Journal of Food and Nutrition Sciences
2021; 9(1): 16-33
http://www.sciencepublishinggroup.com/j/jfns
doi: 10.11648/j.jfns.20210901.13
ISSN: 2330-7285 (Print); ISSN: 2330-7293 (Online)

Review Ariticle

Associations Between Yogurt Consumption and Obesity Risk: A Systematic Review and Meta-analysis of Observational Studies

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To cite this article:
Junhao Wang, Yongjuan Xin, Qianwen Li, Lingling Li, Hongbing Zhang, Hao Wang, Junxia Min, Fudi Wang. Associations Between Yogurt Consumption and Obesity Risk: A Systematic Review and Meta-analysis of Observational Studies. *Journal of Food and Nutrition Sciences*. Vol. 9, No. 1, 2021, pp. 16-33. doi: 10.11648/j.jfns.20210901.13

Received: February 1, 2021; **Accepted**: February 17, 2021; **Published**: February 26, 2021

Abstract: Background: Plenty of studies have shown that yogurt have specific benefits for human health, but the association between yogurt consumption and obesity risk is still indistinct from previous research. Objectives: The aim of this study was to make a systematic review of recent epidemiological studies about yogurt consumption and obesity risk, and conduct a meta-analysis. Methods: Related studies were searched in electronic databases up to 1 November 2020. The meta-analyses synthesize included obesity, overweight and abdominal obesity comparing extreme categories of yogurt consumption. Results: A total of 35 studies from 27 articles were carried out in the review. Yogurt intake could decrease the risk of obesity (OR:0.83, 95% CI: 0.79-0.87), and abdominal obesity (OR: 0.80, 95% CI: 0.69-0.92), but showed no associations with overweight happen (OR: 0.88, 95% CI: 0.58-1.36). A dose-response analysis shows that the risk of obesity de-creased by approximately 44% with increasing intake of yogurt up to ~165 g/day. Moreover, most prospective cohort studies reveal that the intake of yogurt in a long term can reduce weight and waist circumference, but not affect the change of BMI. Conclusions: The meta-analysis indicates that yogurt consumption would reduce the overall obesity and abdominal obesity. In addition, long term consumption of yogurt may contribute to some obesity-related anthropometry change.

Keywords: Yogurt, Obesity, Overweight, Abdominal Obesity

1. Introduction

Obesity has always been a significant public health issue, and the prevalence of overweight and obesity continues to increasing globally [1]. Many epidemiological studies have shown that obesity is a risk factor for many chronic diseases, including cardiovascular disease, diabetes [2], chronic kidney disease [3], and various cancers [4, 5]. As of 2015, about 107.7 million children and 603.7 million adults worldwide were obese, the overall prevalence of obesity was 5.0% and 12.0% respectively [6]. The latest research has predicted that about 1 in 2 adults will be obese in the United States by 2030 [7]. Some factors, such as individual behavior, environment, and gene may lead to imbalance in energy intake and excretion, causing obesity [8]. In order to maintain a good balance of energy metabolism, a sensible diet and physical exercise are necessary for the prevention and treatment of obesity [8]. Furthermore, substantial evidence supports the beneficial role of dairy products in dietary energy distribution [9], may decrease the risk of obesity [10, 11].

Dairy products are a major part of the daily diet and contribute many important nutrients to our daily diet. Yogurt, one of the dairy products, is loved by many people because of its unique flavor and ingredients. Compared with milk, in addition to valuable nutrients such as protein, minerals, vitamins, and fatty acids [12], yogurt also includes some probiotics [13], which can alter the composition of the intestinal flora as well as affect food intake, appetite, weight, and metabolic functions [14, 15]. A meta-analysis suggested that yogurt intake could reduce the metabolic syndrome risk [16]. With the increase in the consumption rate of yogurt, its impact on human health especially obesity has attracted much attention.

Several studies have explored the relationship between yogurt intake and obesity risk. A 2016 meta-analysis suggests a negative correlation between yogurt and the risk of central adiposity [17]. Subsequently, Sayón-Orea et al. [18] have reviewed the prospective study of yogurt on obesity, overweight, and metabolic syndrome, but the correlation has not been confirmed. So we updated related research reviews and performed a meta-analysis with published reports to clarify the relationship between yogurt and obesity incidence.

2. Materials and Methods

This systematic review with meta-analysis was designed, implemented, analyzed, and reported following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) [19] protocol. This systematic review and meta-analysis was registered at PROSPERO as CRD42020191376.

2.1. Search Strategy and Selection Criteria

We searched from PubMed, Embase, and Web of Science for relevant articles that described the associations between yogurt and obesity published up to 1 November 2020, only English articles. We use the following search terms: (yogurt OR yoghurt OR sour milk OR fermented milk OR fermented dairy OR cultured milk) AND (obesity OR overweight OR "Body composition" OR "Body constitution" OR "Weight status" OR body mass index OR BMI OR waist circumference OR WC OR Metabolic Syndrome OR anthropometry) and (prospective OR follow-up OR cohort OR longitudinal OR cross-sectional). Besides, all relevant references that appeared in retrieved articles were searched and reviewed manually to obtain other qualified publications. The search for articles only included full-text journal English articles from the original study and has been done independently by three investigators (J.W. and L.L.), subject to approval by a third reviewer (Y.X.). Any disputes were resolved through group discussions until a consensus was reached.

Studies were included in this systematic review if the following conditions were met: 1) studies were prospective observational or cross-sectional design; 2) the yogurt was the exposed factor; 3) the outcomes were weight or waist circumference change, overweight, obesity, and abdominal obesity, and outcome criteria were appropriately well defined. Furthermore, for meta-analysis also includes; 4) the relationship of yogurt consumption and obesity, overweight, abdominal adiposity are reported with adjusted odds ratio (OR), hazard ratio (HR), or relative risk (RR) and their 95% confidence interval (95% CI) (or provide information that can be used in risk calculations; 5) for the dose-response analysis, yogurt intake in each category was provided. If the same data were used in multiple articles, our analysis use the latest data.

We excluded the study if: 1) the data was only reported other dairy products such as milk, butter or the ingredients of yogurt; 2) the participants of studies were pregnant or lactating females; 3) the study type is meta-analyses, reviews, and case-reports; 4) other non-specified outcomes, such as malnutrition.

2.2. Data Extraction and Quality Assessment

The author (J.W. and L.L.) extracted data and assessed the eligibility of studies from included literature, and were checked by a third investigator (Y.X). The following data were extracted from 32 studies: publication year, the first author's name, geographic location, study design (prospective study or cross-sectional study), participants (number, and Percentage of men), age range, event and cases number, intake comparison, dietary assessment, type of yogurt, outcome type, change of anthropometry (BMI, body weight, waist circumference) and the corresponding OR or HR with 95% CI. The ORs and HRs were extracted of which most adjustment or calculated by the numbers of cases and controls. If appropriate, the extracted information will be used for subgroup analysis.

The methodological quality were assessed using the Newcastle-Ottawa Scale (NOS) [20] for cohort studies with evaluation score ranged from 0 to 9 and using the Agency for Healthcare Research and Quality (AHRQ) methodology checklist [21] for cross-sectional studies with evaluation score ranged from 0 to 11 [22]. The scores of 7-9 and 8-11 are considered as good quality of cohort and cross-sectional studies, respectively. Any inconsistencies were resolved through group discussion with an additional investigators (Q.L., H.W. and F.W.).

2.3. Statistical Methods

We assessed the association between yogurt intake and obesity, overweight, abdominal obesity risk with the pooled OR and 95% CI in this meta-analysis. Studies with a clear number of cases and controls and effect size with 95% CI was included in the synthesis. If quantitative synthesis is not appropriate, we extracted effect size and summarized in the table.

We use the Q test and I^2 statistic to evaluated the heterogeneity, and P <0.10 suggested significant heterogeneity [23]. If $I^2 \leq 50\%$, Mantel-Haenszel fixed-effects model was used, otherwise, Der Simonian and Laird random-effects model was used [24]. A meta-regression was performed to test which heterogeneous sources could have a significant impact on the differences between any studies [25]. To assess the effect of potential key covariates, stratified analyses were performed for geographic location (the U.S., Europe, and South Korea), dietary assessment (validated, non-validated, or not available [N/A]), and adjustment by physical activity/energy intake/smoking/alcohol (yes or no).

Dose-response analyses were conducted with the method described by Greenland and Longnecker [26] for the risk of obesity and the increased intake of yogurt. We extracted information from the selected articles with yogurt consumptions grading. The midpoint of the range was used if the median or mean was not reported. The width of the adjacent category to the top-level category was used if the top category is open-ended, and the lowest boundary was set to zero if the lowest category was open-ended [27]. Then, we evaluated possible non-linear associations between the consumption of yogurt and the risk of obesity by using restricted cubic splines with three knots at the 10%, 50%, and 90% of the distribution [27, 28]. We calculated the non-linear p-value by testing the null hypothesis that the second spline coefficient was equal to zero.

