RESEARCH REPORT

HUMAN NUTRITION

Title: Pork Consumption in Relation to Body Weight and Composition: A Systematic Review and Meta-analysis; **NPB #19-151** revised

(Note: The original project title was "Pork Consumption and Cognitive Function in Children and Adolescents: A Systematic Review". Due to feasibility issue and upon approval by the NPB research review board, the topic has been formally replaced by the current one.)

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Industry Summary: Pork is an essential food in the U.S. and many other countries worldwide. The annual global pork consumption is at approximately 118 metric kilotons. Childhood and adult obesity has become a leading public health concern in the U.S. and worldwide. Over the past few decades, the obesity prevalence more than doubled among U.S. adults and tripled among children. Given the profound nutritional implications of pork consumption, it remains unclear about the effect of pork intake on people's weight management and body composition (e.g., body fat and lean body mass). Findings from previous studies are scarce and mixed—some observational studies documented pork consumption to be positively correlated with weight gain, whereas some controlled trials reported either a null effect or an inverse relationship. This study systematically identified and synthesized scientific evidence on pork consumption in relation to body weight and composition. We conducted a comprehensive literature search in 5 scientific databases. We performed statistical analysis to estimate the effect of pork consumption on body weight and composition. A total of 13 studies (i.e., five randomized controlled trials, two randomized crossover trials, four cross-sectional studies, and two longitudinal studies) met the pre-specified eligibility criteria and were included in the review. Among the experimental studies without daily total energy intake restrictions, pork intake was associated with a reduction in body weight by 0.86 kg and body fat percentage by 0.77%, whereas pork intake was not associated with change in lean mass. Among the experimental studies with energy restrictions, pork intake was associated with a reduction in body weight by 5.56 kg, lean mass by 1.50 kg, and fat mass by 6.60 kg. Among the observational studies, pork intake was not associated with overweight status. In conclusion, findings on pork consumption in relation to body weight/composition differed by study design. Future experimental studies based on representative samples are warranted to examine the effect of fresh and lean pork consumption on body weight and composition among the general population and by subgroups.

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Key Findings:

- We systematically reviewed literature on pork consumption and body weight/composition
- Thirteen studies (7 randomized trials and 6 observational studies) were included
- Pork intake reduced body weight/fat percent in trials without daily kcal restriction
- Pork intake reduced body weight & lean/fat mass in trials with daily kcal restriction
- Pork intake was not associated with overweight status in observational studies
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Keywords: pork; body weight; body composition; obesity; review; meta-analysis

Scientific Abstract:

Objective: Pork is an essential food in the U.S. and many other countries worldwide. This study systematically identified and synthesized scientific evidence on pork consumption in relation to body weight and composition.

Design: Keyword search was performed in Cochrane Library, PubMed, Web of Science, CINAHL, and Google Scholar. Meta-analysis was performed to estimate the pooled effect size of pork consumption on body weight and composition.

Results: A total of 13 studies (i.e., five randomized controlled trials, two randomized crossover trials, four cross-sectional studies, and two longitudinal studies) met the pre-specified eligibility criteria and were included in the review. Among the experimental studies without daily total energy intake restrictions, pork intake was associated with a reduction in body weight by 0.86 (95% confidence interval=0.17–1.55) kg and body fat percentage by 0.77% (0.11%–1.43%), whereas pork intake was not associated with change in lean mass. Among the experimental studies with energy restrictions, pork intake was associated with a reduction in body weight by 5.56 (0.55–10.59) kg, lean mass by 1.50 (1.39–1.62) kg, and fat mass by 6.60 (6.42–6.79) kg. Among the observational studies, pork intake was not associated with overweight status. No publication bias was identified by Egger's and Begg's tests.

Conclusions: Findings on pork consumption in relation to body weight/composition differed by study design. Future experimental studies based on representative samples are warranted to examine the effect of fresh and lean pork consumption on body weight and composition among the general population and by subgroups.

