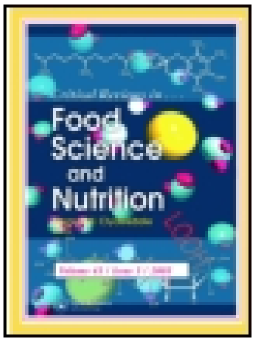

Critical Reviews in Food Science and Nutrition

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/bfsn20

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To cite this article: Mahdieh Golzarand, Asma Salari-Moghaddam & Parvin Mirmiran (2021): Association between alcohol intake and overweight and obesity: a systematic review and dose-response meta-analysis of 127 observational studies, Critical Reviews in Food Science and Nutrition, DOI: 10.1080/10408398.2021.1925221

To link to this article: https://doi.org/10.1080/10408398.2021.1925221

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CRITICAL REVIEWS IN FOOD SCIENCE AND NUTRITION
https://doi.org/10.1080/10408398.2021.1925221

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REVIEW

Association between alcohol intake and overweight and obesity: a systematic review and dose-response meta-analysis of 127 observational studies

Mahdieh Golzarand[a], Asma Salari-Moghaddam[b], and Parvin Mirmiran[a,c]

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ABSTRACT

Several studies have assessed the relationship between alcohol intake and overweight/obesity; however, the reported results are inconsistent. Therefore, the present systematic review and dose-response meta-analysis of observational studies was designed to investigate the association between alcohol intake and general and abdominal obesity among the adults. Literature search was conducted in the PubMed/Medline and Web of Science databases up to August 2020. Odds ratio (OR), risk ratio (RR), or hazard ratio (HR) with 95% confidence interval (95% CI) were used to pool effect size. To conduct dose-response meta-analysis, amount of alcohol intake was classified into three categories including light (<14 g/d), moderate (14–28 g/d), and heavy (>28 g/d). In the present study, 127 eligible studies were included. In cohort studies, there was no significant association between alcohol drinking and risk of overweight (OR: 0.93, 95% CI: 0.46 to 1.89), obesity (OR: 0.84, 95% CI: 0.52 to 1.37), overweight/obesity (OR: 1.15, 95% CI: 0.84 to 1.58), and abdominal obesity (OR: 1.13, 95% CI: 0.90 to 1.41). In cross-sectional studies, alcohol intake was associated with the increased odds of overweight (OR: 1.11, 95% CI: 1.05 to 1.18), overweight/obesity (OR: 1.23, 95% CI: 1.11 to 1.37), and abdominal obesity (OR: 1.19, 95% CI: 1.09 to 1.29); but not obesity (OR: 1.03, 95% CI: 0.95 to 1.12). Results of dose-response analysis indicated that heavy alcohol drinking was positively associated with odds of overweight (OR: 1.12, 95% CI: 1.01 to 1.24), overweight/obesity (OR: 1.32, 95% CI: 1.16 to 1.51), and abdominal obesity (OR: 1.25, 95% CI: 1.12 to 1.38) compared to non- or light alcohol drinking. There was no publication bias among studied on outcomes of interest. In conclusion, our results revealed alcohol drinkers, especially heavy alcohol drinkers, had increased odds of overweight, overweight/obesity, and abdominal obesity than non-alcohol drinker or light alcohol drinkers among cross-sectional studies but not cohort studies.

KEYWORDS
Abdominal obesity; alcohol; obesity; meta-analysis; overweight

Introduction

Obesity as a global challenge is associated with many diseases, such as metabolic disorders, cardiovascular disease (CVD), cancers, arthritis, and mental disorders. These conditions can lead to low quality of life, disability, and mortality. Obesity decreases life expectancy by 2–5 years depending on the type and number of its co-morbidities (Blüher 2019). Evidence shows that the number of adults with obesity has been tripled since 1975. According to the results of a large survey including 1698 population-based studies, mean body mass index (BMI) has been increased by 2.5 and 2.3 kg/m^2 from 1975 to 2014 in men and women, respectively (NCD-RisC 2016). In 2016, 390 million women and 281 million men were reported to suffer from obesity (NCD-RisC 2017), and it has been estimated that 38 and 20% of the adults will be overweight and obese worldwide in 2030, respectively (Hruby and Hu 2015).

Several modifiable and non-modifiable factors contribute to risk of obesity. However, positive energy balance is the main cause of high BMI (Blüher 2019). Over the last decades, changes in dietary habits from healthy diet toward high-calorie diet have increased prevalence of obesity (Hruby and Hu 2015). In parallel with nutrition transition, alcohol intake has increased as well. Alcohol drinking is a component of lifestyle in many regions and recently, its intake has raised in some developed countries (Sayon-Orea, Martinez-Gonzalez, and Bes-Rastrollo 2011). Alcohol consumption is associated with risk of mortality, disability, and many diseases, such as CVD, cancers, and liver diseases (Moriarty 2020; Wakabayashi et al. 2015). Alcohol contains high energy (7.1 kcal/g) and may leads to accumulation of fat mass and development of overweight or obesity by disrupting energy balance (Suter 2005).

Several studies have assessed the relationship between alcohol intake and overweight/obesity; however, the reported

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Supplemental data for this article is available online at https://doi.org/10.1080/10408398.2021.1925221.

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results are inconsistent (Aberg and Farkkila 2020; Kim et al. 2011; Lee 2012; Park, Park, and Hwang 2017; Shelton and Knott 2014; Wakabayashi 2010a, 2011b, 2019; Yoon et al. 2004). Except for two systematic reviews on the relationship between alcohol intake and obesity, no meta-analysis has summarized findings from the previous studies so far. A systematic review on 35 observational studies revealed that daily intake of beer more than 500 mL may cause abdominal obesity. However, results of included studies on general obesity were conflicting. (Bendsen et al. 2013), In another systematic review on 27 studies, results were found to be contradictory (Sayon-Orea, Martinez-Gonzalez, and Bes-Rastrollo 2011). Therefore, the present systematic review and dose-response meta-analysis of observational studies was designed to explore the association between alcohol intake and general and abdominal obesity among the adults.

Methods

This systematic review and meta-analysis was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline (Moher et al. 2009). Protocol of the study was registered in the international prospective register of systematic reviews (PROSPERO) (ID: CRD42020192125).

Search strategy and data sources

Literature search was conducted in the PubMed/Medline and Web of Science databases up to August 2020. Strategy of search was as follows: ("Ethanol" OR "Alcohol Drinking" OR "wine" OR beer OR "alcoholic beverage" OR "alcoholic beverages" OR "whisky" OR "vodka" OR "alcohol consumption" OR "alcohol" OR "alcohols" OR "alcohol intake") AND ("Body Weight" OR "Weight Loss" OR "Weight Gain" OR "Body Weight Changes" OR "Obesity" OR "Obesity, Abdominal" OR "Overweight" OR "adiposity" OR "adipose tissue" OR "fat mass"). No restriction was applied for publication date and language. A manual search of the related papers' references was also performed to avoid missing any relevant published papers. Two reviewers independently screened output of the search to identify potentially eligible studies (M.G and A.SM). Any disagreements between the two reviewers were resolved by consultation with the principal investigator (P.M).

Study selection and definition

Title and abstract of each paper were reviewed to identify relevant studies by two individual researchers (M.G and A.SM). The full texts of publications were reviewed if the abstract suggested that alcohol intake had been studied in relation to overweight, obesity, or abdominal obesity in the adults. Studies met the inclusion criteria if: a) they had observational design, b) including participants aged 18 years old or older, c) considered exposure to alcoholic beverages, d) considered overweight (as BMI), obesity (as BMI), or abdominal obesity (as waist circumference (WC)) as outcome, and e) reported odds ratio (OR), risk ratio (RR), or hazard ratio (HR) with 95% confidence interval (95% CI) for the highest vs. lowest category of alcohol intake or provided the number of overweight or obese subjects and normal-weight subjects in each category of alcohol intake to calculate OR and 95% CI. Studies were excluded if: a) included pregnant or lactating women, b) reported mean (standard deviation), correlation, or regression coefficient as the effect size, and c) had been conducted on the same population.

Data extraction

The following data were extracted from each study: first author's last name, date of publication, country, study design, duration of follow-up and person-years for cohort studies, sex, age, exposure, type of outcome and its definition, number of total subjects and cases in each category of alcohol intake, OR, RR, and HR (95% CI) in each category of exposure intake and the adjusted variables.

Assessment of the risk of bias and quality of the evidence

Risk of bias of the included observational studies was assessed using the Newcastle-Ottawa Scale (NOS) (Wells 2000). NOS tool is comprised of three items including selection, comparability, and outcome. A maximum score of 9 can be given to each study. In the current study, studies with scores of seven or higher were considered as high-quality studies.

The Grading of Recommendations Assessment, Development and Evaluation (GRADE) guidelines were used to assess quality of the evidence for each outcome. According to the GRADE guidelines, quality of evidence was classified as high, moderate, low, or very low quality.

Statistical analysis

Stata software version 12 (StataCrop, College Station, Texas, USA) was used to conduct meta-analysis. ORs (95% CI) and HRs were used to calculate summary effect size for cross-sectional and cohort studies, respectively. If specific effect sizes were reported across categories of sex, age, or other subgroups, they were pooled using fixed-effect model and then, were included in the meta-analysis. If the studies had used the highest category as a reference group, reference category was changed by Excel spreadsheet software (www.pnlee.co.uk/software.htm) (Hamling et al. 2008). For studies that had not reported ORs, HRs, or RRs, ORs and 95% CIs were calculated using relevant formula: OR= (odds of being overweight or obese if exposed to alcohol/odds of being overweight or obese if not exposed to alcohol) and 95% CI = exp[ln (OR)±1.96× SE (ln (OR))] . For summarizing the effect sizes, if the heterogeneity between studies was <50%, the fixed-effect model was used and if it was ≥50%, the random-effect model was applied. *I*-squared (I^2) was used to evaluate heterogeneity level.