We performed a "leave-one-out" sensitivity analysis by removing one study at a time to evaluate the possible influence of each included study [29]. Moreover, we used quantitative Egger [30], and Begg [31] tests to assess the publication bias. All data were analyzed with STATA software (version 11.0; Stat Corp, College Station, TX, USA) and reported *P* values were 2-sided, with $P < 0.05$ was considered statistically significant.

3. Results

3.1. Search Results for Systematic Review and Meta-analysis

We initially retrieved 1138 articles in databases and added 3 manually retrieved articles, then, excluded 465 articles due to duplicates, and 612 articles that did not meet our inclusion criteria. In the rest 64 potentially eligible articles, 11 reviews are excluded, 12 articles were not yogurt consumption, 14 articles were not required outcomes. After all, there were 27 articles included in the review. After we excluded insufficient and confusing data (n= 17 records), 10 articles were included in the final meta-analysis, where 7 articles include cross-sectional studies, and 3 include cohort studies. All the included articles were evaluated by PRISMA. (Figure 1)

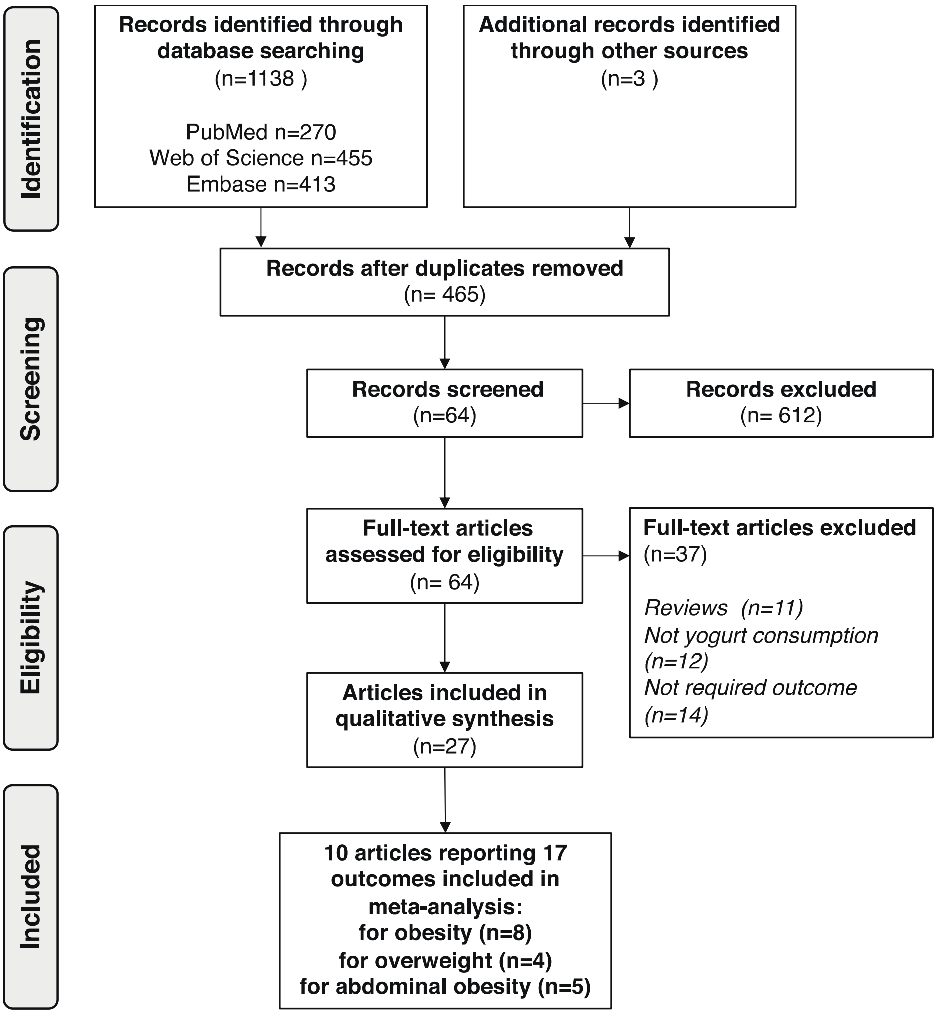

Figure 1. *PRISMA flow diagram of articles included in the present study.*

3.2. Study Characteristics

This review included 27 articles reporting 35 studies listed in Table 1. 8 studies for meta-analysis contain 90,496 controls and 24,648 cases of obesity [32-37]. Four studies with 25,664 cases [32, 33, 38] and five studies with 28,465 cases [18, 33, 39, 40] carry out meta-analysis for overweight and abdominal adiposity, respectively. Where two studies were performed in the United States [34, 37], seven in Europe [18, 32, 33, 35, 38, 40], and five in South Korea [36, 39]. Participants were aged from 13 to 90 years. All information on yogurt consumption was collected through questionnaires except one for 24h-recall [36], and total yogurt exposure was used in this meta-analysis. The studies quality was evaluated with the NOS or AHRQ methodology checklist in Table 2 and Table 3 respectively. Two cross-sectional studies [33, 40] and three prospective studies [18, 37, 39] have good quality, and the rest were medium quality in this meta-analysis.

This review also includes studies on anthropometric changes related to obesity, including BMI, body weight, and waist circumference. Except for the every four years changes of body weight in three studies [41], the remaining studies were annual change. in anthropometry with increased consumption of yogurt per day [42-46]. In terms of the type of yogurt, there were 8 studies on the whole yogurt [41, 43-46] and 3 studies on whole-fat or low-fat yogurt [44, 46, 47].

3.3. Yogurt Intake and Risk of Obesity

Of all the studies that included qualitative synthesis, 15 evaluated the effect of yogurt intake on obesity [32-37, 48-52]. Three of them reported that yogurt has a significant protective effect on obesity [33, 35, 53], nine studies' result were not significant [32, 34-37, 50, 52], but two studies concluded that sour milk consumption will increase the risk of obesity [51]. Only one study shown that eating whole-fat yogurt could reduce the incidence of obesity, while eating low-fat yogurt won't [49] (Table 4). Eight studies with no specific number of cases were excluded while extracting data for statistical analysis [48-52].

Then we found an inverse association between yogurt intake and obesity in the meta-analysis, the pooled OR of obesity risk for the highest level versus the lowest level of yogurt intake was 0.83 (95% CI: 0.79, 0.87; I^2= 0.0%) (Figure 2). Geographical subgroup (Table 5) analysis shows that there is a negative correlation between yogurt intake and obesity, especially in Europe populations (OR: 0.83; 95% CI: 0.80, 0.87), and South Korea populations (OR: 0.80; 95% CI: 0.65, 0.99), However, there is no correlation between yogurt intake and obesity for United States populations (OR: 0.75; 95% CI: 0.55, 1.02). The positive result to obesity only observed in Cross-sectional studies and adults populations. We also calculated the pooled OR (0.86, 95% CI:0.64, 1.15) that adjusted for physical activity, energy intake or alcohol, contrary to not adjusted (OR=0.83, 95% CI: 0.79, 0.87). Whether the race was adjusted has no effect on the pooled OR. A non-linear dose–response association was observed (*P*-trend = 0.03) from 3 studies [32, 33, 36] which shows the risk of obesity decreased by approximately 44% with increasing intake of yogurt up to ~165 g/day (Figure 3).

Table 1. *Characteristics of the 13 articles included in the quantitative meta-analysis.*

Author, Year	Country	Design	Participant Men (%)	Age Range (Years)	Events, Cases	Dietary Assessment	Type of yogurt	Adjustment for Covariates
Abreu al., 2014 [32]	Portugal	Cross-sectional	494 (42.1%)	15-18	Obesity, 35 Overweight, 110	FFQ-91 items, validated	All types of yogurt	N/A
Babio et al., 2015 [54]	Spain	Prospective cohort	1,868 (47.5%)	55–80	Abdominal obesity, N/A	FFQ-137 items, validated	Total, Whole-fat, Low-fat yogurt	Intervention group; sex; age (year); leisure time physical activity; BMI; current smoker; former smoker; and use of hypoglycaemic, hypolipidemic, antihypertensive, and insulin treatment at baseline, mean consumption during the follow-up of vegetables, fruit, legumes, cereals, fish, red meat, cookies, olive oil, and nuts, as well as alcohol, prevalence of Mets components at baseline.
Beydoun et al., 2018 [48]	United States	Prospective cohort	1,580 (N/A)	30–64	Obesity, N/AAbdominal obesity, N/A	24-h dietary recall, validated	Total yogurt	Age, sex, race, socioeconomic status, energy intake at baseline, current smoking, current drug use, and self-rated health.
Brouwer-Brolsma et al., 2018 [33]	Dutch	Cross-sectional	114,682 (41.0%)	≥18	Obesity: 5,782 Overweight: 25,113 Abdominal obesity:	Flower FFQ-110 items, validated	All types of yogurt	Age, sex, alcohol, smoking, education, physical activity, total energy intake and the intake of energy-adjusted bread, pasta, rice, potato, fruit, vegetables, legumes, meat, fish, coffee, tea,

