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Do associations between education and obesity vary depending on the measure of obesity used? A systematic literature review and meta-analysis

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ABSTRACT

Background: Consistent evidence suggests a relationship between lower educational attainment and total obesity defined using body mass index (BMI); however, a comparison of the relationships between educational attainment and total obesity (BMI $\geq$30 kg/m^2) and central obesity (waist circumference (WC) > 102 cm for men and WC > 88 cm for women) has yet to be carried out. This systematic literature review (SLR) and meta-analyses aimed to understand whether i) the associations between education and obesity are different depending on the measures of obesity used (BMI and WC), and ii) to explore whether these relationships differ by gender and region.

Methods: Medline, Embase and Web of Science were searched to identify studies investigating the associations between education and total and central obesity among adults in the general population of countries in the Organisation for Economic Co-operation and Development (OECD). Meta-analyses and meta-regression were performed in a subset of comparable studies (n=36 studies; 724,992 participants).

Results: 86 eligible studies (78 cross-sectional and eight longitudinal) were identified. Among women, most studies reported an association between a lower education and total and central obesity. Among men, there was a weaker association between lower education and central than total obesity (OR central vs total obesity in men 0.79 (95% CI 0.60, 1.03)). The association between lower education and obesity was stronger in women compared with men (OR women vs men 1.66 (95% CI 1.32, 2.08)). The relationship between lower education and obesity was less strong in women from Northern than Southern Europe (OR Northern vs Southern Europe in women 0.37 (95% CI 0.27, 0.51)), but not among men.

Conclusions: Associations between education and obesity differ depending on whether total or central obesity is used among men, but not in women. These associations are stronger among women than men, particularly in Southern European countries.

Introduction

The most recent global estimates for adults suggest that 11.6% (95% confidence interval (CI) 10.6%–12.6%) of males and 15.7% (95% CI 14.6%–16.8%) of females were obese in 2016 (NCD-RisC, 2017). The prevalence is highest among high income countries (Afshin et al., 2017), with a mean prevalence of 19.5% (95% CI not reported) in OECD countries in 2015 (OECD, 2017). This poses enormous individual and public health risks as obesity is associated with increased all-cause mortality and significant morbidity (Abranches et al., 2015; Carbone et al., 2013, 2018; Thijssen et al., 2015). Total obesity is usually identified using body mass index (BMI), where a BMI $\geq$30 kg/m^2 is classed as obese in both men and women (WHO, 2000). However, central obesity has received increased attention because of the additional prognostic information it may provide for some health outcomes, such as cardiovascular disease and type 2 diabetes (Balkau et al., 2007; Janssen et al., 2004). Central obesity is usually identified measuring waist circumference (WC) (>102 cm for men and >88 cm for women). Although there

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are more precise measures of adiposity, such as body fat mass derived from skinfold thickness or dual energy X-ray absorptiometry (DXA), BMI and WC are the most commonly utilised measures as they are inexpensive and practical to use in epidemiological studies and routine clinical practice (Hu, 2008).

The complex factors that play a role in the development of obesity can be described by the 'social determinants of health' model (Whitehead and Dahlgren, 1991), which describes the multiple socioeconomic circumstances that can together influence a person's behaviour and health. Previous reviews have shown that lower socioeconomic position (SEP) is associated with obesity in high-income countries (Cohen, Rai, Rehkopf, & Abrams, 2013a; El-Sayed et al., 2012; Kim et al., 2017; McLaren, 2007; Newton et al., 2017; Parsons et al., 1999; Senese et al., 2009), but not in low-income countries (Cohen, Rai, Rehkopf, & Abrams, 2013a), suggesting that region (or more specifically economic status of a country) may modify the relationship between SEP and obesity. In studies examining SEP-obesity associations in high income countries, this was reported more consistently among women than men, suggesting that gender may modify the relationship between SEP and obesity (Cohen, Rai, Rehkopf, & Abrams, 2013a; El-Sayed et al., 2012; Kim et al., 2017; McLaren, 2007; Newton et al., 2017; Senese et al., 2009). Importantly, most of these studies focussed on BMI and few compared the associations of indicators of SEP with total and central adiposity. One review indicated that men and women with cumulative exposure to lower SEP across life had a higher mean BMI compared with those with a higher SEP across life; however, men with a lower SEP across life had lower mean WC compared with men with a higher SEP across life (Newton et al., 2017). Therefore, associations between SEP and obesity may differ depending on whether the outcome is total or central obesity, but this has not been investigated.

