Research, Society and Development, v. 11, n. 11, e60111133129, 2022
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v11i11.33129

Association between ultra-processed foods frequency of intake and sarcopenia in older adults: a cross-sectional study

Associação entre frequência de consumo de alimentos ultra processados e sarcopenia em idosos: um estudo transversal

Asociación entre frecuencia de ingesta de alimentos ultraprocesados y sarcopenia en ancianos: un estudio transversal

Received: 07/19/2022 | Reviewed: 08/04/2022 | Accept: 08/05/2022 | Published: 08/15/2022

Hellen Cristina de Almeida
ORCID: https://orcid.org/0000-0003-3899-9158
Federal University of Jequitinhonha and Mucuri Valleys, Brazil
E-mail: hellen.nut@gmail.com
Vanessa Kelly da Silva Lage
ORCID: https://orcid.org/0000-0002-0381-5622
Federal University of Jequitinhonha and Mucuri Valleys, Brazil
E-mail: vanessakellysl@hotmail.com
Fabiana Angélica de Paula
ORCID: https://orcid.org/0000-0002-7146-0720
Federal University of Jequitinhonha and Mucuri Valleys, Brazil
E-mail: fabiana.paula@ufvjm.edu.br
Jaqueline de Paula Chaves Freitas
ORCID: https://orcid.org/0000-0002-2688-2676
Federal University of Jequitinhonha and Mucuri Valleys, Brazil
E-mail: jaquelinechavesjp@yahoo.com.br
Lauane Gomes Moreno
ORCID: https://orcid.org/0000-0003-4006-4466
Federal University of Jequitinhonha and Mucuri Valleys, Brazil
E-mail: lauanegomesmoreno@gmail.com
Vinícius Cunha De Oliveira
ORCID: https://orcid.org/0000-0002-8658-3774
Federal University of Jequitinhonha and Mucuri Valleys, Brazil
E-mail: vcunhaoliveira@gmail.com
Alessandra de Carvalho Bastone
ORCID: https://orcid.org/0000-0002-2414-3730
Federal University of Jequitinhonha and Mucuri Valleys, Brazil
E-mail: ale.bastone@gmail.com
Joyce Noelly Vitor Santos
ORCID: https://orcid.org/0000-0001-5244-9182
Federal University of Jequitinhonha and Mucuri Valleys, Brazil
E-mail: joyce_noelly@outlook.com
Liliana Pereira Lima
ORCID: https://orcid.org/0000-0002-6839-4363
Federal University of Jequitinhonha and Mucuri Valleys, Brazil
E-mail: liliplima@hotmail.com
Amanda Cristina Fernandes
ORCID: https://orcid.org/0000-0002-7896-5107
Federal University of Jequitinhonha and Mucuri Valleys, Brazil
E-mail: amandacristina40@gmail.com
Ana Cristina Rodrigues Lacerda
ORCID: https://orcid.org/0000-0001-5366-3754
Federal University of Jequitinhonha and Mucuri Valleys, Brazil
E-mail: lacerdaacr@gmail.com
Elizabethe Adriana Esteves
ORCID: https://orcid.org/0000-0003-1435-8364
Federal University of Jequitinhonha and Mucuri Valleys, Brazil
E-mail: elizabethe.esteves@ufvjm.edu.br
Vanessa Amaral Mendonça
ORCID: https://orcid.org/0000-0002-1696-6091
Federal University of Jequitinhonha and Mucuri Valleys, Brazil
E-mail: vaafisio@hotmail.com

Abstract
Ultra-processed foods (UP) are frequently associated with poor diet quality and lack many nutrients necessary for skeletal muscle health, which could contribute to developing sarcopenia. However, investigations about possible associations between the intake of UP and sarcopenia are missing. This study aimed to describe the magnitude of the exposition to UP (eating frequency) and compare it in older adults with and without sarcopenia. It also described associations between the magnitude of exposition of UP with body composition markers of sarcopenia in all subjects. It was a cross-sectional study with a sample of 118 community-dwelling older adults. Body composition was accessed by Dual-energy X-ray absorptiometry (DXA) and UP intake by a food frequency questionnaire (FFQ). All foods in the FFQ were categorized into two groups: (1) non-UP and (2) UP. SCORE I (mean score for food group 1) and SCORE II (mean score for food group 2) were calculated. The eating frequency of UP was near 3 to 4x/week and higher for sarcopenic subjects ($p<0.05$). Subjects consuming UP more than 1-2x/week were more likely to be sarcopenic than those consuming less than 1-2x/week. Therefore, sarcopenic subjects were more exposed to UP. In addition, even at a low exposition, the intake of UP increases the chances of developing sarcopenia in older adults.
Keywords: Ultra-processed foods; Aging; Sarcopenia; Muscle health; Eating frequency.

Resumo
Os alimentos ultra processados (UP) são frequentemente associados à má qualidade da dieta e deficientes em muitos nutrientes necessários para a saúde do músculo esquelético, o que pode contribuir para o desenvolvimento da sarcopenia. No entanto, faltam investigações sobre possíveis associações entre a ingestão de UP e sarcopenia. Este estudo teve como objetivo descrever a magnitude da exposição à UP (frequência de consumo) e compará-la em idosos com e sem sarcopenia. Também descreveu associações entre a magnitude da exposição aos UP com marcadores de composição corporal e da sarcopenia em todos os sujeitos. Foi um estudo transversal com amostra de 118 idosos. A composição corporal foi acessada por absorciometria de raios X de dupla energia (DXA) e a ingestão de UP por um questionário de frequência alimentar (QFA). Todos os alimentos do QFA foram categorizados em dois grupos: (1) não UP e (2) UP. O SCORE I (escore médio do grupo 1) e o SCORE II (escore médio do grupo 2) foram calculados. A frequência de consumo de UP foi próxima de 3 a 4x/semana e maior para os sarcopênicos ($p<0,05$). Indivíduos que consumiram UP mais de 1-2x/semana foram mais propensos a serem sarcopênicos do que aqueles que consumiram menos de 1-2x/semana. Portanto, os indivíduos sarcopênicos foram mais expostos aos UP. Além disso, mesmo em baixa exposição, a ingestão de UP aumentou as chances de desenvolver sarcopenia nos idosos.
Palavras-chave: Alimentos ultra processados; Envelhecimento; Sarcopenia; Saúde muscular; Frequência de consumo.