Author, Year	Country	Design	Participant Men (%)	Age Range (Years)	Events, Cases	Dietary Assessment	Type of yogurt	Adjustment for Covariates
					20,694			soda/fruit juice and other dairy groups, and currently being on a weight-loss diet.
Crichton et al., 2014 [49]	Luxembourg	Cross-sectional	1,352 (48.6%)	18-69	Obesity, N/A Abdominal obesity, N/A	FFQ-134 items, validated	N/A	Age, education, sex, smoking, physical activity, total carbohydrate, total protein, total fat, total fibber, alcohol, calcium, and total energy intake, HDL, LDL, triglycerides, and systolic and diastolic BP.
Crichton et al., 2019 [34]	United States	Cross-sectional	699 (40.6%)	23-70	Obesity, 297	FFQ-146 items, validated	N/A	N/A
Cormier et al., 2015 [55]	Canada	Cross-sectional	640 (42.5%)	18–55	Overweight or Obesity, 424	Consumption vs. No-consumption	Total yogurt	N/A
Jodkowska al., 2011 Boys [38]	Polish	Cross-sectional	800 (100%)	13-15	Overweight, 180	FFQ, N/A	Kefir or natural yogurt	N/A
Jodkowska al., 2011 Girls [38]	Polish	Cross-sectional	1,106 (0%)	13-15	Overweight, 261	FFQ, N/A	Kefir or natural yogurt	N/A
Johansson et al., 2018 [56]	Sweden	Cross-sectional	90,512 (48.7%)	29-65	Overweight or obesity, N/A	FFQ-84/64-66 items, N/A	Fermented milk	Age, dairy type, screening year, education, BMI, physical activity, smoking, intakes of fruits and vegetables, alcohol and non-alcohol energy.
Kim et al., 2013 [50]	Korea	Cross-sectional	4,862 (41.0%)	≥ 19	Obesity, N/A Abdominal obesity, N/A	24-h dietary recall, validated	Total yogurt	Age, sex, education level, income, smoking status, body mass index, alcohol intake, physical activity, energy intake, fat intake, calcium intake and fiber intake.
Kim et al., 2017 men [39]	Korea	Prospective cohort	1,257 (100.0%)	40-69	Abdominal obesity, 356	FFQ-103 items, validated	All types of yogurt	Age, (sex), BMI, residential location, educational level, household income, smoking status, alcohol intake, physical activity, nutrient intakes such as energy and energy-adjusted Ca and fiber.
Kim et al., 2017 women [39]	Korea	Prospective cohort	694 (0.0%)	40-69	Abdominal obesity, 333	FFQ-103 items, validated	All types of yogurt	Age, (sex), BMI, residential location, educational level, household income, smoking status, alcohol intake, physical activity, nutrient intakes such as energy and energy-adjusted Ca and fiber.
Konieczna et al., 2019 [42]	Spain	Prospective cohort	7,009 (NA)	55–70	Weight change, N/A WC change, N/A	FFQ-137 items, validated	Whole-fat, low-fat yogurt	Time, sex, centre, intervention group, age, baseline BMI and educational level, as well as yearly measured changes in smoking status and physical activity.
Lahti-Koski et al., 2002 men [51]	Finland	Cross-sectional	10,697 (100.0%)	25–64	Obesity, N/A	FFQ, N/A	Sour milk	Age, education, activity level at work, walking or cycling to work, activity level at leisure time, weekly time of leisure-time physical activity, milk, fat, vegetable, sausage, bread, coffee, tea, alcohol, smoking history, perceived health status.
Lahti-Koski et al., 2002	Finland	Cross-sectional	11,846 (0.0%)	25–64	Obesity, N/A	FFQ, N/A	Sour milk	Age, education, activity level at work, walking or cycling to

Author, Year	Country	Design	Participant Men (%)	Age Range (Years)	Events, Cases	Dietary Assessment	Type of yogurt	Adjustment for Covariates
women [51]								work, activity level at leisure time, weekly time of leisure-time physical activity, milk, fat, vegetable, sausage, bread, coffee, tea, alcohol, smoking history, perceived health status.
Lau et al., 2019 [35]	Portugal	Cross-sectional	38,802 (N/A)	≥18	Obesity, 12957	FFQ, N/A	N/A	Age, sex, race, income, education, alcohol intake, smoking according to the origin of probiotics, logarithmic status, physical activity, carbohydrates/kcal per day, protein/kcal per day, fiber/kcal per day, and polyunsaturated/saturated fatty acids ratio.
Lee et al., 2014 men [36]	Korea	Cross-sectional	1,429 (100.0%)	19-65	Obesity, 513	FFQ-63 items, validated	All types of yogurt	Age, gender, survey year, education, smoking, alcohol intake, physical activity, income, energy intake.
Lee et al., 2014 women [36]	Korea	Cross-sectional	1,533 (0.0%)	19-65	Obesity, 435	FFQ-63 items, validated	All types of yogurt	Age, gender, survey year, education, smoking, alcohol intake, physical activity, income, energy intake.
Lee et al., 2014 [36]	Korea	Cross-sectional	5,797 (N/A)	19-65	Obesity, 1740	24-hour recall, validated	All types of yogurt	Age, gender, survey year, education, smoking, alcohol intake, physical activity, income, energy intake.
Martinez-Gonzalez et al., 2014 [57]	Spain	Prospective cohort	8,516 (34.1%)	37.1 ± 10.8	Overweight/obesity, N/A	FFQ-136 items, validated	Total, Whole-fat, Low-fat yogurt	Sex, age, physical activity, hours of TV watching, hours spent sitting down, smoking status, snacking between meals, following a special diet, total energy intake, and adherence to the Mediterranean diet, marital status, and years of education and baseline BMI.
Mena-Sánchez et al., 2018 [40]	Spain	Cross-sectional	6,572 (51.5%)	men: 55-75, women: 60-75	Abdominal obesity, 2840	FFQ-146 items, N/A	Total yogurt	sex, age, education level, physical activity, BMI, smoking habit, total energy intake, Mediterranean 17 points questionnaire and use of hypoglycemic, hypolipidemic, antihypertensive, and insulin treatment
Mozaffarian et al., 2011 NHS [41]	United States	Prospective cohort	50,422 (0.0%)	52.2±7.2	Weight change, N/A	FFQ, validated	Total yogurt	Age, baseline body mass index at the beginning of each 4-year period, sleep duration, and changes in physical activity, alcohol use, smoking, television watching, and other dietary factors.
Mozaffarian et al., 2011 NHS II [41]	United States	Prospective cohort	47,898 (0.0%)	37.5±4.1	Weight change, N/A	FFQ, validated	Total yogurt	Age, baseline body mass index at the beginning of each 5-year period, sleep duration, and changes in physical activity, alcohol use, smoking, television watching, and other dietary factors.
Mozaffarian et al., 2011 HPFS [41]	United States	Prospective cohort	22,557 (0.0%)	50.8±7.5	Weight change, N/A	FFQ, validated	Total yogurt	Age, baseline body mass index at the beginning of each 6-year period, sleep duration, and changes in physical activity, alcohol use, smoking, television watching, and other dietary factors.