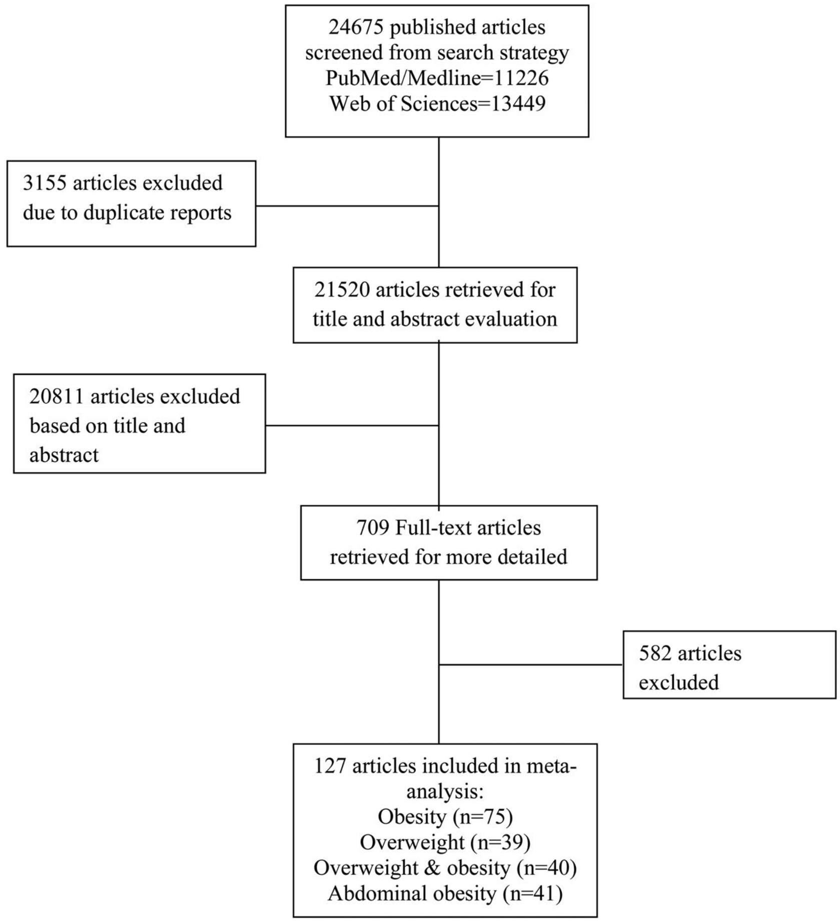

Figure 1. Flow chart of studies reviewed.

For conducting dose-response meta-analysis, amount of alcohol intake was classified into three categories including light (<14 g/d), moderate (14–28 g/d), and heavy (>28 g/d). Subgroup analysis was conducted based on sex, location, outcome definition, and adjustment for confounders using the random-effect model. Sensitivity analysis was performed by excluding one study at a time to assess the effect of studies on the pooled ORs (95% CI). Publication bias among the included studies was assessed using the Bgg's regression test.

Results

Study characteristics

The flow chart of study selection process is presented in Figure 1. A total of 24,675 papers were identified in our initial search in the PubMed/Medline (n = 11,226) and Web of Science (n = 13,449) databases. After excluding duplicate papers (n = 3,155), remaining papers (n = 21,520) were assessed based on their title and abstract and 709 papers remained for further evaluation. Finally, a total of 582 papers were excluded and 127 relevant studies (Aballay et al. 2016; Addo et al. 2015; Ade, Rohrer, and Rea 2011; Agaba et al. 2017; Ahaneku et al. 2014; Ahn et al. 2012; Aladeniyi et al. 2017; Albani et al. 2018; Amoah 2003; Andreenko, Mladenova, and Akabaliev 2015; Anto et al. 2020; Arif and Rohrer 2005; Baalwa et al. 2010; Back et al. 2018; Baik 2018; Barbadoro et al. 2013; Basu et al. 2016; Batty et al. 2009; Bezerra and Alencar 2018; Bogale and Zewale 2019; Brenner et al. 2017; Brumby, Kennedy, and Chandrasekara 2013; Brunner, Chandola, and Marmot 2007; Chaput et al. 2009; Chen et al. 2012; Cho et al. 2009; Clausen, Charlton, and Holmboe-Ottesen 2006; Coulson et al. 2013; da Rocha et al. 2017; Dagne et al. 2019; de Carvalho et al. 2015; de Munter et al. 2015; Dumesnil et al. 2013; Duvigneaud et al. 2007; Erem et al. 2004; Fan et al. 2006; Fan, Russell, et al. 2008; Fan, Cai, et al. 2008; Fazzino et al. 2017; Ferreira et al. 2008; Fezeu et al. 2006; Fezeu et al. 2008; Froom et al. 1999; Gearhardt, Harrison, and McKee 2012; Gigante et al. 1997; Grujic et al. 2017; Gunes et al. 2012; Gutierrez-Fisac et al. 1995; Han et al. 1998; Hu et al. 2002; Inan-Eroglu et al. 2020; Ishikawa, Moriya, and Yokoyama 2017; Jesus et al. 2017; Jin et al. 2011; Kaplan et al. 2003; Kim et al. 2020; Kim and Jeon 2011; Kiros et al. 2019; Kruger, Ham, and Prohaska 2009; Lahti-Koski et al. 2002; Lee et al. 2008; Leon-Munoz et al. 2014; Lourenco, Oliveira, and Lopes 2012; Mabchour et al. 2016; Maksimovic et al. 2016; Mason and Lewis 2015; Mataix et al. 2005; Monteiro et al. 2019; Naimi et al. 2005; Naja et al. 2020; Ng and Su 2018; Nicklas, O'Neil, and Fulgoni 2014; Nonterah et al. 2018; O'Donovan, Stamatakis, and Hamer 2018; Obirikorang et al. 2016; Obisesan et al. 2017; Obry-Roguet et al. 2018; Oh 2018; Ohlsson and Manjer 2020; Olawuyi and Adeoye 2018; Oliveira et al. 2009; Ortiz-Moncada et al. 2010; Osella et al.

2014; Pawlińska-Chmara et al. 2007; Pereira et al. 2016; Pinho et al. 2011; Plourde et al. 2010; Remus Popa et al. 2020; Rengma, Sen, and Mondal 2015; Reyes-Guzman et al. 2015; Rivas-Marino et al. 2015; Rohrer et al. 2005; Samouda et al. 2018; Santos et al. 2008; Savinelli et al. 2020; Sayon-Orea, Bes-Rastrollo, et al. 2011; Schröder et al. 2007; Senekal, Steyn, and Nel 2003; Shapo et al. 2003; Shayo and Mugusi 2011; Sidorenkov, Nilssen, and Grjibovski 2010; Siervogel et al. 2000; Sikorski et al. 2014; Slagter et al. 2014; Souza et al. 2018; Stoutenberg et al. 2013; Suliga et al. 2019; Takeuchi et al. 2009; Tayie and Beck 2016; Thomson et al. 2012; Tolstrup et al. 2005; Tuta-Garcia, Lee-Osorno, and Martinez-Torres 2015; Valdes-Badilla et al. 2017; Vidot et al. 2016; Wakabayashi 2010b, 2011a; Wang et al. 2012; Wang et al. 2010; Wang et al. 2016; Wronka, Suliga, and Pawlińska-Chmara 2013; Xiao et al. 2015; Yoon, Kim, and Doo 2016; Yuan et al. 2020; Zappalà et al. 2018; Zhang and Rodriguez-Monguio 2012; Zhang et al. 2008; Zhao et al. 2020) were selected to include in this systematic review and meta-analysis.

General characteristics of the included studies are presented in Supplementary Tables 1 and 2. These studies included 1,620,177 participants and 1,247,318 cases (652,486 patients with obesity, 267,226 patients with overweight, 247,666 patients with overweight/obesity, and 79,940 patients with abdominal obesity); and had been published between 1995 and 2020. Forty studies had assessed the relationship between alcohol intake and overweight/obesity, 39 studies had investigated alcohol intake in relation to overweight, 75 studies had considered the association of alcohol intake and obesity, and 41 studies had evaluated the association of alcohol intake and abdominal obesity. In 25 studies (Ade, Rohrer, and Rea 2011; Ahaneku et al. 2014; Baik 2018; Barbadoro et al. 2013; Brenner et al. 2017; de Munter et al. 2015; Fan, Russell, et al. 2008; Gearhardt, Harrison, and McKee 2012; Gunes et al. 2012; Gutierrez-Fisac et al. 1995; Kaplan et al. 2003; Kruger, Ham, and Prohaska 2009; Mason and Lewis 2015; Monteiro et al. 2019; Naimi et al. 2005; Obisesan et al. 2017; Ortiz-Moncada et al. 2010; Plourde et al. 2010; Reyes-Guzman et al. 2015; Rohrer et al. 2005; Santos et al. 2008; Senekal, Steyn, and Nel 2003; Siervogel et al. 2000; Wang et al. 2010; Zhang and Rodriguez-Monguio 2012), data on anthropometric indices were self-reported.