Resumen
Los alimentos ultraprocesados (UP) se asocian frecuentemente con una dieta de mala calidad y deficiente en varios nutrientes necesarios para la salud del músculo esquelético, lo que puede contribuir al desarrollo de sarcopenia. Todavia, faltan investigaciones sobre posibles asociaciones entre la ingesta de UP y la sarcopenia. Este estúdio pretende conocer la magnitud de la exposición a UP (frecuencia de alimentación) y compararla en ancianos con y sin sarcopenia. También describe asociaciones entre la magnitud de exposición de UP con marcadores de composición corporal y sarcopenia en todos los sujetos. Fue un estudio transversal con una muestra de 118 ancianos residentes en la comunidad. La composición corporal se evaluó mediante absorciometría de rayos X de energía dual (DXA) y la ingesta de UP mediante un cuestionario de frecuencia alimentaria (FFQ). Los alimentos del FFQ se clasificaron en dos grupos: (1) no UP y (2) UP. Se calcularon la PUNTUACIÓN I (puntuación media para el grupo de alimentos 1) y la PUNTUACIÓN II (puntuación media para el grupo de alimentos 2). La frecuencia de ingesta de UP fue cercana a 3 a 4x/semana y mayor para sarcopénicos ($p<0.05$). Los que consumían UP más de 1-2 veces por semana tenían más probabilidades de ser sarcopénicos que los que consumían menos de 1-2 veces por semana. Asim, los individuos sarcopénicos estuvieron más expuestos a UP. Además, incluso con una exposición baja, la ingesta de UP aumentó las posibilidades de desarrollar sarcopenia en ancianos.
Palabras clave: Alimentos ultraprocesados; Envejecimiento; Sarcopenia; Salud muscular; Frecuencia de alimentación.

1. Introduction

Over the last decade, interest has been growing in elucidating the role of food processing in human health (Marino et al., 2021). Food processing includes the transformation of raw or harvested *in natura* foods into new food products, ensuring safety, improving palatability, and increasing convenience, variety, and shelf-life (Welch & Mitchell, 2000). However, the demand for these food items has led to other natural or artificial ingredients being added to processed foods. In addition, they are often characterized by high sugar, fat, and salt contents, which impair the nutritional quality of these foods (Kearney, 2010).

In this context, in 2014, a Brazilian group of researchers proposed the NOVA classification, which categorizes foods into four main groups based on the extent and purpose of processing: (i) *unprocessed* and minimally processed foods such as seeds, fruits, leaves, stems, roots, milk, eggs, and meats; (ii) processed culinary ingredients such as butter, lard, oils, sugar, and salt; (iii) processed foods such as canned legumes or fish, typically produced by adding oil, salt, sugar, or other substances from group 2 to group 1, and using preservation methods such as canning and bottling; and (iv) ultra-processed foods (UP) (Monteiro et al., 2016). UP comprise formulations of ingredients, primarily for exclusive industrial use, produced through a several industrial processes that include the fractioning of whole foods into substances, the assembly of unmodified and modified food substances, and the use of cosmetic additives, frequently added to improve sensory characteristics of the final product. UP include, amongst others, carbonated soft drinks; sweet, fatty, or salty packaged snacks; candies; ice creams; pastries; margarine; and many others (Monteiro et al., 2019).

Although NOVA classification does not focus on the nutritional quality of foods, UP are nutritionally unbalanced, as they present high energy density due to excess fats and sugar, low fiber and micronutrient content, and excess salt (Brazil, 2014; Monteiro et al., 2016). Therefore, it has been postulated that dietary patterns based on UP may contribute to the burden of non-communicable diseases (NCDs) (Ludwig, 2011; Mertens et al., 2022). Emerging evidence from observational cross-sectional and cohort studies has identified positive associations between UP consumption and at least one adverse NCD outcome (Chen et al., 2020; Elizabeth et al., 2020), such as obesity (Elizabeth et al., 2020), type 2 diabetes (Srour et al., 2020), and a higher risk of cardiovascular disease (Srour et al., 2019) and all-cause mortality (Schnabel et al., 2019). Contrary to UP foods, the recurrent ingestion of unprocessed or minimally processed foods is associated with a more positive pattern of protein consumption, diet quality, and lower NCD risk (Salomé et al., 2021). Because of that, the gold rule proposed by the *Brazilian Food Guide* and NOVA classification is to make unprocessed/minimally processed foods the basis of the diet, reduce processed foods, and exclude ultra-processed foods (Brazil, 2014; Monteiro et al., 2016).

Currently, in many high-income countries such as the USA or UK, UP contribute more than half of dietary energy intake (Rauber et al., 2018; Steele et al., 2016). In middle-income countries, this percentage is lower but is seeing a sharp rise (Monteiro et al., 2018a). In Brazil, a recent study showed that UP are consumed with high frequency in the adult population in the 27 capitals (Costa et al., 2021). In addition to UP being usually rich in energy, saturated fats, sugar, and salt (Monteiro et al., 2018a; Rauber et al., 2018), they also have lower protein content than *in natura*/minimally processed foods, so UP also have been associated with lower protein intake (Martínez Steele et al., 2018; Rauber et al., 2018). To our knowledge, reports relating UP consumption and muscle health, especially in older adults with sarcopenia, are lacking in the literature (Sandoval-Insausti et al., 2020; Zhang et al., 2022).

Sarcopenia is a muscle disease characterized by low muscle strength and mass, leading to a decline in muscles' physiological functions (Cesari et al., 2014; Cruz-Jentoft et al., 2019; Kara et al., 2020). Sarcopenia increases the risk of falls and fractures, is associated with heart (Stenholm et al., 2008) and respiratory diseases (Bai et al., 2017), and contributes to a reduced quality of life, loss of independence, and increased mortality (Beaudart et al., 2017; Cruz-Jentoft et al., 2019; Stenholm et al., 2008; Zamboni et al., 2008). Among dietary factors related to sarcopenia, the putative role of proteins on muscle health has been highlighted (Kiesswetter et al., 2020). It has been shown that the protein daily intake of 0.8 $g \cdot kg^{-1}$ body weight (BW) benefits muscle mass (Beasley et al., 2016), whereas a consumption higher than 1.1 $g. \cdot kg^{-1}$ per day is linked to higher muscle mass and muscle function in older adults (Baum & Wolfe, 2015; Nilsson et al., 2018). However, the exploration of the impact of overall exposure to dietary patterns (how often specific foods or food groups are consumed over time?), rather than single nutrients on skeletal muscle health, the literature lacks. This kind of investigation has the advantage of considering different foods' complex interplay and potential synergistic effects on health outcomes (Papaioannou et al., 2021).

Therefore, it is plausible that high exposure to UP can promote adverse muscle health outcomes. They are frequently low in myoprotective nutrients, increasing the risk of sarcopenia in older adults. In addition, there is a gap in studies investigating the relationships between these foods consumption and sarcopenic older adults. Therefore, our primary objective was to describe the UP exposition magnitude, in terms of eating frequency, by older adults, with and without sarcopenia. We also compared these eating frequencies between those subjects. In addition, we also described the association between the magnitude of exposition of UP with body composition markers of sarcopenia in all subjects. We hypothesized that sarcopenic subjects are more exposed to UP and that the exposition magnitude is associated with a higher risk of developing sarcopenia in the evaluated population.

