampling units (municipalities), census tracts, and households. All older adults aged 50 years and over residents in the selected households were eligible for interview, including 328 participants who needed a proxy. Further details of sampling design and procedures are described elsewhere[28].

ELSI-Brazil followed the standards set by the Declaration of Helsinki and was approved by the ethics board of the Oswaldo Cruz Foundation, Minas Gerais (protocol 34649814.3.0000.5091). All participants signed an informed consent form.

Study variables

Frailty

Frailty was defined according to the number of positive components of the frailty phenotype[1]. Each component was assessed as follows[27]: (1) unintentional weight loss, assessed through self-reported unintentional weight loss higher than > 4.5 kg in the past three months; (2) weakness, directly assessed through the best of three grip strength measures obtained in the dominant hand, using a hand dynamometer. Weakness was defined according to the lowest quintile, after adjusting for sex and BMI quartiles, being bedridden during the interview, and the inability to perform the test (i.e., those who tried but were not able to complete the test); (3) slow walking speed, directly assessed through the 3-meter timed walk test (in seconds), considering the best of two attempts. Slow walking speed was defined according to the highest quintile of time, stratified by sex, height, and the inability to perform the test[29]; (4) self-reported exhaustion, assessed through two questions from the *Center for Epidemiological Studies* (CES-D): "How often in the last week did you feel that everything did was an effort?" and "How often in the last week did you feel that could not get going?"[30]. Exhaustion was defined when reporting frequencies greater than 3-4 days in at least one question; and (5) low physical activity, calculated through a physical activity score considering the metabolic equivalents per week in kilocalories (kcal) based on the short-form of the *International Physical Activity Questionaire* (IPAQ) [31]. Low physical activity was defined according to the lowest quintile, stratified by sex.

The dependent variable was categorized into "frailty" when the participant showed three or more positive components, "pre-frailty" when the participant showed one or two, and "non-frailty" when the participant did not show any positive component of the frailty phenotype[1].

Food consumption indicators

Consumption was assessed according to the following food consumption indicators: (1) meat consumption, considering regular consumption as eating red (beef, pork, lamb) or white (poultry) meats in five or more days per week[32]; (2) fish consumption, considering regular consumption as eating fish in one or two days per week[33]; and (3) fruit and vegetable consumption, considering regular consumption as eating fruits or vegetables in five or more days per week, excluding fruit juice[32].

Anthropometric indicators

Anthropometric indicators included BMI, waist circumference, and waist-to-height ratio:

- BMI: calculated dividing weight in kilograms by height in meters squared (kg/m^2). Weight and height were objectively measured using standard protocols. The participants were asked to wear soft clothes, be barefoot, and remove all accessories and objects from their pockets. Both feet were positioned on a calibrated portable digital scale platform, brand Seca, model 813, equally distributing their weight on both feet, maintaining the arms extended along the body side, and looking at a horizontal line. Height was measured by a portable vertical stadiometer of the brand Nutri-Vida, without shoes and in the stand position. The interviewer placed the interviewee's head in the Frankfurt plane to record the measure. BMI cutoffs were according to the participant's age. For those aged up to 60 years, "underweight" (< 18.5 kg/m^2), "adequate weight" (18.5 to 24.9 kg/m^2), and "overweight" (> 24.9 kg/m^2) groups were based on the World

Health Organization (WHO)'s criteria[34]. For those aged 60 years and over, "underweight" (< 22.0 kg/m^2), "adequate weight" (22.0 to 27.0 kg/m^2), and "overweight" (> 27.0 kg/m^2) groups were based on the Lipschitz's criteria[35].

- Waist circumference: measured with an inextensible metric tape, brand Seca, positioned at the midpoint between the 10th rib and iliac crest with the participant standing, barefoot, feet apart, arms alongside the body, with the raised shirt, and during the expiratory phase. Among those aged up to 60 years, waist circumference was dichotomized as recommended by WHO[34], in "adequate" (< 80 cm for women and < 94 cm for men) or "elevated" (≥ 80 cm for women and ≥ 94 cm for men). For those aged 60 years and over, we used a recent cutoff reported for the older Brazilian adults: "adequate" (< 88.7 cm for women and < 96 cm for men) or "elevated" (≥ 88.7 cm for women and ≥ 96 cm for men)[36].

