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Multimorbidity and Diet in Adults: A Scoping Review

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Abstract

Objective: to map and identify evidence on the relationship between diet and multimorbidity of chronic non-communicable diseases (NCDs) among adults. **Methods:** a scoping review was conducted in the electronic Virtual Health Library (VHL), EMBASE, PubMed, Scientific Electronic Library Online (SciELO), Science Direct and Scopus databases. The inclusion criteria admitted quantitative studies published between 2000 and 2023 whose title and abstract mentioned multimorbidity and diet or used similar words. **Results:** the search retrieved 37 articles, 17 of which were included for analysis using the PRISMA-ScR protocol. Diets rich in fruit and vegetables were associated with decreased risk of multimorbidity, while the main dietary risk factor for multimorbidity was diets rich in red meat and chicken, possibly influenced by dietary patterns and lifestyle factors. **Conclusion:** this review summarised the findings of studies describing the evidence of association between diet and multimorbidity, which has important public health implications.

Keywords

Multimorbidity, Diet, Adult, Review

1. Introduction

Multimorbidity, defined as the co-occurrence of two or more chronic diseases in

the same individual, is considered to be a public health problem for its effects on the individual, the family and the health system [1] [2]. Co-occurrence of multiple chronic diseases constitutes a growing challenge worldwide, especially because the mechanisms underlying the development of these diseases are complex, interrelated and involve biological factors, aging and social determinants of health. In order to meet this challenge properly, it is essential to understand the existing evidence of causality [3], as well as addressing the knowledge gaps, particularly in low- and medium-income countries, where less evidence is available than from the volume of research conducted in high-income countries [4].

One systematic review estimated the combined global prevalence of multimorbidity at 33.1%. In high-income countries, prevalence was 37.9% and, in low-income countries, 29.7% [5]. Data from Brazil's 2013 national health survey (Pesquisa Nacional de Saúde, PNS) [6] showed a 23.6%. prevalence of self-reported multimorbidity. That prevalence was higher among people with a lower level of education (37.2%), those who reported living with a partner (25.1%), in urban areas (24.1%) and being unemployed (33.6%). Using the same PNS database [7], prevalence was found to be higher among women (28.8%) than among men (19%) and also increased with age: 54.7% of people from 65 to 84 years old displayed multimorbidity, against only 5.5% of the population from 18 to 24 years old. Also, from the PNS [8] data, the prevalence of multimorbidity (suffering from more than two diseases) among individuals who reported having an occupational activity was estimated to be 19.9%.

Multiple diseases are associated with various risk factors, which may be genetic, demographic, socioeconomic and behavioural in origin. Prominent among these are genetic risk, sex, level of schooling, income, physical inactivity, misuse of alcohol, smoking and exposure to tobacco, overweight and obesity, as well as inappropriate diet, characterised by high intake of soft drinks, sweets, ultra-processed products and low intake of fruits and vegetables [9]. Specifically as regards dietary pattern, today the demands of daily life have led the population to adopt unhealthy eating habits, such as excessive consumption of practical, fast foods, fatty and processed meats, saturated fats, refined grains, salt and sugars, and to eat little fresh fruit and vegetables, all of which has contributed to the resurgence of multimorbidity [10].

In this scenario, when examining the association between diet and multimorbidity in different populations, the studies identified here tended to diverge in both research question and study design. That posed challenges for summarising the findings comprehensively and precisely. It is not yet clear what information is available overall in this field, which is growing rapidly. Accordingly, this scoping review was performed to examine how studies have approached the relationship between dietary pattern and multimorbidity.

2. Methods

First, the mnemonic PCC = participants (P), concept (C) and context (C) was used

to guide data collection, by helping in identifying key topics [11] [12]. In this case, the concept of multimorbidity was defined as the occurrence of two or more chronic diseases in the same individual, while dietary pattern was taken to be the sector or groups of foods eaten by a given population of adults, defined as individuals aged 18 or older. Considering the complexity of the human diet, the use of dietary patterns in nutritional epidemiology surmounts limitations of analysis by isolated nutrients. This approach assists in public health policy-making. Dietary patterns can be identified, a priori, on the basis of nutritional guidelines or, a posteriori, from empirical data and statistical analyses. This strategy was chosen for reasons relating to the scoping review, which is defined as a type of study that seeks to attain three main goals: 1) to explore the breadth or extent of the literature; 2) to map and summarise the evidence; and 3) to inform future research [12]-[15].

Also, the studies that need to be identified tend to be extremely diverse in both focus and design, making it challenging for the review to be comprehensive and precise. From that perspective, this scoping review used the methodological framework proposed by Arksey & O'Malley (2005) [13] with the amendments by Levac, Colquhoun & O'Brien (2010) [16] and Peters *et al.* (2020) [15]. The review process comprised five stages: 1) identifying the research question; 2) identifying important studies; 3) selecting studies; 4) summarising data in tables; and 5) grouping, summarising and reporting the findings.

2.1. Specifying the Research Question

In this study, the chosen problem was to characterise published Brazilian and international scientific production on dietary pattern and multimorbidity. The concept addressed the prevalence of multimorbidity in adults and its relationship with dietary pattern. The context was set by considering the number of publications in high-and low-income countries in the past 23 years, so as to include the entry of multimorbidity into the scientific literature.

In order to reconcile the key topics of the PCC with the study objectives, the research question for this scoping review was specified as: "What estimates of associations have been presented in studies of multimorbidity and dietary pattern in adults"?

2.2. Eligibility Criteria

Studies were considered eligible if they displayed methodological rigour, a clear description of the method and a level of evidence appropriate to the analyses performed and served as a basis for compiling summaries with the emphasis on public policies.

By the inclusion criteria, studies should be observational and experimental, with adult participants, titles or abstracts mentioning multimorbidity and contained the words "diets", "food" or "dietary pattern", and published between 2000 and 2023.

The exclusion criteria precluded studies that examined the association between

multimorbidity and dietary pattern in groups with specific diseases, such as mental diseases and infectious diseases. Mental health disorders were excluded due to challenges in consistent diagnosis across populations and studies, particularly when relying on self-reported data or variable clinical criteria. Infectious diseases were excluded because the focus of the study was restricted to non-communicable diseases.

2.3. Search Strategy

A limited, initial (pilot) search was conducted in the Cochrane Library and JBI Evidence Synthesis to identify studies on the subject. The terms present in the titles and abstracts of leading articles were examined, as well as the indexing terms used in these articles, so as to develop a search strategy. The pilot search found no review articles on the subject, strengthening the justification for undertaking this scoping review.

The search was conducted between January and March 2023 for articles published between 2000 and 2023. The electronic databases consulted—Virtual Health Library (VHL), Excerpta Medica Database (EMBASE), PubMed, Scientific Electronic Library Online (SciELO), Science Direct and Scopus—included articles available in Portuguese (Brazil and Portugal), English and Spanish.

The combination of descriptors used resulted in the following search strategies for the bases consulted: "dieta" and "alimentação" OR "diet", "padrão alimentar ocidental" OR "diet western", "alimentos ultraprocessados" OR "ultra processed foods" combined with the outcome AND "multimobidade" OR "multimorbidity".

2.4. Study Selection and Data Extraction

The publications found were downloaded from the databases to cloud storage shared between two reviewers, who read them independently. First, the titles and abstracts of the articles were read, and those that did not meet the eligibility criteria were excluded. At this stage, the reviewers also delimited the variables extracted and adjusted the data extraction table.