2. Methodology

Study design and participants

This study was cross-sectional with a sample of older adults. The inclusion criteria were both sexes; aged ≥60 years; postmenopausal women; sedentary (self-report); and controlled chronic diseases. The exclusion criteria were cognitive impairment, bedridden person, acute illness, clinical decompensated disease, and obesity. The eligible subjects were classified as sarcopenic and non-sarcopenic according to the criteria described by the "European Working Group Consensus on Sarcopenia in Older People – EWGSOP" (Cruz-Jentoft et al., 2019). The statistical power of the sample size was calculated by posthoc analysis using the GPOWER 3.1 software and considering the results of Chan et al. (2016), based on the differences between scores of food frequency in sarcopenic and non-sarcopenic with an effect size of 0.28, alpha error of 0.05 and power of 0.8. The total sample was calculated as 110 subjects. The maximum sample size limit was calculated by adding 10% to cover possible losses (n = 121). A total sample of 118 subjects participated in the study.

All subjects were recruited from the Basic Health Units or referred by geriatricians of Diamantina-MG, Brazil. A trained interviewer acquired social demographic and clinical health data during a home visit. All individuals who attended the eligibility criteria and agreed to participate in the study performed the DXA (Lunar Radiation Corporation, Madison, Wisconsin, USA, model DPX) to assess body composition. After that, the FFQ was applied by a trained interviewer. The study lasted from February 2018 to January 2020. The study protocol was approved by the Human Research Ethics Committee of the institution (# 2.282.653).

Sarcopenia diagnosis

All participants were evaluated for diagnosis of sarcopenia by DXA. The following formula was applied: appendicular muscle mass/height^2 (ALM/h^2), according to Baumgartner et al. (1998). These authors defined the appendicular lean mass (ALM) as the sum of the four limbs' muscle mass, generating the relative skeletal muscle mass index (RSMI). The reference values of <7.0 kg / m^2 and <5.5 kg / m^2 for men and women were used as cut-off points (Cruz-Jentoft et al., 2019). The calculation of total muscle mass was obtained directly from the DXA values in kilograms and the fat mass. The older adults who met the diagnostic criteria were included in the sarcopenia group. The control group included the non-sarcopenic participants.

Dietary assessment

For the eating frequency analysis, a validated FFQ was used (Ribeiro & Cardoso, 2002), with some adaptations, in which 77 foods or food groups usually consumed were listed. For the analysis, all foods in the FFQ were categorized into two food groups according to NOVA classification (Monteiro et al., 2016): (1) non-ultra-processed foods (non-UP) and (2) = Ultra-processed foods (UP). To accomplish that, we added in the FFQ the "non-homemade" or "ready-to-eat" information. All FFQ foods, categorized by NOVA classification, are listed in the supplementary material.

In the interview, for each food, subjects were asked to select their usual frequency of intake among seven categories: f1: never consumed; f2: ≤ 1x/month; f3: ≥2≤3x/month; f4: ≥1<2x/week; f5: ≥3≤4x/week; f6: ≥5≤6x/week; and f7: consumed daily. Afterward, all data obtained from the FFQ were analyzed according to de Fornés et al.(de Fornés et al. 2002). Briefly, a score was attributed to each eating frequency category. A maximum score of one (1) for foods consumed daily and zero (0) for those never consumed was determined. All other scores, according to the eating frequencies asked, were obtained employing the equation: $S = (1/365)\ [(a + b)/2]$, being "a" and "b" the number of days of the recorded frequency. The eating frequency scores corresponding to each food in the FFQ were calculated for each participant. In addition, we also calculated the SCORES I and II. SCORE I was the mean score for food group 1 (non-UP), and SCORE II was the mean score for food group 2 (UP). All calculations were performed for sarcopenic and non-sarcopenic subjects.

Anthropometry and body composition

The weight and height were measured by an analogic scale (Welmy, model 110, precision of 0.1 kg) with a coupled stadiometer, and body mass index (BMI kg/m^2) was calculated. Total body mass, fat mass, lean mass, and bone mineral density were assessed using DXA. Fat and lean mass were assessed by total body analysis and body segments (upper, lower, and trunk).

Statistical analysis

All analyses were performed with the IBM SPSS Statistics version 22.0 (IBM Corp., Somers, NY, USA.). The Kolmogorov-Smirnov test verified the distribution of data. Data were expressed as mean±standard deviation, median (interquartile range), or absolute number and percentage (categorical variables). Comparisons of anthropometry body composition, clinical variables, and SCORES I and II between groups were performed using Fisher's exact test (qualitative variables) and unpaired t-test or Mann-Whitney test (quantitative variables). Logistic regression analysis was accomplished to determine the factors associated with sarcopenia. The independent variables tested were age, sex, body fat, SCORE I (non-UP), and SCORE II (UP). The SCORE I and II were categorized by percentile 50, being SCORE $I_{cat.}$ (P50 = 0.305) and SCORE $II_{cat.}$ (P50 = 0.18). For that, we grouped the eating frequencies of UP as "<1-2x/week" and"≥ 1-2x/week" and for non-UP as "<3-4x/week" and"≥ 3-4x/week". Variables associated with sarcopenia in univariate analysis ($p< 0.2$) were included in the multivariable logistic regression analysis. The level of significance was 5%.

3. Results

A total of 167 older adults were recruited, of which 49 were excluded (did not meet the eligibility criteria), and the final sample consisted of 118 participants, 38.1% sarcopenic. Participants' age ranged from 60 to 98 years, with 55% identified as male, without differences between non-sarcopenic and sarcopenic groups ($p>0.05$). The sarcopenic group had lower values for anthropometric and body composition variables ($p<0.05$; Table 1).

Table 1. General characteristics of the participants.

Variables	**Non-sarcopenic (n=73)**	**Sarcopenic (n=45)**	**p-value**
Age (years)	72.2 ± 7.2	74.6 ± 9.3	0.13
Sex, n (%)			
Male	36 (49.3)	29 (64.4)	0.13
Female	37 (50.7)	16 (35.6)	
BMI (Kg/m²)	25.2 ± 2.4	20.9 ± 2.2	**<0.01**
Lean mass (Kg)	38.6 (13.2)	36.0 (9.3)	**<0.01**
Fat mass (Kg)	19.8 ± 4.5	15.5 ± 5.4	**<0.01**
Body fat (%)	33.2 ± 6.8	29.4 ± 8.3	**0.01**
Fat-free mass (Kg)	39.7 (13.4)	37.0 (9.6)	**<0.01**
RSMI (Kg/m²)			
Male	7.7 ± 0.6	6.1 ± 0.5	**<0.01**
Female	6.4 ± 0.6	5.1 ± 0.3	**<0.01**
BMD (g/cm²)	1.1 ± 0.1	1.0 ± 0.1	**0.01**

Data presented as mean ± SD, median (interquartile range), or absolute number (percentage). Independent t-test or Mann-Whitney U-test (for lean mass, fat mass, body fat, and fat-free mass) or Fisher exact test (for sex). Values in bold showed statistical significance (p-value < 0.05). BMI: Body mass index. RSMI: Relative skeletal muscle mass index. BMD: Bone mineral density. Source: Author's elaboration.

