Beef Consumption and Functional Performance in Middle-Aged and Older Adults: A Narrative Review

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REVIEW

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ABSTRACT

Background: Consumption of high-quality protein foods or supplements are associated with acutely elevating muscle protein synthesis and suggested to assist with muscle preservation across the aging process. Maintaining muscle mass, in return, is hypothesized to be beneficial for improving markers of physical function, which is important not only in older adults but also middle-aged populations. On a per gram basis, lean beef is one of the densest proteins and a strong contributor of the amino acid leucine, an activator of muscle protein translation efficiency within skeletal muscle. **Aim:** To review evidence for evaluating the associations between beef intake and functional performance in middle-aged and older adults. **Methods:** A narrative search was conducted through October, 2019. **Results:** Included articles were 20; nine randomized controlled trials, six cross-sectional investigations, three prospective cohort, and two randomized repeated measures studies. Almost all of the studies did not evaluate beef consumption directly, but instead evaluated beef consumption as part of animal-based protein consumption. No studies directly compared the associations of beef consumption to functional performance. **Conclusion:** Based on the articles in this review, evidence of a direct relationship between beef intake and functional performance in middle-age and older adults is lacking. Dietary assessments did not distinguish beef from other foods, thereby making it challenging to determine a causal impact of beef on specific measures of functional performance. Therefore, we suggest that more studies directly measure beef consumption and determine how beef is associated with functional performance. Such information will provide insights for interventions aiming to preserve functioning through diet.

Keywords: Beef, protein foods, dietary assessments, functional performance

INTRODUCTION

Retaining strength is paramount for preserving physical function and independence during aging. Strength is inversely related to self-reported functional limitations

[1]. Additionally, hand grip strength is a component of several different tools used to screen for sarcopenia and to assess frailty, and in some cases, hand grip strength alone is used to evaluate frailty [2]. More important, measures of physical functional performance such as hand grip strength and gait speed are related to cardiovascular disease mortality [3]. Although losses in strength with aging cannot be completely attenuated, evidence suggests that exercise can improve physical functional performance in older adults [4, 5]. There is also an association between protein intake and frailty [6]. However, to our knowledge, only two systematic reviews of dietary protein and physical functional performance with aging have been completed, [7, 8] and only one of these focused on a specific food or type of food: dairy [8]. As such, the contributions of individual foods or food groups for preserving physical function remains unknown.

Beef consumption is of particular interest because, on a per gram basis, it is the densest source of protein [9] and is rich in other nutrients such as, heme-iron, vitamin B12, zinc, [9] and fatty acids [10] that may also help preserve muscle mass and strength during aging. For example, iron plays a key role in hemoglobin, myoglobin, and the electron transport chain [11]. Similarly, vitamin B12 affects hemoglobin synthesis, and deficiencies of either iron or vitamin B12 may result in anemia [12]. Both iron and vitamin B12 are particularly important during aging because anemia is related to decreased functional performance in older adults [13] and [14]. Zinc is a part of many enzymes, and as such, serves many disparate functions within the human body [12]. More importantly, greater zinc intake is related to higher lean body mass in older adults [15]. In addition to these vitamins and minerals, beef is also rich in the amino acid leucine [16]. The relationship between increased leucine intake and the maintenance of physical function with aging is generally positive, and the magnitude of this relationship increases when combined with physical exercise [17]. Fatty acids, particularly n-3 polyunsaturated fatty acids, attenuate age-related losses in physical performance [18]. Most important to functional performance though, may be the protein content of beef as protein can stimulate muscle protein synthesis [19]. About 25 to 30 grams of protein are thought to be needed to stimulate an anabolic response in older adults [20], and 100 grams of cooked flank steak provide 28 grams of protein [21]. Therefore, the nutrient composition of beef may be influential for preserving physical function during aging, and a focused review of the literature is warranted for assessing current evidence and making recommendations for future research. We sought to review evidence for the association of beef intake and functional performance in middle-aged and older adults.