The potentially relevant studies were read independently and in full. Divergences were discussed until a consensus was reached; when there was no consensus, the article was excluded. During the reading in full, the studies were assessed for quality and as regards the clarity and transparency of the description of methods and findings.

Methodological quality is not an essential criterion of a scoping review and, accordingly, that stage of assessment was not performed [13].

2.5. Data Mapping

In order to summarise the articles, spreadsheets were drawn up in Microsoft Excel (version 2406), containing the data extraction table developed by the reviewers responsible for reading the articles. The information extracted included: author; year of publication; study objective; study design and population; sample age; ex-

posure (evaluation of diet, foods considered, variable); multimorbidity (definition, list of diseases, variable); statistical analysis used; and main findings.

The results extracted were discussed with the reviewers to correct any divergences in collecting the information, resulting in Tables 1-4.

For the descriptive analysis of the articles, the results were organised by statistics techniques used, so as to permit comparisons among the findings regarding dietary pattern and multimorbidity. These comparisons provided indications of the strength of the relation found between dietary pattern and multimorbidity in studies with adults in different contexts.

3. Results

On the criteria established for the search strategy, this study located 12 articles in the VHL portal, three in EMBASE, 26 in PubMed, none in the Scientific Electronic Library Online (Scielo), 1247 in Science Direct and three in Scopus. After reading the titles, 17 articles were selected for analysis (Figure 1).

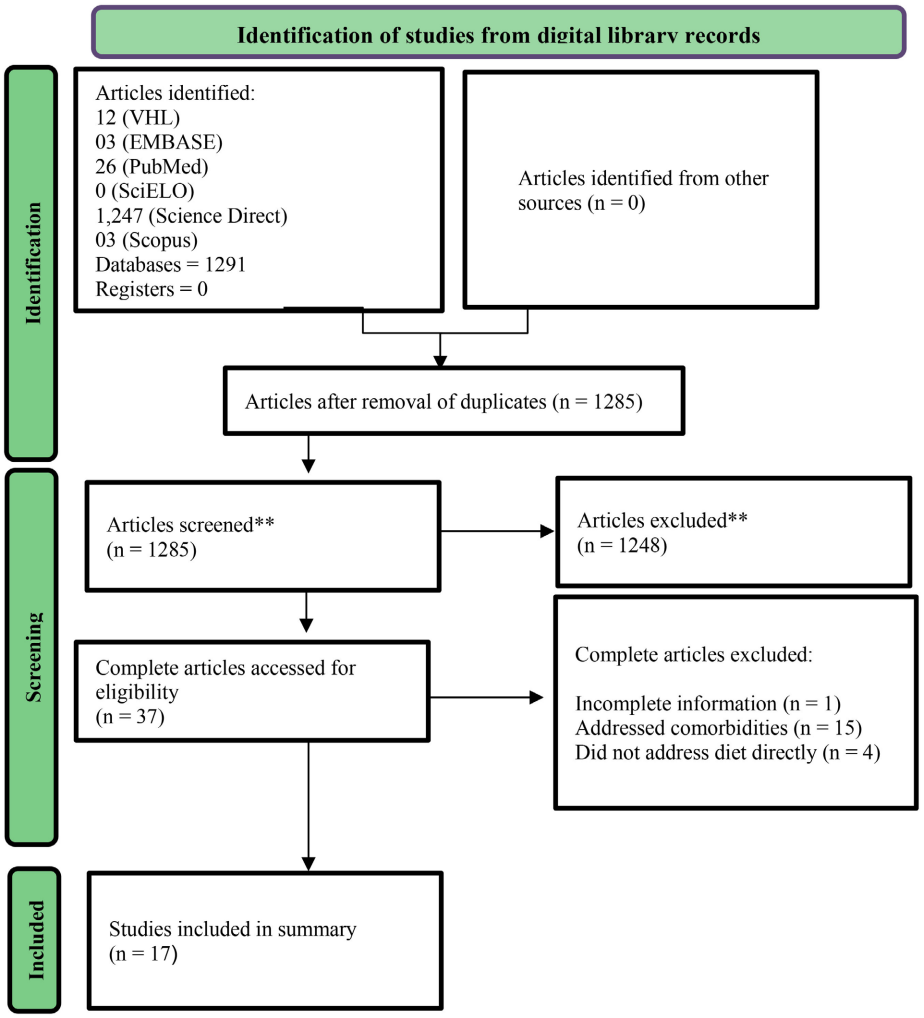

Figure 1. Flow diagram of article searches according to PRISMA-ScR.
(Scr: http://www.acpjournals.org/doi/10.7326/M18-0850).

3.1. Descriptive Characteristics of the Articles

Table 1 shows the descriptive characteristics of the articles selected, 59% (n = 10) of which were cross-sectional in design, six longitudinal and one, a clinical trial. The samples comprised from 1020 to 13,226,778 individuals, aged from 18 to 93 years. Most of the studies included both sexes, while in only one were the participants all women. The studies were conducted in Europe (n = 6), the United States (n = 2), Canada (n = 3), Brazil (n = 2), plus one study in each of Argentina, Australia, China, and South Korea.

Table 1. Descriptive characteristics of the studies included (2000 to 2023).

Study	Site	Study objective	Design	Sample (n)	Age (years)
Ruel *et al.* [17] (2013)	China, Jiangsu Province	To determine the association between nutrition and multimorbidity.	Cross-sectional study with face-to-face interview.	1020 (430 men)	20+
Fortin *et al.* [18] (2014)	Canada, Quebec	To investigate the relation between lifestyle factors and the co-occurrence of multiple chronic diseases.	Cross-sectional study with self-administered questionnaire.	1196 (515 men)	45 - 75
Pereira *et al.* [19] (2014)	Pelotas, Rio Grande do Sul (RS), Brazil	To examine the association between diet quality and multimorbidity in older adults.	Cross-sectional study with face-to-face interview.	1426 (637 men)	60 - 69
Olivares *et al.* [20] (2017)	Diamante, Argentina	To identify risk factors for chronic diseases connected with health-related lifestyle habits, anthropometrics and biochemical blood profile, and characteristics associated with multimorbidity.	Cross-sectional study with face-to-face interview.	1044 (365 men)	18+
Katikireddi *et al.* [21] (2017)	Scotland	To describe the social pattern of multimorbidity and behaviour-related risk factors.	Longitudinal study with self-administered questionnaire	1551 Men: - born at 1930 baseline = 702 - born at 1950 baseline = 656 - born at 1970 baseline = 638	35 - 75
Rodrigues *et al.* [22] (2018)	Portugal.	To characterise the prevalence of multimorbidity and lifestyle among older adults.	Cross-sectional study with face-to-face interview	2393 (854 men)	≥65
Dekker *et al.* [23] (2019)	Holland	To evaluate the association of multimorbidity with dietary patterns.	Cross-sectional study with self-administered questionnaire	129,369 (53,888 men)	18 - 93
Sakakibara *et al.* [24] (2019)	Canada	To evaluate the association between cardiometabolic multimorbidity and lifestyle.	Cross-sectional study with self-administered questionnaire	13,226,778 (6,375,731 men)	50+
Olaya *et al.* [25] (2019)	Spain	To determine the association between fruit and vegetable intake and risk of mortality from all causes.	Longitudinal study	1699 (743 men)	65+
Ng *et al.* [26] (2020)	Canada	To examine the relation between lifestyle and incidence of the first chronic disease.	Cross-sectional study with self-administered questionnaire	112,870 (49,469 men)	20+