According to the table above, it is possible to notice that the values of body composition BMI, Lean mass, Fat mass, Body fat, Fat-free mass, RSMI (in both sexes), and BMD presented statistically relevant differences between Non-sarcopenic and Sarcopenic.

The mean SCORE for all subjects indicated that the eating frequency of non-UP was 3 - 4 times/per week and did not differ between males and females nor sarcopenic and non-sarcopenic (Table 2). The SCORE II for all subjects was near 1-2 per week, but sarcopenic had a higher SCORE II, indicating eating frequency near 3-4 times per week ($p<0.05$; Table 2).

Table 2. Distribution of SCORE I and SCORE II from sarcopenic and non-sarcopenic subjects.

Variables	Mean ± SD	Median (interquartile range)	p
SCORE I			
General	0.3 ± 0.1		
Male	0.2 ± 0.1		0.303†
Female	0.3 ± 0.1		
Sarcopenic	0.3 ± 0.1		0.344†
Non-sarcopenic	0.3 ± 0.1		
SCORE II			
General		0.18 (0.10)	
Male		0.18 (0.11)	0.315‡
Female		0.19 (0.12)	
Sarcopenic		0.34 (0.10)	0.000‡
Non-sarcopenic		0.15 (0.08)	

Data presented as mean ± SD or median (interquartile range). † Independent t-test; ‡Mann-Whitney U-test. SCORE I = mean food group 1 scores; SCORE II = mean food group 2 scores—source: Author's elaboration.

Logistic regression (Table 3) analyses showed that sarcopenia was associated with high UP consumption (p= 0.004) and lower values of body fat (p= 0.009) and lean mass (p= 0.001). In the multivariate analysis, participants consuming UP more than 1-2x/week were more likely to be sarcopenic than those consuming it less than 1-2x/week (OR=24.85, p= <0.001). Each increase by one unit in body fat (OR=0,76) and lean mass (OR=0,77) was associated with less likely to be sarcopenic (Table 3). The SCORE I was not associated with sarcopenia.

Table 3. Independent variables for sarcopenia in older adults (n=118).

Independent	Univariate			Multivariate		
variables	b ± SE	OR (95% CI)	p-value	b ± SE	OR (95% CI)	p-value
SCORE $I_{cat.}$ (ref: >3 a 4 x/week)	-0.36 ± 0.38	0.69 (0.33 – 1.47)	NS			NS
Age (years)	0.04 ± 0.02	1.04 (0.99 – 1.09)	NS			NS
Sex (ref: man)	0.62 ± 0.39	1.86 (0.87 – 3.99)	NS			NS
SCORE $II_{cat.}$ (ref: >1 a 2 x/week)	1.54 ± 0.53	4.68 (1.64 – 13.37)	**0.004**	3.19 ± 0.72	24.85 (6.01 – 99.73)	**<0.001**
Body fat (%)	-0.07 ± 0.03	0.93 (0.89 – 0.98)	**0.009**	-0.27 ± 0.06	0.76 (0.68 – 0.86)	**<0.001**
Lean mass (Kg)	-0.11 ± 0.03	0.90 (0.85 – 0.96)	**0.001**	-0.25 ± 0.07	0.77 (0.68 – 0.88)	**<0.001**

b: beta coefficient; SE: Standard error; OR: Odds Ratio; 95% CI: 95% Confidence Interval. Values in bold showed statistical significance (p-value < 0.05). NS: non-significance. Source: Author's elaboration.

4. Discussion

In this study, we evaluated the association between the magnitude of exposure to UP foods (food frequency) and sarcopenia in older adults. Briefly, (1) the eating frequency of UP was near 3 to 4x/week and higher for sarcopenic subjects

($p<0.05$), and (2) subjects consuming UP more than 1-2x/week were more likely to be sarcopenic compared to those consuming them less than 1-2x/week. These results suggest that exposure to UP, even if low, increases the risk of developing sarcopenia in older adults.

Aging results in changes in several metabolic and physiologic functions. It reduces lean mass, which includes body water, skeletal and smooth muscles, and bones (Ribeiro & Kehayias, 2014). Sarcopenia comprises the accelerated loss of skeletal muscle mass and function by age (Westbury et al., 2021). Despite no differences in the prevalence of comorbidities, sarcopenic subjects had lower values of body composition markers, which agrees with other studies (Kitamura et al., 2021; Petermann-Rocha et al., 2022; Zengin et al., 2021).

Since dietary factors also have been related to sarcopenia (Ganapathy & Nieves, 2020) and UP intake has been associated with chronic conditions and mortality (Chen et al., 2020; Elizabeth et al., 2020; Ludwig, 2011; Mertens et al., 2022; Schnabel et al., 2019; Srour et al., 2019, 2020), we first intended to describe the magnitude of UP consumption, in terms of eating frequency, by older adults, especially sarcopenic. Our main findings indicated that the sarcopenic subjects were exposed to UP near ≥3≤4x/week, which was higher than non-sarcopenic. To the best of our knowledge, we did not find any study investigating UP intake (regardless qualitatively or quantitative) and sarcopenia in older adults. Otherwise, Sandoval-Insausti et al. (2020) found a strong association between UP intake and frailty risk in older adults. More recently, Zhang et al. (2022) associated UP intake with grip strength decline in older adults. These data indicate a possible relationship between the intake of these foods and the decline of muscle mass and function with aging.

UP are affordable, convenient, microbiologically safe, highly palatable, ready to eat, energy-dense, and aggressively advertised and marketed (Louzada et al., 2015; Luiten et al., 2016; Monteiro et al., 2011; Monteiro et al., 2018a). These characteristics make them more likely to be overconsumed, which may increase consumers' total dietary energy intake. Indeed, food purchase surveys and national dietary surveys have informed on UP food intake in some Western countries (Costa et al., 2021; Louzada et al., 2015; Luiten et al., 2016; Monteiro et al., 2011; Monteiro et al., 2018a; Moodie et al., 2013) is increasing, and it currently contributes to 25%-50% of total energy intake (Monteiro et al., 2011). UP intake also has been associated with poorer diet quality (less fiber, fruit, vegetable, and protein intake) (Martínez Steele et al., 2017, 2018; Moubarac et al., 2017; Rauber et al., 2018). Therefore, the exposure to more energy-dense and nutritionally- deficient foods could contribute to a decline in muscle mass over aging and worsen the sarcopenia degree in these subjects.