1. Introduction

Pork is an essential food in the U.S. and many other countries worldwide. The annual global pork consumption is at approximately 118 metric kilotons, with China occupying about 46% [1]. Many of the European Union member states have high levels of pork consumption, such as Austria and Germany (51–52 kg per capita/year), Spain (49 kg per capita/year), Poland (46 kg per capita/year), Italy (40 kg per capita/year), the Netherlands (36 kg per capita/year), and France (33 kg per capita/year) [1]. In the U.S., pork ranks third in annual meat consumption following beef and chicken [2]. Between 2014–2016, U.S. adults averaged 23 kg of pork consumption a year, accounting for over a quarter of overall meat intake [2]. When incorporated into a balanced diet, animal protein such as pork can provide essential nutrients including but not limited to protein, iron, zinc, and multiple B vitamins [3]. In contrast, arguments against pork consumption largely focus on issues related to environmental sustainability, including animal welfare, and health implications of processed meat intake. The carbon footprint of meat production warrants recommendations for reduced pork intake [4], but others argue that the contribution of red meat to diet quality deserves more appreciation in consideration of protein and micronutrients less commonly obtained from plant-based alternatives [5]. A primary concern is the saturated fat content and the preparation method, such as processed meats, which may include or increase unhealthy substances [6]. Others argue that the guidelines regarding reduced consumption of red meats do not adequately differentiate between processed and unprocessed red meat and therefore may be too restrictive [7], and concluded that it was consumption of processed meats, rather than red meats, that was associated with higher disease incidences (e.g. diabetes and certain cancer types) [8, 9]. Fresh and fresh lean pork consumers were found to have comparable daily fat and saturated fat intake compared to non-consumers, suggesting that unprocessed fresh and fresh lean pork can be part of a healthy diet [10–13]. Meanwhile, pork is generally less expensive and more affordable than beef so that pork sometimes serves as an alternative to beef among red meat consumers [12, 13].

Childhood and adult obesity has become a leading public health concern in the U.S. and worldwide. Over the past few decades, the obesity prevalence more than doubled among U.S. adults and tripled among children. According to the World Health Organization, approximately

1.9 billion adults worldwide were overweight, and of these 650 million were obese [14]. Forty-one million children under the age of five and 340 million children and adolescents aged 5–19 years worldwide were overweight or obese [14]. Given the profound nutritional implications of pork consumption, it remains unclear about the effect of pork intake on people's weight management and body composition (e.g., body fat and lean body mass). Findings from previous studies are scarce and mixed—some observational studies documented pork consumption to be positively correlated with weight gain, whereas some controlled trials reported either a null effect or an inverse relationship.

This study aimed to systematically identify and synthesize the scientific evidence on pork consumption in relation to body weight and composition. It contributed to the literature in three aspects. First, it served as the first attempt to comprehensively document and summarize study findings pertaining to the effect of pork intake on weight-related outcomes. Moreover, it covered a wide range of study designs from controlled experiments to observational studies and contrasted their findings. Finally, findings from this review may shed light on future pork-related dietary recommendations and inform future study designs in order to advance research on pork consumption in relation to weight and body composition.

2. Methods

2.1. Study selection criteria

Studies that met all of the following criteria were included in the review: (1) Study designs: Controlled trials and observational studies; (2) Study subjects: children and adults; (3) Exposure: pork and/or pork product consumption; (4) Outcomes: body weight and/or composition; (5) Article type: peer-reviewed publications; (6) Time window of search: from the inception of an electronic bibliographic database to August 15, 2019; and (7) Language: articles written in English.

Studies that met any of the following criteria were excluded from the review: (1) Studies that incorporated no outcome pertaining to pork consumption in relation to body weight and/or composition; (2) Studies that examined the influence of overall red meat consumption or certain dietary patterns (e.g., Mediterranean diet) on body weight and/or composition without differentiating the independent effect of pork consumption; (3) Letters, editorials, study protocols, conference proceedings, books, or review articles; and (4) Articles not written in English.