- Waist-to-height ratio: obtained by dividing the measured waist circumference (centimeters) by the measured height (centimeters) and further dichotomized into "adequate" (< 0.5) or "elevated" (≥ 0.5), for those aged up to 60 years[37] and dichotomized into "adequate" (< 0.58) or "elevated" (≥ 0.58) for those aged 60 years and over[36].

Anthropometric measures were performed twice, using the mean of both measures. Further details about procedures and protocols can be consulted at "Interview Handbook" from ELSI-Brazil[38] (available at the ELSI-Brazil homepage: http://elsi.cpqrr.fiocruz.br/en/).

Edentulism

Edentulism was defined as the absence of any natural teeth ("no" or "yes"), collected using the following self-reported question: "How many teeth do you have?".

Potential confounding variables

Potential confounding variables were based on statistically variables associated with frailty in previously published studies[16,27,39]:

- *Sociodemographic characteristics*: sex (female or male); years of age ("50-59", "60-69", "70-79", or "80 years and over"); marital status (living with a partner or not, i.e. single, widowed or divorced); education, considering the complete years of schooling ("< 8", "8-11" or "≥ 12"); and household income *per capita*, based on the total monthly gross household income divided by the number of residents, categorized into terciles, from the poorest to the richest[40].

- *Health-related characteristics:* current smoking status investigated through the question "Do you currently smoke?" ("no" or "yes", i.e., whether the individual positively answered the question, independently of the number of smoking cigarettes and the duration of the smoking habit); self-rated health ("excellent/very good or good", "fair", or "bad/very bad"); the number of chronic conditions diagnosed by a physician based on self-report, including hypertension, diabetes, depression, cancer, arthritis or rheumatism, high cholesterol, stroke, and cardiovascular disease ("none", "one" or "two or more"); and activity limitations, measured by participants' self-reports of any difficulty to carry out at least one out of six basic Activities of Daily Living (ADLs), including walking in the same floor, transferring, toileting, bathing, dressing, and eating [41] ("no" or "yes").

Statistical analyses

Initially, we described differences in the variables' distribution according to frailty using the Pearson chi-square test with Rao-Scott correction. We used multinomial logistic regression to estimate odds ratio (OR) and their 95% confidence intervals (95%CI) to examine the strength of the association between the independent variables (food consumption indicators [meat, fish, and fruit and vegetable consumption], and anthropometric indicators [BMI, waist circumference, and waist-to-height ratio]) and frailty, using the non-frailty category as the reference. Adjusted multivariate analysis was performed separately for each of the three anthropometric indicators because of collinearity, including all food consumption indicators in each model. We made the adjustments in the sequential models as follows: (1) sociodemographic characteristics (Model 1); (2) health-related characteristics (Model 2) and, finally, (3) Models 1 and 2 together (fully adjusted model – Model 3). We also tested the interaction of edentulism with the food consumption indicators previously associated with frailty in Model 3 and plotted the results in charts.

All analyses were performed using STATA software (Stata Corp., College Station, United States), version 14.0, using the svy command, which allows us to consider the complex design and surveys weights. The significant level was set at 5%.

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Results

Of the 9,412 ELSI-Brazil participants, 8,629 had complete information on frailty and were included in the current analyses. Those included mainly were female (53.7%), with a mean age of 62.2 years (± 9.6). They tended to be younger and showed a lower prevalence of low-educated ($p < 0.05$) than those excluded. The prevalence of frailty was 9.1%, pre-frailty was 53.5%, and non-frailty was 37.4%. Non-regular meat and fruit and vegetable consumption were reported by 23.9% and 20% of the participants, respectively. More than half participants (55.6%) have non-regular fish consumption. Regarding anthropometric indicators, 7.4% of the participants had underweight, and 61.3% were overweight, according to BMI. Prevalence rates of elevated waist circumference and waist-to-height ratio were 62.6% and 70.2%, respectively. The characteristics with significant different distribution across frailty categories were: meat consumption, fish consumption, fruit and vegetable consumption, BMI, waist circumference, waist-to-height ratio, sex, age, marital status, education, per capita household income, self-rated health, number of chronic conditions, activity limitations, and edentulism. Table 1 shows these descriptive results.