Twelve studies were of cohort design (Ahn et al. 2012; Batty et al. 2009; Brunner, Chandola, and Marmot 2007; Fazzino et al. 2017; Froom et al. 1999; Ortiz-Moncada et al. 2010; Pereira et al. 2016; Sayon-Orea, Bes-Rastrollo, et al. 2011; Souza et al. 2018; Stoutenberg et al. 2013; Thomson et al. 2012; Wang et al. 2010) one of them was a case-control research (Siervogel et al. 2000), and the remaining 114 studies were of cross-sectional design (Aballay et al. 2016; Addo et al. 2015; Ade, Rohrer, and Rea 2011; Agaba et al. 2017; Ahaneku et al. 2014; Aladeniyi et al. 2017; Albani et al. 2018; Amoah 2003; Andreenko, Mladenova, and Akabaliev 2015; Anto et al. 2020; Arif and Rohrer 2005; Baalwa et al. 2010; Back et al. 2018; Baik 2018; Barbadoro et al. 2013; Basu et al. 2016; Bezerra and Alencar 2018; Bogale and Zewale 2019; Brenner et al. 2017; Brumby, Kennedy, and Chandrasekara 2013; Chaput et al. 2009; Chen et al. 2012; Cho et al. 2009; Clausen, Charlton, and Holmboe-Ottesen 2006; Coulson et al. 2013; da Rocha et al. 2017; Dagne et al. 2019; de Carvalho et al. 2015; de Munter et al. 2015; Dumesnil et al. 2013; Duvigneaud et al. 2007; Erem et al. 2004; Fan et al. 2006; Fan, Russell, et al. 2008; Fan, Cai, et al. 2008; Ferreira et al. 2008; Fezeu et al. 2006; Fezeu et al. 2008; Gearhardt, Harrison, and McKee 2012; Gigante et al. 1997; Grujic et al. 2017; Gunes et al. 2012; Gutierrez-Fisac et al. 1995; Han et al. 1998; Hu et al. 2002; Inan-Eroglu et al. 2020; Ishikawa, Moriya, and Yokoyama 2017; Jesus et al. 2017; Jin et al. 2011; Kaplan et al. 2003; Kim et al. 2020; Kim and Jeon 2011; Kiros et al. 2019; Kruger, Ham, and Prohaska 2009; Lahti-Koski et al. 2002; Lee et al. 2008; Leon-Munoz et al. 2014; Lourenco, Oliveira, and Lopes 2012; Mabchour et al. 2016; Maksimovic et al. 2016; Mason and Lewis 2015; Mataix et al. 2005; Monteiro et al. 2019; Naimi et al. 2005; Naja et al. 2020; Ng and Su 2018; Nicklas, O'Neil, and Fulgoni 2014; Nonterah et al. 2018; O'Donovan, Stamatakis, and Hamer 2018; Obirikorang et al. 2016; Obisesan et al. 2017; Obry-Roguet et al. 2018; Oh 2018; Ohlsson and Manjer 2020; Olawuyi and Adeoye 2018; Oliveira et al. 2009; Osella et al. 2014; Pawlińska-Chmara et al. 2007; Pinho et al. 2011; Plourde et al. 2010; Remus Popa et al. 2020; Rengma, Sen, and Mondal 2015; Reyes-Guzman et al. 2015; Rivas-Marino et al. 2015; Rohrer et al. 2005; Samouda et al. 2018; Santos et al. 2008; Savinelli et al. 2020; Schröder et al. 2007; Senekal, Steyn, and Nel 2003; Shapo et al. 2003; Shayo and Mugusi 2011; Sidorenkov, Nilssen, and Grjibovski 2010; Sikorski et al. 2014; Slagter et al. 2014; Suliga et al. 2019; Takeuchi et al. 2009; Tayie and Beck 2016; Tolstrup et al. 2005; Tuta-Garcia, Lee-Osorno, and Martinez-Torres 2015; Valdes-Badilla et al. 2017; Vidot et al. 2016; Wakabayashi 2010b, 2011a; Wang et al. 2012; Wang et al. 2016; Wronka, Suliga, and Pawlińska-Chmara 2013; Xiao et al. 2015; Yoon, Kim, and Doo 2016; Yuan et al. 2020; Zappalà et al. 2018; Zhang and Rodriguez-Monguio 2012; Zhang et al. 2008; Zhao et al. 2020). Two studies had cohort design (de Munter et al. 2015; Zhao et al. 2020); however, their baseline data were used to calculate ORs and 95% CIs. Therefore, these studies were considered as cross-sectional studies. Twenty-four studies were from north America (Ade, Rohrer, and Rea 2011; Arif and Rohrer 2005; Brenner et al. 2017; Chaput et al. 2009; Fan et al. 2006; Fan, Russell, et al. 2008; Fazzino et al. 2017; Gearhardt, Harrison, and McKee 2012; Kaplan et al. 2003; Kruger, Ham, and Prohaska 2009; Mason and Lewis 2015; Naimi et al. 2005; Nicklas, O'Neil, and Fulgoni 2014; Obisesan et al. 2017; Plourde et al. 2010; Reyes-Guzman et al. 2015; Rohrer et al. 2005; Siervogel et al. 2000; Stoutenberg et al. 2013; Tayie and Beck 2016; Thomson et al. 2012; Vidot et al. 2016; Wang et al. 2010; Zhang and Rodriguez-Monguio 2012), 38 studies were from Europe (Albani et al. 2018; Andreenko, Mladenova, and Akabaliev 2015; Barbadoro et al. 2013; Batty et al. 2009; Brunner, Chandola, and Marmot 2007; de Munter et al. 2015; Dumesnil et al. 2013; Duvigneaud et al. 2007; Grujic et al. 2017; Gutierrez-Fisac et al. 1995; Han et al. 1998; Inan-Eroglu et al. 2020; Lahti-Koski et al. 2002; Leon-Munoz et al. 2014; Lourenco, Oliveira, and Lopes 2012; Maksimovic et al. 2016; Mataix et al. 2005; O'Donovan, Stamatakis, and Hamer 2018; Obry-Roguet et al. 2018; Ohlsson and Manjer 2020; Ortiz-

Table 1. Summary of findings.

Outcome	No. subjects, studies	Summary effect (95% CI)	Quality of the evidence (GRADE)
Cross-sectional studies			
Overweight	260005, 37 studies	1.11 (95% CI: 1.05 to 1.18)	⊕◯◯◯ very low[1,2]
Obesity	645227, 68 studies	1.03 (95% CI: 0.94 to 1.12)	⊕◯◯◯ very low[1]
Overweight/obesity	237122, 34 studies	1.23 (95% CI: 1.11 to 1.37)	⊕◯◯◯ very low[1,2]
Abdominal obesity	74400, 38 studies	1.19 (95% CI: 1.09 to 1.29)	⊕◯◯◯ very low[1,2]
Cohort studies			
Overweight	7221, 2 studies	0.93 (95% CI: 0.46 to 1.89)	⊕◯◯◯ very low[1]
Obesity	7259, 7 studies	0.84 (95% CI: 0.52 to 1.37)	⊕◯◯◯ very low[1]
Overweight/obesity	10370, 5 studies	1.15 (95% CI: 0.84 to 1.58)	⊕◯◯◯ very low[1]
Abdominal obesity	5540, 3 studies	1.13 (95% CI: 0.90 to 1.41)	⊕◯◯◯ very low[1]

GRADE Working Group grades of evidence.
High quality: Further research is very unlikely to change our confidence in the estimate of effect.
Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low quality: We are very uncertain about the estimate.
[1]Downgrade by two level due to severe inconsistency.
[2]Upgrade by one level due to dose-response association.

Moncada et al. 2010; Osella et al. 2014; Pawlińska-Chmara et al. 2007; Pereira et al. 2016; Remus Popa et al. 2020; Samouda et al. 2018; Santos et al. 2008; Savinelli et al. 2020; Sayon-Orea, Bes-Rastrollo, et al. 2011; Schröder et al. 2007; Shapo et al. 2003; Sidorenkov, Nilssen, and Grjibovski 2010; Sikorski et al. 2014; Slagter et al. 2014; Suliga et al. 2019; Tolstrup et al. 2005; Wronka, Suliga, and Pawlińska-Chmara 2013; Zappalà et al. 2018), 29 studies were from Asia (Ahn et al. 2012; Baik 2018; Basu et al. 2016; Chen et al. 2012; Cho et al. 2009; Erem et al. 2004; Fan, Cai, et al. 2008; Froom et al. 1999; Gunes et al. 2012; Hu et al. 2002; Ishikawa, Moriya, and Yokoyama 2017; Jin et al. 2011; Kim et al. 2020; Kim and Jeon 2011; Lee et al. 2008; Naja et al. 2020; Ng and Su 2018; Oh 2018; Rengma, Sen, and Mondal 2015; Takeuchi et al. 2009; Wakabayashi 2010b, 2011a; Wang et al. 2012; Wang et al. 2016; Xiao et al. 2015; Yoon, Kim, and Doo 2016; Yuan et al. 2020; Zhang et al. 2008; Zhao et al. 2020), 14 studies were from Latin America (Aballay et al. 2016; Back et al. 2018; Bezerra and Alencar 2018; da Rocha et al. 2017; de Carvalho et al. 2015; Ferreira et al. 2008; Gigante et al. 1997; Mabchour et al. 2016; Monteiro et al. 2019; Oliveira et al. 2009; Pinho et al. 2011; Souza et al. 2018; Tuta-Garcia, Lee-Osorno, and Martinez-Torres 2015; Valdes-Badilla et al. 2017), 19 studies were from Africa (Addo et al. 2015; Agaba et al. 2017; Ahaneku et al. 2014; Aladeniyi et al. 2017; Amoah 2003; Anto et al. 2020; Baalwa et al. 2010; Bogale and Zewale 2019; Clausen, Charlton, and Holmboe-Ottesen 2006; Dagne et al. 2019; Fezeu et al. 2006; Fezeu et al. 2008; Jesus et al. 2017; Kiros et al. 2019; Nonterah et al. 2018; Obirikorang et al. 2016; Olawuyi and Adeoye 2018; Senekal, Steyn, and Nel 2003; Shayo and Mugusi 2011), two studies were from Oceania (Brumby, Kennedy, and Chandrasekara 2013; Coulson et al. 2013), and one study was comprised of several countries including China, Ghana, India, Mexico, Russia, and South Africa (Rivas-Marino et al. 2015). In 34 studies (Ahaneku et al. 2014; Albani et al. 2018; Amoah 2003; Brenner et al. 2017; Brumby, Kennedy, and Chandrasekara 2013; Cho et al. 2009; Clausen, Charlton, and Holmboe-Ottesen 2006; da Rocha et al. 2017; de Carvalho et al. 2015; de Munter et al. 2015; Erem et al. 2004; Fan, Cai, et al. 2008; Ferreira et al. 2008; Gearhardt, Harrison, and McKee 2012; Grujic et al. 2017; Kim et al. 2020; Kim and Jeon 2011; Monteiro et al. 2019; Naimi et al. 2005; Naja et al. 2020; Nonterah et al. 2018; Obirikorang et al. 2016; Osella et al. 2014; Pawlińska-Chmara et al. 2007; Remus Popa et al. 2020; Rivas-Marino et al. 2015; Shayo and Mugusi 2011; Siervogel et al. 2000; Sikorski et al. 2014; Slagter et al. 2014; Vidot et al. 2016; Wronka, Suliga, and Pawlińska-Chmara 2013; Zhang and Rodriguez-Monguio 2012; Zhao et al. 2020), ORs, RRs, or HRs (95% CI) had not been reported, therefore, ORs (95% CIs) were calculated based on relevant formula. In addition, five studies had considered the highest category of alcohol intake as the reference category (Gigante et al. 1997; O'Donovan, Stamatakis, and Hamer 2018; Senekal, Steyn, and Nel 2003; Souza et al. 2018; Zappalà et al. 2018). Therefore, the reference category of these studies was changed to the lowest intake and the effect sizes were recalculated.

According to the NOS tool, 53 studies (40.9%) were of high quality (Aballay et al. 2016; Addo et al. 2015; Agaba et al. 2017; Anto et al. 2020; Arif and Rohrer 2005; Batty et al. 2009; Bezerra and Alencar 2018; Bogale and Zewale 2019; Chaput et al. 2009; Chen et al. 2012; Coulson et al. 2013; Dagne et al. 2019; Dumesnil et al. 2013; Duvigneaud et al. 2007; Fan et al. 2006; Fazzino et al. 2017; Hu et al. 2002; Inan-Eroglu et al. 2020; Ishikawa, Moriya, and Yokoyama 2017; Jin et al. 2011; Kiros et al. 2019; Lahti-Koski et al. 2002; Leon-Munoz et al. 2014; Lourenco, Oliveira, and Lopes 2012; Mabchour et al. 2016; Mataix et al. 2005; O'Donovan, Stamatakis, and Hamer 2018; Oh 2018; Ohlsson and Manjer 2020; Olawuyi and Adeoye 2018; Pereira et al. 2016; Sayon-Orea, Bes-Rastrollo, et al. 2011; Schröder et al. 2007; Shapo et al. 2003; Sidorenkov, Nilssen, and Grjibovski 2010; Sikorski et al. 2014; Slagter et al. 2014; Stoutenberg et al. 2013; Suliga et al. 2019; Takeuchi et al. 2009; Tayie and Beck 2016; Thomson et al. 2012; Tolstrup et al. 2005; Tuta-Garcia, Lee-Osorno, and Martinez-Torres 2015; Valdes-Badilla et al. 2017; Vidot et al. 2016; Wakabayashi 2010b, 2011a; Wang et al. 2010; Xiao et al. 2015; Yuan et al. 2020; Zhang et al. 2008).

Results regarding assessment of quality of the evidence are presented in Table 1. According to the GRADE guidelines, overall quality of the included evidence was low. The inconsistency was known as responsible factor for low quality of these findings.