2.2. Search strategy

A keyword search was performed in five electronic bibliographic databases: Cochrane Library, PubMed, Web of Science, Cumulative Index of Nursing and Allied Health (CINAHL), and Google Scholar. The search algorithm included all possible combinations of keywords from the following two groups: (1) "pork"; and (2) "body composition", "obesity", "obese", "adiposity", "adipose", "overweight", "weight", "body weight", "body mass", "BMI", "skinfold thickness", "waist circumference", "WC", "hip circumference", "HC", "waist/hip ratio", "WHR", "waist-hip ratio", "waist to hip", "waist-to-hip", "lean mass", "abdominal", "lean body", "fat", "muscle mass", or "anthropometric". The MeSH terms "body composition", "obesity", "overweight", "body weight", "body mass index", "skinfold thickness", "waist circumference", and "waist-hip ratio" were included in the PubMed search. All keywords in PubMed were searched with the "(All fields)" tag, which are processed using Automatic Term Mapping. The search function TS = Topic was used in Web of Science, which launches a search for topic terms in the fields of title, abstract, keywords, and Keywords Plus®. The search algorithm in PubMed is provided in **Appendix 1**. Titles and abstracts of the articles identified through the keyword search were screened against the study selection criteria. Potentially relevant articles were retrieved for an evaluation of the full text. Two co-authors independently conducted the title and abstract screening and identified potentially relevant articles for the full-text review. Inter-rater agreement was assessed using the Cohen's kappa ($\kappa = 0.87$). Discrepancies were resolved through face-to-face discussions between the two co-authors. Articles identified from the title and abstract screening were reviewed in full texts. The two co-authors jointly determined the final pool of articles included in the review.

2.3. Data extraction and synthesis

A standardized data extraction form was used to collect methodological and outcome variables from each selected study, including authors, publication year, country, sample size, sample age distribution, sample gender distribution, sample weight status, study design, body weight/composition outcome and measure, number of repeated measures, statistical model, attrition rate, and main study results and findings.

2.4. Meta-analysis

Meta-analysis was performed to estimate the pooled effect size of pork consumption on body weight and composition. The outcomes included body weight, overweight status, fat mass, body fat percentage, and lean mass. Three articles were excluded from the meta-analysis due to the following two reasons: less than two studies reported the same outcome [15, 16], and neither standard error nor confidence interval (CI) was reported [17]. Separate meta-analysis was performed on the experimental studies with overall daily energy intake restrictions, those without restrictions, and observational studies. Study heterogeneity was assessed using the I^2 index. The level of heterogeneity represented by I^2 was interpreted as modest ($I^2 \leq 25\%$), moderate ($25\% < I^2 \leq 50\%$), substantial ($50\% < I^2 \leq 75\%$) or considerable ($I^2 > 75\%$). A fixed-effect model was estimated when modest to moderate heterogeneity was present, and a random-effect model was estimated when substantial to considerable heterogeneity was present. Publication bias was assessed by a visual inspection of the funnel plot and Begg's and Egger's tests. All statistical analyses were conducted using Stata 15.0 SE version (StataCorp, College Station, TX). All analyses used two-sided tests, and p-values less than 0.05 were considered statistically significant.

2.5. Study quality assessment

We designed a study quality assessment tool that rates each study based on the following eight criteria. (1) Was the research question or objective clearly stated? (2) Was the study population clearly specified? (3) Was the study a randomized controlled trial? (4) Was a sample size justification (e.g., power analysis) provided? (5) Were pork consumption measures clearly defined, valid, reliable, and implemented consistently across all study participants? (6) Were body weight and/or body composition assessed more than once over time? (7) Were body weight and/or body composition objectively measured? (8) Were the outcome assessors blinded to the exposure status of participants? For each criterion, a score of one was assigned if 'yes' was the response, whereas a score of zero was assigned otherwise. A study-specific global score ranging from zero to eight was calculated by summing up scores across all criteria. The study quality assessment helped measure the strength of scientific evidence but was not used to determine the inclusion of studies.

3. Results

3.1. Study selection

Figure 1 shows the study selection flow chart. We identified a total of 1265 articles through the keyword and reference search, including 616 articles from PubMed, 441 articles from Web of Science, 104 articles from CINAHL, 104 articles from Cochrane Library, four articles from a hand search in Google Scholar, and two articles from forward and backward search. After removing duplicates, 1172 unique articles underwent title and abstract screening, in which 1147 articles were excluded. Full texts of the remaining 25 articles were reviewed against the study selection criteria. Of these, 12 articles were excluded. The reasons for exclusion included: nine articles did not measure body weight or composition [18–26], two articles did not include pork consumption [27, 28], and the remaining one was a review [29]. The remaining 13 articles that examined pork consumption in relation to body weight and composition were included in the review [15-17, 37, 40, 42-49], of which nine were further included in the meta-analysis [37, 42-49].