Considering that the estimates in the fully adjusted models were similar when entering the anthropometric indicators (BMI, waist circumference, and waist-to-height ratio), the results from models with BMI, the most commonly used anthropometric indicator, were shown separately in Table 2. The results from models of the association between frailty and nutritional status adjusted and for waist circumference and waist-to-height ratio were presented in Table 3. According to Table 2, after adjustments, pre-frail were more likely to non-regularly consume meat (OR = 1.22, 95%CI 1.03-1.44) than non-frail participants, as well as frail older adults (OR = 1.44, 95%CI 1.10-1.89). Also, frail older adults were more likely to show non-regular fish consumption (OR = 1.38, 95%CI 1.11-1.72) and being underweighted (OR = 1.74, 95%CI 1.17-2.58) than non-frail older adults.

Additionally, we fitted models with the interaction terms between food consumption indicators previously associated with frailty in Model 3 (meat and fish consumption) and edentulism, finding a marginal interaction between meat consumption and edentulism (p-value = 0.051). After splitting the odds of frailty by categories of edentulism, we found that non-regular meat consumption remained positively associated with frailty only among those who were edentulous (OR = 1.97; 95%CI 1.27-3.04) (data not shown). As plotted in Figure 1 (A), it means that the probability of frailty increased from 7.5% (95%CI 6.2-8.9%) in those with regular meat consumption to 10.3% (95%CI 7.4-13.2%) in those with non-regular meat consumption, while the probability of frailty remained around 8% among non-edentulous, independently of meat consumption. The different pattern among edentulous and non-edentulous was not observed for fish consumption (B).

Discussion

Our results showed a prevalence of frailty and pre-frailty of 9.1% and 53.5%, respectively, among older Brazilian adults. After adjustments, pre-frailty was associated with meat consumption, whereas frailty was associated with meat and fish consumption and being underweight. Models considering interaction terms reveled that non-regular meat consumption increased the odds of frailty only among those who were edentulous, despite their marginal statistical association.

Studies encompassing the role of food consumption on frailty show that some food and nutrient consumptions, including protein and overall diet quality, are essential to avoid this syndrome[7,15,42]. In the current study, meat consumption was associated with frailty, and pre-frailty, corroborating longitudinal studies[7,15,42]. Overall, meat is a good protein source, which is fundamental to muscle mass anabolism and maintenance[11], and carries out a diversity of functions: structural, enzymatic, hormonal, protection, and transportation. Moreover, meat is a lipid and complex B vitamins source. Lipides, along with proteins, contribute to achieving an adequate energy intake[42]. Complex B vitamins, mainly vitamin B_{12} or cyanocobalamin, acting as a central nervous system metabolism cofactor. Lower vitamin B_{12} may cause motor and sensorial impairments, weakness, numbness in the distal limb, balance problems, and gait ataxia[43].

However, our results demonstrated that non-regular meat consumption was statistically associated with frailty only when having edentulism, corroborating the evidence of a poor nutrition pathway between worse oral health and frailty, although increasing edentulism with age in our sample (from 15.3% of the participants aged

Table 1. Distribution of participants' characteristics according to frailty. Brazilian Longitudinal Study of Aging (ELSI-Brazil), 2015-2016.