Most reviews about SEP and obesity use multiple indicators of SEP including educational attainment, occupation, income or deprivation (El-Sayed et al., 2012; McLaren, 2007; Newton et al., 2017; Senese et al., 2009). However, McLaren (2007) reported that adiposity outcomes vary by SEP indicator and thus they cannot be used interchangeably. This review focuses on educational attainment (numbers of years at school/highest qualifications obtained), because more so than occupation or income, it is an important indicator of SEP in early life, reflecting a family's lifestyle, material and intellectual resources, and it is also a strong predictor of SEP and life chances across adulthood (Beebe-Dimmer et al., 2004; Smith et al., 1997). It has been proposed that increased health literacy and material and financial resources among people with higher levels of educational attainment lead to healthier lifestyles and reduced obesity rates (Hulshof et al., 1991; Mazzocchi et al., 2009). Other advantages of studying educational attainment over other SEP indicators is that it is easy to measure, usually has a high response rate when measured in studies and can be assessed in all people regardless of age or working circumstances (Galobardes et al., 2006). Understanding the link between educational attainment and different definitions of obesity may lead to the development of targeted education-based policy interventions that help to prevent obesity and related chronic diseases (Devaux et al., 2011).

We therefore aimed to conduct a systematic literature review (SLR) and meta-analysis to: 1) understand whether the associations between educational attainment and obesity are different depending on the measures used to identify obesity (BMI and WC), and 2) explore whether these relationships differ by gender and region.

Methods

The review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009). The following PICO model defined the search strategy (Table S1): Population (P), adults (aged ≥16 years) from the Organisation for Economic Co-operation and Development (OECD) countries (as of 2020 (OECD, 2020a)); Intervention/exposure (I), educational attainment/years of education; Comparison (C), none (limited to observational studies); and Outcome (O), total obesity (BMI ≥30 kg/m^2) and central obesity (WC > 102 cm for men and WC > 88 cm for women).

Inclusion and exclusion criteria

Medline, Embase and Web of Science were searched for studies from January 1, 2000 until February 28, 2021 to summarise the literature most relevant to today's social environment. The inclusion criteria were 1) peer-reviewed articles including statistical analysis with an effect size for the association between educational status and obesity in the total study population and/or by gender, 2) total obesity or central obesity defined by BMI ≥30 or WC > 102 cm for men and WC > 88 cm for women (WHO, 2000), 3) participants aged ≥16 years, 4) cross-sectional or prospective observational cohort studies, 5) OECD countries as of March 2020 (OECD, 2020a), and 6) English language articles only. Conference abstracts were excluded.

We focussed specifically on the state of total obesity or central obesity as weight change is not a definite proxy for excess adiposity. Only studies with participants aged ≥16 years were included in this review as children and younger adolescents were unlikely to have completed their education. Lastly, Cohen et al. (2013a) reported that the direction of the association between education and obesity depends on a country's economic status; therefore, only countries within the OECD as of 2020 were included to minimise sources of heterogeneity between studies.

Screening

Titles and abstracts were independently screened by RW and JG, and disagreements were solved through consensus discussion. Subsequently, full texts were screened by one reviewer (RW) and a random sample of 10% by a second reviewer (JMG) to confirm agreement. Disagreements of inclusion and exclusion of articles were resolved with an independent reviewer (SV). Reference lists of two previously conducted systematic literature reviews (Cohen, Rai, Rehkopf, & Abrams, 2013a; Kim et al., 2017) and of the included studies were also screened.

Data abstraction

Descriptive data on study population and design were extracted from all manuscripts using a standard pro forma. If a study presented results from unadjusted and adjusted models, only the independent effect sizes from the adjusted models were included in this review. If different countries, ethnicities or multiple time points were assessed in one article, estimates from each country, ethnicity or time point were reported as separate 'data points' where possible, though some studies pooled multiple time points into one data point. Countries were grouped by geographic region using the United Nations 'M49 standard' (UNSD, 1999).

Data synthesis

For both BMI and WC, meta-analyses were performed if studies stratified results based on gender and if they reported an odds ratio (OR) with three or four educational categories. For BMI, an additional meta-analysis was performed for studies that estimated the effect of education with the relative index of inequality (RII) separately for men and women. RII is a regression based measure that compares the risk of obesity between those with the lowest and the highest education in a sample (Mackenbach & Kunst, 1997). For the meta-analyses, pooled ORs were calculated using random-effect models. The lowest with the highest educational category was compared; if studies did not report in this order, an inverse of the OR and 95% CI was calculated. All meta-analyses were checked for publication bias using the Egger's test for asymmetry. Moreover, random-effect meta-regression analyses were performed to investigate differences between measures (BMI vs WC), gender (women vs men) and regions. Only the different regions in Europe were included in the meta-regression as there was a lack of data on the other regions. All statistical analyses were performed using Stata version 14, with Metan and Metareg packages. Studies that did not meet the above criteria for the meta-analyses and meta-regression are reported in a narrative summary.

Quality assessment

Study quality was assessed by RW using the Quality In Prognosis Studies (QUIPS) tool (Hayden et al., 2013), recommended by the Cochrane Prognosis Methods Group (Riley et al., 2019). Six domains were evaluated for each study: study participation, study attrition, prognostic factor measurement, outcome measurement, confounding and statistical analysis and reporting. For each domain, the risk of bias was rated 'low', 'moderate' or 'high'.

Results

The initial database search identified 3230 articles of which 2506 were unique records (Fig. 1). After full-text review and reference list screening, 86 studies were included.