Another interesting finding was that, for all subjects, the exposition to non-UP was between ≥2<3x/week and ≥3≤4x/week, without differences between male and female or sarcopenic and non-sarcopenic. In addition, non-sarcopenics were exposed to UP less than ≥1<2x/week. Although we considered the exposition to non-UP must be higher for all subjects to achieve good health, we can speculate that as non-sarcopenic were less exposed to UP, they were more protected from sarcopenia, which did not happen with sarcopenic subjects.

Indeed, our data also showed that subjects exposed to UP more than 1-2x/week were more likely to be sarcopenic (OR = 0.29) compared to those exposed to them less than 1-2x/week. It has been shown that the shifts in UP intake worldwide have been parallel to an increase in chronic diseases. Several longitudinal studies observed that UP intake was associated with a higher incidence of dyslipidemia (Rauber et al., 2015), hypertension (Mendonça et al., 2016a), and cancer (Fiolet et al., 2018). Moreover, cross-sectional (Canella et al., 2014; Monteiro et al., 2018b) and longitudinal studies (Mendonça et al., 2016b) found a relationship with obesity. To the best of our knowledge, this is the first study that has explored UP exposition and sarcopenia. As previously stated, UP are frequently associated with poor diet quality, lacking many essential nutrients for muscle health, such as protein, fiber, vitamins, and minerals.

Several mechanisms may explain the association between the exposition to UP and sarcopenia or markers of muscle health. UP negatively affect muscle protein synthesis since they are generally rich in saturated fats, added sugars, trans fats, and sodium and poor in fiber, protein, and micronutrients (McGlory et al., 2019). UP contain many non-natural ingredients and additives such as artificial flavors, stabilizers, emulsifiers, and preservatives. These ingredients may create an environment in the gut that is an evolutionarily unique selection ground for microbes that can promote chronic inflammation (Chassaing et al., 2015, 2017; Zinöcker & Lindseth, 2018). Pro-inflammatory cytokines (e.g., tumor necrosis factor-α and interleukin-6) contribute to the decline of muscle mass and function and sarcopenia (Dalle & Koppo, 2020; Schaap et al., 2009). Advanced glycation end products, produced during food processing and preparation, are associated with poor muscle health (Sharma et al., 2015). Finally, UP intake may increase the exposure to chemicals (e.g., phthalates and bisphenols) used in food packaging and production (Buckley et al., 2019). A recent population-based study showed that exposure to phthalates was inversely associated with grip strength, one of the markers of muscle health and sarcopenia (Sun et al., 2021). These studies provide potential explanations linking exposure to UP and sarcopenia.

5. Conclusion

Our data evidenced that sarcopenic subjects were more exposed to UP. In addition, even at low exposition (1-2x/week), the intake of UP increases the chances of developing sarcopenia in older adults.

Some potential limitations of this study deserve mention. We did not obtain nutrient intake since we used a descriptive and qualitative FFQ. However, we were interested in the magnitude of exposition to foods according to their extent and degree of processing. In addition, habitual exposure to a specific food or food group is one of the determinants of food ingestion. In addition, FFQs are reliable tools to investigate associations between diet and diseases (Willett, 2012), which was our aim. Another limitation is that the food intake report using an FFQ depends on the memory, which declines over aging, turning into complex data acquisition. However, the interviewer was previously trained to help the participants remember their food habits more appropriately, minimizing possible bias.

We believe our great strength was attempting to describe and relate UP exposition, as a food group, to sarcopenia. Several observational and intervention studies have used a single nutrient approach to investigate the relationship between diet and sarcopenia, which is not exclusively related to the number of nutrients ingested. Therefore, analyzing the magnitude of exposition to UP could contribute to developing food guidelines that also consider the impact of food intake based on the extent and purpose of processing in the decline of muscle mass and function in older adults.

As a suggestion for future work, it would be interesting to carry out a longitudinal study addressing the issue and evaluate the contribution of ultra-processed foods to the intake of calories and nutrients, especially proteins. In addition, including biomarkers of muscle health would be relevant for assessing nutritional status.

Acknowledgments

This study was supported by the Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG APQ-01328-18), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq-402574/2021-4), (CNPq-309216/2021-4) and the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Capes).

References

Bai, H., Sun, J., Du, G., & Jiao, F. (2017). Association of moderate aerobic exercise & rho-Associated kinase 2 concentration in subjects with dyslipidemia. *Archives of Medical Science*, *13*(4), 807–812. https://doi.org/10.5114/aoms.2017.68142

Baum, J. I., & Wolfe, R. R. (2015). The link between dietary protein intake, skeletal muscle function and health in older adults. *Healthcare (Switzerland)*, *3*(3), 529–543. https://doi.org/10.3390/healthcare3030529

Baumgartner, R. N., Koehler, K. M., Gallagher, D., Romero, L., Heymsfield, S. B., Ross, R. R., Garry, P. J., & Lindeman, R. D. (1998). Epidemiology of sarcopenia among the elderly in New Mexico. *American Journal of Epidemiology*, *147*(8), 755–763. https://doi.org/10.1093/oxfordjournals.aje.a009520

Beasley, J. M., Deierlein, A. L., Morland, K. B., Granieri, E. C., & Spark, A. (2016). Is meeting the recommended dietary allowance (RDA) for protein related to body composition among older adults?: Results from the Cardiovascular Health of Seniors and Built Environment Study. *The Journal of Nutrition, Health & Aging*, *20*(8), 790–796. https://doi.org/10.1007/s12603-015-0707-5

Beaudart, C., Zaaria, M., Pasleau, F., Reginster, J.-Y., & Bruyère, O. (2017). Health Outcomes of Sarcopenia: A Systematic Review and Meta-Analysis. *PLOS ONE*, *12*(1), e0169548. https://doi.org/10.1371/journal.pone.0169548

Brazil. (2014). Dietary Guidelines for the brazilian population. In *Ministry of Health of Brazil* (2nd ed., Vol. 2).