Variable	Total %	Non-frailty %	Pre-frailty %	Frailty %	p-value *
Food consumption indicators					
Non-regular meat consumption	23.9	19.7	26.0	29.5	< 0.001
Non-regular fish consumption	55.6	53.5	55.8	62.9	0.002
Non-regular fruit and vegetable consumption	20.0	16.5	21.8	23.9	< 0.001
Anthropometric indicators					
Body mass index [1]					< 0.001
Adequate weight	31.3	31.2	31.3	32.3	
Underweight	7.4	5.6	7.4	15.5	
Overweight	61.3	63.2	61.3	52.2	
Elevated waist circumference	62,6	62.5	63.6	56.4	0.007
Elevated waist-to-height ratio	70,2	70.4	71.3	62.2	0.001
Sociodemographic characteristics					
Sex female	53.7	50.8	55.3	56.2	0.007
Age					< 0.001
50-59	48.3	55.7	47.3	23.7	
60-69	29.9	31.0	29.6	27.1	
70-79	15.4	11.3	16.3	26.6	
80 years and over	6.4	2.0	6.8	22.6	
Living with a partner	64.9	69.7	63.2	56.1	< 0.001
Education (years)					< 0.001
< 8	63.6	54.0	67.3	81.3	
8-11	28.2	34.7	25.7	16.6	
≥ 12	8.2	11.3	7.0	2.1	
Per capita household income					< 0.001
1st tertile (poorest)	31.6	26.8	33.7	39.0	
2nd tertile	32.9	32.0	33.0	36.4	
3rd tertile (richest)	35.5	41.2	33.3	24.6	
Health-related characteristics					
Current smoking	17.0	16.0	17.6	17.8	0.235
Self-rated health					< 0.001
Excellent/very good or good	43.8	56.3	38.9	20.6	
Fair	44.8	39.4	48.5	45.4	
Bad/very bad	11.4	4.3	12.6	34.0	
Number of chronic conditions					< 0.001
None	18.2	23.1	16.1	10.3	
One	27.2	30.0	26.4	20.8	
Two or more	54.6	46.9	57.5	68.9	
Activity limitations	7.6	2.0	7.3	32.2	< 0.001
Edentulism	29.0	23.5	29.9	46.6	< 0.001
Total (n) [2]	8,629	3,117	4,655	857	

[1] Body mass index cutoffs: For those aged up to 60 years, "underweight" (< 18.5 kg/m^2), "adequate weight" (18.5 to 24.9 kg/m^2), and "overweight" (> 24.9 kg/m^2); For those aged 60 years and over, "underweight" (< 22.0 kg/m^2), "adequate weight" (22.0 to 27.0 kg/m^2), and "overweight" (> 27.0 kg/m^2). [2] Number of interviewees, not including corrections according to sampling parameters. * p-value based on the Pearson's chi-square test with Rao-Scott correction.

Source: Authors.

50-59 to 63.1% of those aged 80 years and over, data not shown). Edentulism is associated with overall lower consumption of essential and higher of ultra-processed food, independent of dental prosthesis use. These associations are probably explained by the poorer eating ability and mas-

Table 2. Results of the crude and fully adjusted models of the association of food consumption indicators and body mass index with pre-frailty and frailty. Brazilian Longitudinal Study of Aging (ELSI-Brazil), 2015-2016.

	Pre-frailty			
	Crude analysis OR (95%CI)	**Model 1 OR (95%CI)**	**Model 2 OR (95%CI)**	**Fully adjusted Model OR (95%CI)**
Food consumption indicators				
Meat consumption				
Regular	1.00	1.00	1.00	1.00
Non-regular	1.29 (1.09-1.52)*	1.26 (1.06-1.48)*	1.21 (1.02-1.42)*	1.22 (1.03-1.44)*
Fish consumption				
Regular	1.00	1.00	1.00	1.00
Non-regular	1.08 (0.95-1.22)	1.04 (0.92-1.19)	1.07 (0.95-1.20)	1.06 (0.94-1.20)
Fruit and vegetable consumption				
Regular	1.00	1.00	1.00	1.00
Non-regular	1.23 (1.02-1.49)*	1.20 (0.99-1.46)	1.18 (0.97-1.43)	1.17 (0.96-1.42)
Body mass index [1]				
Adequate weight	1.00	1.00	1.00	1.00
Underweight	1.32 (1.08-1.61)*	1.13 (0.92-1.38)	1.27 (1.03-1.56)*	1.11 (0.90-1.37)
Overweight	0.97 (0.87-1.09)	1.06 (0.94-1.20)	0.92 (0.81-1.04)	1.00 (0.89-1.13)
	Frailty			
Food consumption indicators				
Meat consumption				
Regular	1.00	1.00	1.00	1.00
Non-regular	1.60 (1.27-2.02)*	1.69 (1.31-2.18)*	1.30 (0.99-1.69)	1.44 (1.10-1.89)*
Fish consumption				
Regular	1.00	1.00	1.00	1.00
Non-regular	1.49 (1.20-1.84)*	1.36 (1.09-1.70)*	1.40 (1.14-1.73)*	1.38 (1.11-1.72)*
Fruit and vegetable consumption				
Regular	1.00	1.00	1.00	1.00
Non-regular	1.23 (0.92-1.65)	1.18 (0.86-1.61)	1.17 (0.85-1.61)	1.16 (0.81-1.65)
Body mass index [1]				
Adequate weight	1.00	1.00	1.00	1.00
Underweight	2.64 (1.94-3.59)*	1.71 (1.21-2.42)*	2.43 (1.69-3.49)*	1.74 (1.17-2.58)*
Overweight	0.81 (0.68-0.96)*	1.09 (0.91-1.30)	0.72 (0.60-0.86)*	0.97 (0.80-1.18)