3.2. Basic characteristics of the included studies

Table 1 summarizes the basic characteristics of the 13 articles, including five randomized controlled trials, two randomized crossover trials, four cross-sectional studies, and two longitudinal studies. Five studies were conducted in U.S., three in Australia, one each in Netherlands, Denmark, Canada, and China, and one in four countries including Belgium, Denmark, Germany and Poland. Sample size varied substantially across studies, with a median of 164 participants, and a range from 12 to 29145 participants. Only one study recruited children averaged 10 years of age, whereas the other studies recruited adults 18–70 years old. Two of the 13 studies exclusively recruited females, one exclusively recruited males, whereas females and males were largely equally distributed in the other studies.

Table 2 summarizes the measures, statistical methods and outcomes of the studies included in the review. Ten studies adopted objective measures of body weight and/or composition (e.g., dual-energy X-ray absorptiometry (DEXA), stadiometer, or floor scale), and the other three used self-reported body weight and height. Participants' weight status varied across studies—five recruited people with overweight or obesity, four recruited people of normal weight, and four recruited people of different weight categories (e.g. underweight, normal weight, overweight and obesity). The outcomes pertaining to body weight and composition were measured more than once in nine of the 13 studies. A variety of statistical models were applied across studies, including paired t-test, Mann-Whitney test, ANOVA, repeated-measure ANOVA, linear mixed-effect model, and logistic regression. Attrition rates across the studies ranged from 12% to 35%.

Table 2 summarizes the main findings regarding the effect of pork consumption on body weight and/or composition. The studies can be classified into two categories by study design—experimental studies (n = 7) and observational studies (n = 6). Experimental studies include controlled trials with (n = 3) or without restrictions on daily total caloric intake (n = 4). Six of the seven experimental studies reported that pork consumption decreased body weight and/or improved body composition among participants, whereas the remaining one reported a null effect. Four of the six observational studies reported no association between pork consumption and body composition, whereas the remaining two found the association between pork consumption and body weight/composition differed by consumption frequency and gender. Pork products consumed by study participants included fresh pork, lean pork, cooked pork (e.g. loin, ham, or Canadian bacon), and other processed pork products.

3.3. Meta-analysis

Table 3 summarizes results from the meta-analysis. Among the experimental studies without daily total energy intake restrictions, pork intake was associated with a reduction in body weight by 0.86 (95% CI = 0.17, 1.55) kg and body fat percentage by 0.77% (95% CI = 0.11%, 1.43%), whereas pork intake was not associated with change in lean mass (p-value > 0.05). Among the experimental studies with energy restrictions, pork intake was associated with a reduction in body weight by 5.56 (95% CI = 0.55, 10.59) kg, lean mass by 1.50 (1.39, 1.62) kg, and fat mass by 6.60 (6.42, 6.79) kg. Among the observational studies, pork intake was not associated with overweight status (p-value > 0.05). No publication bias was identified by Egger's tests or Begg's tests (p-values > 0.05).

3.4. Study quality assessment

Appendix 2 reports criterion-specific and global ratings from the study quality assessment. The included studies on average scored 5.4 out of eight, with a range from three to seven. All 13 studies included in the review clearly stated the research question and/or study objective, specified and defined the study population, and pork consumption was properly defined, valid, reliable, and implemented consistently across study participants. Seven of the 13 studies adopted a randomized experimental design. Nine of the 13 studies assessed body weight and/or composition more than once over time. In contrast, none of the studies had outcome assessors blinded to the exposure status of participants.

4. Discussion

Our findings on null or inverse associations between pork intake and body weight, body fat percentage, and fat mass appear to contradict results of some previous observational studies. Using data from the National Health and Nutrition Examination Survey, Wang and Beydoun (2009) found overall meat consumption to be positively associated with risk for obesity and central obesity [(30)]. A recent systematic review and meta-analysis of prospective cohort studies reported red meat consumption to be positively associated with weight gain and risk for abdominal obesity [(31)]. However, observational studies are prone to confounding bias (e.g., other unhealthy habits correlated with meat consumption that cause obesity) and reverse causality (e.g., people with obesity are more likely to consume meat). This review conducted meta-analysis on randomized controlled and crossover trials that assessed the causal impact of pork consumption on body weight and/or composition. Both trials with and without daily overall energy restrictions confirmed an inverse relationship between pork intake and body weight. Not surprisingly, trials with energy restrictions found a much larger reduction in body weight (5.56 kg) in comparison to those without energy restrictions (0.86 kg). Moreover, pork intake was also associated with a reduction in lean and fat mass as well as body fat percentage. It is thought that pork consumption may improve body composition and lean mass through increasing satiety, enhancing thermogenesis, and facilitating glycemic control [(32–36)]. The amino acids present in pork protein enhance protein synthesis and turnover rates, which may increase thermogenesis and energy expenditure leading to less fat deposition [(37)]. The rapid empty of gastric and postprandial increase in plasma amino acid concentrations after ingestion of specific proteins may increase satiety due to a greater stimulatory effect on gastrointestinal hormones (e.g., cholecystokinin and glucagonlike peptide-1) [(36–38)]. Another possible reason is that pork consumed in those trials is healthier (e.g., lean or fresh pork vs. processed or high-fat pork) than that generally consumed in the population. High-fat diet has been consistently linked to weight gain and adiposity, whereas protein-rich diet with balanced energy intake is suggested to help weight management [(39)].