Continued

Chudasama *et al.* [27] (2020)	United Kingdom, Wales and Scotland	To investigate the associations between healthy lifestyle and life expectancy in persons with and without multimorbidity.	Longitudinal study with self-administered questionnaire and face-to-face interviews	480,940 (262,112 men)	38 - 73
Jeong *et al.* [28] (2020)	South Korea	To identify patterns of multimorbidity in adults.	Cross-sectional study with interview	9011 (3882 men)	19 - 64
Espeland *et al.* [29] (2020)	United States	To evaluate an education and caloric reduction intervention on increase in multimorbidity.	Clinical trial	5145 (1044 case men and 1038 control men)	45 - 76
Shang *et al.* [30] (2020)	Australia	To examine the association between modifiable health factors and multimorbidity.	Longitudinal study with self-administered questionnaire	53,867 (23,416 men)	45 - 54
Bishop *et al.* [31] (2021)	United States	To ascertain whether diet quality moderated the association between multimorbidity and change in mobility constraints.	Longitudinal study with face-to-face interviews	3320 (1494 men)	65+
Zhang *et al.* [32] (2022)	United Kingdom, Wales and Scotland	To examine for association between dietary patterns and long-term risk of multimorbidity.	Longitudinal study with self-administered questionnaire and face-to-face interviews.	348,290 (158,860 men)	40 - 69
Sturmer *et al.* [33] (2022)	São Leopoldo, RS, Brazil	To investigate the association between dietary patterns and multimorbidity.	Cross-sectional study with self-administered questionnaire.	1128 women	20 - 69

Tables 2-4 show the approaches used to evaluate food intake. Seven studies examined food intake from answers to questions about daily fruit and vegetable intake, six applied food frequency questionnaires, one used a three-day food record, one used 24-hour dietary recall, another evaluated intake of foods and prepared foods and one conducted a dietary intervention with healthy foods. The foods most often considered were fruit and vegetables, meats, milks and dairy products. Food frequency was the variable most often examined, particularly as regards fruit and vegetables, in line with WHO recommendations, considering intake of more than five portions daily. Also used were indices such as a diet quality index for older adults (Índice de Qualidade da Dieta de Idosos, IQD-I) and the Alternative Healthy Eating Index-2010 (AHEI-2010). The more recent studies used factor analysis to derive dietary patterns.

In most of the articles, the criterion defining multimorbidity was the presence of two or more diseases and from six to 40 conditions were considered. The diseases most often examined were arterial hypertension, diabetes, stroke, heart attack, cancer and depression.

The most common statistical analyses in the observational studies were logistic regression models, while the longitudinal studies used the Cox regression model.

The main variables used to adjust the models included sex, schooling, smoking, alcohol use and physical activity.

Three cross-sectional studies and two longitudinal studies identified an association between dietary pattern and multimorbidity. One study presented a controversial finding by suggesting that a healthy dietary pattern could be a risk factor for the development of a pattern of cardiometabolic multimorbidity.

3.2. Cross-Sectional Articles with Descriptive Analyses

In the articles with descriptive analyses [17] [20] [22] in **Table 2**, the samples comprised men and women, adults 18 to ≥64 years old and only older adults ≥65 years old. Food intake was measured by questions about daily intake of five or more portions of fruit and vegetables [20] [22] and "How many times a week do you eat or drink …?" soups and vegetables, fresh fruit, milk and dairy products, meat and chicken and water, the response categories being: every day, 6 times a week, 3 - 5 times a week, 1 - 2 times a week, rarely and never [22]. One study measured food intake by a three-day weighted food record [17].

In the case of the population of older adults (n = 1044) of the town of Diamante, in a socioeconomically disadvantaged area of central Argentina, the prevalence of multimorbidity was 33.1%. Low consumption of fruit and vegetables was more prevalent among individuals without multimorbidity (94.1%) than among those with multimorbidity (87%) and the association was positive ($p < 0.001$) [20].

In the EpiDoC Cohort [22] of the population of older adults residing in Portugal (n = 2393), overall prevalence of multimorbidity was 73.8%. By considering the means of weekly food intake variables, the study identified two diet clusters. Comparison of the means showed a clear difference between clusters as regards food intake patterns. Cluster 1 (n = 1312), classified as the "meat-based dietary pattern", featured fewer meals per week, as well as lower frequency of intake of soup, vegetables, fresh fruit, fish, milk/dairy products and little intake of water. On the other hand, cluster 2 (n = 4642), denominated the "fruit- and vegetable-based dietary pattern", showed more meals per week, high-frequency intake of soup, vegetables, fresh fruit, fish, milk/dairy products and high intake of water. Also, in cluster 2, the majority, about 85.0%, consumed meat less often than in cluster 1 [22].

In the Jiangsu Longitudinal Nutrition Study (JLN) [17] of participants 20 years old or more in a subsample from six counties in a rural area of Jiangsu province in China, prevalence of multimorbidity was 14%. In the sample of 1020 Chinese participants, the multimorbidity groups were classified into: healthy; healthy with one chronic disease; stable with one chronic disease; healthy with multimorbidity; stable with multimorbidity; and increasing multimorbidity. Fruit intake was greater in the healthy group than in the other groups ($p < 0.05$). Total fruit and vegetable intake among healthy participants who developed a first chronic disease and stable individuals with one chronic disease was greater than among those with stable or increasing multimorbidity ($p < 0.05$) [17].

Table 2. Methodological characteristics of the variables, descriptive statistical analyses and main findings (2000 to 2023).

Study	1. Food intake assessment 2. Foods considered 3. Variable	1. Assessment of multimorbidity 2. List of diseases 3. Variable	Statistical analysis	Main findings
Ruel *et al.* [17] (2013)	1. Three-day food records. 2. Fruit, vegetables. Pork, beef, poultry, fish, offal. Nuts, legumes (dried and fresh). Dairy products. Eggs. Wheat, cakes and grains. 3. Daily intake in grams of fruit and vegetables; meats; oilseeds and legumes; grains.	1. Two or more chronic diseases. 2. Clinical and biochemical tests and self-reported medical diagnosis of 11 chronic conditions: hypertension, diabetes, hypercholesterolemia, coronary heart disease, asthma, stroke, cancer, fracture, arthritis and hepatitis. 3. Healthy; healthy to first chronic disease; stable with one chronic disease; healthy to multimorbidity; stable with multimorbidity; and increasing multimorbidity.	Analysis of variance (ANOVA) between groups. Association. Pearson's Coefficient of Correlation. Adjusted for age, sex, smoking status, annual income, marital status, schooling, BMI and sedentarity.	Prevalence of multimorbidity was 14%. "(…) mean daily intake of fruits and vegetables is higher in the healthy, healthy to first chronic disease and the stable with one chronic disease groups than in the stable and increasing multimorbidity groups" ($p \leq 0.05$).
Olivares *et al.* [20] (2017)	1. Eating five or more portions daily of fruit and vegetables. 2. Foods not specified. 3. Intake of less than five portions daily of fruit and vegetables = Insufficient.	1. Two or more health problems. 2. Clinical and biochemical tests and prior medical diagnosis and history of nine chronic diseases: hypertension, diabetes, dyslipidemia, heart attack, asthma, hypothyroidism, coeliac disease, cancer, other chronic diseases. 3. With and without multimorbidity.	Chi-square test and Mann-Whitney t-test.	Prevalence of multimorbidity was 33.1%. Both groups, with or without multimorbidity, returned high prevalence of low intake of fruit and vegetables, but the group without multimorbidity returned lower intake of these groups of foods ($p < 0.001$).
Rodrigues *et al.* [22] (2018)	1. Questions on frequency of foods and prepared foods. 2. Soups, vegetables, fresh fruit, milk and dairy products, meat and fish. How many meals eaten per week and per day and how much water intake per day? 3.To clusters were formed: meat dietary pattern and fruit and vegetables dietary pattern.	1. Two or more chronic diseases. 2. Self-reported prior diagnosis of 12 chronic diseases: hypercholesterolemia, hypertension, rheumatic diseases, allergy, gastrointestinal disease, mental disease, diabetes, thyroid or parathyroid disease, pulmonary disease, hyperuricaemia, cancer and neurological disease. 3. Two or more chronic diseases.	Absolute and weighted frequencies were used to summarise the categorical variables. Continuous variables were described by weighted mean values and standard deviations.	Prevalence of multimorbidity was 78.3% in the ≥65 years old. Intake of fruit and vegetables was 85.4% of all the older adults.