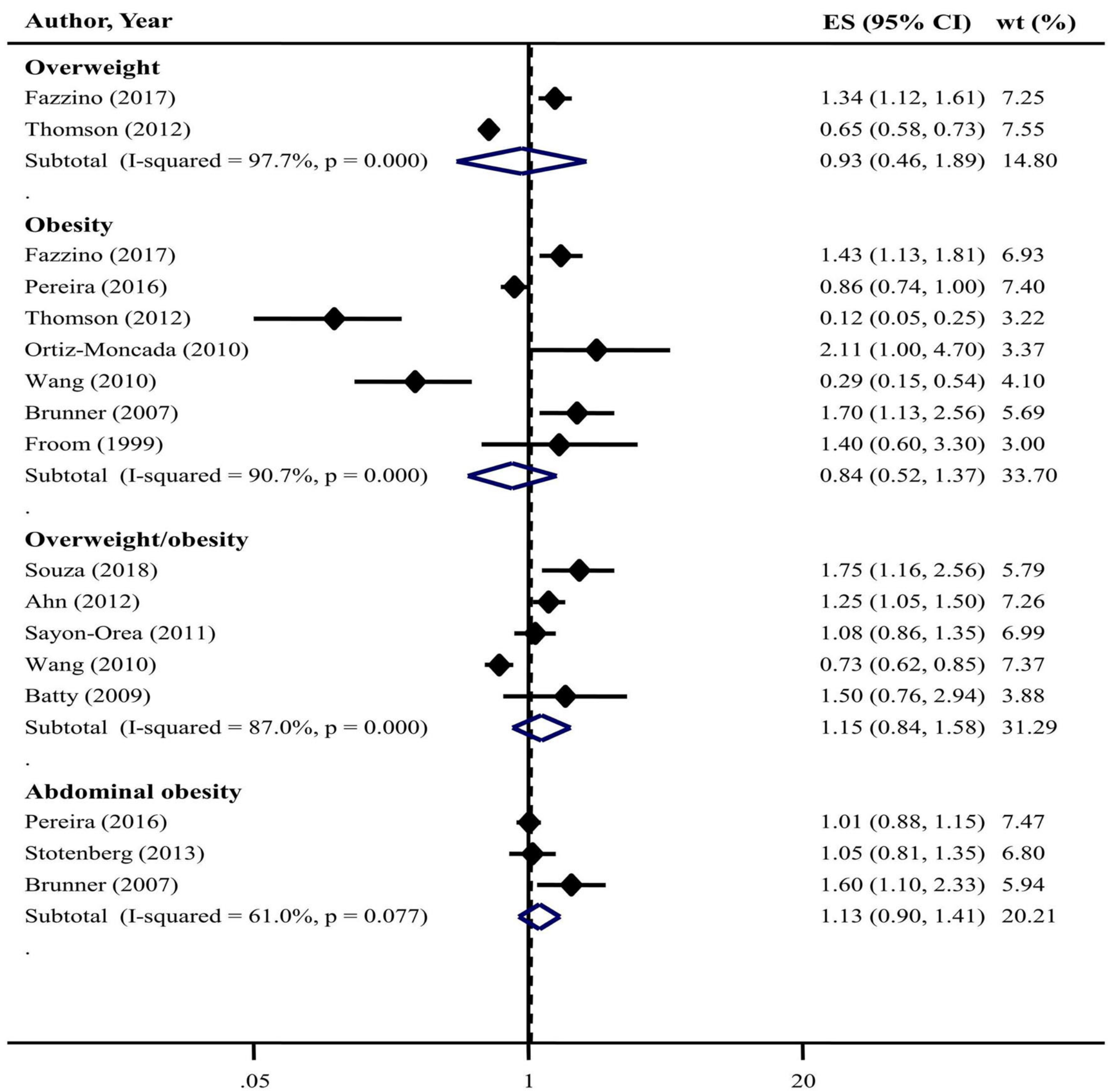

Figure 2. Forest plot of association between alcohol intake and overweight or obesity in cohort studies.

Results of meta-analysis for cohort studies

There was no significant association between alcohol drinking and risk of overweight (HR: 0.93, 95% CI: 0.46 to 1.89; I^2=97.7 $p = 0.84$), obesity (HR: 0.84, 95% CI: 0.52 to 1.37; I^2=90.7, $p = 0.48$), overweight/obesity (HR: 1.15, 95% CI: 0.84 to 1.58; I^2=87.0, $p = 0.37$), and abdominal obesity (HR: 1.13, 95% CI: 0.90 to 1.41; I^2=61.0, $p = 0.28$) (Figure 2). However, due to the limited number of studies, subgroup analysis was not performed to find possible sources of heterogeneity.

Sensitivity analysis indicated that no study had significant effect on overall pooled effect size for obesity and abdominal obesity. With regarding to overweight/obesity, a significant positive association was found between alcohol intake and risk of overweight/obesity after removing the study by Wang et al. (2010) (HR: 1.27, 95% CI: 1.05 to 1.52, $p = 0.01$).

No evidence of publication bias was found among the studies conducted on obesity (Begg's test = 0.36), overweight/obesity (Begg's test = 0.80), and abdominal obesity (Begg's test = 0.29). Sensitivity analysis and publication bias assessment were not performed for overweight due to the lack of papers (n = 2).

Results of meta-analysis for cross-sectional studies

Alcohol intake was found to increase odds of being overweight (OR: 1.11, 95% CI: 1.05 to 1.18; I^2=87.7, $p = 0.001$) (Figure 3). However, there was no significant relationship between alcohol intake and odds of obesity (OR: 1.03, 95% CI: 0.95 to 1.12; I^2=95.1, $p = 0.48$) (Figure 4). In addition, a significant positive association was observed between alcohol intake and odds of overweight/obesity (OR: 1.23, 95% CI: 1.11 to 1.37; I^2=83.0, $p < 0.001$) (Figure 5).

Results of subgroup analyses are presented in Table 2. Interestingly, in the studies that had measured body weight and height rather than using self-reported data, alcohol intake was associated with higher odds of overweight (OR: 1.19, 95% CI: 1.09 to 1.31), and overweight/obesity (OR: 1.20, 95% CI: 1.08 to 1.34).

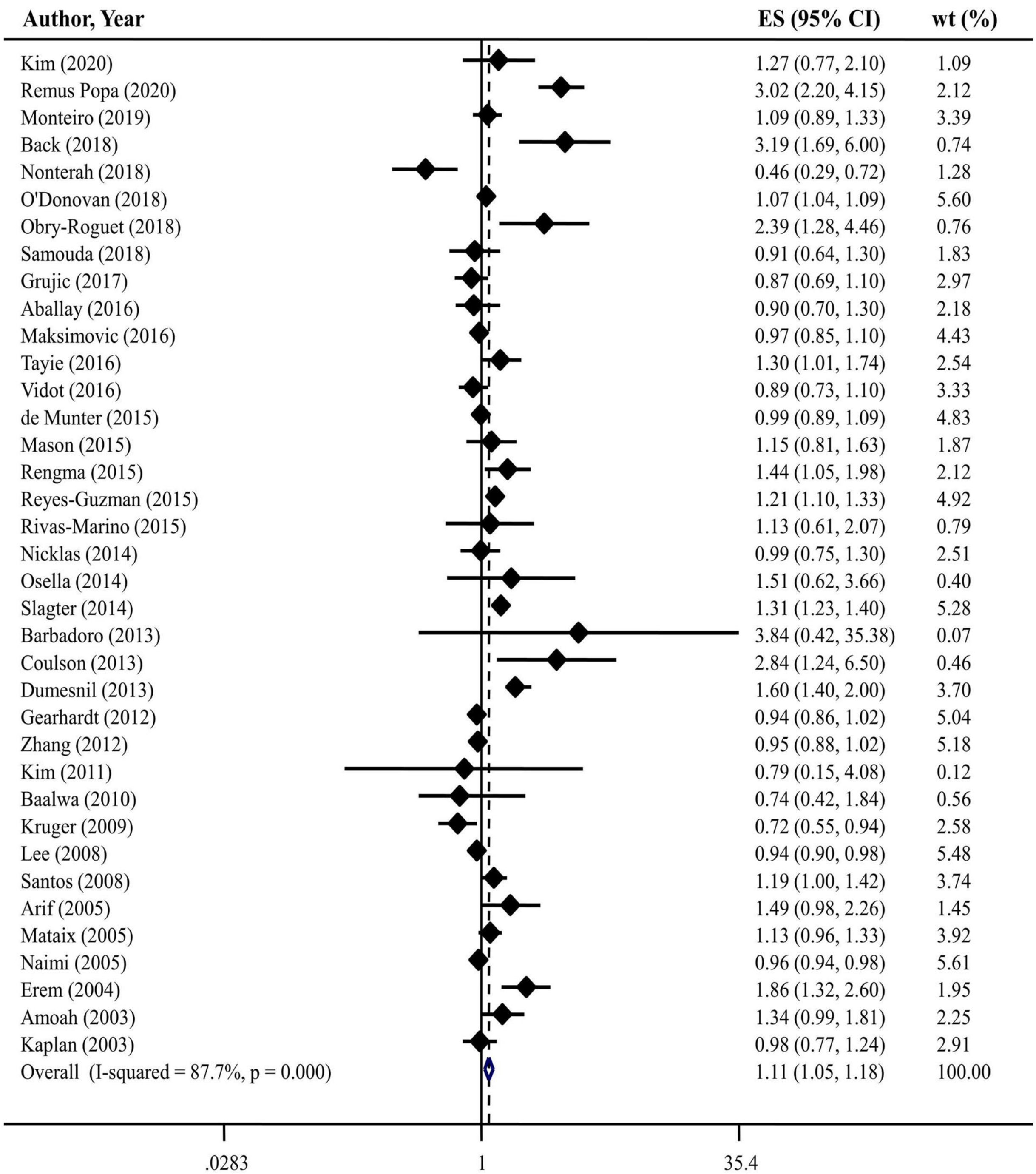

Figure 3. Forest plot of association between alcohol intake and overweight in cross-sectional studies.

In the dose-response analysis, no significant association was found between light (OR: 1.01, 95% CI: 0.92 to 1.11, $p = 0.79$) and moderate (OR: 1.01, 95% CI: 0.92 to 1.10, $p = 0.88$) alcohol intake and odds of overweight. Nevertheless, heavy alcohol drinking was positively associated with odds of overweight (OR: 1.12, 95% CI: 1.01 to 1.24, $p = 0.02$) (Figure 6). With regard to obesity, moderate alcohol drinkers had 16% lower odds of being obese compared to non-drinkers or light alcohol drinkers (OR: 0.84, 95% CI: 0.74 to 0.95, $p = 0.006$). However, light (OR: 0.84, 95% CI: 0.68 to 1.03, $p = 0.09$) and heavy (OR: 0.94, 95% CI: 0.86 to 1.03, $p = 0.18$) alcohol intake was not associated with obesity (Figure 7). In terms of overweight/obesity, heavy alcohol intake was found to increase odds of overweight/obesity by 32% (OR: 1.32, 95% CI: 1.16 to 1.51, $p < 0.001$). However, there was no significant association between light (OR: 0.99, 95% CI: 0.74 to 1.33, $p = 0.98$) and moderate (OR: 0.95, 95% CI: 0.83 to 1.09, $p = 0.77$) alcohol intake and odds of overweight/obesity (Figure 8).