MATERIALS AND METHODS

Data source and search strategy

Originally, a systematic literature electronic search was conducted on the PubMed and Science Direct databases through October, 2019. The search terms included (beef OR “animal-based food” OR “animal-based protein”) AND (“functional performance” OR “physical function” OR “muscle function” OR “muscle strength” OR “task performance” OR “functional abilities”) AND (middle-aged OR “middle aged” OR “older adults” OR aging OR aged OR elderly), using a Boolean command. Figure 1 includes a clarification of terms and concepts used in the review. A total of 216 search permutations were assessed from both databases, as part of two independent searches conducted by two separate research assistants. Full-text articles, assessed for eligibility (n=27), were independently screened by five researchers until consensus was reached as part of weekly face-to-face discussions until all articles were discussed. Searches were not limited by using filters or other similar filtering tools. The title, journal, year of publication, first author’s last name and reason for exclusion were recorded for each search result and are available as supplementary data.

Eligibility Criteria

In order to be included, each article must have been written in English-language, published in a peer-reviewed journal by 1997, and based on original research using human subjects aged at least 40 years including correlational, longitudinal, experimental and clinical trial studies. A wide approach was employed to be sure to include observational and cross-sectional studies, regardless of the number of subjects in the study. Included article references were also checked manually to search for further relevant articles. Articles were excluded if they did not assess or manipulate beef intake or investigate functional performance. Works were also excluded if they were case studies, reviews, editorials, opinions, theses, dissertations, or conference presentations.

Study Selection, Quality Assessment and Data Extraction

Search results were first evaluated for inclusion according to their titles and abstracts. Articles that were not excluded based on their title and abstract were downloaded, and the full text was reviewed for inclusion by each investigator. With a large heterogeneity of variables and outcomes, it was not possible to use Grading of Recommendation Assessment Development and Evaluation system. Due to the considerable differences in methods, variables and outcomes, and a limited number of included articles, we chose to compare and contrast relevant articles into a narrative review, rather than force a systematic review of dissimilar variables. Nonetheless, articles must have included a measure of (1) functional ability and (2) dietary meat consumption in a conducted research study with human subjects in order to be evaluated and part of this review. An independent appraisal of all articles was executed by each investigator, and then subsequently discussed during meetings. Any disagreements over inclusion or exclusion was discussed until a consensus was reached for each article regarding the required components.

RESULTS

A total of 3,520 hits were found during the database searches. After duplicates were removed, there were 814 unique search hits. Of these, 789 were excluded based on their title or abstract. Thus, 25 full-texts, plus references, were reviewed. During these full text reviews, we discovered that two of the works used data from previous studies, so two additional articles were identified and included, resulting in a total of 27 articles whose full text were reviewed. After full texts were reviewed, seven studies were excluded.

Study Characteristics

Nine randomized controlled trials, six cross-sectional, three prospective and two randomized repeated measures studies were included. Papers were published between 2002 and 2019 and ranged from 19 to 419,075 participants. The total number of included articles was 20. Figure 1 illustrates the exclusion and inclusion screening process. Studies were excluded for the following reasons: study not conducted yet, age range too young, study did not measure or report functional performance, and/or meat consumption not tracked. Table 1 describes the included studies.

DISCUSSION

Summary of Main Findings

Based on this narrative review, the association of beef intake on functional performance remains unexplained because no studies directly linked beef intake to functional performance, regardless of study design. The relationship between increased protein and leucine intake and the maintenance of physical function with aging is generally positive, and the magnitude of this relationship increases when combined with physical exercise [17]. Nutrient-rich beef is a good source of leucine plus a long list of macro- and micro-nutrients needed for long-term health. However, evidence regarding animal-based foods individually, specifically regarding lean beef, is limited, and due to heterogeneity of the identified articles, comparisons among study methods were nearly impossible to determine. This is due to variation in several factors including the following: study design, meat type, exercise interventions, methods to determine functional performance, sex, age, and ethnicity of research subjects, dietary measures used, and interventions used.

Individual Study Designs

The most remarkable result of this project is the number of studies that both measured or included beef as part of an intervention and examined functional performance but neglected to examine any relationships between the two variables. Of the 11 studies that had an experimental design, [22–32] only five examined this relationship [23, 25, 26, 31, 32]. Studies with non-experimental designs were more explorative; seven investigated the correlation between beef intake and functional performance, [33–39] whereas only two did not [40, 41].