3.3. Articles Reporting Cross-Sectional Designs with Multiple Analyses

Studies that used logistic regression [18] [21] [23] [24] [28] (**Table 3**) were cross-sectional in design and the dietary analyses were based on questions about fruit and vegetable intake [18] [21] [24] [28], as recommended by the WHO (2003)

[34], or extracted by principal component analysis to derive dietary patterns such as: "bread and biscuits"; "snack"; "meat, alcohol and potato" and "vegetables, fish and fruit" [23].

In the studies with a sample from Quebec, Canada, conducted by the Program of Research on the Evolution of a Cohort Investigating and Health System Effects (PRECISE) [18] project, prevalence of multimorbidity, assessed as the combination of two or more diseases, was 15.7% among men and 16.7% among women, aged 45 years or more. The prevalence of multimorbidity as two or more diseases, in the West of Scotland Twenty-07 Cohort Study ("Twenty-07") [21], was 35% among individuals over 55 years of age. In the Canadian Community Health Survey (CCHS) [24], multimorbidity was specified as the combination of diabetes mellitus, stroke and cardiac disease, the most prevalent combination being cardiometabolic multimorbidity, comprising cardiac disease and diabetes (2.2%).

One study determined the prevalence of multimorbidity from a morbidity score for previously specified (cardiovascular, endocrine and/or renal) diseases. A two-disease score had a prevalence of 8.5%, while increasing score was associated with advancing age, better physical activity level, smoking and less schooling [23].

Table 3. Methodological characteristics of the variables, multiple statistical analysis by logistic or Poisson regression and main findings (2000 to 2023).

Study	1. Food intake assessment 2. Foods considered 3. Variable	1. Assessment of multimorbidity 2. List of diseases 3. Variable	Statistical analysis	Main findings
Fortin *et al.* [18] (2014)	1. Consumption of five portions daily of fruit and vegetables (1 portion = 125 g). 2. Foods not specified. 3. Consumption of less than five portions daily of fruit and vegetables = Insufficient.	1. Three or more chronic diseases. 2. Self-reported diagnosis of 14 chronic conditions: hypertension, high cholesterol, asthma, chronic obstructive pulmonary disease, diabetes, thyroid disorders, osteoarthritis, rheumatoid arthritis, osteoporosis, diseases of the colon, angina/coronary artery disease, stroke, congestive heart failure and cancer. 3. Presence of three or more chronic conditions.	Logistic regression analysis adjusted for age, education and economic class.	Prevalence of multimorbidity with three chronic conditions was 15.7% among men and 16.7% among women. No association was found between multimorbidity and consumption of less than the recommended amount of fruit and vegetables.
Dekker *et al.* [23] (2019)	1. Application of a semi-quantitative food frequency questionnaire with 110 items. 2. Foods described in the 1997/1998 Dutch National Food Consumption Survey. 3. Dietary patterns were "bread and biscuits"; "snack"; "meat, alcohol and potato" and "vegetables, fish and fruit".	1. Two or more diseases in the cardiometabolic and endocrine or renal scores. 2. Referenced to the 2010 International Classification of Diseases. 3. Multimorbidity were calculated considering the cardiovascular, endocrine and renal disease domains to be affected when at least one disease was present in the domain.	Logistic regression model.	Prevalence of cardiovascular, renal and endocrine disease multimorbidity was 19.1%, 1.17% and 21.0% among men and 15.7%, 0.8% and 19.2% among women. The results showed a significant inverse association between quintiles of the "bread and sweets pattern" and the cardiovascular domain.

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Sakakibara *et al.* [24] (2019)	1. Daily consumption of fruit and vegetables, by interview. 2. Foods not specified. 3. Fewer than 5 portions/day" and "5 or more portions/day" of fruit and vegetables.	1. At least two of stroke, cardiac disease or diabetes = cardiometabolic multimorbidity. 2. Medical Diagnosis of stroke, cardiac disease or diabetes lasting six months or more. 3. Eight mutually exclusive diagnostic groups: i) no cardiometabolic condition; ii) stroke; iii) cardiac disease; iv) diabetes; v) cardiac disease and stroke; vi) stroke and diabetes; vii) cardiac disease and diabetes; and viii) stroke, cardiac disease and diabetes.	Logistic regression model.	The most prevalent form of cardiometabolic disease was a combination of cardiac disease and diabetes (2.2%), followed by stroke and cardiac disease (0.5%) and stroke, cardiac disease and diabetes (0.4%). Daily consumption of fruit and vegetables did not differ significantly by cardiometabolic condition group.
Jeong *et al.* [28] (2020)	1. 24-hour dietary recall. 2. foods were classified into 18 groups: grains, potatoes, sugars, beans, nuts, vegetables, mushrooms, fruit, meats, eggs, fish, seaweed, dairy products, oils, beverages, seasonings, processed foods. 3. Diet factors examined were meal frequency, skipping breakfast, frequency of dining out and use of nutrition labels.	1. Two or more chronic diseases. 2. Self-report and tests of 24 chronic diseases were assessed: hypertension, dyslipidemia, stroke, cardiovascular disease (e.g., myocardial infarction, angina pectoris), osteoarthritis and osteoporosis, cataract, depression, asthma, pulmonary tuberculosis, hepatitis B, cancer, thyroid disease, anaemia, sinusitis, allergic rhinitis, atopic dermatitis and tympanitis. 3. From principal axis factoring, three patterns of multimorbidity were classified: cardiometabolic; cancer and other diseases; and inflammatory diseases.	Logistic regression model.	Prevalence of two-pattern multimorbidity was 17.9%. Greater intake of fruit and vegetables was associated with lesser prevalence of cardiometabolic pattern than in those who ate less fruit. However, after adjustment, only fruit intake [tercile 2 OR: 0.818 (CI: 0.717 - 0.933); tercile 3 OR: 0.841 (CI: 0.736 - 0.960), p for trend = 0.0001] was associated negatively with the cardiometabolic pattern.
Pereira *et al.* [19] (2014)	1. Food frequency questionnaire. 2. Rice and beans; whole foods; vegetables; fruit; meats; milk and dairy products; sweets, soft drinks and industrialised juices; fried foods; conserves, cold meats and tinned foods; frozen foods; and snacks (fast foods). 3. One-week food or food group frequency was classified into four categories. For frozen foods, snacks (fast foods) and meats, the information was dichotomised. Besides frequency, the Diet Quality Index for Older Adults (IQD-I) was also calculated.	1. Five or more health problems. 2. Self-reported medical diagnosis of 28 health problems: arterial hypertension, diabetes, cardiac problems, heart failure, asthma, bronchitis, emphysema, arthritis, Parkinson's disease, kidney failure, hypercholesterolaemia, convulsions, stomach ulcer, osteoporosis, urinary incontinence, constipation, faecal incontinence, depression, glaucoma, deafness, difficulty swallowing, insomnia, fainting, rhinitis, difficulty speaking, stroke, mental disorders and cancer. 3. Five or more diseases present.	Poisson regression model.	Prevalence of multimorbidity (five or more morbidities) was 60.0% in the overall sample, but greater among the women (66.9%) than the men (47.5%). No statistically significant association was found between IQD-I terciles and number of diseases. No association was found with intake every day of foods considered to be healthy.