Description of included studies

Studies from thirty-two OECD countries were included in this review, representing all geographic regions of the M49 standard, except for South America. Of the 86 studies, the majority were cross-sectional (n=78), which means that the exposure (educational attainment) and outcome (obesity) were measured at the same time point. The median sample size of all studies was 6548 (interquartile range (IQR): 3410, 11,497). Mean age ranged from 18 years (SD: not reported (NR)) (a sample of 18 year old Portuguese conscripts)(Padez, 2006) to 68.7 years (SD: 0.2 [sic]) (Pérez-Hernández et al., 2017), but the majority of studies (n=78, 90.7%) reported a mean age of above 40 years. Overall, studies were of good quality (Table S6). The domains 'attrition/response rate', 'outcome measurement' and 'statistical analysis' received the most moderate to high bias ratings due to, respectively, no information about missing data, self-reported instead of measured height and weight data and no reporting of the obesity reference category (healthy weight or non-obese). The measurement of educational attainment and categorisation of educational level varied across studies (Table S3). Tables 1 and 3 report estimates comparing the lowest and highest educational categories.

Total and central obesity prevalence in different study samples are shown in Table S2. In studies that reported estimates separately for men and women, total obesity prevalence was similar in men and women (mean prevalence 16.9% in women vs 17.0% in men), whereas prevalence of central obesity was often higher in women than men (mean prevalence 34.3% in women vs 23.8% in men). In studies presenting both measures (BMI and WC), central obesity prevalence was generally higher than total obesity prevalence. Obesity prevalence varied across countries and within countries: generally, the highest total and central obesity prevalence estimates were found in Northern America (survey years range 1993–2016) and Spain (survey years range 1997–2013) (ranges from 7.0 to 44.1% for total obesity and 21.8–59.7% for central obesity), and the lowest were found in Italy (survey years 2000, 2005), France (survey years range 1996–2008) and Denmark (survey years range 1994–2003) (ranges from 4.8 to 12% for total obesity and 13.6–15.4% for central obesity) (Table S2).

Association between educational attainment and obesity defined by BMI

In total, 85 studies reported on associations between education and obesity defined using BMI (Table S3). There were eight longitudinal

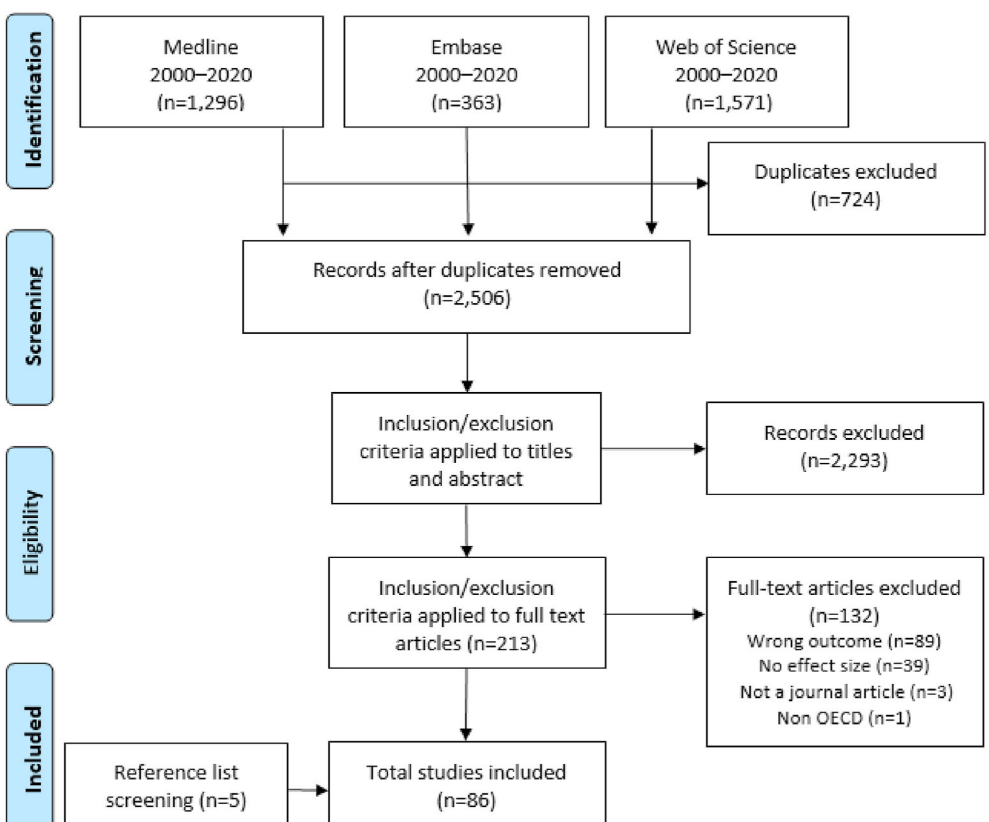


Fig. 1. PRISMA flowchart of the selection of studies.

Table 1
Association between education and total obesity defined by BMI ≥30 kg/m² lowest vs highest educational categories.