Such results may lead one to think that non-experimental designs are preferable. Yet, studies with non-experimental designs often yielded less favorable results in regard to beef intake and functional performance. Nonetheless, only two non-experimental studies showed a negative relationship between beef intake and functional performance. More specifically, in both works, high red meat intakes, as part of larger dietary patterns, were related to decreased hand grip strength [36,38]. In one of these two articles, high red meat intake was also related to increased timed-up-and-go time [36]. Similarly, although not a performance measure, red and processed meat intake was also related to increased risk of mortality in another study that employed a non-experimental design, but the relationship was mitigated by physical activity [33]. Two studies using non-experimental designs reported no relationship between beef intake and functional performance [34, 39]. One non-experimental study found a positive relationship between animal-based protein intake and hand grip strength [37], and another discovered an inverse relationship between animal-based protein intake and self-reported functional task limitations [35]. On a whole, the inability to separate beef from other foods or dietary patterns makes interpretation of these results difficult if not impossible.

In contrast, experimental or interventional projects produced more striking results, at least when the relationship between beef intake and functional performance was investigated. Older women consuming 160g cooked beef per day as opposed to a serving of pasta increased their leg extension strength to a greater extent during a resistance training program [23] and reported greater benefits in self-reported quality of life as measured by the Health-Related Quality of Life 36-Item Short Form (SF-36) [31]. Similarly, during a six-month weight loss and exercise intervention, older men and women who were consuming supplemental beef showed greater Short Physical Performance Battery (SPPB) scores than those in the control group [32]. However, others did not find a benefit with beef protein compared to an equivalent amount protein from a lacto-ovo-vegetarian diet [25, 26]. Lastly, it must be noted that no study used the gold-standard nutrition research design: a controlled feeding study.

Accounting for Beef and Other Foods

The ability to identify and to quantify dietary intake, or specifically certain foods, that impact health acutely, or long-term, is subjective and, frustratingly, limited by a long list of obstacles to targeted estimation specificity. Dietary record collection must be study-specific to account for differences in culture, age, and other demographic differences [42]. In fact, 7-day food records have been identified as the "gold standard" for dietary intake collection studies [43]. Daly and colleagues [23], Kim and colleagues [27], and Torres and colleagues [31] reportedly used repeated food records and involved "trained research dietitians" as facilitators and/or subject educators.

A limitation of food frequency questionnaires (FFQs) is the small number of food choices. An average supermarket in the United States carries at least 30,000 different foods [44], and other cultures add to this number of foods. In contrast, a typical FFQ has about 100 food choices. In this review, the least number of food choices was 29 different foods [33] and the greatest was 150 [22, 38]. Reduced variability can be achieved by a repeated measure design with multiple FFQ's. As part of this review, the following studies reported that they repeated collection of a food log or FFQ for greater than 3 days: Bradlee, Mustafa, Singer, and Moore (6 days) [35], Daly, O'Connell, Mundell, Grimes, Dunstan, and Nowson (4 days) [23], Kikafunda and Lukwago (7 days) [40], Kobza and colleagues (4 days) [28], and doubly reported Payne and colleagues [30] and Porter Starr and colleagues [32]: >20 days reported in each paper and each utilized the same data set. Other studies, namely Perälä and colleagues [38] collected dietary intake data only at baseline and projected functional ability findings up to 10 years later solely on the baseline data.

Several studies used a 24-hour food recall [31, 35, 36, 39]. However, after data collection, more than a few studies only reported dietary patterns [27, 36, 37, 45]. Our goal was to find studies that track how beef consumption is linked to functional performance. While the 2015-2020 Dietary Guidelines for Americans emphasize the importance of an overall dietary pattern for a potential impact on long-term health [46], dietary pattern research severely limits the ability to generalize how or why a pattern might impact certain chronic diseases. For example, Granic and colleagues [36] compared three patterns. One of the three patterns included "high red meat," which not only included red meat but also potatoes and gravy. Hashemi and colleagues' "Western" pattern included "high red meat" but also many other foods [37]. Both of these studies seem to ignore potential differences that could be attributed to following either a diet very high in saturated fat or potentially a diet that includes ample lean non-processed beef (or pork or lamb). Lastly, beef was aggregated with other variables in a couple of studies. One group of researchers combined red meat and processed meat as one variable [33], and another combined beef with eggs and dairy [27]. Combining beef or red meat with other foods makes it impossible to determine the effects of beef or red meat alone on functional performance.