Author, Year	Country	Design	Participant Men (%)	Age Range (Years)	Events, Cases	Dietary Assessment	Type of yogurt	Adjustment for Covariates
Pereira et al., 2002 [37]	United States	Prospective cohort	923 (N/A)	18–30	Obesity, 374	FFQ-700 items, validated	N/A	Age; sex; calorie intake per day; study center; baseline BMI; educational level; alcohol intake; smoking status; physical activity; vitamin supplements, dietary factors, fiber and protein.
Rautiainen et al., 2016 [58]	United States	Prospective cohort	18,438 (0.0%)	≥45	Overweight/obesity, 3558	FFQ-131 items, validated	Total yogurt	Age, randomization treatment, smoking status, physical activity, postmenopausal status, postmenopausal hormone use, history of hypercholesterolemia, history of hypertension, multivitamin use, alcohol intake, energy intake, and fruit and vegetable intake, baseline BMI.
Romaguera et al., 2011 [43]	Italy, UK, Netherlands Germany, Denmark	Prospective cohort	48,631 (40.5%)	≤65	WC change, N/A	FFQ, validated	Total, Whole-fat, Low-fat yogurt	Total energy intake, age, baseline weight, baseline height, baseline WC_{BMI}, smoking, alcohol intake, physical activity, education, follow-up duration, menopausal status (women only), and hormone replacement therapy use (women only).
Santiago et al., 2016 [44]	Spain	Prospective cohort	4,545 (N/A)	Men: 55-80, women: 60-80	Reversion of Abdominal obesity, 371 WC change, N/A	FFQ-137 items, validated	Total, Whole-fat, Low-fat yogurt	Age, sex, physical activity, Mediterranean Diet adherence, total energy intake, smoking status, baseline BMI, intervention group and center.
Sayón-Orea et al., 2015 [18]	Spain	Prospective cohort	8,063 (34.2%)	20-90	Abdominal obesity, 2029	FFQ-136 items, validated	Total, Whole-fat, Low-fat yogurt	Age, sex, baseline weight, total energy intake, alcohol intake, soft drinks, red meat, French fries, fast food, Mediterranean diet, physical activity, sedentary behavior, hours sitting, smoking status, snacking between meals, following special diet.
Snijder et al., 2007 [45]	Netherlands	Cross-sectional	1,896 (44.9%)	50-75	BMI change, N/A WC change, N/A	FFQ-92 items, N/A	Total yogurt	Total energy intake, fiber intake, level of physical activity, alcohol intake, smoking status, income, educational level, and antihypertensive medication use.
Song et al., 2020 [52]	China	Cross-sectional	3,871 (43.9%)	≥18	Obesity, N/A Abdominal obesity, N/A	FFQ, validated	All types of yogurt	Investigation year, age, gender, education, residential region, income, smoking, wine-drinking, labor intensity, physical activities, and total energy.
Trichia et al., 2020 [46]	United Kingdom	Prospective cohort	14,227 (N/A)	40–78	BMI change, N/A Weight change, N/A WC change, N/A	FFQ-130 items, validated	Whole-fat, low-fat yogurt	Age, sex, educational level, age at completion of full-time education, marital status, socio-economic status based on occupation, individual follow-up time physical activity level, smoking status, lipid-lowering medication, anti-hypertensive medication, hormone-replacement therapy, total energy intake, intakes of some diet. When analyzing waist circumference +MBI.
Vergnaud et al., 2008	France	Prospective cohort	2,267 (55.0%)	>45	Weight change, N/A	24-h dietary recall	Total yogurt	Intervention group, baseline value of the outcome, educational level,

Author, Year	Country	Design	Participant Men (%)	Age Range (Years)	Events, Cases	Dietary Assessment	Type of yogurt	Adjustment for Covariates
[59]					WC change, N/A			smoking status, physical activity level, energy intakes, mean adequacy ratio, intakes of alcohol, milk and cheese.
Wang et al., 2014 [10]	United States	Prospective cohort	3,440 (45%)	54.5 ± 9.6	Weight change, N/A WC change, N/A	FFQ-126 items, validated	Total yogurt	Sex and time-varying variables including age, smoking status, physical activity, and waist circumference at the beginning of each exam interval, and average total energy intake and DGAI score during each exam-interval.

Table 2. *Quality assessment of cohort studies with the Newcastle-Ottawa Scale.*

Author, year	Study	Selection	Comparability	Outcome	Overall quality
Babio et al., 2015 [54]	PREDIMED	3	2	3	8
Beydoun et al., 2018 [53]	HANDLS	3	2	3	8
Kim et al., 2017 [39]	KoGES	2	2	3	7
Konieczna et al., 2019 [42]	PREDIMED	3	2	3	8
Martinez-Gonzalez et al., 2014 [57]	SUN	2	2	2	6
Mozaffarian et al., 2011 [41]	NHS/NHS II/HPFS	2	2	2	6
Pereira et al., 2002 [37]	CARDIA	3	2	3	8
Rautiainen et al., 2016 [58]	The Women's Health	2	2	2	6
Romaguera et al., 2011 [43]	EPIC	2	2	2	6
Santiago et al., 2016 [44]	PREDIMED	3	2	3	8
Sayón-Orea et al., 2015 [18]	SUN	3	2	2	7
Trichia et al., 2020 [46]	EPIC-Norfolk	2	2	3	7
Vergnaud et al., 2008 [59]	SU.VI.MAX	3	2	3	8
Wang et al., 2014 [39]	FHS Offspring Cohort	2	2	3	7

For each study, the evaluation score was ranged from 0 to 9, and the scores of 0-3, 4-6 and 7-9 were considered as bad, medium and good quality respectively.

Table 3. *Quality assessment of cross-sectional studies with ARHQ methodology checklist*

Author, year	1) Definition of information	2) Criteria of subjects	3) Patients identification time period	4) Subjects' consecutive	5) Subjective influence of evaluator	6) Assessments for quality assurance
Abreu al., 2014 [32]	1	1	1	0	0	1
Brouwer-Brolsma et al., 2018 [33]	1	1	1	1	0	1
Crichton et al., 2014 [49]	1	1	1	1	0	1
Crichton et al., 2019 [34]	1	1	1	1	0	1
Jodkowska al., 2011 [38]	1	1	1	1	0	0
Johansson et al., 2018 [56]	1	1	1	1	0	0
Kim et al., 2013 [50]	1	1	1	1	0	1
Lahti-Koski et al., 2002 [51]	1	1	1	1	0	0
Lau et al., 2019 [35]	1	1	1	1	0	0
Lee et al., 2014 [36]	1	1	1	1	0	0
Mena-Sánchez et al., 2018 [40]	1	1	1	1	0	0
Snijder et al., 2007 [45]	1	1	1	1	0	0
Song et al., 2020 [52]	1	1	1	1	0	0

Table 3. *Continue.*

Author, year	7) Explain excluded patients	8) Describe confounding	9) Treatment of missing data	10) Patient response rates, completeness of data collection	11) Follow-up	Total scale
Abreu al., 2014 [32]	1	0	1	1	0	7
Brouwer-Brolsma et al., 2018 [33]	1	1	0	1	0	8
Crichton et al., 2014 [49]	1	1	0	1	0	8
Crichton et al., 2019 [34]	1	0	0	1	0	7
Jodkowska al., 2011 [38]	1	0	0	1	0	6
Johansson et al., 2018 [56]	1	1	0	1	0	7
Kim et al., 2013 [50]	1	1	0	1	0	8
Lahti-Koski et al., 2002 [51]	1	1	0	1	0	7

Author, year	7) Explain excluded patients	8) Describe confounding	9) Treatment of missing data	10) Patient response rates, completeness of data collection	11) Follow-up	Total scale
Lau et al., 2019 [35]	1	1	0	1	0	7
Lee et al., 2014 [36]	1	1	0	1	0	7
Mena-Sánchez et al., 2018 [40]	1	1	0	1	1	8
Snijder et al., 2007 [45]	1	1	0	1	0	7
Song et al., 2020 [52]	1	1	0	1	0	7

An item would be scored "1" if it was answered "YES", and if the answer was "NO" or "UNCLEAR" it would be scored "0". For each study, the evaluation score was ranged from 0 to 11, and the scores of 0-3, 4-7 and 8-11 were considered as low, moderate and high quality respectively.

Table 4. *Odds Ratios for yogurt consumption and obesity incidence.*

Author, Year	Obesity Define (BMI Cut-off points, kg/m^2)	Intake Comparison (Highest vs. Lowest)	Cases/Controls	OR (95%CI)	*p*-value
Total yogurt[1]					
Abreu al., 2014 [32]	≥30 (18y)[2]	≥53.57 g/day vs. <53.57 g/day	35/349	1.49 (0.69, 3.18)	-
Beydoun et al., 2018 [53]	≥30	Per fl oz equivalent of yogurt	N/A	0.57 (0.40,0.82)[3]	-
Brouwer-Brolsma et al., 2018 [33]	≥30	≥65 g/day vs. 0 g/day	8,297/57,153	0.83 (0.79, 0.88)	<0.01
Crichton et al., 2019 [34]	≥30	≥1 serves/week vs. <1 serves/week	297/404	0.78 (0.57, 1.07)	-
Kim et al., 2013 [50]	≥25	≥once per day vs. none or rarely	N/A	0.77 (0.56, 1.04)	0.51
Lau et al., 2019 [35]	≥30	Exposed vs. not exposed	12,957/25,845	0.84 (0.76, 0.93)	-
Lee et al., 2014 men [36]	≥25	≥1 time/day vs. none	513/916	0.73 (0.51, 1.05)	0.45
Lee et al., 2014 women [36]	≥25	≥1 time/day vs. none	435/1,098	0.82 (0.55, 1.20)	0.21
Lee et al., 2014 [36]	≥25	≥137.8 g/day vs. 0 g/day	1,740/4,057	0.86 (0.61, 1.21)	0.23
Lahti-Koski et al., 2002 men [51]	≥30	1 glasses/day change	-/10,697	1.15 (1.10, 1.19)	-
Lahti-Koski et al., 2002 women [51]	≥30	1 glasses/day change	-/11,846	1.14 (1.09, 1.20)	-
Pereira et al., 2002 [37]	≥30 or waist-hip ratio ≥0.90 (men), ≥0.85 (women)	Daily eating vs. not eating	374/674	0.47 (0.16, 1.43)	-
Song et al., 2020 men [52]	≥28	≥100 g/day vs. 0 g/day	N/A	0.51 (0.21, 1.26)	0.15
Song et al., 2020 women [52]	≥28	≥00 g/day vs. 0 g/day	N/A	0.74 (0.32-1.70)	0.49
Whole-fat yogurt					
Crichton et al., 2014 [34]	≥30	Tertiles 3 vs. tertiles 1	N/A	0.57 (0.39-0.85)	-
Low-fat yogurt					
Crichton et al., 2014 [34]	≥30	Tertiles 3 vs. tertiles 1	N/A	1.54 (1.07, 2.23)	-

[1]Total yogurt include all kind of yogurt and undefined type.
[2]Obesity was defined as BMI ≥30 kg/m^2 when the participants' age over 18 years and for child the BMI cut offs cover the age range 2-18 years were based on the adult cut offs of 30 at 18 years.