Country (year(s) of survey)	N	Association with obesity (effect size (95% CI))	
		Women	Men
Eastern Europe (total inverse associations)		*6 out of 6 (100%)*	*4 out of 6 (66.7%)*
Czech Republic (Roskam et al., 2010) (2002) ‖	789	RII 5.3 (1.5, 18.2)†	RII 3.6 (1.1, 12.2)†
Hungary (Devaux & Sassi, 2013) (2000, 2003)	8543	RII 2.9 (95% CI NR)†	RII 1.8 (95% CI NR)†
Hungary (Roskam et al., 2010) (2000, 2003) ‖	3618	RII 2.3 (1.6, 3.3)†	RII 1.4 (1.0, 2.2)
Hungary (Rurik et al., 2014) (2013) ‖	40,331	OR 2.4 (2.2, 2.7)†	OR 1.5 (1.4, 1.7)†
Poland (Zatońska et al., 2011) (2011)	3854	OR 2.1 (1.7, 2.5)†	OR 1.5 (1.2, 1.9)†
Slovak Republic (Roskam et al., 2010) (2002) ‖	635	RII 5.9 (1.4, 24.2)†	RII 1.6 (0.5, 4.8)
Meta-analysis pooled RII	***5042***	***3.14 (1.67, 5.90), I^2=33.3%***	***1.59 (1.09, 2.31), I^2=0.0%***
Meta-analysis pooled OR	***40,331***	***2.44 (2.21, 2.69), I^2=-****	***1.52 (1.36, 1.70), I^2=-****
Northern Europe (total inverse associations)		*21 out of 26 (80.8%)*	*19 out of 27 (70.4%)*
Denmark (Sarlio-Lähteenkorva et al., 2006) (1994) ‖	3081	OR 2.8 (1.5, 5.2)†	OR 2.3 (1.3, 3.9)†
Denmark (Roskam et al., 2010) (2000) ‖	5821	RII 2.7 (1.7, 4.3)†	RII 3.1 (1.9, 5.2)†
Denmark (Groth et al., 2009) (2002)	2013	OR 6.5 (2.3, 18.7)†	OR 2.9 (1.4, 5.9)†
Denmark (Nielsen et al., 2005) (2003)	783	NR	OR 1.9 (1.1, 3.3)†
England (Devaux & Sassi, 2013) (Annually 1995–2007)	144,807	RII 1.9 (95% CI NR) †	RII 1.4 (95% CI NR)†
England (Wardle et al., 2002) (1996)	15,061	OR 1.8 (1.4, 2.4)†	OR 1.8 (1.3, 2.4)†
England (Roskam et al., 2010) (2001) ‖	5583	RII 2.2 (1.7, 2.9)†	RII 1.7 (1.3, 2.3)†
Estonia (Klumbiene et al., 2004) (1994, 1996, 1998) ‖	3759	OR 2.3 (1.6, 3.2)†	OR 0.9 (0.6, 1.5)
Estonia (Roskam et al., 2010) (2002, 2004) ‖	1740	RII 3.3 (1.7, 6.7)†	RII 1.7 (0.8, 3.4)
Finland (Sulander and Uutela, 2007)(Biannually 1993–2003)	11,486	OR 1.5 (1.3, 1.8)†	OR 1.4 (1.2, 1.8)†
Finland (Sarlio-Lähteenkorva et al., 2006) (1994) ‖	6474	OR 2.7 (1.8, 3.9)†	OR 1.7 (1.3, 2.3)†
Finland (Klumbiene et al., 2004) (1994, 1996, 1998) ‖	9488	OR 1.8 (1.4, 2.3)†	OR 1.7 (1.3, 2.2)†
Finland (Roskam et al., 2010) (Biannually 1994–2004) ‖	8223	RII 1.6 (1.1, 2.4)†	RII 1.5 (1.0, 2.3)†
Finland (Laaksonen et al., 2004) (2000, 2001) ‖	6227	OR 1.1 (0.7, 1.6)	OR 1.2 (0.6, 2.3)
Finland (Seppänen-Nuijten et al., 2009) (2001) ‖	6300	OR 1.7 (1.3, 2.2)†	OR 1.8 (1.3, 2.3)†
Finland (Salonen et al., 2009) (2004) ‖	2003	OR 1.4 (0.9, 2.1)	OR 1.3 (0.7, 2.0)
Latvia (Roskam et al., 2010) (1998, 2000, 2002, 2004) ‖	3537	RII 1.5 (0.9, 2.5)	RII 0.9 (0.5, 1.6)
Lithuania (Klumbiene et al., 2004) (1994, 1996, 1998) ‖	5635	OR 1.4 (1.1, 1.9)†	OR 1.2 (0.8, 1.7)
Lithuania (Roskam et al., 2010) (Biannually 1994–2004) ‖	5465	RII 2.7 (1.8, 3.9)†	RII 1.0 (0.6, 1.6)
Northern Ireland (Hughes et al., 2017) (2011)	3239	RII 2.1 (95%CI NR)†	RII 1.1 (95%CI NR)†
Norway (Roskam et al., 2010) (2002) ‖	2529	RII 1.8 (0.8, 4.0)	RII 3.4 (1.7, 6.9)†
Republic of Ireland (Roskam et al., 2010) (1995, 2002)	2064	RII 2.0 (0.9, 4.2)	RII 1.3 (0.7, 2.7)
	8707		
Table 1 *(continued)*			