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Katikireddi *et al.* [21] (2017)	1. 7-day intake of fruit and vegetables. 2. Foods not specified. 3. Ate fruit or vegetables every day, ate fruit or vegetables on some days and did not eat fruit or vegetables.	1. Two or more chronic diseases. 2. 40 chronic conditions, hypertension, depression, respiratory conditions, coronary heart disease, dyspepsia, diabetes, thyroid, rheumatoid arthritis, hearing problems, anxiety, stress, irritable bowel syndrome, cancer, alcohol problems, other psychoactive substance misuse, constipation, stroke, chronic kidney disease, diverticular disease of intestine, atrial fibrillation, peripheral vascular disease, heart failure, prostate disorders, glaucoma, epilepsy, dementia, psychoses, psoriasis or eczema, inflammatory bowel disease, migraine, blindness, sinusitis, learning disability, anorexia or bulimia, bronchiectasis, Parkinson's disease, multiple sclerosis, viral hepatitis, chronic liver disease, pain. 3. Two or more of the 40 relevant conditions.	Multilevel logistic regression models. Adjusted for age, sex, cohort, time between waves and multimorbidity at the previous data collection point.	Prevalence of multimorbidity differed by age (2.6% up to 19 years, 4.2% up to 35 years, and 35% at 55 or more years of age). Prevalence of multimorbidity increased substantially over the 20-year period in all age groups. Women showed higher levels of multimorbidity in all cohorts at baseline and in the three waves. In the adjusted regression model, intake of a diet poor in fruit and vegetables proved to be a significant predictor of multimorbidity. No fruit/vegetable intake in the prior week, as compared with daily intake, returned OR 1.57 (CI: 1.33 - 1.84).
Bishop *et al.* [31] (2020)	1. Food frequency questionnaire 2. 164 foods 3 Alternative Healthy Eating Index-2010 (AHEI-2010), with possible scores ranging from 0 to 110 and higher scores indicting greater diet quality.	1. Sum of 9 self-reported items. 2. 9 self-reported chronic diseases: hypertension, cancer, diabetes, pulmonary disease, cardiac disease, stroke, arthritis, depression, tooth loss. 3. Continuous variable.	Poisson regression model.	Mean multimorbidity was 2.64, SD, 1.44. A one-point increase in AHEI-2010 score was associated with a 5% reduction in expected rate of mobility limitations [IRR: 0.95 (CI: 0.93, 0.97)]. In the interaction model, AHEI-2010 moderated the association between multimorbidity and change in limitations [IRR = 1.03 (CI = 1.02, 1.04)].
Sturmer *et al.* [33] (2022)	1. Food frequency questionnaire. 2. 82 food items consumed in the prior three months. Food items for which intake was <20% were excluded. 3. Dietary patterns were derived by principal component analysis. Three dietary patterns – "Healthy", "Risk" and "Brazilian" – were identified.	1. The women were interviewed at home. 2. 26 self-reported chronic conditions: hypertension, common mental disorders, acidity-related digestive disorders, dyslipidaemia, thyroid diseases, diabetes, circulatory disorders, chronic pain, osteoporosis/osteopenia, rheumatic diseases, asthma/bronchitis, other cardiac diseases, migraine, labial rhinitis, allergic disease, epilepsy, HIV/AIDS, acne, cancer, inflammatory bowel disease, glaucoma, gout, lupus, Parkinson's disease, Sjogren's syndrome and attention deficit/hyperactivity syndrome. 3. Cardiometabolic pattern, endocrine-articular pattern and psychosomatic pattern.	3. Poisson regression model.	High (34.8%) prevalence of cardiometabolic multimorbidity pattern among women from 60 to 69 years. High (32.4%) prevalence of endocrine-articular multimorbidity pattern in women from 60 to 69 years. The "Brazilian" dietary pattern was a protective factor for the cardiometabolic pattern [PR: 0.68 (CI: 0.51 - 0.89)] and psychosomatic pattern of multimorbidity [PR: 0.63 (CI: 0.47 - 0.84)]. In contrast, the "Healthy" dietary pattern was a risk factor for the cardiometabolic [PR: 1.69 (CI: 1.27 - 2.25)] and endocrine-articular [PR: 2.05 (CI: 1.39 - 3.02)] patterns of multimorbidity. The "Risk" dietary pattern was not associated with any multimorbidity pattern.

In the Korean National Health and Nutrition Examination Survey (KNHANES VI) [28], multimorbidity was examined by factor extraction, which returned prevalences of 35.9% for the Cardiometabolic Pattern, 10.5% for the Inflammatory Diseases Pattern and 4.7% for the Cancer and Other Diseases Pattern. In the United States, using data from the Health and Retirement Study (HRS) and the Health Care and Nutrition Study (HCNS) [31], multimorbidity was examined as a continuous variable of seven diseases, depression and tooth loss; the mean number of chronic diseases, that is, multimorbidity, was 2.64 (SD ± 1.44).

The PRECISE [18] findings showed no statistically significant association between multimorbidity and intake of less than the recommended amounts of fruit and vegetables [men: OR: 0.95 (CI: 0.59 - 1.54) and women: OR: 1.46 (CI: 0.94 - 2.26)]. The CCHS [24] study also showed no positive association with the cardiometabolic pattern (adjusted OR = 1.06 [CI: 0.78 - 1.45]) [24]. In the "Twenty-07" [21] study, insufficient fruit and vegetable intake was found to be a significant predictor of multimorbidity. Not having eaten fruit and vegetables in the prior week, as compared with eating them daily, returned an odds ratio of 1.57 (CI: 1.33 - 1.84).

The Lifelines Cohort study [23], which examined food records using principal component analysis, identified four dietary patterns. Statistically significant association was found in the fifth quintile of the bread and biscuit pattern [ORQ5 = 0.65 (CI: 0.60 - 0.70), $p \leq 0.001$], indicating a protective effect, as compared with the first quintile, where intake of these foods was lower. The snack [ORQ5: 1.12 (CI: 1.04 - 1.20), $p \leq 0.001$] and meat, potato and alcohol [ORQ5: 1.48 (CI: 1.37 - 1.59), $p \leq 0.001$] patterns showed greater risk in the fifth quintile than in the first.