Exercise Interventions

Recommendations for mitigating sarcopenia and dynapenia advocate for synchronous implementation of both an exercise program and a diet rich in high-quality proteins [47]. However, only five of the studies included some type of structured, monitored, or documented exercise training intervention [23–26, 31]. Protocols across research groups varied but appeared to be predominantly resistive based, focusing on muscle hypertrophy and strength gains. It should also be noted that some of the studies also appeared to be from the same original data set [25, 26], but this cannot be confirmed from this review. In addition, one study utilized exercise and a protein intervention designed for weight loss [32]. A negative energy balance is a different type of physiological stimulus as it pertains to functional performance compared to neutral or positive energy balance. For example, it is plausible, depending on the task, that reduced body mass may improve performance, while, concurrently, lower energy stores worsen performance. Overall, future recommendations should include a greater emphasis on concurrent resistance and aerobic training with a defined protein source if the goal is to increase functional capability and performance. This type of programming would be more consistent with exercise recommendations for older adults [48].

Functional Performance Measures

The loss of physical performance with aging is one characteristic of sarcopenia [49, 50]. Because it can be difficult to separate muscle strength from physical performance, studies using various direct and/or indirect outcomes for both, referred to as muscle functional performance, were included. Direct methods using quantitative data were most common (n=9). However, indirect methods with qualitative data (n=4), and combination methods (n=7) were also used. Direct methods included hand grip strength [27, 29, 30, 32–34, 36–38], habitual gait speed [27, 29, 37], stork stand time with eyes open [29], SPPB [30, 32, 39], various methods of upper and lower body strength [23, 26–28, 31, 38, 51], 4-square step test [23], timed up and go (TUG) [23, 36], sit to stand [23, 52], and stair ascent/descent power [52]. Indirect methods included self-reported gait speed, SF-36 [29–32], Rosow-Breslau scale [35, 39], Oral Health Impact Profile for the Edentulous [22], Nagi scale [35], 6-item self-reported Activities of Daily Living questionnaire [40], Instrumental Activities of Daily Living [41], and Activities of Daily Living scores [41].

Qualitative methods like questionnaires can be useful for determining physical function in clinical settings [50]. However, it has been suggested that future studies should use SPPB, gait speed, 400m walking distance, and hand grip strength outcomes for physical functional performance and hand grip strength, chair rise, and knee extension strength as outcomes for muscle strength [49]. Although indirect outcomes are feasible, we suggest increasing consistency by designing research to examine the effects of, or relationships between, lean beef intake and physical performance using direct outcomes or a combination of direct and indirect outcomes. For example, a randomized controlled trial (RCT) examining the associations between lean beef intake and physical performance might examine several of the direct outcomes, while an observational study might combine indirect outcomes with a simple direct outcome like hand grip strength.

Sex, Age, and Ethnicity

Sex, age, and ethnicity are demographic risk factors for functional deficits [53]. As such, healthcare providers should inform persons of their demographic risks, and interventions aiming to preserve functional performance should acknowledge these factors when targeting populations. Given that diet is influential in preventing functional disability [54], studies that examine the association of beef intake and functional performance may also want to consider demographic factors such as sex. However, our findings revealed that the majority of studies included more women [23, 28–36, 38–41] than men [25, 26, 51]. Although the prevalence of functional disability is higher in American women [53], to improve generalizability of findings we recommend that more investigations emphasize the inclusion of men for the association between beef consumption and functional performance. Studies should also consider sex differences between implicit and explicit attitudes toward meat as a potential facilitator and barrier to beef consumption [55]. This may help to mitigate the large gap in those eating beef [56].