Buckley, J. P., Kim, H., Wong, E., & Rebholz, C. M. (2019). Ultra-processed food consumption and exposure to phthalates and bisphenols in the US National Health and Nutrition Examination Survey, 2013–2014. *Environment International*, *131*(July), 105057. https://doi.org/10.1016/j.envint.2019.105057

Canella, D. S., Levy, R. B., Martins, A. P. B., Claro, R. M., Moubarac, J. C., Baraldi, L. G., Cannon, G., & Monteiro, C. A. (2014). Ultra-processed food products and obesity in Brazilian households (2008-2009). *PLoS ONE*, *9*(3), 1–6. https://doi.org/10.1371/journal.pone.0092752

Cesari, M., Landi, F., Vellas, B., Bernabei, R., & Marzetti, E. (2014). Sarcopenia and physical frailty: Two sides of the same coin. *Frontiers in Aging Neuroscience*, *6*(JUL), 1–4. https://doi.org/10.3389/fnagi.2014.00192

Chan, R., Leung, J., & Woo, J. (2016). A Prospective Cohort Study to Examine the Association Between Dietary Patterns and Sarcopenia in Chinese Community-Dwelling Older People in Hong Kong. *Journal of the American Medical Directors Association*, *17*(4), 336–342. https://doi.org/10.1016/j.jamda.2015.12.004

Chassaing, B., Koren, O., Goodrich, J. K., Poole, A. C., Srinivasan, S., Ley, R. E., & Gewirtz, A. T. (2015). Dietary emulsifiers impact the mouse gut microbiota promoting colitis and metabolic syndrome. *Nature*, *519*(7541), 92–96. https://doi.org/10.1038/nature14232

Chassaing, B., Van De Wiele, T., De Bodt, J., Marzorati, M., & Gewirtz, A. T. (2017). Dietary emulsifiers directly alter human microbiota composition and gene expression ex vivo potentiating intestinal inflammation. *Gut*, *66*(8), 1414–1427. https://doi.org/10.1136/gutjnl-2016-313099

Chen, X., Zhang, Z., Yang, H., Qiu, P., Wang, H., Wang, F., Zhao, Q., Fang, J., & Nie, J. (2020). Consumption of ultra-processed foods and health outcomes: A systematic review of epidemiological studies (Consumo de alimentos ultraprocessados e resultados para a saúde: uma revisão sistemática de estudos epidemiológicos). *Nutrition Journal*, *19*(1), 1–10.

Costa, C. D. S., Sattamini, I. F., Steele, E. M., Louzada, M. L. D. C., Claro, R. M., & Monteiro, C. A. (2021). Consumption of ultra-processed foods and its association with sociodemographic factors in the adult population of the 27 Brazilian state capitals (2019). *Revista de Saude Publica*, *55*, 1–9. https://doi.org/10.11606/s1518-8787.2021055002833

Cruz-Jentoft, A. J., Bahat, G., Bauer, J., Boirie, Y., Bruyère, O., Cederholm, T., Cooper, C., Landi, F., Rolland, Y., Sayer, A. A., Schneider, S. M., Sieber, C. C., Topinkova, E., Vandewoude, M., Visser, M., Zamboni, M., Bautmans, I., Baeyens, J. P., Cesari, M., … Schols, J. (2019). Sarcopenia: Revised European consensus on definition and diagnosis. *Age and Ageing*, *48*(1), 16–31. https://doi.org/10.1093/ageing/afy169

Dalle, S., & Koppo, K. (2020). Is inflammatory signaling involved in disease-related muscle wasting? Evidence from osteoarthritis, chronic obstructive pulmonary disease and type II diabetes. *Experimental Gerontology*, *137*(May), 110964. https://doi.org/10.1016/j.exger.2020.110964

de Fornés, N. S., Martins, I. S., Velásquez-Meléndez, G., & Dias de Oliveira Latorre, M. do R. (2002). Food consumption scores and serum lipids levels in the population of São Paulo, Brazil. *Revista de Saude Publica*, *36*(1), 12–18. https://doi.org/10.1590/s0034-89102002000100003

Elizabeth, L., Machado, P., Zinöcker, M., Baker, P., & Lawrence, M. (2020). Ultra-processed foods and health outcomes: A narrative review. *Nutrients*, *12*(7), 1–36. https://doi.org/10.3390/nu12071955

Fiolet, T., Srour, B., Sellem, L., Kesse-Guyot, E., Allès, B., Méjean, C., Deschasaux, M., Fassier, P., Latino-Martel, P., Beslay, M., Hercberg, S., Lavalette, C., Monteiro, C. A., Julia, C., & Touvier, M. (2018). Consumption of ultra-processed foods and cancer risk: Results from NutriNet-Santé prospective cohort. *BMJ (Online)*, *360*. https://doi.org/10.1136/bmj.k322

Ganapathy, A., & Nieves, J. W. (2020). Nutrition and sarcopenia—what do we know? *Nutrients*, *12*(6), 1–25. https://doi.org/10.3390/nu12061755

Kara, M., Özçakar, L., Kaymak, B., Ata, A. M., & Frontera, W. (2020). A "neuromuscular look" to sarcopenia: Is it a 'movement disorder'? *Journal of Rehabilitation Medicine*, *52*(4), 10–12. https://doi.org/10.2340/16501977-2672

Kearney, J. (2010). Food consumption trends and drivers. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *365*(1554), 2793–2807. https://doi.org/10.1098/rstb.2010.0149

Kiesswetter, E., Sieber, C. C., & Volkert, D. (2020). Protein intake in older people: Why, how much and how? *Zeitschrift Fur Gerontologie Und Geriatrie*, *53*(4), 285–289. https://doi.org/10.1007/s00391-020-01723-4

Kitamura, A., Seino, S., Abe, T., Nofuji, Y., Yokoyama, Y., Amano, H., Nishi, M., Taniguchi, Y., Narita, M., Fujiwara, Y., & Shinkai, S. (2021). Sarcopenia: prevalence, associated factors, and the risk of mortality and disability in Japanese older adults. *Journal of Cachexia, Sarcopenia and Muscle*, *12*(1), 30–38. https://doi.org/10.1002/jcsm.12651

Louzada, M. L. da C., Martins, A. P. B., Canella, D. S., Baraldi, L. G., Levy, R. B., Claro, R. M., Moubarac, J. C., Cannon, G., & Monteiro, C. A. (2015). Ultra-processed foods and the nutritional dietary profile in Brazil. *Revista de Saude Publica*, *49*, 1–11. https://doi.org/10.1590/S0034-8910.2015049006132

Ludwig, D. S. (2011). Technology, diet, and the burden of chronic disease. *JAMA - Journal of the American Medical Association*, *305*(13), 1352–1353. https://doi.org/10.1001/jama.2011.380

Luiten, C. M., Steenhuis, I. H. M., Eyles, H., Mhurchu, C. N., & Waterlander, W. E. (2016). Ultra-processed foods have the worst nutrient profile, yet they are the most available packaged products in a sample of New Zealand supermarkets. *Public Health Nutrition*, *19*(3), 530–538.

https://doi.org/10.1017/S1368980015002177

Marino, M., Puppo, F., Del Bo', C., Vinelli, V., Riso, P., Porrini, M., & Martini, D. (2021). A systematic review of worldwide consumption of ultra-processed foods: Findings and criticisms. *Nutrients*, *13*(8). https://doi.org/10.3390/nu13082778