Some observational studies included in the review reported the relationship between pork consumption and body weight/composition varied by consumption frequency and gender. High but not medium frequency pork consumers was found to be associated with elevated overweight risk; and only women, but not men, were associated with higher BMI when comparing high to low daily pork consumption quantity. These findings suggest that daily total quantity of meat consumption, rather than the specific type of meat consumed, may serve as the driving factor for weight gain [(40)]. Moreover, gender differences in energy metabolism [(41)], which is poorly known to date, might moderate the effect of pork intake on weight outcomes.

The limitations pertaining to this review and the selected studies warrant future research. A small and heterogeneous set of studies were included in the review. Studies were conducted in different countries with diverse study designs (i.e., controlled trials vs. observational studies) samples of different age groups, which confined the generalizability of review findings. Pork was provided in different forms such as fresh lean pork, cooked pork (i.e., loin, ham, or Canadian bacon), and other processed pork products, which may exert differential impact on body weight and composition outcomes, a formal test of which is beyond the scope of this review. Future research should adopt an experimental study design, recruit nationally or regionally representative sample, and examine the effect of fresh and lean pork consumption on body weight and composition among population subgroups (e.g., by age group and gender).

5. Conclusions

Pork is an essential food source in the U.S. and many other countries. This study systematically reviewed scientific literature associating pork consumption with body weight and composition. Thirteen studies satisfied the eligibility criteria and were included in the review. Meta-analysis found that: among the experimental studies without energy restrictions, pork intake was associated with a reduction in body weight by 0.86 kg and body fat percentage by 0.77%; among the experimental studies with energy restrictions, pork intake was associated with a reduction in body weight by 5.56 kg, lean mass by 1.50 kg, and fat mass by 6.60 kg; and among the observational studies, pork intake was not associated with overweight status. This review has limitations pertaining to the small and heterogeneous body of literature included. Future experimental studies based on representative samples are warranted to examine the effect of fresh and lean pork consumption on body weight and composition among the general population and by subgroups.

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Figure 1. Study selection flowchart