In the KNHANES VI [28] sample, principal component analysis showed the cardiometabolic multimorbidity pattern to be associated with fruit intake terciles, and demonstrated the protective effect with statistical significance [ORT2 = 0.818 (CI: 0.717 - 0.933) and ORT3 = 0.841 (CI: 0.736 - 0.960)]. However, no significant association was found with intake of cereals, vegetables or meats.

Of the studies that used Poisson regression and multilevel models, four applied the food frequency questionnaire [19] [31] [33] and one assessed fruit and vegetable intake [21]. The analyses included use of índices [19] [31], principal component analysis33 and food intake frequency [21].

Prevalence of multimorbidity in older adults in the urban area of Pelotas (Rio Grande do Sul, Brazil) was 60% [19]. In São Leopoldo (Rio Grande do Sul, Brazil), principal component analysis returned prevalences among women of 34.8% for the cardiometabolic pattern, 32.4% for the endocrine-articular pattern and 28.8% for the psychosomatic pattern [33].

In the above study of older adults living in the urban area of Pelotas (RS, Brazil) [19], a short food frequency questionnaire grouped foods by categories, e.g., rice and beans; vegetables; milks and dairy products; whole foods (wholemeal bread, wholemeal biscuits, wholegrain rice, oats); meats; sweets, soft drinks and industrialised juices; fried foods; conserves, cold meats and tinned foods; and snacks

(fast food). It also found an association with the Diet Quality Index for Older Adults (IQD-I).

The Pelotas study [19] found no statistically significant association between multimorbidity and intake of unhealthy foods, such as sweets, soft drinks and industrialised juices [PR = 1.01 (CI: 0.90 - 1.12)]; fried foods [PR = 1.04 (CI: 0.62 - 1.74)]; conserves, cold meats and tinned foods [PR = 1.01 (CI: 0.79 - 1.30)]; and snacks [PR = 0.86 (CI: 0.67 - 1.09)] and healthy foods, such as rice with beans [PR = 1.01 (CI: 0.87 - 1.17)], vegetables [PR = 0.98 (CI: 0.83 - 1.17)] and fruit [PR = 0.91 (CI: 0.79 - 1.05)]. No association was found between IQD-I terciles and the number of diseases, in either men (p = 0.513) or women (p = 0.674).

In the study of women living in São Leopoldo [33], southern Brazil, a food frequency questionnaire comprising 82 food items and analysed by principal component analysis found three patterns. The "Brazilian" dietary pattern proved a statistically significant protective factor for cardiometabolic and psychosomatic multimorbidity, respectively, PR: 0.68 (CI: 0.51 - 0.89) and PR: 0.63 (CI: 0.47 - 0.84). Meanwhile, the "Healthy" dietary pattern proved to be a risk factor for cardiometabolic and endocrine-articular multimorbidity, respectively, PR: 1.69 (CI: 1.27 - 2.25) and PR: 2.05 (CI: 1.39 - 3.02). The "Risk" dietary pattern showed no significant association with multimorbidity patterns.

In the study using HRS/HCNS [31] records, diet was assessed using the Alternative Healthy Eating Index-2010 (AHEI-2010), by which higher scores indicate better diet quality. A one-unit increase in AHEI-2010 score was associated with a 5% reduction in the expected rate of mobility limitations [IRR: 0.95 (CI: 0.93, 0.97]. Also, interaction analysis found that the AHEI-2010 moderated the association between multimorbidity and change in limitations [IRR = 1.03 (CI: 1.02, 1.04)].

The "Twenty-07" [21] study assessed the frequency of fruit and vegetable consumption in the prior seven days. The results indicated a statistically significantly greater risk of multimorbidity among those who consumed fruit and vegetables on only some days [OR: 1.06 (CI: 0.95 - 1.19)] or on no days [OR: 1.57 (CI: 1.33 - 1.84)].

3.4. Articles with Longitudinal Designs and Multivariate Analyses

In articles reporting use of multivariate regression (**Table 4**), all analyses were longitudinal. One study used a food frequency questionnaire [32], another examined what was eaten at breakfast (cereal, milk and fruit), chicken, red meat and vegetables30, while three studies assessed daily consumption of portions of fruit and vegetables [25]-[27].

Edad con Salud [25], a longitudinal survey, by domicile, of the non-institutionalised adult population of Spain, begun in 2011, considered individuals 65 years or more of age (n = 1699). Prevalence of multimorbidity, with two or more chronic conditions, was 56.2%. A cohort study in Ontario, Canada, with data from the Canadian Community Health Survey (CCHS) [26], representing 98% of the population and ongoing since 2000, considered a sample of 112,870 participants who had completed at least two cycles of medical treatment of the six cycles stud-

ied. Incidence was 1.98 chronic diseases per 100 person-years, but greater among men than among women (2.09 vs. 1.90 per 100 person-years). The cumulative incidence of any of the six chronic diseases was greater in women up to 48 years of age, but from that age onwards, came to be greater among the men [26].

Table 4. Methodological characteristics of the longitudinal and experimental observational studies, multivariate statistical analysis with Cox model and main findings (2000 to 2023).

Study	1. Food intake assessment 2. Foods considered 3. Variable	1. Assessment of multimorbidity 2. List of diseases 3. Variable	Statistical analysis	Main findings
Olaya *et al.* [25] (2019)	1. Daily consumption of WHO-recommended number of 80-g portions of fruit and vegetables. 2. 18 fruit and vegetables, except tubers. The foods were not specified. 3. Portions of fruit and vegetables in terciles: low (3/day), medium (4/day) and high (5/day).	1. Two or more medical conditions. 2. Self-reported prior diagnosis of seven chronic diseases: arthritis, asthma, chronic obstructive pulmonary disease, angina, stroke, hypertension and diabetes. 3. Two or more of three chronic diseases.	Cox regression model.	Prevalence of multimorbidity was 56.2% for two or more chronic conditions. Eating five or more portions of fruit daily increased the likelihood of survival by 27% as compared with those who consumed two portions a day or fewer.
Ng *et al.* [26] (2020)	1. Consumption of portions de fruit and vegetables six or more times a day. 2. Foods not specified. 3. Consumption of portions de fruit and vegetables six or more = Sufficient.	1. Incidence of first chronic disease, cancer, dementia and arthritis. 2. Self-reported prior diagnosis of six chronic diseases: congestive heart failure, chronic obstructive pulmonary disease, diabetes, lung cancer, heart attack and stroke. 3. Two or more of these conditions.	Cox regression models.	Overall, the cohort returned 1.98 chronic diseases per 100 person-years, but incidence was greater in men than in women (2.09 vs. 1.90 per 100 person-years). In both sexes, relative risk of incidence of any first chronic disease increased with decreasing daily consumption of fruit and vegetables.
Chudasama *et al.* [27] (2020)	1. Daily consumption of fruit and vegetables. 2. Foods not specified. 3. Eating fewer than five portions of fruit/vegetables per day = unhealthy diet.	1. Two or more clinical diagnoses. 2. Self-report of 36 chronic conditions: anaemia, angina, anxiety/panic attacks, asthma, atrial fibrillation, bronchiectasis, cancer, kidney disease, chronic obstructive pulmonary disorder, sinusitis, cirrhosis, dementia, depression, diabetes, eczema/dermatitis, epilepsy, glaucoma, heart failure, hepatitis, hypertension, inflammatory bowel disease, irritable bowel syndrome, meningitis, migraine, multiple sclerosis, heart attack, osteoporosis, Parkinson's disease, vascular disease, prostate problems, rheumatoid arthritis, schizophrenia, stroke, thyroid problems, tuberculosis or vestibular disorder. 3. Two or more of these chronic diseases.	Royston-Parmar flexible parametric proportional-hazards model.	Prevalence of multimorbidity was 19.5%. The association between consumption of five or more portions of fruit and vegetables and multimorbidity was not statistically significant.