Note: OR, Odds Ratio, based on the multinomial logistic regression models; 95%CI, 95% Confidence Interval.

[1] Body mass index cutoffs: For those aged up to 60 years, "underweight" (< 18.5 kg/m^2), "adequate weight" (18.5 to 24.9 kg/m^2), and "overweight" (> 24.9 kg/m^2); For those aged 60 years and over, "underweight" (< 22.0 kg/m^2), "adequate weight" (22.0 to 27.0 kg/m^2), and "overweight" (> 27.0 kg/m^2); * p-value <0.05. Model 1: adjusted for sociodemographic characteristics (including sex, age, marital status, education, and per capita household income). Model 2: adjusted for health-related characteristics (current smoking, self-rated health, number of chronic conditions, activity limitations, and edentulism). Fully adjusted Model: Model 1 + Model 2. Reference category: non-frailty. N total of the fully adjusted model: 8,131.

Source: Authors.

ticatory efficiency among edentulous individuals, difficulty the consumption of hard-to-crew foods such as meat[5]. Therefore, other easy-to-crew protein sources intake should be encouraged, such as beans, traditional in Brazilian cuisine, and the expansion of oral health teams among primary care.

In the current study, fish was measured separately from red and white meat. Fish is a vitamin D source and lower vitamin D concentration determines frailty onset within three years[44]. Moreover, most vitamin D sources are also rich in omega-3 PUFAs, an essential nutrient to reduce inflammation[14]. Thus, less fish consumption also raises frailty risk[45].

Despite prior evidences of higher fruit and vegetable consumption leading to a lower frail-

Table 3. Results of the crude and fully adjusted models of the association of food consumption indicators and anthropometric indicators (waist circumference and waist-to-height ratio) with pre-frailty and frailty. Brazilian Longitudinal Study of Aging (ELSI-Brazil), 2015-2016.

	Pre-frailty		Frailty	
	Crude analysis OR (95%CI)	Fully adjusted Model OR (95%CI)	Crude analysis OR (95%CI)	Fully adjusted Model OR (95%CI)
Food consumption indicators				
Meat consumption				
Regular	1.00	1.00	1.00	1.00
Non-regular	1.29 (1.09-1.52)*	1.22 (1.03-1.44)*	1.56 (1.23-1.99)*	1.41 (1.07-1.86)*
Fish consumption				
Regular	1.00	1.00	1.00	1.00
Non-regular	1.07 (0.94-1.22)	1.06 (0.94-1.20)	1.49 (1.20-1.84)*	1.40 (1.11-1.75)*
Fruit and vegetable consumption				
Regular	1.00	1.00	1.00	1.00
Non-regular	1.24 (1.03-1.50)*	1.17 (0.96-1.42)	1.25 (0.93-1.69)	1.17 (0.82-1.66)
Waist circumference				
Adequate	1.00	1.00	1.00	1.00
Elevated	1.07 (0.95-1.20)	1.05 (0.93-1.20)	0.80 (0.65-0.98)*	0.87 (0.68-1.11)
Food consumption indicators				
Meat consumption				
Regular	1.00	1.00	1.00	1.00
Non-regular	1.28 (1.09-1.51)*	1.22 (1.03-1.44)*	1.58 (1.25-2.00)*	1.42 (1.08-1.87)*
Fish consumption				
Regular	1.00	1.00	1.00	1.00
Non-regular	1.07 (0.94-1.22)	1.06 (0.94-1.20)	1.48 (1.19-1.83)*	1.39 (1.11-1.74)*
Fruit and vegetable consumption				
Regular	1.00	1.00	1.00	1.00
Non-regular	1.24 (1.03-1.50)*	1.17 (0.95-1.42)	1.26 (0.94-1.70)	1.17 (0.82-1.67)
Waist-to-height ratio				
Adequate	1.00	1.00	1.00	1.00
Elevated	1.05 (0.92-1.20)*	1.13 (0.97-1.30)	0.69 (0.55-0.87)*	0.95 (0.71-1.28)

Note: OR, Odds Ratio, based on the multinomial logistic regression models; 95%CI, 95% Confidence Interval.