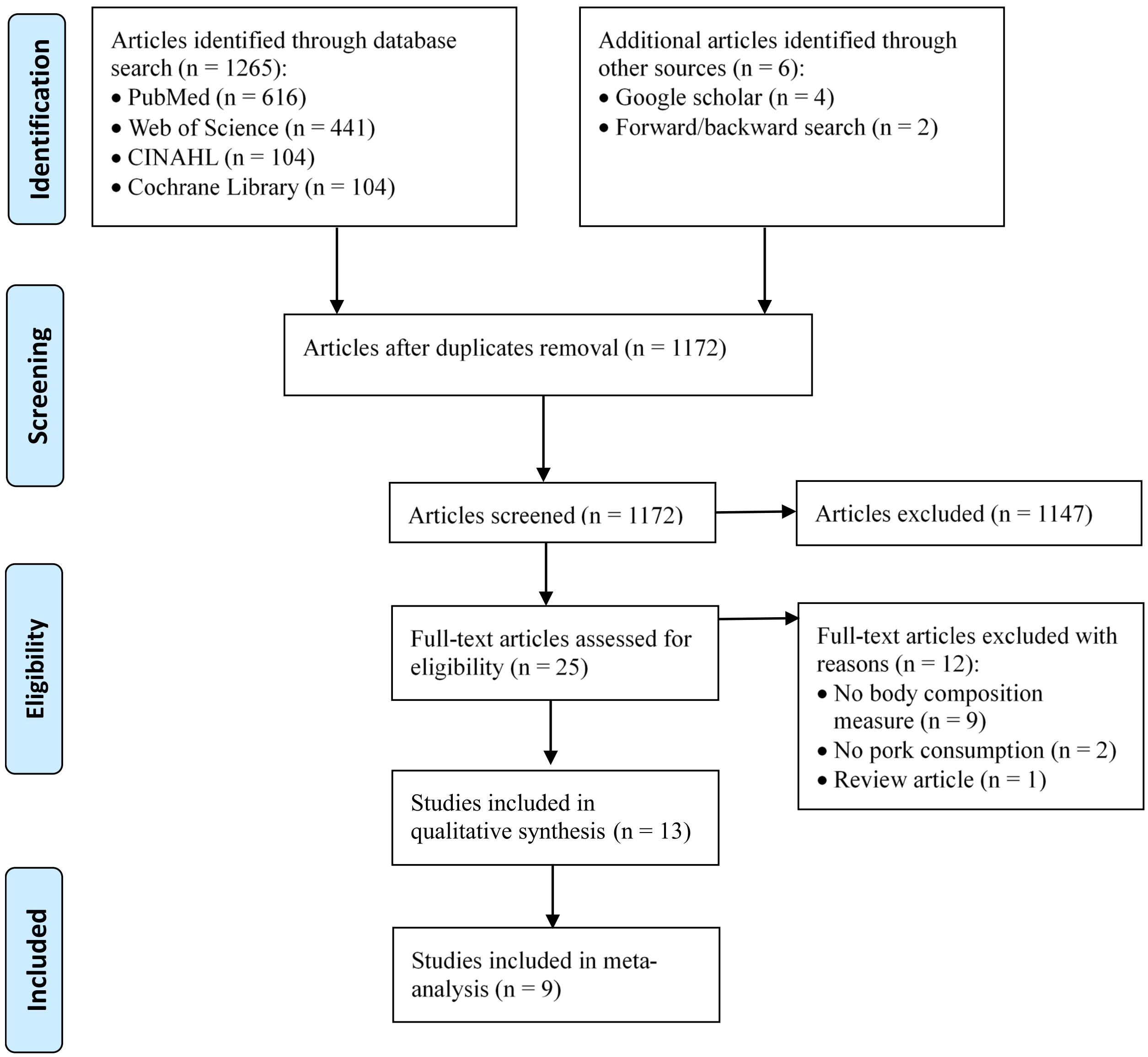

Table 1. Basic characteristics of the studies included in the review

Study ID	First Author (year)	Country	Sample size	Age	Female (%)	Age group	Study design	Attrition (%)
1	Mikkelsen (2000) [37]	Denmark	12	26	0	Young men	Randomized cross-over trial	0
2	Nicklas (2003) [42]	USA	1562	10	51	Children	Cross-sectional study	/
3	Leidy (2007) [43]	USA	46	50	100	Women	RCT	15
4	Brunt (2010) [44]	Canada	557	21	60.3	Young adults	Cross-sectional study	/
5	Campbell (2010) [45]	USA	28	>20	100	Women	RCT	15
7	Verbeke (2011) [46]	Belgium, Denmark, Germany, and Poland	1931	20–70	51	Adults	Cross-sectional study	/
6	Gilsing (2012) [17]	Netherlands	3902	55–69	49	Older Adults	Longitudinal study	/
8	Murphy (2012) [47]	Australia	164	18–65	/	Adults	RCT	12
9	Murphy (2014) [48]	Australia	49	50	51	Adults	Randomized cross-over trial	23
10	Sayer (2015) [16]	USA	19	61	68	Adults	RCT	32
11	Zou (2015) [15]	China	5577	53	64	Adults	Cross-sectional study	/
12	Charlton (2016) [49]	Australia	48	≥65	65	Older Adults	RCT	35
13	Kim (2018) [40]	USA	29145	≥20	/	Adults	Longitudinal study	/

Table 2. Measures, statistical methods, outcomes and main results of the studies included in the review