Country (year(s) of survey)	N	Association with obesity (effect size (95% CI))	
		Women	Men
Eastern Europe (total inverse associations)		*6 out of 6 (100%)*	*4 out of 6 (66.7%)*
Republic of Ireland (Hughes et al., 2017) (2007)		RII 1.7 (95%CI NR)†	RII 1.5 (95%CI NR)†
Sweden (Lindström et al., 2003) (1994) ‖	3788	OR 2.3 (1.4, 3.8)†	OR 2.3 (1.5, 3.5)†
Sweden (Molarius, 2003) (2000) ‖	6394	OR 2.3 (1.3, 4.2)†	OR 2.5 (1.3, 4.8)†
Sweden (Devaux & Sassi, 2013) (2000)	4350	RII 3.3 (95% CI NR)†	RII 2.8 (95% CI NR)†
Sweden (Roskam et al., 2010) (2000, 2001) ‖	3990	RII 3.9 (2.1, 7.0)†	RII 4.3 (2.4, 7.8)†
Meta-analysis pooled RII	***90,037***	***2.25 (1.85, 2.74), I^2=32.1%***	***1.81 (1.30, 2.52), I^2=72.4%***
Meta-analysis pooled OR	***53,149***	***1.82 (1.52, 2.17), I^2=56.5%***	***1.61 (1.35, 1.91), I^2=45.2%***
Western Europe (total inverse associations)		*18 out of 18 (100%)*	*16 out of 18 (88.9%)*
Austria (Devaux & Sassi, 2013) (1999, 2007)	42,059	RII 2.0 (95% CI NR)†	RII 2.3 (95% CI NR)†
Belgium (Roskam et al., 2010) (1997, 2001) ‖	6932	RII 6.3 (4.1, 9.7)†	RII 2.2 (1.5, 3.2)†
Belgium (Charafeddine et al., 2009) (2004)	9709	RR 3.3 (2.4, 4.6)†	RR 2.6 (1.9, 3.7)†
France (Czernichow et al., 2004) (1996) ‖	6705	OR 1.8 (1.3, 2.6)†	OR 1.6 (1.2, 2.1)†
France (Devaux & Sassi, 2013) (Annually 1995–98, 2000, 2002, 2004, 2006)	67,780	RII 4.8 (95% CI NR)†	RII 3.2 (95% CI NR)†
France (Singh-Manoux et al., 2009) (2003) ‖	14,727	RII 4.8 (3.6, 6.4)†	RII 2.5 (1.9, 3.3)†
France (Roskam et al., 2010) (2004) ‖	6048	RII 4.2 (2.5, 7.2)†	RII 3.3 (1.7, 6.2)†
Germany (Icks et al., 2007) (1992, 1998) ‖	13,049	OR 4.8 (3.3, 6.9)†	OR 2.6 (1.8, 3.8)†
Germany (Roskam et al., 2010) (1998) ‖	2786	RII 5.1 (3.0, 8.7)†	RII 1.7 (1.1, 2.6)†
Germany (Kuntz & Lampert, 2010) (2003) ‖	8318	OR 1.7 (1.3, 2.2)†	OR 1.5 (1.2, 2.0)†
Luxembourg (Tchicaya and Lorentz, 2012) (2007) ‖	7768	OR 2.1 (1.4, 3.0)†	OR 0.8 (0.5, 1.1)
Luxembourg (Samouda et al., 2018) (2015) ‖	1484	OR 3.0 (1.5, 6.3)†	OR 1.2 (0.6, 2.4)
Netherlands (Roskam et al., 2010) (2003, 2004) ‖	5607	RII 2.9 (1.9, 4.3)†	RII 3.6 (2.3, 5.7)†
Switzerland (Faeh et al., 2011) (1993, 1997, 2002, 2007) ‖	53,588	OR 3.0 (2.3, 3.9)†	OR 1.9 (1.5, 2.5)†
Switzerland (Marques-Vidal et al., 2010) (1993, 1997, 2002, 2007) ‖	63,782	OR 3.0 (2.3, 3.6)†	OR 1.9 (1.5, 2.5)†
Switzerland (Marques-Vidal et al., 2008) (2003) ‖	6186	OR 2.9 (2.4, 3.3)†	OR 2.3 (2.0, 2.7)†
Switzerland (Stringhini et al., 2012) (2006) ‖	6303	RII 4.8 (3.2, 7.2)†	RII 3.0 (2.1, 4.2)†
Switzerland (Vinci et al., 2019) (2015) ‖	2057	OR 1.9 (1.7, 2.2)†	OR 0.8 (0.7, 0.8)†
Meta-analysis pooled RII	***42,403***	***4.54 (3.69, 5.57), I^2=30.3%***	***2.56 (2.09, 3.14), I^2=34.7%***
Meta-analysis pooled OR	***162,937***	***2.54 (2.05, 3.15), I^2=82.8%***	***1.59 (1.00, 2.53), I^2=98.7%***
Southern Europe (total inverse associations)		*17 out of 17 (100%)*	*12 out of 18 (66.7%)*
Greece (Tzotzas et al., 2010) (2003) ‖	16,073	OR 1.6 (1.2, 2.0)†	OR 1.3 (1.0, 1.7)
Italy (Devaux & Sassi, 2013) (1995, 2000, 2003, 2005)	215,664	RII 6.8 (95% CI NR)†	RII 2.2 (95% CI NR)†
	41,613	RII 6.0 (4.7, 7.7)†	