* p-value < 0.05. Fully adjusted Model: Model 1 (adjusted for sociodemographic characteristics, including sex, age, marital status, education, and per capita household income) + Model 2 (adjusted for health-related characteristics, including current smoking, self-rated health, number of chronic conditions, activity limitations, and edentulism). Reference category: non-frailty. N total of the fully adjusted model: waist circumference = 8,130; waist-to-height ratio = 8,120.

Source: Authors.

ty risk[16,17], our findings do not demonstrate an association. These food groups include a wide range of vegetables with high nutrients content. They are energy, dietary fibers, vitamin A and C, minerals sources, and more recently described as antioxidants, phytoestrogens, and anti-inflammatory agents due to phytochemicals[18]. One hypothesis for the absence of an association with frailty in the ELSI-Brazil sample is the few years of education of older Brazilian adults: 63.6% of the participants have less than eight years of education. This group concentrates the higher prevalence of the non-regular fruit and vegetable consumption (76.6%) and has limited income resources (mean per capita household income of R$ 832.00 corresponding to 323 dollars at the beginning of 2015) to maintain a more appropriate food variety intake[46].

Historically, inadequate food ingestion was suggested as the initial part of the frailty development cycle in aging, because it contributes to malnutrition and weight loss[1]. Therefore, the relationship between malnutrition and frailty has been studying for years. Our results showed that

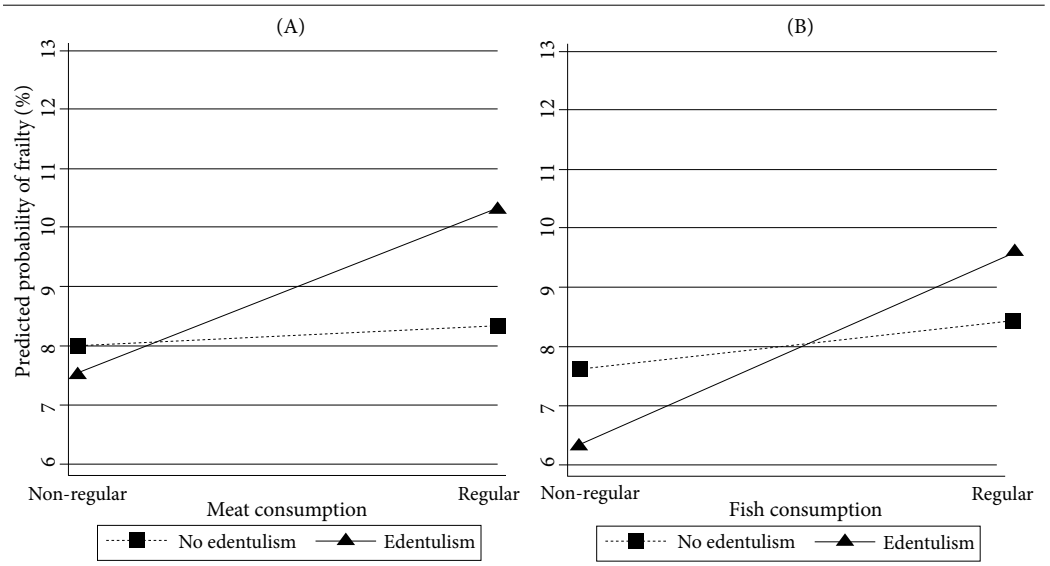

Figure 1. Predicted probability* of frailty according to food consumption indicators and edentulism: meat consumption (A) and fish consumption (B). Brazilian Longitudinal Study of Aging (ELSI-Brazil), 2015-2016.