Thirty-eight studies had assessed the association between alcohol drinking and abdominal obesity. Accordingly, alcohol intake was shown to be associated with the increased odds of abdominal obesity such that, those in the highest category of alcohol intake had 19% increased odds of abdominal obesity compared to those in the lowest category (OR: 1.19, 95% CI: 1.09 to 1.29, $p < 0.001$). A significant between-study heterogeneity

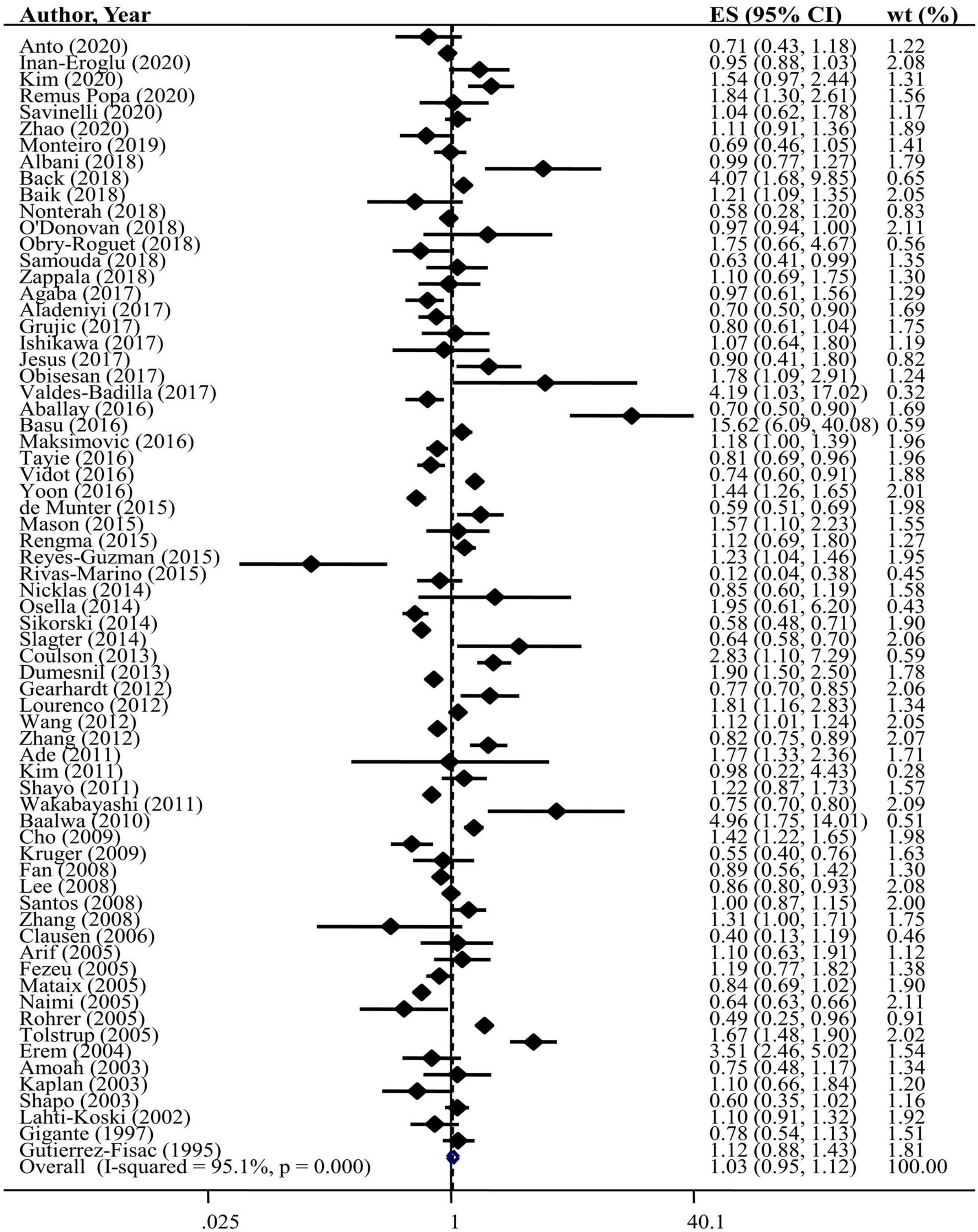

Figure 4. Forest plot of association between alcohol intake and obesity in cross-sectional studies.

was also observed (I^2=87.5%) (Figure 9). Results of subgroup analysis revealed that alcohol intake increased odds of abdominal obesity in both genders. In addition, the association between alcohol intake and abdominal obesity was significant in the studies that had measured WC (OR: 1.19, 95% CI: 1.09 to 1.30) instead of self-reported WC (Table 2).

In the dose-response analysis, heavy alcohol drinkers had increased odds of abdominal obesity than non-alcohol drinkers or light alcohol drinkers (OR: 1.25, 95% CI: 1.12 to 1.38, $p < 0.001$). However, there was no significant association between light (OR: 1.02, 95% CI: 0.86 to 1.20, $p = 0.83$) and moderate (OR: 1.01, 95% CI: 0.93 to 1.09,

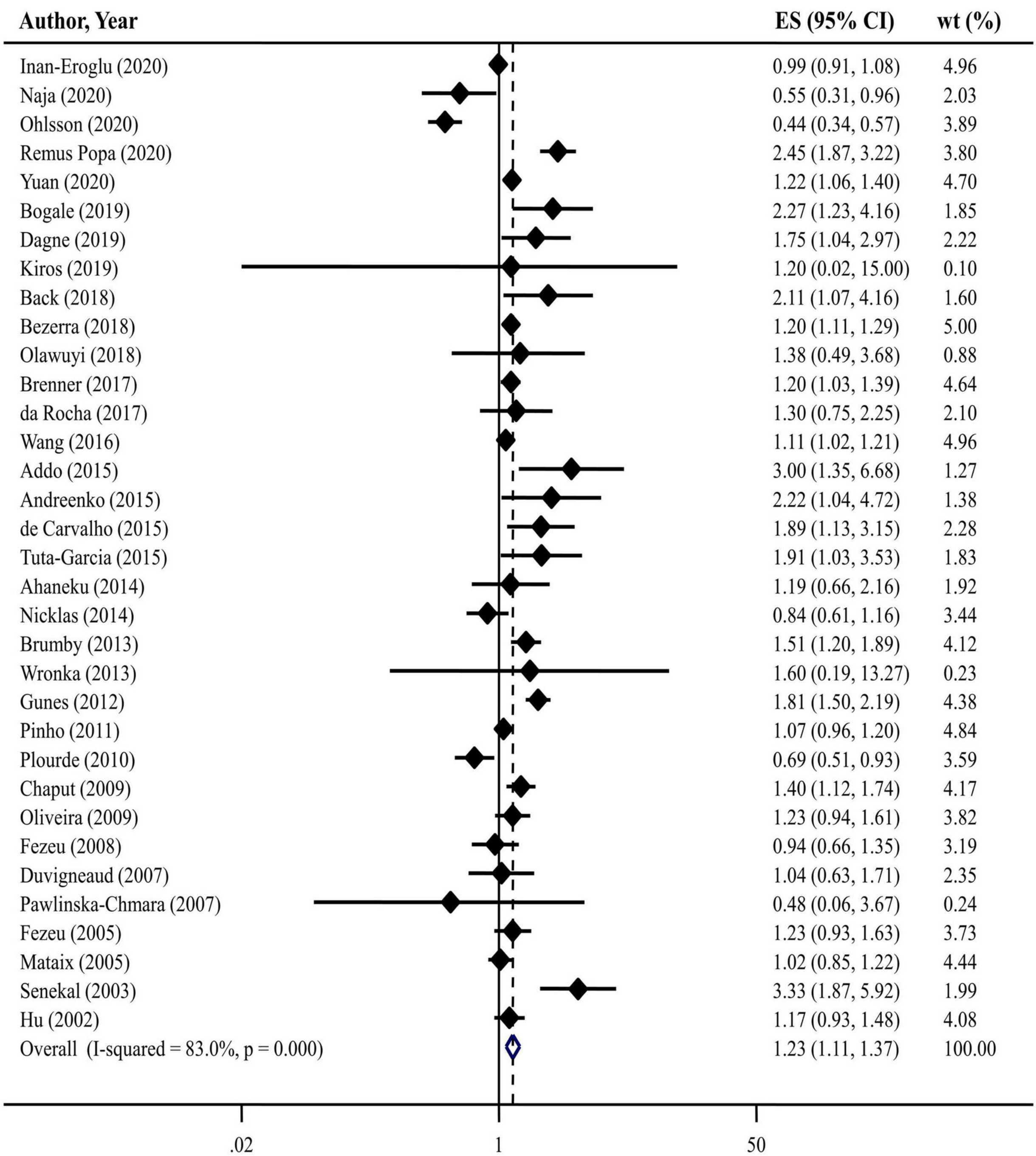

Figure 5. Forest plot of association between alcohol intake and overweight/obesity in cross-sectional studies.

$p = 0.88$) alcohol intake and odds of abdominal obesity (Figure 10).

Begg's test detected no publication bias among the studies conducted on overweight ($p = 0.22$), obesity ($p = 0.24$), overweight/obesity ($p = 0.51$), and abdominal obesity ($p = 0.68$).

Discussion

In the present study, 127 eligible studies were included in the meta-analysis. According to the cohort studies, no significant relationship was observed between alcohol intake and risk of being overweight or obese. In contrast, results of cross-sectional studies indicated a significant positive association between alcohol intake and odds of overweight, overweight/obesity, and abdominal obesity. However, no significant association we found between alcohol drinking and obesity. At the same time, alcohol intake was shown to increase odds of being obese in Asian populations for which the modified BMI classification has been used (i.e. BMI $\geq 25\,kg/m^2$), rather than World Health Organization (WHO) criteria (BMI $\geq 30\,kg/m^2$). In addition, there was a dose-response association between heavy alcohol drinking and odds of overweight, overweight/obesity, and abdominal obesity. But, the association between alcohol intake and odds of obesity was U-shaped such that, moderate alcohol drinkers had lower odds of obesity compared to non-, light, and heavy alcohol drinkers. However, our results should be interpreted with caution because of high heterogeneity between the studies. In addition, cross-

Table 2. Subgroup analysis to determine source of heterogeneity among cross-sectional studies.