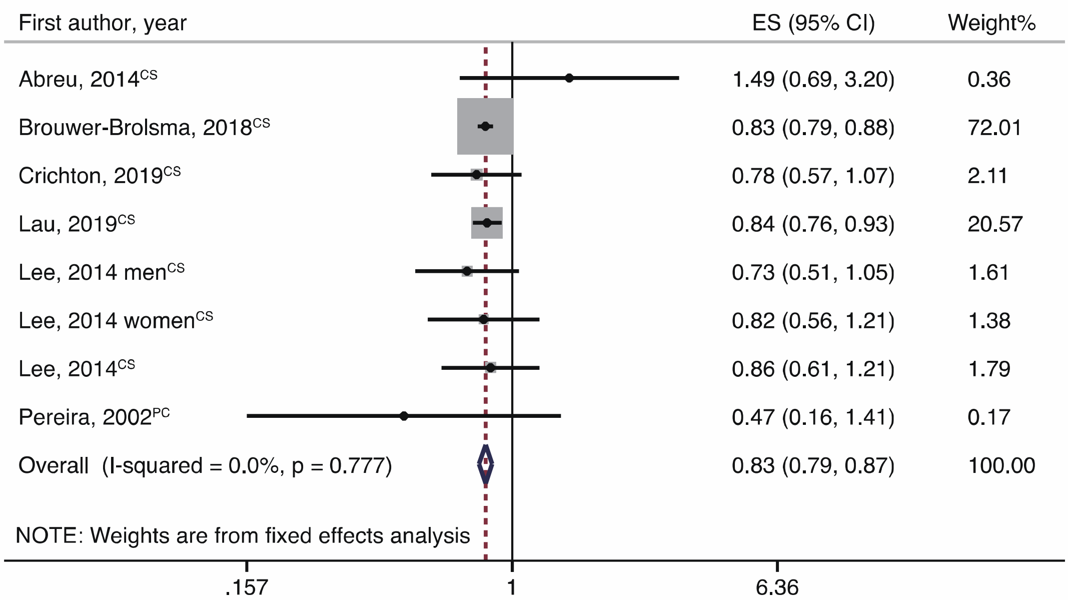

Figure 2. *Forest plot showing the associations between yogurt consumption and obesity incidence risk.*

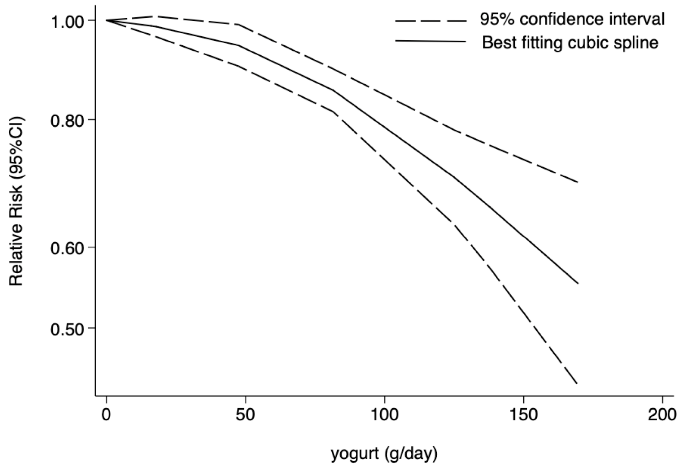

Figure 3. *Non-linear dose-response relation between daily intake of yogurt risk of obesity.*

3.4. Yogurt Intake and Risk of Overweight

We also found Yogurt intake does not affect the risk of the overweight occurs with a pooled OR of 0.88 (95% CI: 0.58, 1.36; I^2= 82.8%) (Figure 4) calculated using a random effects model. Only one study with 64,939 participants adjusted for confounding factors (OR: 0.94; 95% CI: 0.91, 0.98) [33]. The OR of the other three studies was calculated by cases and the number of controls [32, 38] (Table 6). We did not conduct a dose-response analysis due to insufficient number of studies.

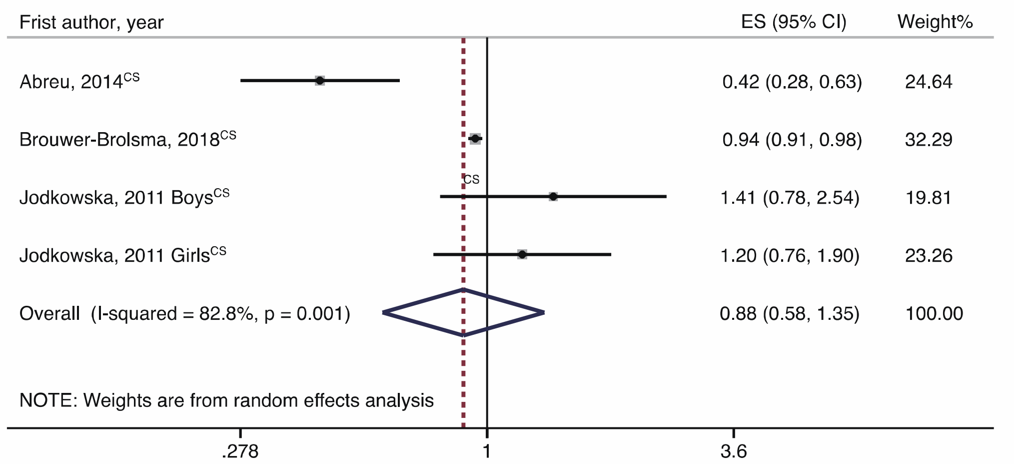

Figure 4. *Forest plot showing the associations between yogurt consumption and overweight incidence risk.*

There still have 4 articles about yogurt consumption and the risk of being overweight or obese that do not meet the meta-analysis conditions [55-58] (Table 5). The data from a Prospective cohort study after a median follow-up of 6.6 years was analyzed by Martinez-Gonzalez et al. [57] and 1860 individuals were identified as overweight/obesity. The group of high (>7 servings/week) intake of total and whole-fat yogurt had lower incidence of overweight/obesity than lower intake (0-2 servings/week) (OR:0.80; 95% CI:0.68, 0.94; P-trend= 0.001; and OR=0.62; CI:0.47, 0.82; P-trend <0.001). In participants with higher fruit consumption this trend was more obvious. But this inverse association was not found in the low-fat yogurt category (OR:0.84; 95% CI:0.61, 1.15; P-trend =0.601). A longitudinal analysis was conducted by Johansson et al. [56] after 8–12 years follow-up of 27,682 participants in Northern Sweden. Higher intake (Quartile 5) of fermented milk had lower incidence of overweight/obesity than lower intake (Quartile 1) in men (OR:0.92; 95% CI:0.85, 0.99; P-trend =0.035), not in the women participants (OR:0.98; 95% CI:0.91, 1.06). In the study of Cormier et al. [55] obesity incidence was no difference between yogurt consumers and non-consumers. Calculated from a prospective cohort study about middle-aged and older women, Rautiainen et al. [58] found yogurt consumption will lead a higher risk of overweight/obesity (HR:1.16; 95% CI:1.02, 1.31; P-trend =0.002). As for the yogurt subgroup analysis, only one study shown that eating whole-fat yogurt could reduce the incidence of obesity, while eating low-fat yogurt won't [57].

3.5. Yogurt Intake and Risk of Abdominal Obesity

The pooled OR of abdominal obesity risk of yogurt intake was 0.80 (95% CI: 0.69, 0.92; I^2= 88.8%) (Figure 5), indicating that increased consumption of yogurt would degrade the occurrence of abdominal obesity. We also did not conduct a dose-response analysis due to lack of sufficient data.

Two studies have used OR [18, 33], and two studies have used HR [39, 54] and one has used RR [40]. Only one study has suggested that yogurt consumption would not affect abdominal obesity [40], while the others showed that the yogurt consumption would reduce the possibility of being abdominal obesity [18, 33, 39, 54]. There five other studies not included in the analysis because of no cases number (Table 8). In a follow-up study, the HR of abdominal obesity was 0.74 (95% CI:0.61, 0.91) Comparing tertile 3 and tertile 1 of yogurt consumption in elderly individual [54]. Song et al. [52] has found a higher intake (≥100 g/d) of yogurt had a lower incidence of abdominal obesity in men compared to no intake (OR:0.41; 95% CI:0.24, 0.70; *P*-trend<0.01), rather than women (OR:0.65; 95% CI:0.37, 1.13; *P*-trend<0.12). And in a survey from Korea yogurt did not affect the incidence of abdominal obesity if it's consumption above 1 once per day [50]. Nevertheless, after five years follow-up, the risk of abdominal obesity has increased with annual rates of change in yogurt consumption (OR:1.21, 95% CI: 1.01, 1.44; *P*-trend<0.05) in HANDLS cohort [48].