* Estimated by multinomial logistic regression models, adjusted for sociodemographic characteristics, including sex, age, marital status, education, and per capita household income; health-related characteristics, including current smoking, self-rated health, number of chronic conditions, and activity limitations; and the interaction term with edentulism. Reference category: non-frailty. N total of the fully adjusted model: 8,129.

Source: Authors.

being underweight was associated with frailty. Underweight has been related with skeletal muscle mass decrease due to an imbalance between muscle protein degradation and synthesis related to sarcopenia, cachexia, and sedentarism. All those are described as frailty risk factors[47], including evidence in Brazilian studies[23,24,26].

On the other hand, although international and Brazilian growing evidence[23-26,48,49] have linked overweight to frailty, we did not observe this association in the current study, independently of the anthropometric indicator used (elevated BMI, elevated waist circumference, or elevated waist-to-height ratio). A 22-year follow-up study showed that middle-aged and obese adults were five times more likely to develop frailty than individuals with adequate weight[50]. Obesity has been associated with a wide range of inflammatory markers probably implicated in the genesis of frailty[51] and the decrease of anabolic hormones necessary to maintain physiologic systems' integrity and function[50]. Lower levels of anabolic hormones could lead to worse physical functioning and reduced muscle strength, contributing to frailty[52]. The absence of association in the current study might be partially explained by different cutoffs used in the above-mentioned studies. However, we also used waist circumference and waist-to-height ratio to measure overweight, which are described as more accurate abdominal obesity indicators in older ages[51]. Again, we did not find any association with frailty. Another explanation is that we did not use weight estimates among those participants whose objectively measured weight was not possible, such as bedridden participants. This approach might have excluded a higher proportion of frailty participants from the analysis. And finally, survival bias might occur in cross-sectional studies, once the probability of survival is lower among overweight and frail individuals.

Older-adult long-term care is a worldwide concern linked to aging due to common health problems at older ages, including frailty. Frail and pre-frail older adults tend to overload health care services and contribute to significant health costs' expansion. Therefore, efforts to enlarge independence and maintain adequate nutritional status are necessary. The association of underweight and non-regular meat consumption with frailty is highlighted from our results, which demand

multiprofessional health care in clinical practice. However, several gaps related to adequate nutritional status in older adults remain, and more researches are necessary. We suggest that researchers establish cutoffs for frailty components, such as weakness and slow walking speed, to facilitate their use in routine nutritional practice.

To the best of our knowledge, this was the first study encompassing an older-adult nationally representative sample in Brazil about nutritional status indicators and frailty. Our results highlight the comprehensiveness of care, in which oral health should be along with nutrition to improve health in aging. It permits the diagnosis of underweight and food consumption indicators inadequacies associated with frailty. Therefore, using a large nationally representative sample of older adults living in Brazil and including a methodological rigor, we premise that oral health interventions might improve nutritional status, and consequently avoid, delay or reverse frailty. Moreover, we included in our analyses participants who were unable to perform the objective tests to classify frailty as having the worst performance stead of missing data, to avoid differential losses in frailty group.

However, some limitations should be raised. First, the cross-sectional design precludes us from establishing causality between anthropometric/food consumption indicators/edentulism and frailty among older adults. Longitudinal studies concerning food consumption[15-17], and edentulism[4-6], corroborate the direction of our findings (i.e., these variables leading to frailty), although prior evidences of bidirectionality[3,53]. Second, the ELSI-Brazil also does not include any muscle mass indicator to include sarcopenia in the analyses. Third, the exclusion of older and low-educated older adults tended to attenuate the coefficients leading to non-observation of marginally associated variables.

Conclusion

Our results showed that non-regular meat and fish consumption and underweight were higher among frailty. However, non-regular meat consumption seems to increase the odds of frailty only among those who were edentulous. These results highlight the importance of the oral health and nutritional assessment in older adults to avoid, delay, and/or reverse frailty. Therefore, primary care strategies targeting food and nutrition education should be considered to promote healthier food consumption and to keep adequate weight across the life span, as well as expanding oral health teams.

Collaborations

MF Lima-Costa designed research; NTM Ygnatios, JL Torres, and MF Lima-Costa conducted research, analyzed data, wrote the paper, read and approved the final manuscript.

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