Subgroup	Number of study	Effect size (95% CI)	*p* value	Heterogeneity (%)
Overweight				
Gender				
Women	1	1.15 (0.81 to 1.63)	0.43	–
Men	8	1.18 (1.03 to 1.34)	0.01	88.3
Both	28	1.10 (1.01 to 1.19)	0.01	87.8
Continent				
North America	11	1.01 (0.93 to 1.08)	0.92	73.3
Europe	13	1.21 (1.08 to 1.36)	0.001	89.1
Asia	5	1.28 (0.89 to 1.83)	0.16	82.7
South America	3	1.32 (0.81 to 2.16)	0.25	84.0
Africa	3	0.78 (0.37 to 1.65)	0.52	86.8
Oceania	1	2.84 (1.24 to 6.50)	0.01	–
Weight assessment				
Measured	26	1.19 (1.09 to 1.31)	<0.001	87.7
Self-reported	11	1.01 (0.94 to 1.07)	0.78	72.5
Adjustment for confounders				
Yes	11	1.16 (1.03 to 1.30)	0.02	86.8
No	26	1.08 (1.00 to 1.16)	0.01	82.0
Outcome definition				
International classification	33	1.11 (1.04 to 1.18)	0.001	88.8
Modified classification	4	1.13 (0.84 to 1.51)	0.41	63.3
Quality assessment				
High	9	1.20 (1.06 to 1.36)	0.004	87.6
Low	28	1.07 (1.00 to 1.15)	0.03	81.8
Obesity				
Gender				
Women	1	1.57 (1.10 to 2.23)	0.01	–
Men	11	1.05 (0.91 to 1.21)	0.50	92.0
Both	56	1.01 (0.91 to 1.13)	0.72	94.8
Continent				
North America	14	0.92 (0.78 to 1.08)	0.31	93.2
Europe	22	1.00 (0.88 to 1.13)	0.95	92.6
Asia	15	1.29 (1.08 to 1.55)	0.005	94.2
South America	5	1.09 (0.66 to 1.88)	0.71	79.6
Africa	10	0.91 (0.70 to 1.18)	0.48	60.0
Oceania	1	2.83 (1.09 to 7.28)	0.03	–
Weight assessment				
Measured	53	1.05 (0.96 to 1.15)	0.22	90.4
Self-reported	15	0.94 (0.79 to 1.11)	0.48	95.9
Adjustment for confounders				
Yes	31	0.93 (0.84 to 1.03)	0.18	90.7
No	37	1.13 (0.99 to 1.30)	0.06	95.5
Outcome definition				
International classification	54	0.98 (0.89 to 1.08)	0.77	95.0
Modified classification	14	1.21 (1.01 to 1.44)	0.03	93.3
Quality assessment				
High	21	0.96 (0.85 to 1.09)	0.30	94.8
Low	47	1.06 (0.94 to 1.20)	0.60	93.1
Overweigh/obesity				
Gender				
Women	2	0.86 (0.19 to 3.76)	0.84	–
Men	1	2.22 (1.04 to 4.72)	0.03	0
Both	30	1.22 (1.10 to 1.36)	<0.001	84.7
Continent				
North America	4	1.01 (0.76 to 1.35)	0.91	83.2
Europe	8	1.10 (0.75 to 1.60)	0.62	91.8
Asia	5	1.19 (0.96 to 1.48)	0.09	86.1
South America	7	1.23 (1.09 to 1.40)	0.001	49.0
Africa	9	1.62 (1.18 to 2.22)	0.002	62.1
Oceania	1	1.23 (1.11 to 1.36)	<0.001	–
Weight assessment				
Measured	29	1.20 (1.08 to 1.34)	0.001	80.9
Self-reported	5	1.37 (0.93 to 2.04)	0.11	90.0
Adjustment for confounders				
Yes	15	1.20 (1.03 to 1.41)	0.01	85.4
No	19	1.26 (1.08 to 1.46)	0.002	80.8
Outcome definition				
International classification	32	1.25 (1.11 to 1.41)	<0.001	83.9
Modified classification	2	1.14 (1.04 to 1.24)	0.002	22.3
Quality assessment				
High	14	1.16 (1.00 to 1.36)	0.04	84.7
Low	20	1.28 (1.11 to 1.49)	0.001	81.7
Abdominal obesity				
Gender				
Women	2	0.91 (0.58 to 1.52)	0.73	91.3
Men	8	1.20 (0.98 to 1.47)	0.07	83.7

(*continued*)

Table 2. Continued.

Subgroup	Number of study	Effect size (95% CI)	*p* value	Heterogeneity (%)
Both	28	1.20 (1.08 to 1.34)	0.001	88.4
Continent				
North America	4	0.82 (0.47 to 1.44)	0.49	90.8
Europe	10	1.38 (1.16 to 1.63)	<0.001	94.1
Asia	11	1.10 (0.99 to 1.23)	0.06	80.5
South America	6	1.39 (1.13 to 1.71)	0.002	11.2
Africa	5	0.85 (0.51 to 1.42)	0.55	79.2
Oceania	2	1.99 (0.99 to 3.98)	0.05	58.6
Weight assessment				
Measured	36	1.19 (1.09 to 1.30)	<0.001	87.8
Self-reported	2	0.93 (0.46 to 1.88)	0.84	86.4
Adjustment for confounders				
Yes	27	1.20 (1.08 to 1.32)	<0.001	89.9
No	11	1.13 (0.96 to 1.34)	0.13	70.3
Outcome definition				
International classification	21	1.21 (1.06 to 1.39)	0.005	90.0
Modified classification	16	1.10 (1.00 to 1.22)	0.04	76.6
Quality assessment				
High	23	1.18 (1.06 to 1.32)	0.003	90.6
Low	15	1.19 (1.04 to 1.35)	0.007	70.9

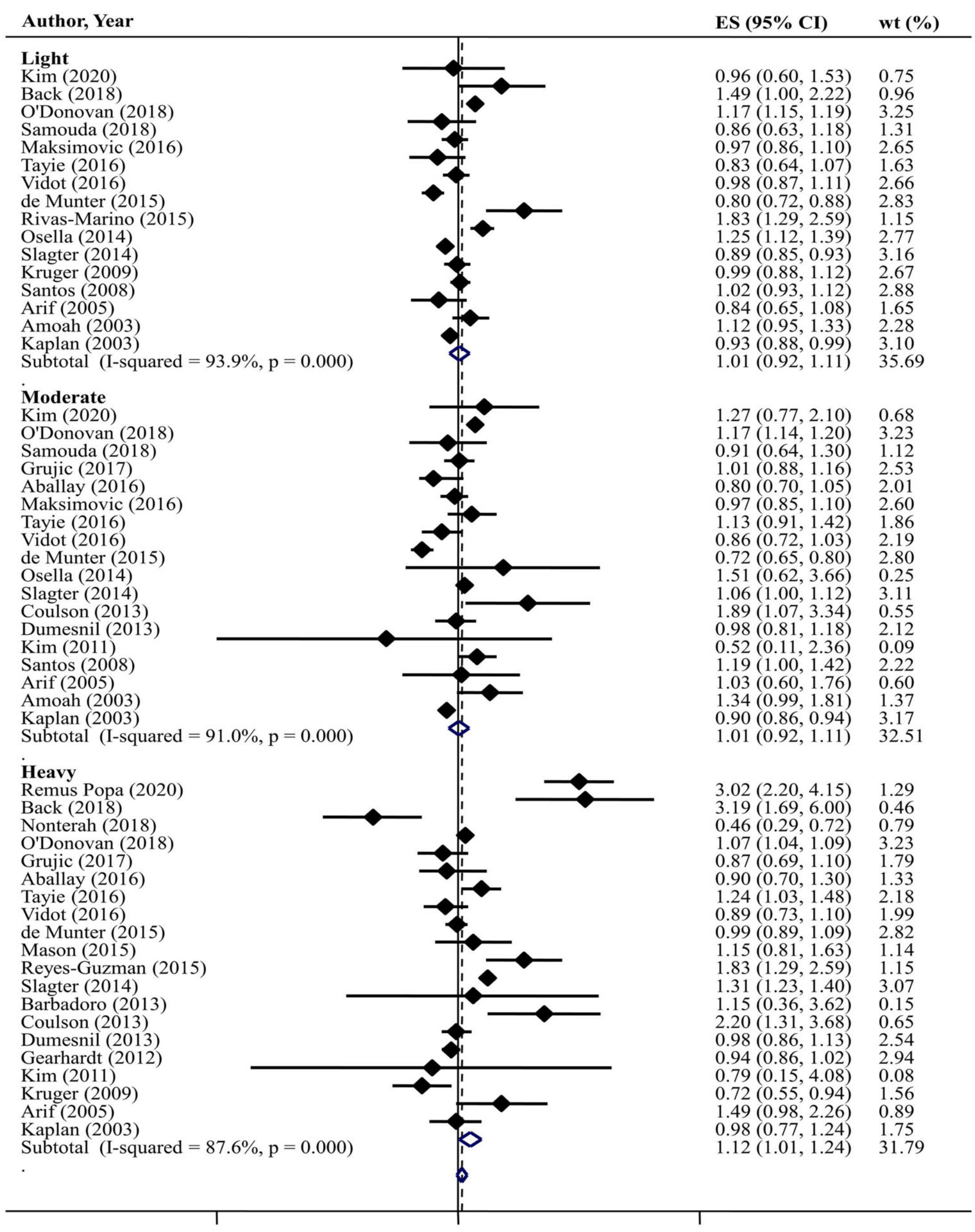

Figure 6. Forest plot of association between amount of alcohol and overweight in cross-sectional studies.