Martínez Steele, E., Popkin, B. M., Swinburn, B., & Monteiro, C. A. (2017). The share of ultra-processed foods and the overall nutritional quality of diets in the US: Evidence from a nationally representative cross-sectional study. *Population Health Metrics*, *15*(1), 1–11. https://doi.org/10.1186/s12963-017-0119-3

Martínez Steele, E., Raubenheimer, D., Simpson, S. J., Baraldi, L. G., & Monteiro, C. A. (2018). Ultra-processed foods, protein leverage and energy intake in the USA. *Public Health Nutrition*, *21*(1), 114–124. https://doi.org/10.1017/S1368980017001574

McGlory, C., van Vliet, S., Stokes, T., Mittendorfer, B., & Phillips, S. M. (2019). The impact of exercise and nutrition on the regulation of skeletal muscle mass. *Journal of Physiology*, *597*(5), 1251–1258. https://doi.org/10.1113/JP275443

Mendonça, R. de D., Lopes, A. C. S., Pimenta, A. M., Gea, A., Martinez-Gonzalez, M. A., & Bes-Rastrollo, M. (2016a). Ultra-Processed Food Consumption and the Incidence of Hypertension in a Mediterranean Cohort: The Seguimiento Universidad de Navarra Project. *American Journal of Hypertension*, *30*(4), hpw137. https://doi.org/10.1093/ajh/hpw137

Mendonça, R. de D., Pimenta, A. M., Gea, A., de la Fuente-Arrillaga, C., Martinez-Gonzalez, M. A., Lopes, A. C. S., & Bes-Rastrollo, M. (2016b). Ultraprocessed food consumption and risk of overweight and obesity: the University of Navarra Follow-Up (SUN) cohort study. *The American Journal of Clinical Nutrition*, *104*(5), 1433–1440. https://doi.org/10.3945/ajcn.116.135004

Mertens, E., Colizzi, C., & Peñalvo, J. L. (2022). Ultra-processed food consumption in adults across Europe. *European Journal of Nutrition*, *61*(3), 1521–1539. https://doi.org/10.1007/s00394-021-02733-7

Monteiro, C. A., Cannon, G., Levy, R. B., Moubarac, J. C., Louzada, M. L. C., Rauber, F., Khandpur, N., Cediel, G., Neri, D., Martinez-Steele, E., Baraldi, L. G., & Jaime, P. C. (2019). Ultra-processed foods: What they are and how to identify them. *Public Health Nutrition*, *22*(5), 936–941. https://doi.org/10.1017/S1368980018003762

Monteiro, C. A., Cannon, G., Levy, R., Moubarac, J.-C., Jaime, P., Martins, A. P., Canella, D., Louzada, M., & Parra, D. (2016). NOVA. The Star Shines Bright (Food Classification. Public Health). *World Nutrition*, *7*(1–3), 28–38.

Monteiro, C. A., Cannon, G., Moubarac, J. C., Levy, R. B., Louzada, M. L. C., & Jaime, P. C. (2018a). The un Decade of Nutrition, the NOVA food classification and the trouble with ultra-processing. *Public Health Nutrition*, *21*(1), 5–17. https://doi.org/10.1017/S1368980017000234

Monteiro, C. A., Levy, R. B., Claro, R. M., De Castro, I. R. R., & Cannon, G. (2011). Increasing consumption of ultra-processed foods and likely impact on human health: Evidence from Brazil. *Public Health Nutrition*, *14*(1), 5–13. https://doi.org/10.1017/S1368980010003241

Monteiro, C. A., Moubarac, J. C., Levy, R. B., Canella, D. S., Da Costa Louzada, M. L., & Cannon, G. (2018b). Household availability of ultra-processed foods and obesity in nineteen European countries. *Public Health Nutrition*, *21*(1), 18–26. https://doi.org/10.1017/S1368980017001379

Moodie, R., Stuckler, D., Monteiro, C. A., Sheron, N., Neal, B., Thamarangsi, T., Lincoln, P., & Casswell, S. (2013). Profits and pandemics: Prevention of harmful effects of tobacco, alcohol, and ultra-processed food and drink industries. *The Lancet*, *381*(9867), 670–679. https://doi.org/10.1016/S0140-6736(12)62089-3

Moubarac, J. C., Batal, M., Louzada, M. L., Martinez Steele, E., & Monteiro, C. A. (2017). Consumption of ultra-processed foods predicts diet quality in Canada. *Appetite*, *108*, 512–520. https://doi.org/10.1016/j.appet.2016.11.006

Nilsson, A., Rojas, D. M., & Kadi, F. (2018). Impact of meeting different guidelines for protein intake on muscle mass and physical function in physically active older women. *Nutrients*, *10*(9). https://doi.org/10.3390/nu10091156

Papaioannou, K. G., Nilsson, A., Nilsson, L. M., & Kadi, F. (2021). Healthy eating is associated with sarcopenia risk in physically active older adults. *Nutrients*, *13*(8). https://doi.org/10.3390/nu13082813

Petermann-Rocha, F., Balntzi, V., Gray, S. R., Lara, J., Ho, F. K., Pell, J. P., & Celis-Morales, C. (2022). Global prevalence of sarcopenia and severe sarcopenia: a systematic review and meta-analysis. *Journal of Cachexia, Sarcopenia and Muscle*, *13*(1), 86–99. https://doi.org/10.1002/jcsm.12783

Rauber, F., Campagnolo, P. D. B., Hoffman, D. J., & Vitolo, M. R. (2015). Consumption of ultra-processed food products and its effects on children's lipid profiles: A longitudinal study. *Nutrition, Metabolism and Cardiovascular Diseases*, *25*(1), 116–122. https://doi.org/10.1016/j.numecd.2014.08.001

Rauber, F., Louzada, M. L. da C., Steele, E. M., Millett, C., Monteiro, C. A., & Levy, R. B. (2018). Ultra-processed food consumption and chronic non-communicable diseases-related dietary nutrient profile in the UK (2008–2014). *Nutrients*, *10*(5). https://doi.org/10.3390/nu10050587

Ribeiro, A. B., & Cardoso, M. A. (2002). Construção de um questionário de freqüência alimentar como subsídio para programas de prevenção de doenças crônicas não transmissíveis. *Revista de Nutrição*, *15*(2), 239–245. https://doi.org/10.1590/S1415-52732002000200012

Ribeiro, S. M. L., & Kehayias, J. J. (2014). Sarcopenia and the analysis of body composition. *Advances in Nutrition*, *5*(3), 260–267. https://doi.org/10.3945/an.113.005256