Age is a hallmark risk factor for functional disability [53]. Thus, dietary recommendations have suggested that protein intake should be elevated at older age [57, 58]. The majority of studies included in this review parallel with the notion that an added focus should be placed on protein intake for older adults [22, 23, 25, 26, 29–32, 34, 36, 37, 39–41]. Although placing an emphasis on protein intake for decelerating the disabling process remains important, focusing on younger age cohorts (i.e., middle-aged adults) for the association between beef intake and functional performance may also yield impactful health benefits. For example, the adoption of a new health behavior in older adults is difficult due to social, emotional, and cognitive factors [59]. Moreover, observing efficacy in a health outcome after practicing wellness behaviors can be limited in older populations [60]. Therefore, encouraging healthy lifestyle behaviors earlier in life that help to prevent poor health outcomes later in life may improve lifespan adherence to such behaviors and their influence on functional performance.

Ethnicity is also an important demographic factor in functional disability prevalence [53, 61]. While our review did not directly evaluate ethnicity in the investigations we included, we anecdotally report that the strong majority of studies were in non-Hispanic whites. This aligns with the small number of federally funded clinical trials in diverse populations, despite federal mandates that have prioritized the inclusion of racial and ethnic minorities [62, 63]. Future investigations assessing the association between beef intake and functional performance should emphasize the inclusion of diverse populations. This may also help to increase beef consumption among racial or ethnic groups that consume low levels of beef [56].

Although sex, age, and ethnicity may factor into the association between beef consumption and functional performance, there was a dearth of studies that were able to directly link beef consumption to functional performance. We strongly recommend that more research be conducted for evaluating the direct association of lean beef intake as a single food, not as part of a dietary pattern, on functional performance regardless of experimental design. Because lean beef is much more nutrient-dense than fattier or processed beef, studies should specifically single out this key source of leucine and micronutrients. Until more research is performed that directly analyzes beef intake on functional performance, the role of sex, age, and ethnicity in such studies remains opaque.

CONCLUSIONS

How dietary intake of nutrient-rich lean beef and other animal-based foods are directly associated with functional performance across the lifespan, but especially in middle-aged and older adults is unknown and should be more closely studied. Such investigations should clearly examine beef and/or animal-based protein intake with appropriate dietary measures and controls. Evaluating the association of beef and other animal-based protein intake with a variety of functional measures (e.g., activities of daily living, gait speed, etc.) will help to determine how consumption of beef and/or animal-based protein foods differentially impact specific measures of functional performance. Further, examining how physical activity and demographic characteristics factor into these associations may provide insights into the role of concurrent health behaviors and potentially at-risk populations. Recommending such criteria for cross-sectional investigations would be the first step to help build data for the association of beef intake and functional performance, which in turn, may lead to stronger study designs with precise measures in targeted populations.

Based on the review of the included articles, the association of beef intake on functional performance remains unclear primarily because no studies directly linked beef intake to functional performance, regardless of study design. Similarly, dietary assessments for the articles we evaluated did not distinguish beef from other foods including red meat, thereby making it especially challenging to evaluate the direct impact of beef on specific measures of functional performance. Given that there was a paucity of studies that revealed a direct signal for beef intake and functional performance, and the assessment of beef in diets was unclear, how other important factors (e.g., physical activity, demographic characteristics) may have contributed to the association of beef intake and functional performance remains unknown.

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PEER REVIEW

Not commissioned. Externally peer reviewed.

TABLES

Table 1. Descriptive Information Regarding Included Studies.