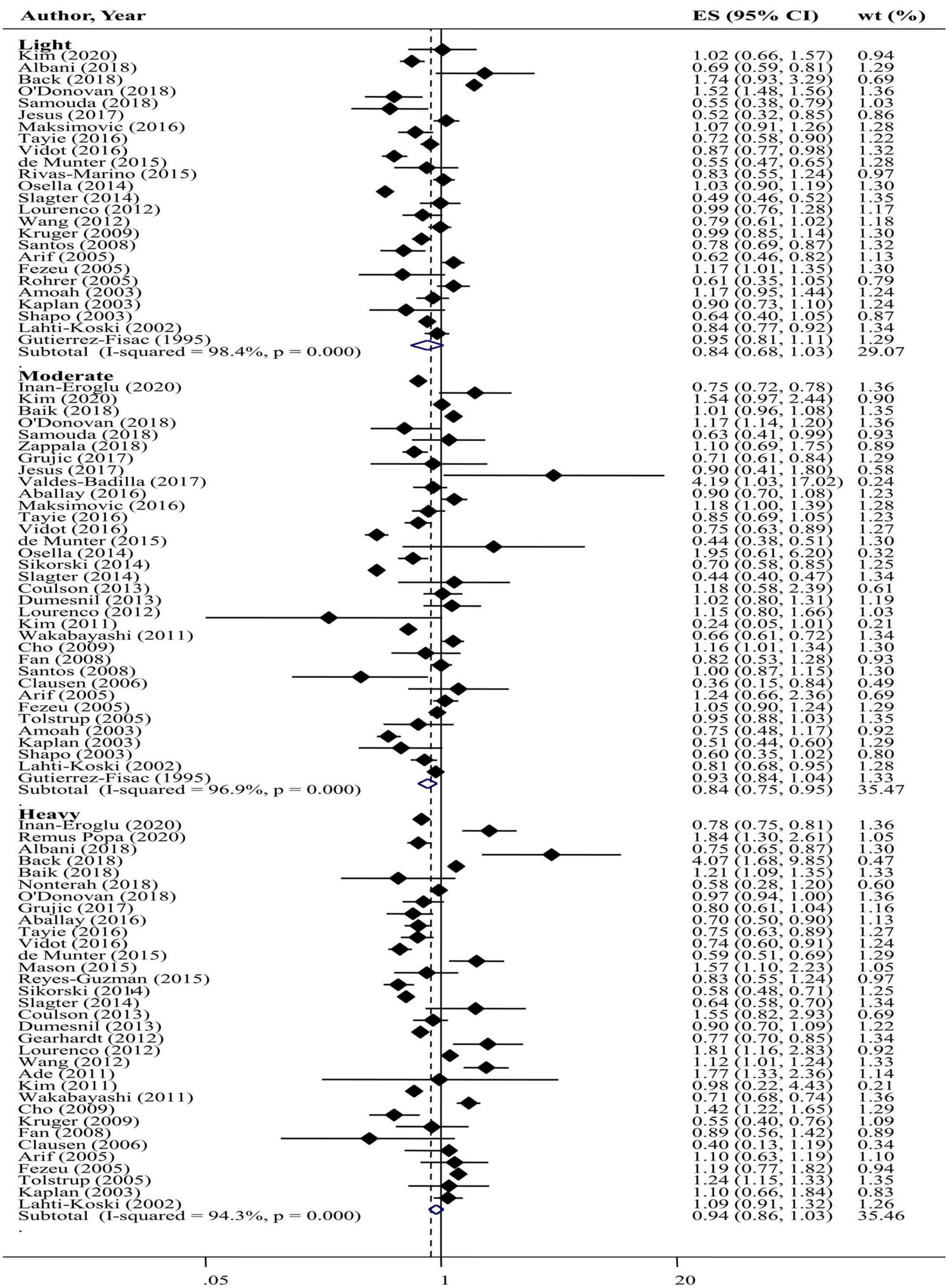

Figure 7. Forest plot of association between amount of alcohol and obesity in cross-sectional studies.

sectional studies did not show causal relationship between alcohol intake and odds of overweight and/or obesity.

The previous observational studies investigating the association between alcohol intake and high BMI or WC have reported contradictory results. Results of a cross-sectional study on 42,529 adults showed that odds of obesity and abdominal obesity in heavy alcohol drinkers was 21% (1.21; 95% CI: 1.09–1.35) and 28% (1.28; 95% CI: 1.14–1.43)

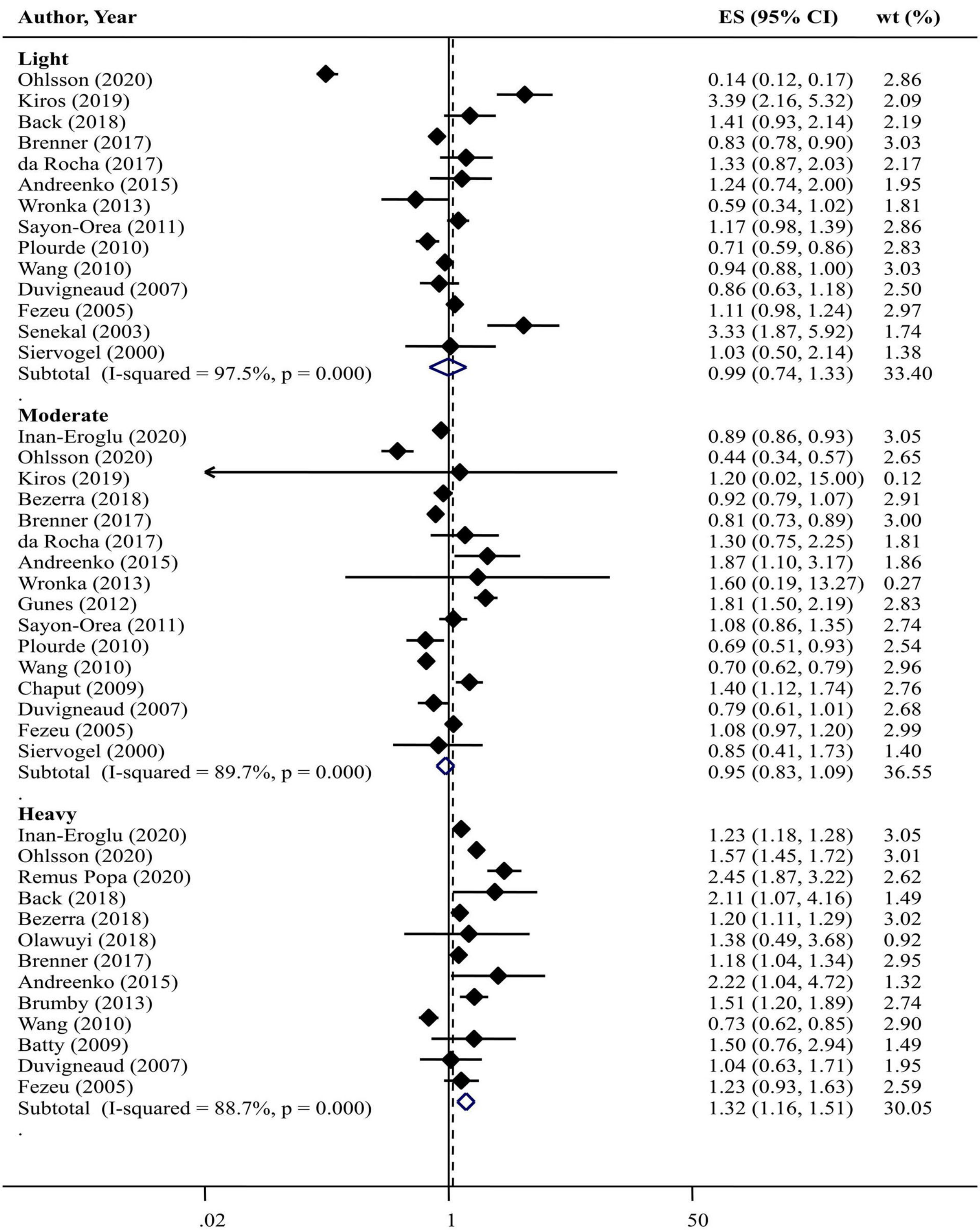

Figure 8. Forest plot of association between amount of alcohol and overweight/obesity in cross-sectional studies.

higher than non-alcohol drinkers, respectively (Baik 2018). In another cross-sectional study, alcohol intake (>28 g/d) increased odds of overweight by 31% (1.31; 95% CI: 1.23–1.40) and abdominal obesity by 10% (1.10; 95% CI: 1.03–1.18) however, odds of obesity was decreased by 36% (0.64; 95% CI: 0.58–0.70). In contrary, results of a large study on 235,730 subjects revealed an inverse relationship between alcohol intake and overweight (0.96, 95% CI: 0.94–0.98) and obesity (0.64, 95% CI: 0.63–0.66) (Naimi et al. 2005). In addition, results of two cohort studies suggested that alcohol intake reduced risk of overweight and obesity (Thomson et al. 2012; Wang et al. 2010). However, another cohort study showed no association between alcohol drinking and risk of obesity and abdominal obesity (Pereira et al. 2016). Such findings have also been reported in the other studies (Inan-Eroglu et al. 2020; Sayon-Orea, Bes-

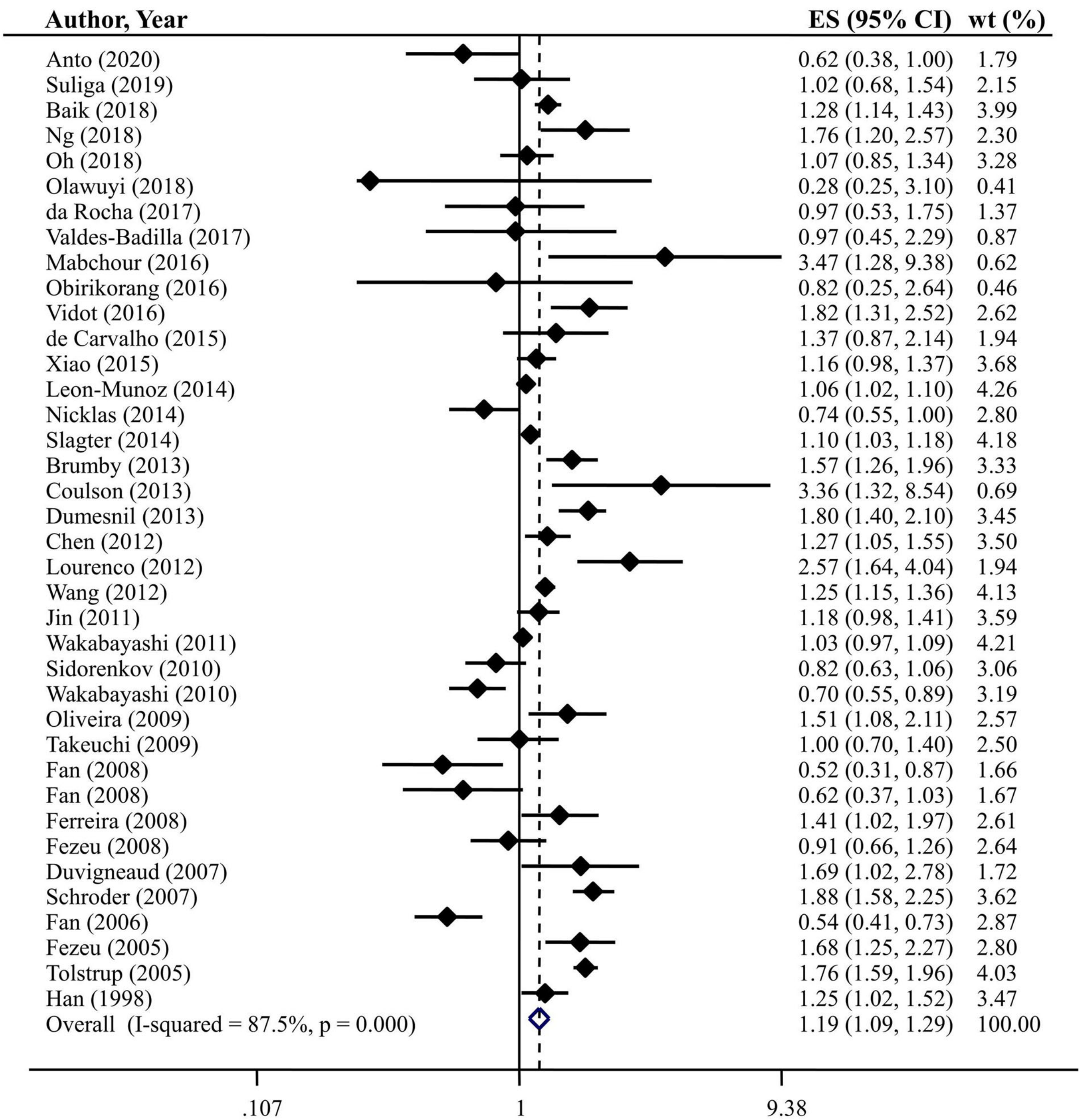

Figure 9. Forest plot of association between alcohol intake and abdominal obesity in cross-sectional studies.