(continued on next page)

Table 1 (*continued*)

Country (year(s) of survey)	N	Association with obesity (effect size (95% CI))	
		Women	Men
Eastern Europe (total inverse associations)		*6 out of 6 (100%)*	*4 out of 6 (66.7%)*
Italy (Roskam et al., 2010) (1999, 2000) ‖			RII 2.3 (1.9, 2.8)†
Portugal (Padez, 2006) (Annually 1986–2000)	850,081	NR	OR 2.7 (2.7, 2.7)
Portugal (Marques-Vidal et al., 2011) (1996, 1999, 2005) ‖	102,540	OR 3.8 (3.3, 4.4)†	OR 1.8 (1.6, 2.1)†
Portugal (Moreira & Padrão, 2006) (1998) ‖	39,640	OR 5.3 (3.7, 7.1)†	OR 2.5 (1.9, 3.3)†
Portugal (Roskam et al., 2010) (1998, 1999) ‖	12,297	RII 5.1 (3.1, 8.4)†	RII 2.7 (1.9, 3.9)†
Portugal (Camões et al., 2010) (2008)	1621	RR 2.3 (1.2, 4.5)†	RR 1.6 (0.6, 4.5)
Portugal (Sardinha et al., 2012) (2009) ‖	6908	OR 3.6 (2.7, 4.9)†	OR 2.0 (1.4, 2.7)†
Portugal (Gaio et al., 2018) (2015)	4819	PR 2.8 (2.0, 3.8)†	PR 1.9 (1.4, 2.5)
Portugal (Santos and Barros, 2003) (NR) ‖	1436	OR 5.3 (3.7, 7.1)†	OR 2.5 (1.9, 3.3)
Spain (Martínez-Ros et al., 2001) (1993) ‖	3091	OR 3.5 (1.4, 4.8)†	OR 1.2 (0.7, 2.0)
Spain (Aranceta et al., 2001) (1994) ‖	5388	OR 1.8 (1.8, 1.8)†	OR 2.4 (2.3, 2.4)†
Spain (Gutiérrez-Fisac et al., 2002) (1995, 1997)	2880	PR 3.5 (1.5, 8.2)†	PR 1.5 (1.0, 2.3)
Spain (Devaux & Sassi, 2013) (1995, 1997, 2001, 2003)	39,826	RII 18 (95% CI NR)†	RII 2.2 (95% CI NR)†
Spain (Roskam et al., 2010) (2001) ‖	7741	RII 5.1 (3.1, 8.4)†	RII 2.7 (1.9, 3.9)†
Spain (Pérez-Hernández et al., 2017) (2010) ‖	2699	OR 3.6 (2.2, 5.6)†	OR 1.7 (1.2, 2.3)†
Spain (Palomo et al., 2014) (NR)	2833	OR 2.5 (1.5, 4.2)†	OR 1.5 (1.0, 2.3)†
Meta-analysis pooled RII	***61,651***	***6.05 (4.98, 7.34), I^2=0.0%***	***2.32 (1.99, 2.70), I^2=0.0%***
Meta-analysis pooled ORs	***177,775***	***3.19 (2.20, 3.20), I^2=96.0%***	***1.82 (1.50, 2.21), I^2=84.5%***
Eastern Asia (total inverse associations)		*5 out of 5 (100%)*	*0 out of 5 (0%)*
Japan (Asahara et al., 2020) (2018)	5425	OR 1.69 (1.29, 2.22)	OR 1.16 (0.96, 1.40)
South Korea (Yoon et al., 2006) (1998) ‖	7962	OR 2.6 (1.9, 3.7)†	OR 0.8 (0.6, 1.1)
South Korea (Devaux & Sassi, 2013) (1998, 2001, 2005)	19,113	RII 17 (95% CI NR)†	RII 0.8 (95% CI NR)
South Korea (Chung et al., 2017) (2012) ‖	17,245	OR 1.7 (1.3, 2.2)†	OR 0.7 (0.6, 0.9)
South Korea (Chung & Kim, 2020) (2016) ‖	9991	OR 3.03 (1.79, 5.26)	OR 0.75 (0.54, 1.04)
Meta-analysis pooled OR	***25,207***	***2.27 (1.57, 3.29), I^2=68.7%***	***0.74 (0.63, 0.87), I^2=0.0%***
Western Asia (total inverse associations)		*4 out of 4 (100%)*	*0 out of 1 (0%)*
Turkey (Martorell et al., 2000) (1993)	2401	OR 2.2 (95% CI NR), p < 0.001†	NR
Turkey (Dursun et al., 2018) (Biannually 2008–16)	13,546	OLS estimate h vs l −0.051 (SE 0.008)‡, p < 0.001†	OLS estimate h vs l 0.014 (0.010), not sig
Turkey (Bayram et al., 2019) (2015)	833	OR 9.7 (5.6, 16.6)†	NR
Turkey (Kilicarslan et al., 2006) (NR) ‖	1500	OR 1.4 (1.4, 9.1)† [sic]	NR
Meta-analysis pooled OR	***1500***	***1.41 (0.56, 3.58), I^2=0.0%****	***Not enough data***
Northern America (total inverse associations)		*8 out of 16 (50%)*	*6 out of 11 (54.5%)*
Canada (Huot et al., 2004) (1993, 1997) ‖	10,014	OR 2.6 (1.6, 4.0)†	OR 1.6 (1.1, 2.3)†