Authors, Year, Country	Study Design	Sample Size (N)	Number of Female Subjects (%)	Age in Years [Range] and/or (Mean ± SD)	Dietary Assessments	Foods Included with Beef in Analysis or Used as Intervention	Outcome Measures
Amagai and colleagues, 2017, Japan [22]	RCT	70 Enrolled; 62 Finished (11.4% Attrition)	31 (50.0%)	(77 ± 7.6)	25% of 150 Item FFQ	Pork & Beef	OHIP-EDENT-J
Argyridou and colleagues, 2019, U.K. [33]	Cross-sectional	419,075	229,885 (54.9%)	[40-69]	FFQ Over 1 Year (29 Food Items, 18 Alcohol)	Beef, Lamb/Mutton, Pork	HG, GS
Asp and colleagues, 2012, U.S. [34]	Cross-sectional	142	95 (66.9%)	[60-88] (73.5 ± 6.7)	124 Item FFQ Over 1 Year	Beef	HG
Bradlee and colleagues, 2018, U.S. [35]	Prospective	2,349	1,333 (56.7%)	[41-64]	Framingham Offspring Data; Two 3-Day Records	Beef, Lamb, Pork; Animal Protein Foods	Rosow-Breslau Scale and Nagi Scale
Daly, O'Connell, Mundell, 2014, Australia [23]	Cluster RCT	100 Enrolled; 91 Finished (9.0% Attrition)	100 (100.0%)	[60-90] Treatment: (72.1 ± 6.4); Control (73.6 ± 7.7)	Four 24-H Dietary Recalls Using Trained Research Dietitians	Cooked beef, veal, lamb	4-Square Step Test, TUG, STS, Lower-body 1-RM
Granic and colleagues, 2016, U.K. [36]	Prospective	791	489 (61.8%)	[>85]	24-Hr Multiple-Pass Dietary; Broken Down into Three Dietary Patterns Described Elsewhere -- Three Dietary Patterns: High Red Meat, Potato and Gravy Dishes, Low Red Meat, High Butter	Red Meats/ Meat Dishes, Gravy and Potato	HG, TUG
Hashemi and colleagues, 2015, Iran [37]	Cross-sectional	300	150 (50.0%)	[>55] (66.8±7.72)	117 Item FFQ	Three dietary patterns identified: Mediterranean, Western, and Mixed (Beef, Lamb, Ground Beef, Chicken, Egg)	HG, GS
Haub, Wells, Tarno-polsky, and Campbell, 2002, U.S. [25]	Randomized Repeated Measures Study	26 Enrolled; 21 Finished (19.2% Attrition)	0 (0.0%)	(65±5)	Three 3-day food Diaries, Each Checked by RD	Beef Supplement as Cube Steak, Ground Beef, and Beef Tips	Upper and Lower-Body 1-RM
Haub, Wells, and Campbell, 2005, U.S. [26]	Randomized Repeated Measures Study	26 Enrolled; 21 Finished (19.2% Attrition)	0 (0.0%)	(65±5)	Three 3-day Food Diaries, Each Checked by RD	Beef Supplement as Cube Steak, Ground Beef, and Beef Tips	Upper and Lower-Body 1-RM
Iglay and colleagues, 2007, U.S. [24]	RCT	50 Enrolled; 32 Finished Performance Measures (36.0% Attrition)	19 (54.3%)	Lower Protein: [50-80] (62 ± 2); Higher Protein: [50-75] (61 ± 2)	Four 7-Day Food Diaries	Egg, Striated Tissue (Beef, Poultry, Pork, Fish)	1-RM_c