Rastrollo, et al. 2011). Different findings might be explained by the discrepancy in study design, general characteristics of participants, methodological approach for data collection, the use of various cutoff points to categorize alcohol intake, different definitions for obesity or abdominal obesity, and the lack of adjustment for potential confounders.

Sayon-Orea et al. (2011), in a systematic review including 27 observational studies (14 cross-sectional and 13 prospective studies) indicated inconsistent results on the association between alcohol intake and body weight. They reported that heavy alcohol drinking was associated with higher weight and abdominal obesity in most of cross-sectional studies; however, results of cohort studies were conflicting. In the present study, a positive association was found between alcohol intake and odds of overweight/obesity, overweight, and abdominal obesity in cross-sectional studies. In contrast, no significant relationship was found between alcohol drinking and general and abdominal obesity in cohort studies. Bendsen et al. (2013), in another systematic review on 35 observational studies (25 cross-sectional and 10 prospective studies) showed that the association between beer intake and obesity was contradictory. They reported that daily beer consumption more than 500 mL may be related to high WC and waist-to-hip ratio (WHR). It must be noted that Bendsen et al., have only focused on beer and ignored other sources of alcohol. The previous studies have also indicated the type of alcohol involved in the relationship between alcohol drinking and weight (Kim and Jeon 2011; Tayie and Beck 2016). So that, wine drinkers consumed more healthy diet and had better lifestyle than beer and spirits drinkers (Inan-Eroglu et al. 2020). In the present study, the association between different types of alcohol beverages with overweight and obesity was not evaluated due to lack of information regarding source of alcohol in most included studies.

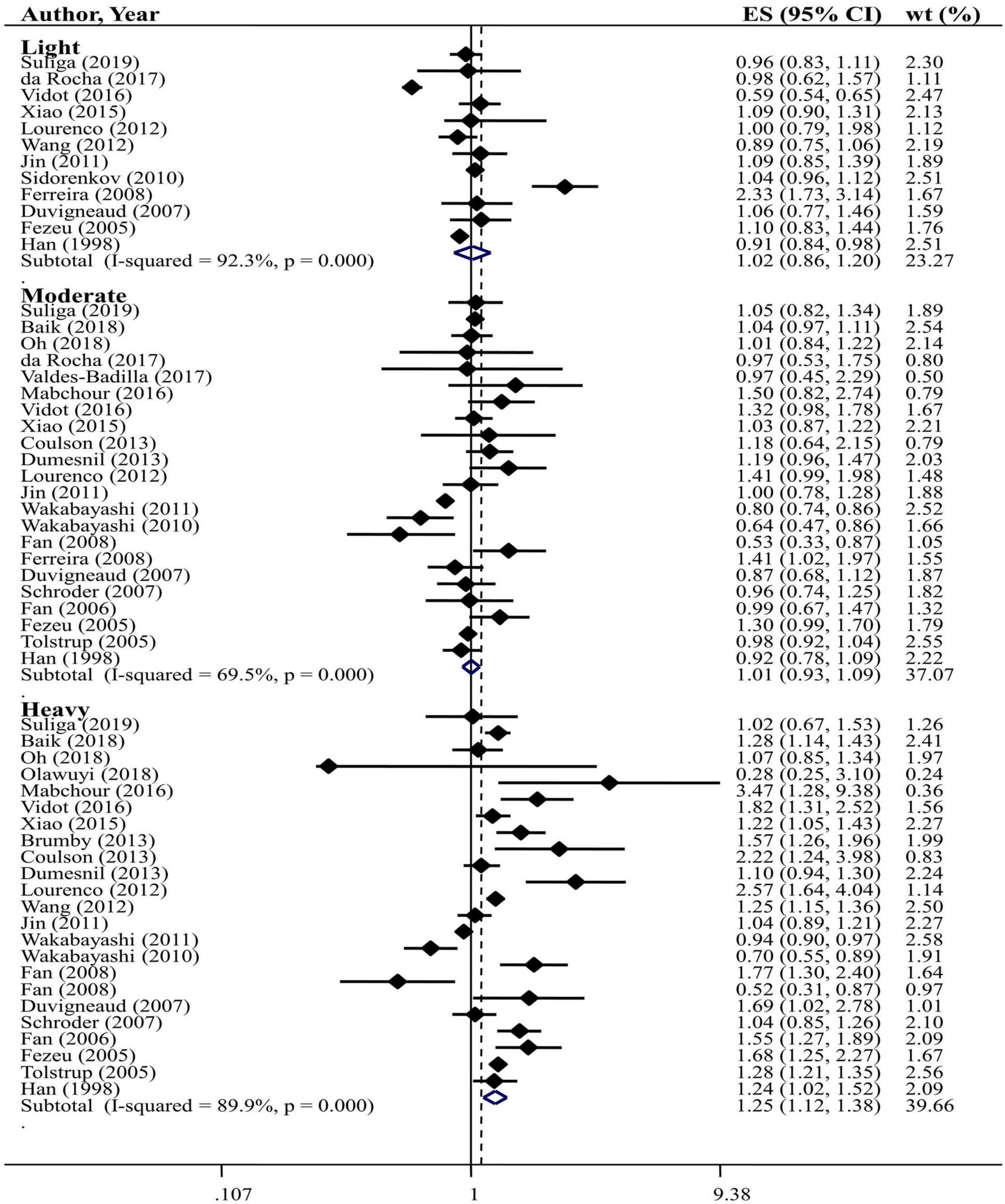

Figure 10. Forest plot of association between amount of alcohol and abdominal obesity in cross-sectional studies.

Alcohol may increase risk of being overweight or obese through several mechanisms. Alcohol has high calorie and can increase the subject's daily energy intake by 5–10% (da Rocha et al. 2017). Acetate, a metabolite of alcohol, is a source of energy preventing fat oxidation and favoring adiposity especially in visceral region (Albani et al. 2018; de Carvalho et al. 2015). In addition, alcohol enhances cortisol release via hypothalamic-pituitary-adrenal (HPA) axis, and therefore, leading to abdominal obesity (Oh 2018). Alcohol induces appetite (Bogale and Zewale 2019; Coulson et al. 2013) by influencing secretion of anorexigenic agents, such as leptin, glucagon-like peptide-1 (GLP-1), and serotonin, and orexigenic agents, such as γ-aminobutyric acid (GABA) and neuropeptide Y (NPY) (Tayie and Beck 2016), so concomitantly stimulating food intake, which contributes to weight gain (de Carvalho et al. 2015). Moreover, the evidence indicates that some alcohol drinkers consumed unhealthier foods, which may be a risk factor for high BMI and WC in heavy alcohol drinkers (Ahn et al. 2012; Albani et al. 2018; Clausen, Charlton, and Holmboe-Ottesen 2006).

However, some studies have reported a J-shaped or U-shaped relationship between alcohol intake and BMI such that, light to moderate alcohol drinkers had lower BMI than non- or heavy alcohol drinkers (Arif and Rohrer 2005; Lukasiewicz et al. 2005). In the present study, a U-shaped association was found between alcohol intake and obesity. Some documents have suggested that moderate alcohol drinking has protective effect against some chronic diseases (Fueki et al. 2007; O'Keefe et al. 2018; Riserus and Ingelsson 2007). In addition, it has been stated that patient subjects drink lower amount of alcohol than healthy subjects resulting in J-shaped or U-shaped curves (Ferreira et al. 2008). One explanation for the U-shaped relationship observed in our study may be associated with abstinence from alcohol intake in some moderate alcohol drinkers as a result of obesity-related co-morbidities (Albani et al. 2018). Other reasons may be related to compensatory behavior by reducing food consumption following alcohol intake (Duvigneaud et al. 2007) or having a healthy lifestyle, which may provide protection against obesity (O'Donovan, Stamatakis, and Hamer 2018). However, due to the cross-sectional design of the studies, the causal association between moderate alcohol drinking and obesity was unclear.

The present systematic review and meta-analysis had some strengths and limitations. Although, the two previous systematic reviews have assessed the association between alcohol intake and general and abdominal obesity; however, in the current study, a meta-analysis was designed in order to pool the evidence and to report an overall effect size. Large number of the included studies was the main strength of the current study. In addition, the dose-response association between alcohol intake and odds of body weight was also evaluated. There was no publication bias among the studies and several subgroup analyses were performed. In this study, a significant relationship was found between the measured weight, height, and WC and alcohol intake providing reliable results and reducing reporting bias compared to the self-reported data.

However, interpretation of the results is difficult due to high heterogeneity between-studies. Source of alcohol had not been reported in the most included studies. Therefore, it was not possible to assess the relationship between different types of alcohol and general and abdominal obesity. In addition, some studies had measured amount of alcohol intake while the others had measured frequency of intake. Also there were different criteria for defining abdominal obesity in various studies. Nevertheless, the association between alcohol intake and weight is complex and is mediated by several factors, such as physical activity, dietary habits, energy intake, genetics, sex, and smoking. Therefore, further well-designed cohort studies considering all of these confounders are required to elucidate the association between alcohol intake and general and abdominal obesity.

In conclusion, the results of our study showed a positive association between alcohol intake and odds of overweight, overweight/obesity, and abdominal obesity in cross-sectional studies. According to the dose-response analysis, this association was significant between heavy alcohol drinking and odds of overweight, overweight/obesity, and abdominal obesity. No significant association was found between alcohol intake and BMI and WC in cohort studies.

Statement of authorship

MG contributed to the study conception, literature search, data extraction, data analysis, and manuscript drafting. ASM contributed to the literature search, data extraction, and manuscript drafting. PM contributed to manuscript drafting and approving the final manuscript. All authors have read and approved the final manuscript.

Conflict of interest

The authors declare there is no conflict of interest.

Abbreviation

BMI	body mass index
CVD	cardiovascular disease
95% CI	confidence interval
GABA	gama-aminobutyric acid
GLP-1	glucagon-like peptide-1
GRADE	Grading of Recommendations Assessment, Development and Evaluation
HR	hazard ratio
HPA	hypothalamic-pituitary-adrenal
NPY	neuropeptide Y
I^2	I-squared
NOS	Newcastle-Ottawa Scale
OR	Odds ratio
PRISMA	Preferred Reporting Item for Systematic Reviews and Meta-Analysis
RCT	randomized controlled trial
WC	waist circumference
WHR	waist-to-hip ratio
WHO	World Health Organization

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