Table 5. *Subgroup analyses between the intake of yogurt and the risk of obesity.*

Subgroup	N	Cases/Controls	OR (95%CI)	I^2	*p*-Value
Geographic Location					
Europe	3	21,289/83,347	0.83(0.80, 0.87)	11.80%	0.32
United States	2	671/1,078	0.75(0.55, 1.02)	0.00%	0.38
South Korea	3	2,688/6,071	0.80(0.65, 0.99)	0.00%	0.81
study design					
Cross-Sectional	7	24,274/89,822	0.83(0.79, 0.87)	0.00%	0.81
Prospective Cohort	1	374/674	0.47(0.16, 1.41)	-	-
Age					
<18	1	35/349	1.49(0.69, 3.18)	-	-
≥18	7	24,613/90,147	0.83(0.79, 0.87)	0.00%	0.94
Adjustment for physical activity					
yes	6	24,316/89,743	0.86(0.64, 1.15)	57.60%	0.13
no	2	332/753	0.83(0.79, 0.87)	0.00%	0.90
Adjustment for energy intake					
yes	6	24,316/89,743	0.86(0.64, 1.15)	57.60%	0.13
no	2	332/753	0.83(0.79, 0.87)	0.00%	0.90
Adjustment for alcohol					
yes	6	24,316/89,743	0.86(0.64, 1.15)	57.60%	0.13
no	2	332/753	0.83(0.79, 0.87)	0.00%	0.90
Adjustment for race					
yes	1	8,297/57,153	0.83(0.79, 0.88)	-	-
no	7	16,351/33,343	0.83(0.76, 0.91)	0.00%	0.67

Table 6. *Odds Ratios for yogurt consumption and overweight.*

Author, Year	Overweight Define (BMI Cut-off points, kg/m²)	Intake Comparison (Highest vs. Lowest)	Cases/Controls	OR (95%CI)	*p*-value
Abreu al., 2014 [32]	≥ 25, <30 (18y)[1]	Appropriate intake vs. Low intake	110/595	0.42 (0.28, 0.64)	-
Brouwer-Brolsma et al., 2018 [33]	≥ 25, <30	≥65 g/day vs. 0 g/day	25,113/39,826	0.94 (0.91, 0.98)	<0.01
Jodkowska al., 2011 Boys [38]	≥85 percentiles	Often vs. never	180/163	1.41 (0.79, 2.56)	-
Jodkowska al., 2011 Girls [38]	≥85 percentiles	Often vs. never	261/255	1.20 (0.77, 1.94)	-

[1]Obesity was defined as BMI ≥30 kg/m² when the participants' age over 18 years and for child the BMI cut offs cover the age range 2-18 years were based on the adult cut offs of 30 at 18 years.

Table 7. *Odds Ratios for yogurt consumption and overweight/obesity.*

Author, Year	Overweight/Obesity Define (BMI Cut-off points, kg/m²)	Intake Comparison (Highest vs. Lowest)	Cases/ Controls	OR (95%CI)	*p*-value
Total yogurt[1]					
Cormier et al., 2015 [55]	≥25	Consumption vs. No-consumption	424/240	0.68 (0.41, 1.11)	-
Johansson et al., 2018 man [56]	≥25	Quartile 5 vs. quartile 2	N/A	0.92 (0.85, 0.99)	<0.05
Johansson et al., 2018 women [56]	≥25	Quartile 5 vs. quartile 1	N/A	0.98 (0.91, 1.06)	-
Martinez-Gonzalez et al., 2014 [57]	≥25	≥7 servings/week vs. 0-2 servings/week	N/A	0.80 (0.68, 0.94)[2]	<0.01
Rautiainen et al., 2016 [58]	≥25	≥1 servings/d vs. 0 servings/d	3,558/8,047	1.16 (1.02, 1.31)[2]	<0.01
Whole-fat yogurt					
Martinez-Gonzalez et al., 2014 [57]	≥25	≥7 servings/week vs. 0-2 servings/week	N/A	0.62 (0.47, 0.82)[2]	<0.01
Low-fat yogurt					
Martinez-Gonzalez et al., 2014 [57]	≥25	≥7 servings/week vs. 0-2 servings/week	N/A	0.84 (0.61, 1.15)[2]	0.60

[1]Total yogurt include all kind of yogurt and undefined type.
[2]Hazard Ratio and 95% CI.

Table 8. *Odds Ratios for yogurt consumption and abdominal obesity.*

Author, year	Abdominal obesity define (WC cut-off points, cm)	Intake comparison (Highest vs. Lowest)	Cases/Controls	OR (95%CI)	*p*-value
Total yogurt[1]					
Babio et al., 2015 [54]	≥102 (men), ≥88 (women)	Tertiles 3 vs. tertiles 1	N/A	0.74 (0.61, 0.91)[2]	0.23
Beydoun et al., 2018 [48]	≥102 (men), ≥88 (women)	per fl oz equivalent of yogurt	N/A	1.21 (1.01, 1.44)[2]	-
Brouwer-Brolsma et al., 2018 [33]	≥102 (men), ≥88 (women)	≥65 g/day vs. 0 g/day	20,694/44,692	0.94 (0.90, 0.98)	<0.01
Kim et al., 2013 [50]	≥90 (men), ≥80 (women)	≥once per day vs. none or rarely	N/A	0.82 (0.53, 1.27)	0.91
Kim et al., 2017 men [39]	≥90	≥4 serves/week vs. none	356/901	0.48 (0.36, 0.64)[2]	<0.01
Kim et al., 2017 women [39]	≥80	≥4 serves/week vs. none	333/361	0.64 (0.51, 0.81)[2]	<0.01
Mena-Sánchez et al., 2018 [40]	≥102 (men), ≥88 (women)	Quartile 4 vs. quartile 1	5,053/231	1.03 (0.96, 1.11)[3]	0.38
Santiago et al., 2016 [44]	≥102 (men), ≥88 (women)	Quartile 5 vs. quartile 1	371/1,447	1.29 (0.96, 1.73)[4]	0.36
Sayón-Orea et al., 2015 [60]	≥94 (men), ≥80 (women)	≥875 g/week vs. 0-250 g/week	2,029/2,945	0.85 (0.74, 0.98)	-
Song et al., 2020 men [52]	≥85	≥100 g/day vs. 0 g/day	N/A	0.41 (0.24, 0.70)	<0.01
Song et al., 2020 women [52]	≥80	≥100 g/day vs. 0 g/day	N/A	0.65 (0.37, 1.13)	0.12
Whole-fat yogurt					
Babio et al., 2015 [54]	≥102 (men), ≥88 (women)	Tertiles 3 vs. tertiles 1	N/A	0.80 (0.65, 0.98)[2]	<0.05
Crichton et al., 2014 [49]	≥102 (men), ≥88 (women)	Tertiles 3 vs. tertiles 1	N/A	0.58 (0.41, 0.83)	-
Mena-Sánchez et al., 2018 [40]	≥102 (men), ≥88 (women)	Quartile 4 vs. quartile 1	3,059/227	1.01 (0.93, 1.09)[3]	0.71
Santiago et al., 2016 [44]	≥102 (men), ≥88 (women)	Quartile 5 vs. quartile 1	340/1,478	1.43 (1.06, 1.93)[4]	0.26
Sayón-Orea et al., 2015 [60]	≥94 (men), ≥80 (women)	≥875 g/week vs. 0-250 g/week	2,336/3,306	0.85 (0.73, 0.99)	-
Low-fat yogurt					
Babio et al., 2015 [54]	≥102 (men), ≥88 (women)	Tertiles 3 vs. tertiles 1	N/A	0.78 (0.63, 0.97)[2]	0.10
Crichton et al., 2014 [49]	≥102 (men), ≥88 (women)	Tertiles 3 vs. tertiles 1	N/A	1.45 (1.04, 2.01)	-
Mena-Sánchez et al., 2018 [40]	≥102 (men), ≥88 (women)	Quartile 4 vs. quartile 1	3,079/205	1.01 (0.94, 1.09)[3]	0.62
Santiago et al., 2016 [44]	≥102 (men), ≥88 (women)	Quartile 5 vs. quartile 1	399/1,419	1.02 (0.73, 1.44)[4]	0.85
Sayón-Orea et al., 2015 [60]	≥94 (men), ≥80 (women)	≥875 g/week vs. 0-250 g/week	2,723/4,098	1.12 (0.96, 1.30)	-

[1]Total yogurt include all kind of yogurt and undefined type.
[2]Hazard Ratio and 95% CI.
[3]Relative Risk and 95% CI.
[4]Odds Ratio and 95% CI of reversion of abdominal obesity and yogurt intake.