Table 1 (*continued*)

Country (year(s) of survey)	N	Association with obesity (effect size (95% CI))	
		Women	Men
Eastern Europe (total inverse associations)		*6 out of 6 (100%)*	*4 out of 6 (66.7%)*
Canada (Kaplan et al., 2003) (1997)	5980	OR 1.5 (1.2, 1.8)†	OR 2.2 (1.8, 2.6)†
Canada (Devaux & Sassi, 2013) (1995, 2001, 2003, 2005)	266,782	RII 2.2 (95% CI NR)†	RII 1.6 (95% CI NR)†
Canada (Ng et al., 2011) (2004)	Ab 334; Non -ab 6259	OR Ab 0.6§ (95% CI NR), p=0.005; Non-ab h 1.4§ (95% CI NR) p=0.024†	OR Ab 2.0§(95% CI NR), p=0.019†; Non-ab 1.7§(95% CI NR), p=0.001†
USA (Martorell et al., 2000) (1988–94, NR how many cross-sectional surveys included)	5219	OR 0.8 (95% CI NR), not sig	NR
USA (Zhang and Wang, 2004) (1999)	2657	OR l W 1.2 (0.7, 1.9) B 0.6 (0.3, 1.5) vs m	OR l W 0.9 (0.5, 1.7) B 1.7 (0.7, 3.9) vs m
USA (Devaux & Sassi, 2013) (Biannually 2000–2008)	24,243	RII 1.6 (95% CI NR)†	RII 1.0 (95% CI NR)
USA (Salsberry and Reagan, 2009) (2002)	NR	OR M-A: 0.4 (0.2, 0.7); W: 1.4 (0.9, 2.2); A-A: 1.4 (0.9, 2.2)	NR
USA (Borders et al., 2006) (2003) ‖	5078	OR 1.5 (1.0, 2.2)	OR 1.8 (1.0, 3.1)
USA (Coogan et al., 2012) (2009)	21,457	RR 1.7 (1.5, 1.9)†	NR
USA (von Hippel & Lynch, 2014) (2010)	8665	OR 1.3 (SD 0.1)†	OR 1.1 (SD 0.1)†
USA (Hales et al., 2018) (2014, 2016)	10,792	PR 1.5 (1.3, 1.6)†	PR 1.1 (0.95, 1.3)
Meta-analysis pooled ORs	***15,092***	***1.28 (0.78, 2.11), I^2=82.2%***	***1.64 (1.19, 2.25), I^2=0.0%***
Central America (total inverse associations)		*4 out of 5 (100%)*	*0 out of 2 (0%)*
Mexico (Martorell et al., 2000) (1987)	3681	OR 1.7 (95% CI NR), P < 0.001†	NR
Mexico (Buttenheim et al., 2010) (2000)	38,901	OR U 2.0 (1.4, 2.5)†; R 1.4 (1.0, 2.0)†	OR U 1.3 (0.7, 2.0); R 0.8 (0.5, 1.3)
Mexico (Perez Ferrer et al., 2014) (2012) ‖	U 9588 R 4943	RII U 1.6 (1.3,1.8)†; R 1.1 (0.9, 1.4)	NR
Meta-analysis pooled RII	***14,531***	***1.34 (0.97, 1.83), I^2=78.9% ****	***Not enough data***
Oceania (total inverse associations)		*4 out of 4 (100%)*	*3 out of 3 (100%)*
Australia (Lawlor et al., 2005) (1996) ‖	14,099	RII 0.3 (0.3, 0.4)†	NR
Australia (Cameron et al., 2003) (2000) ‖	11,247	OR 2.1 (1.2, 3.8)†	OR 2.4 (1.6, 3.6)†
Australia (Brown & Siahpush, 2007) (2001)	26,863	RR 1.4 (1.2, 1.7)†	RR 2.1 (1.7, 2.6)†
Australia (Devaux & Sassi, 2013) (1995, 2001, 2005)	80,215	RII 1.9 (95% CI NR)†	RII 1.6 (95% CI NR)†
Meta-analysis pooled RII	***14,099***	***2.20 (1.59, 3.04), I^2=-****	***Not enough data***
Meta-analysis pooled OR	***11,247***	***2.12 (1.18, 3.80), I^2=-****	***2.40 (1.59, 3.62) I^2=-****
Total inverse associations of all studies		*87 out of 101 (86.1%)*	*60 out of 91 (65.9%)*
Meta-analysis of all studies RII	***227,763***	***2.95 (2.37, 3.68), I^2=89.9%***	***2.12 (1.80, 2.48), I^2=63.2%***
Meta-analysis of all studies OR	***497,229***	***2.02 (1.78, 2.31), I^2=92.7%***	***1.46 (1.16, 1.83), I^2=98.6%***