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Shang *et al.* [30] (2021)	1. Reported diet. 2. Cereal at breakfast, milk, chicken, red meat, vegetables and fruit. 3. Cereal at breakfast (poor or rich in food fibre); milk (none, full-cream, semi-skimmed, skimmed and soy); Chicken (none, 1 portion/week, 2 portions/week, 3 or more portions/week); red meat and vegetables (none or 1 portion/week, 2 portions/ week, 3 or 4 portions/week, 5 or more portions/week).	1. Co-occurrence of two, three or four chronic conditions 2. Self-report of 11 chronic conditions: cardiac disease, stroke, hypertension, cancer, diabetes, Alzheimer's disease, Parkinson's disease, depression, arthritis, osteoporosis and hip fracture. 3. Incidence of multimorbidity was defined as the co-occurrence of ≥2, ≥3 and ≥4 chronic conditions based on the first appearance of the second, third and fourth condition, respectively.	Machine learning: logistic regression, random forest, gradient boosting algorithm and deep learning. Cox multivariate regression analysis.	In men and women, prevalence of two chronic conditions was 42.4% and 57.6%; three, 47.2% and 52.8%; and four, 55.0% and 45.0%, respectively. Among the five main predictors of multimorbidity in men with ≥2 chronic conditions were chicken and red meat and, in men with ≥4 chronic conditions, red meat.
Zhang *et al.* [32] (2022)	1. Food frequency questionnaire. 2. Weekly consumption frequency and how many portions per day of: processed meat, beef, lamb, pork, poultry, oily fish, non-oily, fresh fruit, dried fruit, raw vegetables, cooked vegetables, cheese, bread and cereals. 3. Principal axis analysis resulted in the "Western", "White Meat" and "Prudent" dietary patterns.	1. Two or more chronic conditions 2. Diabetes, heart attack, stroke, chronic obstructive pulmonary disease, breast cancer (women), prostate cancer (men), lung cancer, hip fracture, rheumatoid arthritis, Alzheimer's disease, Parkinson's disease and mental disorder. 3 Number of chronic diseases.	Cox regression model.	Incidence of multimorbidity was 14.6%. The Western dietary pattern showed strongest association with multimorbidity in the largest quintile.
Espeland *et al.* [29] (2020)	Food and energy interventions in participants divided into intense lifestyle intervention (ILI) case groups and diabetes support and education (DSE) control groups, which were followed up annually for 8 years.	1. Multimorbidity index. 2. List of nine self-reported and laboratory-measured chronic diseases: cancer, cardiac arrhythmia, renal disease, CHF, coronary artery disease, depression, dyslipidaemia, hypertension, stroke. 3. Multimorbidity index.	Covariance analysis.	Over the 8 years, multimorbidity index scores increased in the DSE group, as compared with the ILI group.

A study using the records of the UK Biobank [27], involving adults from 38 to 73 years old, recruited at 22 sites in England, Wales and Scotland between 2006 and 2010, and considering a total sample of 480,940 individuals, found prevalence of multimorbidity of 19.5%. In another study using the same records of the UK Biobank [32], found 14.6% prevalence of multimorbidity in a final sample of 348,290 adults from 40 to 69 years of age.

In the New South Wales (NSW) [30] cohort, in Australia, which included 53,867 participants from 45 to 64 years of age at baseline between 2006 and 2009, prevalence of two chronic conditions was 42.4% and 57.6% in men and women, respectively; three conditions, 47.2% and 52.8%; and four conditions, 55.0% and

45.0%.

In the Edad con Salud [25] cohort, food intake was measured as daily consumption of portions of fruit and vegetables, considering a portion to be 80 g. Participants were classified into three groups (terciles): low (3 portions per day), medium (4 portions per day) and high consumption (5 portions per day). The Kaplan-Meier curves estimated indicated that fruit and vegetable intake level had a significant positive impact on survival. Individuals who consumed five or more portions daily and had two chronic diseases were at 27% less risk of mortality [HR = 0.38 (CI: 0.21 - 0.69)] than participants who consumed three or fewer portions.

The CCHS [26] study examined daily frequency of fruit and vegetable intake between 2001 and 2014, classified into three categories: from 0 to 3 times a day; from three to six times a day; and more than six times a day.

Participants in the UK Biobank [27] cohort were classified into two groups: Group 0 were those with no regular physical activity, current smokers, consuming fewer than five portions daily of fruit and vegetables and excessive alcohol consumption, while Group 1 featured regular physical activity, non-smokers, consuming five or more portions daily of fruit and vegetables and moderate or no use of alcohol. At baseline, a healthy diet was reported by slightly more participants with multimorbidity than those with no multimorbidity (39.2% versus 37.7%). After adjustment for covariables, life expectancy increased as level of healthy lifestyle rose: at 45 years of age, a healthy score in men with multimorbidity was associated with an increase of 4.5 years (CI: 3.3 - 5.7; $p < 0.001$); a very healthy score, with 6.3 years (CI: 5.0 - 7.7; $p < 0.001$). Among women, a healthy score resulted in an increase of 6.4 years (CI: 4.8 - 7.9; $p < 0.001$) and a very healthy score led to an increase of 7.6 years (CI: 6.0 - 9.2; $p < 0.001$).

From 14 items on the UK Biobank [32] cohort food frequency questionnaire and dietary patterns derived by exploratory factor analysis, three dietary patterns were identified: Western, White Meat and Prudent. The Cox regression model was used to estimate the association between dietary pattern and multimorbidity. The results showed that the Western dietary pattern was associated most strongly with multimorbidity in the largest quintile [HRQ5: 1.06 (CI: 1.03 - 1.09)], the White Meat dietary pattern returned the weakest association with multimorbidity in the third quintile [HRQ3: 0.97 (CI: 0.94 - 0.99)] and the Prudent pattern was associated with the lowest risk of developing multimorbidity [HRQ5: 0.92, CI: 0.90 - 0.95)].

In the NSW [30] cohort, the gradient boosting algorithm—a machine learning technique used for problems of regression and classification, which generates a predictive model—showed that, in men, the main food predictors for multimorbidity with two or more diseases were: low consumption of fruit (11.3%) and a diet rich in red meat (13.7%) and chicken (5.8%). Among the women, the food predictors for two or more diseases were: low consumption of fruit (1.5%) and a diet rich in red meat (14.3%) and chicken (31.5%).

Data from the Action for Health in Diabetes (AHEAD) [29] controlled, ran-

domised clinical trial were used to assess whether eight years of intervention (2004-2012) reduced the increase of an index of multimorbidity, including chronic diseases and deaths from all causes. The intervention consisted in losing weight by reducing total energy (calorific) intake to 1200 - 1500 kcal/day for participants with body mass of less than 114 kg and 1500 - 1800 kcal/day for those with body mass of 114 kg or more. The total calorific value of the diet was distributed as follows: <30% from fats, <10% from saturated fats and ≥15% from protein.

The dietary intervention was accompanied by increased physical activity. An Intensive Lifestyle Intervention (ILI) group was formed for comparison with a control Diabetes Support and Education (DSE) group, which received no specific goals as regards diet, physical activity or weight change, but was invited to three group sessions per year focusing on diet, physical activity and social support.