Study ID	Sample weight status	Measure(s) of body weight and composition	Statistical model	No. of repeated measures	Main results
1	Overweight and obesity	Objective measure: DEXA	Paired t-test	2	Body weight associated with pork fat-reduced diet revealed no difference compared to the baseline, and pork diet had no difference compared with soy or carbohydrate diets on body weight ($P > 0.05$).
2	Normal weight, overweight and obesity	Objective measure: A balance-beam metric scale and a stand board	ANOVA	1	Odd ratio of pork consumption on obesity was 1.03 (95% CI = 0.98, 1.09, $P > 0.05$).
3	Overweight and obesity	Objective measure: An electronic platform scale and DEXA	Repeated-measure ANOVA	2	Both high protein (40% pork, HP) and normal protein groups (NP) lost BMI, fat mass and lean mass ($P < 0.001$) throughout the 12-week intervention. However, the HP group had greater preservation of lean mass compared with NP ($P < 0.05$).
4	Underweight, normal weight, overweight, and obesity	Self-reported	ANOVA	1	The proportion of people who reported to eat pork was higher in obese and overweight college students. However, pork intake was not associated with overweight (OR = 1.31, 95% CI = 0.67, 2.57) or obesity (OR = 2.14, 95% CI = 0.77, 5.27).
5	Overweight	Objective measure: DEXA	Repeated-measure ANOVA	2	Postmenopausal women in both NP and HP (40% pork) energy restriction diet groups showed decrease in BMI, fat mass, and lean mass ($P < 0.001$). However, no difference was found between normal protein and higher protein diet on BMI, fat mass and lean mass.
6	Normal weight	Self-reported	Linear mixed-effect model	3	Pork nonconsumers are negatively associated with overweight (OR = 0.69, 95% CI = 0.49, 0.97) and obesity (OR = 0.59, 95% CI = 0.59, 0.89). Overweight (OR = 1.41, 95% CI = 1.06, 1.88) and obese (OR = 1.58, 95% CI = 1.16, 2.16) respondents are more likely to be “high variety, high frequency” pork consumers. However, “low variety, low frequency” and “high variety, medium frequency” pork intake was not associated with overweight or obesity.
7	Underweight, normal weight, overweight, and obesity	Self-reported	Logistic regression	1	When retrospectively examining the association between pork consumption reported at baseline and weight change from 20 years old to 55–69 years old, the change of BMI was significant when compared highest category intakes of pork to the lowest intakes of pork in women, whereas man showed no difference.
8	Overweight	Objective measure: A metric tape and DEXA	Repeated-measure ANOVA	3	Compared with the control group, the pork group significantly reduced their weight, BMI, waist circumference and body composition including body fat (%), fat mass and abdominal fat (time × treatment effect: $P < 0.01$ in all cases). These reductions in adiposity measures were still evident after 6 months of intervention. However, there was no change in lean mass, which indicates that the reduction in weight was due to loss of fat mass.

9	Overweight or obesity	Objective measure: A stadiometer, a floor scale, body fat scale and DEXA	GLS	4	There was no difference in BMI, body fat percentage, fat mass, abdominal fat, lean mass, WC, and HC when comparing pork group with beef or chicken diet group (P > 0.05). WHR was lower in pork group than beef and chicken group (P = 0.046). These were not significant when adjusting for multiple comparisons.
10	Normal weight with elevated BP	Objective measure: Body composition tracking system	Repeated-measure ANOVA	3	Body weight was 2.3± 0.2 kg lower at post-intervention than at pre-intervention (post: 83.3 ± 2.6 kg; pre: 85.5 ± 2.6 kg; P < 0.05), and the body fat percentage tended to be lower at post-intervention (pre: 41.1 ± 1.5%; post: 39.2 ± 1.6%; P = 0.06). However, this effect was not moderated by diet type (DASH-P vs. DASH-CF).
11	Normal weight	Objective measure: A stadiometer and a calibrated beam scale	Mann-Whitney test	1	The intake of pork in obese and non-obese people was not different (City: z = -0.142, P = 0.887; Township: z = 0.579, P = 0.563; and Rural area: z = 1.938, P = 0.053).
12	Normal weight	Objective measure: A stadiometer, a floor scale and a body fat scale	Linear mixed regression	3	No difference was found when comparing BMI and body fat of pork diet intervention with baseline (P > 0.05). The BMI of pork group did not differ from chicken group (P = 0.08); and body fat of pork group and chicken group also did not differ (P = 0.86).
13	Normal weight, overweight, and obesity	Objective method: A stadiometer and a calibrated beam scale	Linear regression	6	The mean intake of pork was not different across various body weight status (overweight: 0.42 ± 0.04 kg; normal weight: 0.38 ± 0.02 kg, P > 0.05).