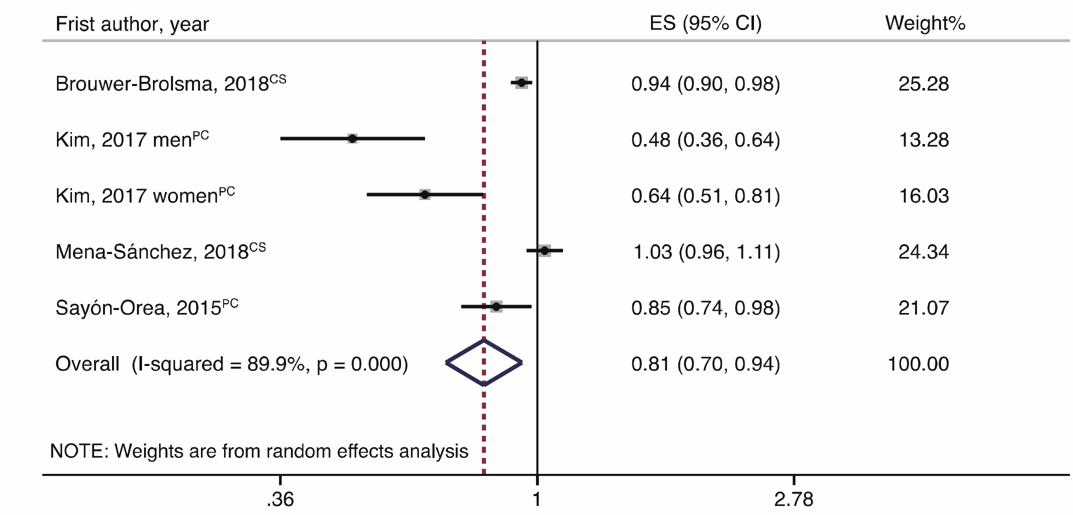

Figure 5. *Forest plot showing the associations between yogurt consumption and abdominal obesity incidence risk.*

As for the yogurt subgroup analysis, three studies have protective effects in whole-fat yogurt [49, 54, 60], while the other has no effect [40]; low-fat yogurt has one protective effect [54] and one promoting effect [49] respectively, and the other two have no effect [18, 40]. In addition, the result of the other one study is that long-term consumption of whole-yogurt would increase the reversion of abdominal obesity, but total/low-fat yogurt have not effect [44].

3.6. Yogurt Intake and Anthropometry Change

Eight studies have evaluated the relationship between yogurt intake and anthropometry (BMI, body weight, waist circumference) changes. The results shown in Figure 6 express the anthropometry changes of one year or four years by the consumption of one serving (125g) yogurt or in the highest quintile per day. Two studies have mentioned that total yogurt consumption would not affect the change of BMI, respectively Snijder et al. [45] (β:0.1; 95% CI: -0.04, 0.24) and Trichia et al, [46] (β: -0.09; 95% CI: -0.18, 0).

As shown in Figure 6, four studies have shown that total yogurt consumption can reduce body weight [41, 46]. In the study of Wang et al. [61], the annualized body weight change of the high-dose (3.74; 95% CI:3.00, 24.50 servings/week) group was also lower than that of the low-dose (0; 95% CI:0, 0.74 servings/week) group (0.07±0.04 kg vs. 0.16±0.02 kg; P-trend =0.03). Vergnaud et al. [59] have assessed body weight and waist circumference changes in middle-aged French adults who consumed yogurt. The participants were divided into normal-weight/overweight at baseline groups. The weight of people who eat more yogurt (Quartile 4) decreased than the weight of people who eat less (Quartile 1) in normal-weight women at baseline (P-trend =0.04) and overweight men at baseline (P-trend =0.01). We can also see the change in waist circumference in the Figure 6. Three studies have showed that total yoghurt intake reduced waist circumference [43, 46], while two also decreased but without statistical difference [44, 45]. Wang et al. [61] have found that the waist circumference annualized increase of the high-dose group was lower than that of the low-dose group (0.57±0.04 cm vs. 0.71±0.02 cm; P-trend =0.008). Another study conducted by Vergnaud et al. [59] has founded high yogurt intake changed less than low-intake only in overweight men at baseline (0.33 ± 0.43 cm vs. 1.62 ± 0.42 cm; P-trend =0.03), and others did not change. When the yogurt was classified, the influence trend of whole-fat (Figure 7) and low-fat yogurt (Figure 8) on the anthropometry change was not too uniform.

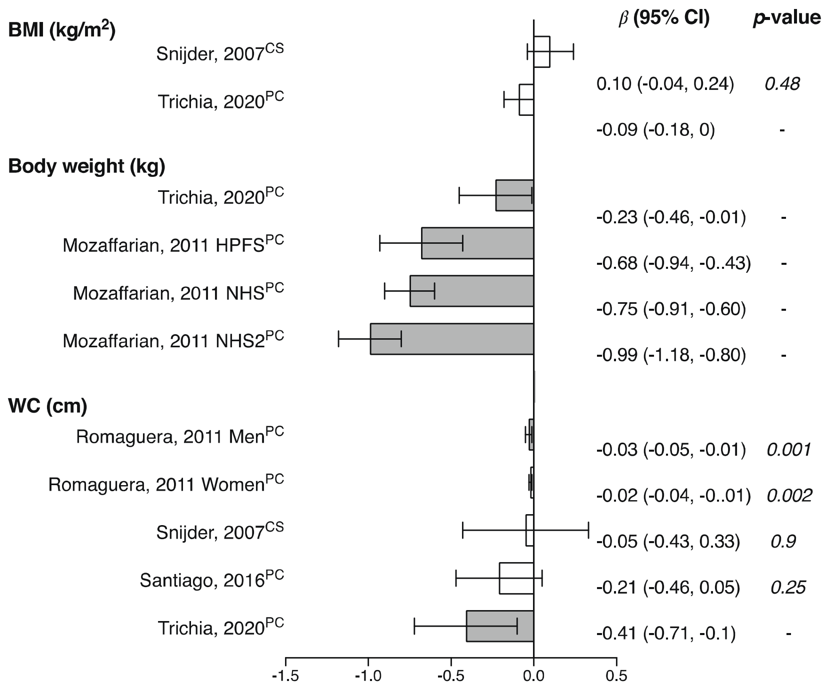

Figure 6. Association of total yogurt intake (every additional 1 serving/day or highest quintile per day than those in the lowest quintile) with yearly changes in anthropometry (BMI, body weight, waist circumference).

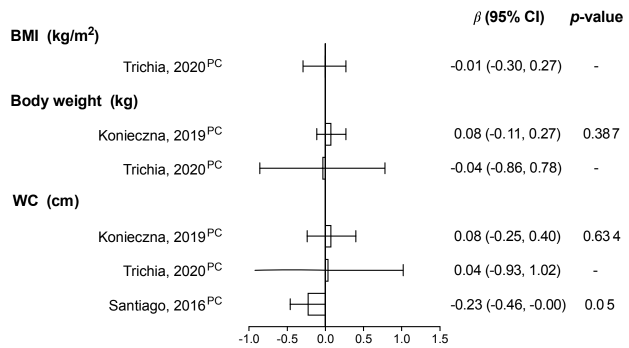

Figure 7. Association of whole-fat yogurt intake (every additional 1 serving/day or highest quintile per day than those in the lowest quintile) with yearly changes in anthropometry (BMI, body weight, waist circumference). β (95% CI) represents the yearly change in BMI (kg/m²) /body weight (kg)/ waist circumference (cm) associated with increased consumption of total yogurt.

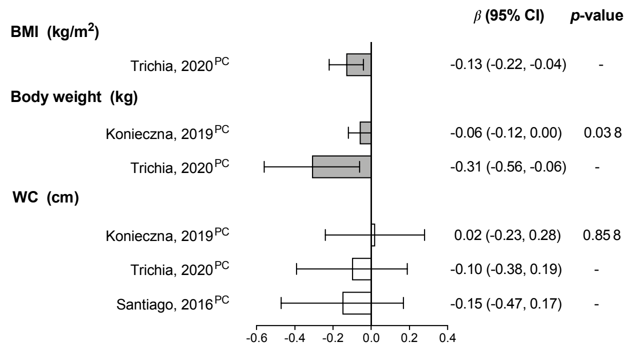

***Figure 8** Association of low-fat yogurt intake (1 serving/d or highest quintile per day) with yearly changes in anthropometry (BMI, body weight, waist circumference). β (95% CI) represents the yearly change in BMI (kg/m²) /body weight (kg)/ waist circumference (cm) associated with increased consumption of total yogurt. The gray bars indicate that upper limits of the 95% CI of this effect is less than zero.*

3.7. Sensitivity Analysis and Publication Bias

Sensitivity analysis shows that no separate study affects the combined effect. In the funnel plots, no potential publication bias for obesity risk was observed (Figure 9). Then, we looked for publication bias with Egger [30] and Begg [31] tests and found that no significant publication bias for obesity risk (*P* value for Begg: 0.54; Egger: 0.87). No publication bias testing has been performed, as there were few studies on overweight and abdominal obesity.