Salomé, M., Arrazat, L., Wang, J., Dufour, A., Dubuisson, C., Volatier, J. L., Huneau, J. F., & Mariotti, F. (2021). Contrary to ultra-processed foods, the consumption of unprocessed or minimally processed foods is associated with favorable patterns of protein intake, diet quality and lower cardiometabolic risk in French adults (INCA3). *European Journal of Nutrition*, *60*(7), 4055–4067. https://doi.org/10.1007/s00394-021-02576-2

Sandoval-Insausti, H., Blanco-Rojo, R., Graciani, A., Lopez-GarcÃ-A, E., Moreno-Franco, B., Laclaustra, M. N., Donat-Vargas, C., OrdovÃis, J. M., RodrÃ-Guez-Artalejo, F., & Guallar-Castillen, P. (2020). Ultra-processed Food Consumption and Incident Frailty: A Prospective Cohort Study of Older Adults. *Journals of Gerontology - Series A Biological Sciences and Medical Sciences*, *75*(6), 1126–1133. https://doi.org/10.1093/GERONA/GLZ140

Schaap, L. A., Pluijm, S. M. F., Deeg, D. J. H., Harris, T. B., Kritchevsky, S. B., Newman, A. B., Colbert, L. H., Pahor, M., Rubin, S. M., Tylavsky, F. A., & Visser, M. (2009). Higher inflammatory marker levels in older persons: Associations with 5-year change in muscle mass and muscle strength. *Journals of Gerontology - Series A Biological Sciences and Medical Sciences*, *64*(11), 1183–1189. https://doi.org/10.1093/gerona/glp097

Schnabel, L., Kesse-Guyot, E., Allès, B., Touvier, M., Srour, B., Hercberg, S., Buscail, C., & Julia, C. (2019). Association between Ultraprocessed Food Consumption and Risk of Mortality among Middle-aged Adults in France. *JAMA Internal Medicine*, *179*(4), 490–498. https://doi.org/10.1001/jamainternmed.2018.7289

Sharma, C., Kaur, A., Thind, S. S., Singh, B., & Raina, S. (2015). Advanced glycation End-products (AGEs): an emerging concern for processed food industries. *Journal of Food Science and Technology*, *52*(12), 7561–7576. https://doi.org/10.1007/s13197-015-1851-y

Srour, B., Fezeu, L. K., Kesse-Guyot, E., Allès, B., Debras, C., Druesne-Pecollo, N., Chazelas, E., Deschasaux, M., Hercberg, S., Galan, P., Monteiro, C. A., Julia, C., & Touvier, M. (2020). Ultraprocessed Food Consumption and Risk of Type 2 Diabetes among Participants of the NutriNet-Santé Prospective Cohort. *JAMA Internal Medicine*, *180*(2), 283–291. https://doi.org/10.1001/jamainternmed.2019.5942

Srour, B., Fezeu, L. K., Kesse-Guyot, E., Allès, B., Méjean, C., Andrianasolo, R. M., Chazelas, E., Deschasaux, M., Hercberg, S., Galan, P., Monteiro, C. A., Julia, C., & Touvier, M. (2019). Ultra-processed food intake and risk of cardiovascular disease: Prospective cohort study (NutriNet-Santé). *The BMJ*, *365*(June). https://doi.org/10.1136/bmj.l1451

Steele, E. M., Baraldi, L. G., Da Costa Louzada, M. L., Moubarac, J. C., Mozaffarian, D., & Monteiro, C. A. (2016). Ultra-processed foods and added sugars in the US diet: Evidence from a nationally representative cross-sectional study. *BMJ Open*, *6*(3), 1–8. https://doi.org/10.1136/bmjopen-2015-009892

Stenholm, S., Harris, T. B., Rantanen, T., Visser, M., Kritchevsky, S. B., & Ferrucci, L. (2008). Sarcopenic obesity: Definition, cause and consequences. *Current Opinion in Clinical Nutrition and Metabolic Care*, *11*(6), 693–700. https://doi.org/10.1097/MCO.0b013e328312c37d

Sun, L., Fan, J., Song, G., Cai, S., Fan, C., Zhong, Y., & Li, Y. (2021). Exposure to phthalates is associated with grip strength in US adults. *Ecotoxicology and Environmental Safety*, *209*, 111787. https://doi.org/10.1016/j.ecoenv.2020.111787

Welch, R. W., & Mitchell, P. C. (2000). Food processing: A century of change. *British Medical Bulletin*, *56*(1), 1–17. https://doi.org/10.1258/0007142001902923

Westbury, L. D., Syddall, H. E., Fuggle, N. R., Dennison, E. M., Harvey, N. C., Cauley, J. A., Shiroma, E. J., Fielding, R. A., Newman, A. B., & Cooper, C. (2021). Relationships Between Level and Change in Sarcopenia and Other Body Composition Components and Adverse Health Outcomes: Findings from the Health, Aging, and Body Composition Study. *Calcified Tissue International*, *108*(3), 302–313. https://doi.org/10.1007/s00223-020-00775-3

Willett, W. C. (2012). *Nutritional Epidemiology* (Oxford University Press (ed.); 3th ed.). https://www.amazon.com.br/Nutritional-Epidemiology-40-Walter-Willett/dp/0199754039

Zamboni, M., Mazzali, G., Fantin, F., Rossi, A., & Di Francesco, V. (2008). Sarcopenic obesity: A new category of obesity in the elderly. *Nutrition, Metabolism and Cardiovascular Diseases*, *18*(5), 388–395. https://doi.org/10.1016/j.numecd.2007.10.002

Zengin, A., Kulkarni, B., Khadilkar, A. V., Kajale, N., Ekbote, V., Tandon, N., Bhargava, S. K., Sachdev, H. S., Sinha, S., Scott, D., Kinra, S., Fall, C. H. D., & Ebeling, P. R. (2021). Prevalence of Sarcopenia and Relationships Between Muscle and Bone in Indian Men and Women. *Calcified Tissue International*, *109*(4), 423–433. https://doi.org/10.1007/s00223-021-00860-1

Zhang, S., Gu, Y., Rayamajhi, S., Thapa, A., Meng, G., Zhang, Q., Liu, L., Wu, H., Zhang, T., Wang, X., Dong, J., Zheng, X., Cao, Z., Zhang, X., Dong, X., Sun, S., Wang, X., Zhou, M., Jia, Q., … Niu, K. (2022). Ultra-processed food intake is associated with grip strength decline in middle-aged and older adults: a prospective analysis of the TCLSIH study. *European Journal of Nutrition*, *61*(3), 1331–1341. https://doi.org/10.1007/s00394-021-02737-3

Zinöcker, M. K., & Lindseth, I. A. (2018). The western diet–microbiome-host interaction and its role in metabolic disease. *Nutrients*, *10*(3), 1–15. https://doi.org/10.3390/nu10030365