Notes: WC, waist circumference; WHR, waist to hip ratio; HC, hip circumference; BMI, body mass index; DEXA, Dual energy x-ray absorptiometry; BP, blood pressure; GLS, generalized least squares; DASH-P, Dietary Approaches to Stop Hypertension diet with pork; DASH-CF, DASH diet with chicken and fish; NP, normal protein; and HP, high protein. All values are means ± SEs.

Table 3. Results from meta-analysis

Study design	Outcome	Contrast	Studies included in meta-analysis	I^2 index	Pooled effect size (95% CI)	Model	Publication bias test	
							P-value Egger's test	P-value Begg's test
Interventions without energy restriction	Body weight	Pre-intervention vs. post-intervention	Murphy, 2012; Murphy, 2014; Charlton, 2016	0%	β: -0.86 (-1.55, -0.17)	FE	1.00	0.20
	Lean mass	Pre-intervention vs. post-intervention	Murphy, 2014; Charlton, 2016	98.4%	β: 1.79 (-1.74, 5.32)	RE	1.00	/
	Body fat percentage	Pre-intervention vs. post-intervention	Murphy, 2012; Murphy, 2014; Charlton, 2016	90.4%	β: -0.77 (-1.43, -0.11)	RE	1.00	0.84
Interventions with energy restriction	Body weight	Pre-intervention vs. post-intervention	Mikkelsen, 2000; Leidy, 2007; Campbell, 2010	98.7%	β: -5.56 (-10.59, -0.55)	RE	0.60	0.56
	Lean mass	Pre-intervention vs. post-intervention	Leidy, 2007; Campbell, 2010	0%	β: -1.50 (-1.62, -1.39)	FE	0.32	/
	Fat mass	Pre-intervention vs. post-intervention	Leidy, 2007; Campbell, 2010	0%	β: -6.6 (-6.79, -6.42)	RE	1.00	/
Observational studies	Overweight	Eating vs. non-eating pork	Nicklas, 2003; Brunt, 2008; Verbeke, 2011	74.3%	OR: 1.39 (0.82, 1.95)	RE	0.12	0.10

Note: FE: fixed-effect model; RE: random-effect model

Appendix 1 Search Algorithm in PubMed

"pork" AND ("body composition" [MeSH] or "body composition" or "obesity"[MeSH] or "obesity" or "obese" or "adiposity" or "adipose" or "overweight"[MeSH] or "overweight" or "weight" or "body weight"[MeSH] or "body weight" or "body mass" or "body mass index"[MeSH] or "BMI" or "skinfold thickness"[MeSH] or "skinfold thickness" or "waist circumference"[MeSH] or "waist circumference" or "WC" or "hip circumference" or "HC" or "waist/hip ratio" or "WHR" or "waist-hip ratio" or "waist to hip" or "waist-to-hip"[MeSH] or "waist-to-hip" or "lean mass" or "abdominal" or "lean body" or "fat" or "muscle mass" or "anthropometric") AND ("humans"[MeSH])AND (English[lang])

Appendix 2. Study quality assessment

Criterion	Study ID												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1. Was the research question or objective clearly stated?	1	1	1	1	1	1	1	1	1	1	1	1	1
2. Was the study population clearly specified?	1	1	1	1	1	1	1	1	1	1	1	1	1
3. Was the study a randomized controlled trial?	1	0	1	0	1	0	0	1	1	1	0	1	0
4. Was a sample size justification (e.g., power analysis) provided?	0	0	0	0	0	0	0	1	1	1	0	1	0
5. Were pork consumption measures clearly defined, valid, reliable, and implemented consistently across all study participants?	1	1	1	1	1	1	1	1	1	1	1	1	1
6. Were body weight and/or body composition assessed more than once over time?	1	0	1	0	1	1	0	1	1	1	0	1	1
7. Were body weight and/or body composition objectively measured?	1	1	1	0	1	0	0	1	1	1	1	1	1
8. Were the outcome assessors blinded to the exposure status of participants?	0	0	0	0	0	0	0	0	0	0	0	0	0
Total score	6	4	6	3	6	4	3	7	7	7	4	7	6