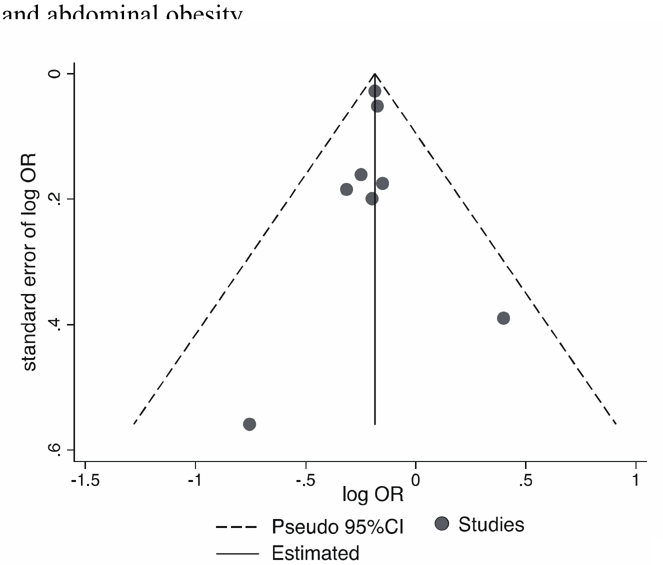

Figure 9. *Funnel plot of 8 studies included in the meta-analysis. Visual inspection demonstrates no publication bias, as confirmed by Egger's test (t =-0.17; p = 0.87).*

4. Discussion

This systematic review includes 35 studies, updates the review about the relationship between yogurt intake and obesity risk. As far as we know, only one systematic review [18] adopted ten cohort studies to sum up the association between yogurt intake and the changes in body weight, waist circumference, as well as the risk of overweight and obesity. In that review, Sayón-Orea et al. have concluded that the inverse relationship between yogurt intake and obesity risk was still not clear. Therefore, we collected more research and extracted some of the available data for meta-analysis to further clarify the relationship between yogurt intake and the risk of obesity, overweight and abdominal obesity.

The results showed a clear inverse relationship between yogurt consumption and obesity. The underlying mechanism has been revealed in some studies. Yogurt contains calcium that can reduce fat content in fat cells [62, 63], inhibits fat cell hypertrophy [64], trigger mature fat cell apoptosis [65, 66], enhance thermogenesis [67], and increase excretion of fecal fat [68, 69]. Furthermore, yogurt consumption may increase the proportion of beneficial gut flora by regulating energy absorption and extraction, and these microorganisms are thought to be related to weight maintenance [41, 70]. One review mentioned that eating yogurt can improve intestinal health and reduce chronic inflammation by enhancing immune responses, intestinal barrier function, lipid distribution, as well as regulating appetite [71]. In the analysis of Barengolts et al. [72], it has not been shown that the consumption of probiotics compared to traditional yogurt could improve glycemic control in diabetic or obese patients..

In the subgroup analysis of geographical, no relevance for United States populations, which is possibly because that the baseline level of BMI is already overweight [37] or that confounding factors have not been adjusted [34]. Even many Americans are not following the recommendations of the Dietary Guidelines for Americans (DGA) still consuming more than the recommended amount of sugar and saturated fat and lower vegetables, fruit, dairy [73]. Only one study population was younger than 18 years and showed no effect of yogurt on obesity [32]. The OR value was calculated without adjusting for confounding factors. In the subgroup analysis, physical activity, energy intake and alcohol consumption were identified as confounder separately. Only one article was adjusted for race [35], and the results were no different from others.

Several studies have different results on yogurt consumption and obesity or abdominal obesity. Song et al. [52] have explained that yogurt has a specific regulatory effect on the function of the gut, and the degree of effect on obesity and abdominal obesity was different. In the study conducted by Beydoun et al. [48], the reason maybe yogurt intake at a low average consumption may not be reliable like other dairy foods. Lahti-Koski et al. [51] have found that people may start drinking milk and change into a healthy lifestyle after becoming obese.

The other finding showed there were no significant associations observed for the occurrence of overweight. Overweight, like obesity, is defined by BMI. So, the underlying influence mechanism was similar, and might be explained by the heterogeneity associated with yogurt.

The results also showed that yogurt intake is inversely related to the risk of abdominal obesity, which is consistent with the result of Schwingshackl et al. [17]. The underlying mechanism behind this is similar to obesity. Moreover, the meta-analysis results show that yogurt intake does not affect overweight, which is possibly because the number of related studies was not enough and the heterogeneity. After we eliminated an article that reduced heterogeneity, the results showed a negative correlation between yogurt consumption and overweight. When it comes to the relationship between yogurt consumption and obesity or overweight, Martínez-González et al. [57] (HR=0.80; 95% CI: 0.68, 0.94), Johansson et al. [56] (OR=0.95; 95% CI: 0.82, 1.10) and Susanne et al. [58] (HR=1.16; 95% CI: 1.02, 1.31) have different result trends, which may be due to the lack of uniformity in the types of yogurt, degree of BMI change, and the differences in populations among the studies.

Most of the studies included in this review have shown that total yogurt or low-fat yogurt can make some anthropometric indicators healthier [41-44, 46]. Trichia et al. [46] have explained the possible mechanisms that the intestinal flora may reduce the caloric effects of various macronutrients or affect appetite-related gastrointestinal hormones to reducing obesity [74]. Santiago et al.[44] have found that people who eat yogurt regularly are more likely to have a healthy lifestyle, as well as had more calcium intake and probiotics [55]. The difference in the effect of whole-fat yogurt and low-fat yogurt on body weight may be that obese or normal-weight people have different weight control strategies.

Yogurt is a nutrient-rich, easy-to-digest food that contains bioactive proteins, lipids, live microorganisms, and specific amino acids [75, 76]. Furthermore, yogurt can be used as a carrier of some probiotics and/or prebiotic compounds to exert health benefits [76, 77]. Obesity is a risk factor for many diseases, and a lot of research evidence suggests that yogurt seems to play a protective role in these diseases. Certain nutrients in yogurt, such as proteins, specific lipids, vitamin D, calcium, magnesium, and bioactive nutrients, may have favorable effects on cardiac metabolic diseases risk factors [78, 79]. Frequent consumption of yogurt is associated with better diet quality and a healthier insulin situation in American children [80], reduces the intake of high-calorie foods [81], lower the intakes of grains, alcohol [34], and increasing satiety [82]. A cross-sectional study [83] conducted that yogurt intake is associated with better diet quality and metabolic profile among US people. In a randomized controlled trial [84], compared to non-dairy control foods, the biomarkers of chronic inflammation and endotoxin in premenopausal women were reduced after eating low-fat yogurt for 9 weeks. A randomized controlled study has mentioned that the overweight/obese premenopausal women had significantly lower serum levels of lipoproteins after 8 weeks of the intervention of kefir than those in the control group [70]. Yogurt may reduce blood lipids, inflammation, oxidative stress, and LPS to improve insulin resistance in obese women with both nonalcoholic fatty liver disease and metabolic syndrome [85]. Much evidence strongly suggests that eating yogurt can prevent the occurrence of type 2 diabetes [86-88].

Our systematic review contains more comprehensive research on prospective observational or cross-sectional studies about yogurt consumption and the risk of obesity. Furthermore, our meta-analysis has three strengths. First, to our knowledge, this is the first study to analyze the consumption of yogurt and the risk of obesity with epidemiological data. Second, we evaluated the evaluation of dose-response relationship for obesity risk. Third, our results cover a wide range of ages.

The limitations of our study include the following aspects: 1) Most of the data used in our meta-analysis came from cross-sectional studies. 2) Insufficient data are available for subgroup analysis of yogurt types.

5. Conclusions

Overall, the result of our meta-analysis shows that total yogurt intake could reduce obesity risk in adults and daily consumption 165g yogurt can reduce the risk of overall obesity approximately 44% among all people. Yogurt intake might reduce the occurrence of abdominal obesity and the anthropometric variables such as body weight and waist circumference. However, yogurt consumption would not affect overweight incidence. In general, yogurt has a protective effect on the excessive increase of BMI, which is beneficial to human health. In order to clarify the role of different types of yogurt on the risk of obesity there is still a need to identify the more sizeable prospective cohort studies and randomized controlled trials.

Acknowledgements

The authors' contributions were as follows—J.W. and Y.X.: designed the research and project conception; J.W., Y.X., Q.L., L.L., H.Z. and H.W.: conducted the research and acquisition, analysis, or interpretation of data; J.W. and Y.X. drafted the paper; J.W.: performed the statistical analyses and had primary responsibility for final content; F.W. and J.M.: critically reviewed the manuscript. None of the authors had any conflict of interest related to the study.

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