Kikafunda and Lukwago, 2004, Uganda [40]	Cross-sectional	100	56 (56.0%)	[60-90]	FFQ Over 7 Days	Red Meat (Mutton, Beef, Game)	ADLs
Kim and colleagues, 2018, U.S. [52]	RCT	19 Enrolled; 14 Finished (26.3% Attrition)	8 (57.1%)	[51-69] EVEN or Control (58.1 ± 2.4); UNEVEN or Treatment (60.3 ± 2.4)	Food Records Used to Establish Baseline; to Individualize Intervention, and Check Compliance	Egg, Dairy, Beef	Lower-body 1-RM, HG, STS, Stair Test, GS,
Kim and colleagues, 2011, Korea [41]	Cross-sectional	562	562 (100.0%)	[51-69] (72.5 ± 5.9)	63 Item Study-Specific FFQ Over 1 Year	Meats (Beef, Chicken, Pork, Ham and Sausage)	$IADL_{I}$, ADL_{I}
Kobza and colleagues, 2013, U.S. [28]	RCT	50 Enrolled; 32 Finished Performance Measures (36.0% Attrition)	19 (54.3%)	[50-80] (61 ± 8)	Four 7-Day Food Diaries	Eggs, Striated Tissues (Beef, Poultry, Pork, Fish) and Dairy Products	$1\text{-}RM_{C}$
Kwon and colleagues, 2015, Japan [29]	Three-armed RCT	89 Enrolled; Note: Attrition varies according to time point (i.e., post-intervention or follow-up) and test performed; greatest attrition occurred (n = 68; 23.6% Attrition) at follow-up for hand grip strength.	89 (100.0%)	[>70] Age; Exercise and Nutrition: (76.5 ± 3.8); Exercise (77.0 ± 4.2); Control (76.9 ± 3.9)	Cooking, Nutrition Edu. Program Led by RD (No Data)	Foods Rich in Protein and Vitamin D, Including Meats	HG, Stork Stand Time with Eyes Open, GS,HRQoL/SF-36
Payne and colleagues, 2018, U.S. [30]	RCT	67 Enrolled; 47 Finished (30.0% Attrition)	53 (79.0%) Before Intervention; Post Intervention Data Not Available	[≥60] (68.2 ± 5.6)	Weekly 3-Day Food Diaries (>20)	Cooked Lean Beef	SPPB, HG, HRQoL/SF-36
Perälä and colleagues, 2017, Finland [38]	Cross-sectional	1,072	600 (54.8%)	[>65] NDS quartiles F: Q1 (60.9 ± 2.8), Q2 (61.2 ± 3.1), Q3 (61.7 ± 3.1), Q4 (61.4 ± 2.7); M: Q1 (61.1 ± 2.7), Q2 (61.3 ± 2.6), Q3 (61.1 ± 2.5) Q4 (61.5 ± 2.6).	128 Item FFQ Over 1 Year	Nordic Diet Score (0-25); Negative Points for Intake of Red and Processed Meat; Higher Score Indicates Better Adherence to the Healthy Nordic Diet.	HG, lower body strength,
Porter Starr and colleagues, 2016, U.S. [32]	RCT	67 Enrolled; 47 Finished (30.0% Attrition)	53 (79.0%) Before Intervention; Post Intervention Data Not Available	[≥60] (68.2 ± 5.6)	Three 3-Day Food Diaries, Each Checked by RD	Cooked Lean Beef (Ground Sirloin, Deli Roast Beef, Flank Steak)	SPPB, HG, HRQoL/SF-36

Struijk and colleagues, 2018, Spain [39]	Prospective	2982; 2681 for agility (10.1% Attrition); 2732 for mobility (8.4% Attrition); 2982 (0.0% Attrition) for lower-extremity function.	By processed meat tertile: T1 (62%), T2 (54.5%), T3 (44.9%); by red meat tertile: T1 (64.6%), T2 (55.8%), T3 (40.1%)	[≥60]; By processed meat tertile: T1 (70.2 ± 7.0); T2 (68.8 ± 6.4) T3 (68.2 ± 6.2); age by red meat tertile: T1 (70.2 ± 7.1, 2); T2 (68.9 ± 6.4); T3 (68.0 ± 5.9)	Computer-Assisted Face-to-Face Diet History.	Processed Meat (Including Bacon, Salami, and Sausages), Red Meat (Including Beef, Lamb, Pork) and Poultry (Including Several Types of Fowl and Rabbit).	Rosow and Breslau scale; SPPB
Torres and colleagues, 2017, Australia [31]	Cluster RCT	100	100 (100F); 48X, 43C finished	[60-90] Treatment: (72.1 ± 6.4); Control (73.6 ± 7.7)	Four 24-Hr Dietary Recalls Performed by RD	Lean Red Meat (Beef, and Lamb Veal)	HRQoL/SF-36, lower body 1-RM

OHIP-EDENT-J = Oral Health Impact Profile for the Edentulous, GSs= self-selected gait speed, HG= hand grip strength, TUG = timed up and go, STS= sit to stand, 1-RM = one repetition maximum, GS = gait speed, FFQ=food frequency questionnaire, ADLs= activities of daily living questionnaire, IADLI = face-to-face interview of instrumental activities of daily living, ADLI = face-to-face interview of activities of daily living, 1-RMc = one repetition maximum composite score, HRQoL/SF-36 = Health Related Quality of Life 36 Item Short Form, RD=registered dietitian.