The cohort comprised 5145 individuals (2001 to 2004), aged from 45 to 76 years, with overweight or obesity and a diagnosis of type-2 diabetes, the goal being to induce ≥7% mean weight loss in the first year of follow-up and then maintain it. Mean multimorbidity was observed to increase over the eight years, with HR = 0.89 (CI: 0.85 - 0.93) in the ILI group and HR = 0.97 (CI: 0.94 - 1.07) in the DSE group. The ILI group returned smaller increases in the multimorbidity index after eight years.

After 12 months, the ILI group showed significantly lower intake of fats and cholesterol and greater intake of fibres than the DSE group. The ILI group consumed more portions/day of fruit, vegetables, milk, yoghurt and cheese, and fewer portions/day of fats, oils and sweets than the DSE group. A higher percentage of ILI group participants followed the recommendations regarding fats and most of the food groups than the DSE group [35] [36].

4. Discussion

The association between dietary pattern and multimorbidity varied with study design, statistics technique used, food consumption variable and analytical plan. In order to facilitate comparison of findings between studies, the articles were organised by the statistical analysis employed. In all, 11 articles reported longitudinal studies [17] [18] [21]-[23] [25]-[27] [29] [30] [32] and six used multivariate analyses [25]-[30] [32].

The longitudinal studies examined fruit and vegetable intake [25]-[27], following WHO recommendations, as well as deriving dietary patterns [32] and food intake at meals, particularly items such as cereals and breakfast and amounts of red meat, white meat and vegetables [30]. Of the studies that used Cox regression models to evaluate fruit and vegetable intake, two found increased risk of incidence of multimorbidity associated with lower fruit intake [25] [26], while one found no significant association [27]. In all the longitudinal analyses, fruit and vegetable intake was measured and stratified; high intake of these foods was found to reduce the relative risk of multimorbidity.

In one study that applied factor analysis to derive dietary patterns, the Western

pattern (beef, pork, lamb/mutton, poultry) was associated more strongly with multimorbidity than the Prudent pattern (vegetables, fruit and cereals) [32]. As the Cox model is more flexible, when applied in the analytical plan, it enabled the hazard rate ratio to be estimated, indicating the likelihood of the individuals' developing multimorbidity over time [37].

The experimental study assessed an energy food intervention. The group that received guidance on lifestyle and diet took longer to develop multimorbidity [29]. Also, with age, fruit and vegetable intake showed a protective effect against the progression of a number of diseases.

Among the studies that used logistic regression models and investigated fruit and vegetable intake, the Canadian studies found no significant association [18] [24]. However, one study in Scotland showed an important relationship between not eating fruit and vegetables and multimorbidity [21]. There were significant differences among participants who did not eat these foods, those who ate them in the prior week and those who ate them daily [21]. Use of the "fruit and vegetable intake" variable in dichotomous format (Yes/No) could be a limitation on explaining this relationship, because an association was identified when stratified into more detailed categories.

In studies that applied factor analysis to derive dietary patterns [23], a significant inverse association was found between quintiles of the "bread and sweets pattern" in the cardiovascular domain. Meanwhile, the "Brazilian" dietary pattern [33] proved to be a protective factor for the cardiometabolic and psychosomatic multimorbidity patterns. However, the "Healthy" pattern was found to be a risk factor for the cardiometabolic multimorbidity pattern, while the "Risk" dietary pattern showed no association with any pattern of multimorbidity.

Studies that used indices to evaluate dietary pattern [19] [31] produced diverse results. The IQD-I and number of diseases [19] showed no statistically significant association. Meanwhile, the AHEI-2010 2010 indicated that scorers of ≥48.4 moderated the association between multimorbidity and change in mobility limitations [31]. Dietary quality indices such as the AHEI-2010 and MEDAS have been linked to a reduced risk of various chronic diseases. However, evidence on their association with multimorbidity remains limited [38].

An evaluation of dietary factors in 18 food groups [28] found that a greater fruit and vegetable intake was associated with lower risk of cardiometabolic multimorbidity, as compared with individuals who consumed less fruit. However, when the statistical models were adjusted, fruit intake in isolation returned a negative association with this pattern of multimorbidity.

Treatment of diet as a variable varied significantly among the studies that applied Poisson regression [19] [31] [33], which addressed from the exclusive consumption of fruit and vegetables through to patterns derived by factor analysis and diet indices. The results were inconsistent, comprising both statistically significant associations and no association. However, studies that derived patterns of multimorbidity indicated that fruit and vegetables [22] [23] [32] and the "Brazil-

ian" dietary pattern [33] were associated with lower risk of cardiometabolic multimorbidity.

The descriptive articles [17] [20] [22] examined intake of different food groups, such as cereals, legumes, milk and dairy products, meat products, fruit and vegetables, with varying results. Greater fruit and vegetable intake [20] was observed among individuals without multimorbidity, while high intake of these foods was more frequent among older adults.

Assessment of human food intake is complex, calling for integrated analysis of nutrients, food groups and diet patterns, guided by the principles of proportionality, variety and moderation. Ioannidis (2005) [39] stressed that epidemiological studies of food and health outcomes find small effects that are difficult to interpret.

One paradoxical result observed was the association of healthy dietary patterns with risk profiles. That finding may result from reversed causality in cross-sectional studies or a biases in food reporting influenced by social desirability. Cohort studies help to understand the prevalence of risk factors, by considering the impact of eating habits acquired in prior periods, especially among older adults. A geographical influence was also observed, in that lifestyles vary with cultural context.

The findings reported by Afshar *et al.* (2016) [40], which indicated a global age-standardized prevalence of multimorbidity of 7.8% across 27 low and middle-income countries (LMICs) and one high-income countries (HIC), are consistent with the broader literature, highlighting a higher prevalence among women, older adults, and notably, among younger individuals in low- and middle-income settings. In countries with higher gross domestic product (GDP), socioeconomic status was inversely associated with multimorbidity, suggesting a protective effect of higher socio-economic status (SES).

In the present review, although the studies included differing methodological design and were conducted across eight different countries, seven out of seventeen studies followed the World Health Organization's recommendation on daily fruit and vegetable consumption. This methodological consistency may have contributed to a more uniform basis for comparing dietary influences on multimorbidity. Nonetheless, the limited scope of dietary variables analyzed—excluding other culturally and nutritionally relevant components of participants' habitual diets—may have influenced the observed associations.

Also, the predominant use of self-reported data increases the risk of memory bias and of responses influenced by social norms. Furthermore, the heterogeneity in study designs, populations, and analytical strategies limits the generalizability and comparability of results, despite efforts to organize the findings based on the statistical approaches employed by the original authors.

This scoping review did not apply instruments to assess the quality of the publications examined. Also, although the search was wide, it was limited to specific bibliographical databases in the health field.

5. Conclusion

This review summarises the evidence on the relationship between food intake and multimorbidity, with important implications for public health. Diets rich in fruit and vegetables were consistently associated with lower risk of multimorbidity, while the main dietary risk factor, in both men and women, was intake of red meat and chicken. The evidence of the importance of diet is still not completely clear, but what is certain is that particularly fruit and vegetables must be included in preventing the simultaneous occurrence of various chronic conditions. Also, change in eating habits can influence the course of multimorbidity and contribute to reducing risk and increasing life expectancy.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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