FIGURES

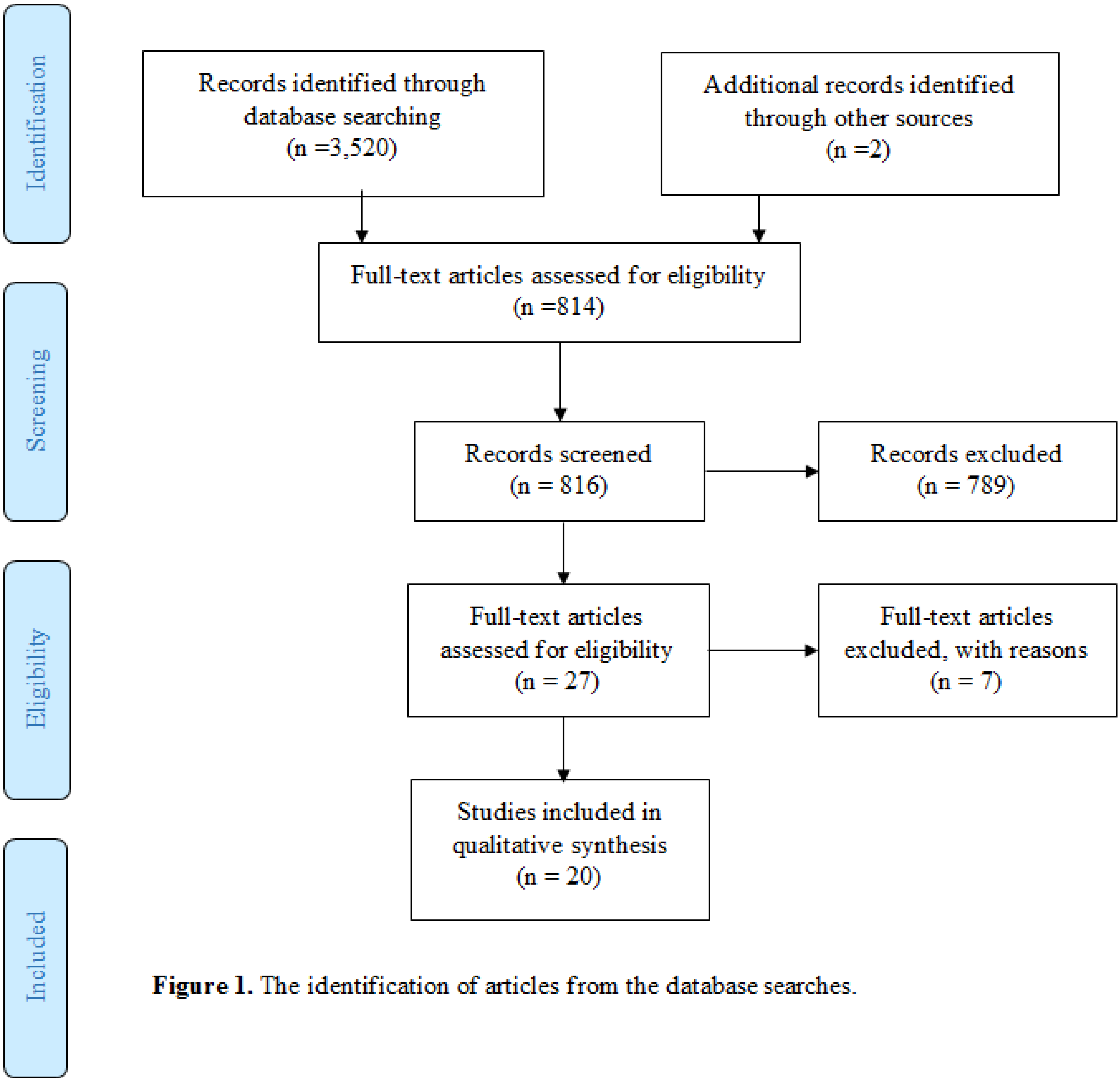

Figure 1. The identification of articles from the database searches.