N, sample size; CI, confidence interval; RII, relative index of inequality; NR, not reported; OR, odds ratio; RR, risk ratio; PR, prevalence ratio; SE, standard error; SD, standard deviation; USA, United States of America; U, urban; R, rural; B, Black; W, White; M-A, Mexican-American; A-A, African American. Only the estimate of the most recent year and of the lowest vs the highest or the highest vs the lowest education categories are shown here; however, all estimates are shown in Table S3.*Subgroup meta-analysis based on one study †Indicate an inverse association (i.e. an association between lower education and obesity) based on statistical significance. ‡Estimates from linear probability models. §Regression coefficients from multivariable logistic regression models converted to ORs. ‖Included in meta-analyses and meta-regression analyses (Tables 2a and 2b).

studies (follow-ups were five (Camões et al., 2010), 10 (Chung and Kim, 2020), 13 (von Hippel & Lynch, 2014), 14 (Coogan et al., 2012), 23 (Salsberry and Reagan, 2009), 29 (Cohen, Rehkopf, Deardorff, & Abrams, 2013b), 33 (Salonen et al., 2009) and 36 years (Kim, 2016)). Six studies reported results of multiple countries (Devaux & Sassi, 2013; Drewnowski et al., 2005; Hughes et al., 2017; Klumbiene et al., 2004; Roskam et al., 2010; Sarlio-Lähteenkorva et al., 2006). Another six studies, all performed in the USA, reported on multiple ethnicities (Beltrán-Sánchez et al., 2016; Cohen, Rehkopf, Deardorff, & Abrams, 2013b; Ng et al., 2011; Qobadi and Payton, 2017; Salsberry and Reagan, 2009; Zhang and Wang, 2004). Therefore, the 85 studies included 101 data points for women, 91 for men and 35 data points for studies that combined men and women. 82 of the 85 studies reported results adjusted for covariates, and for three studies it was not clear (Kilicarslan et al., 2006; Rurik et al., 2014; Zatońska et al., 2011). 65 studies reported stratified results for men and women (Table 1). Five studies were eligible for the meta-analysis for studies that reported on the association of education modelled as RII, and 31 studies were included in the meta-analysis of studies that compared three or four educational categories. In both these meta-analyses, there was no evidence of publication bias using Egger's test (p=0.217 and p=0.686, respectively) (funnel plots are shown in Figs. S1 and S2).

Of the data points including women, 86.1% (87/101) found an association between lower levels of education (for example, fewer years of schooling or no qualifications) and higher odds of total obesity. This was 65.9% (60/91) for men. Subgroup meta-analysis of data points that reported on the association of education modelled as RII and odds of obesity showed higher pooled ORs for women (2.95 (95% CI 2.37, 3.68), I^2=89.9% and 2.02 (95% CI 1.78, 2.31), I^2=92.7%) compared with men (2.12 (95% CI 1.80, 2.48), I^2=63.2% and 1.46 (95% CI 1.16, 1.83), I^2=98.6%). These gender differences were tested in meta-regression analyses (Table 2a) and were found to be statistically significant: adjusted for region and number of educational categories the ORs were 1.66 (95% CI 1.32, 2.08), I^2=58.92% for the RII subset of studies and 1.40 (95% CI 1.09, 1.81), I^2=94.46%) for the OR subset of studies. Statistical heterogeneity was higher in studies that looked at the odds of obesity with three and four educational categories compared with RII, and subgroup meta-analysis indicate high statistical heterogeneity particularly in Western and Southern Europe (Table 1).

The association between a lower education and total obesity was more consistent in women than men in Northern America and Eastern, Western and Southern Europe compared with Northern Europe and Oceania, where effect sizes differed less between genders. These differences were confirmed by the meta-regression analyses in a subset of RII and studies with three or four educational categories respectively, which showed that there was a stronger association between a lower education and total obesity in women in Southern compared with Northern Europe (ORs for Northern vs Southern Europe: 0.37 (95% CI 0.27, 0.51), I^2=20.31% and 0.59 (95% CI 0.40, 0.88), I^2=91.81%), but this was not the case for men (ORs for Northern vs Southern Europe 0.77 (95% CI 0.40, 1.51), I^2=67.05% and 0.88 (95% CI 0.66, 1.16), I^2=74.0%) (Table 2b). There were no statistically significant differences between other regions in Europe (Table S5), and due to a small amount of studies it was not possible to formally test differences between the other regions.

Table 2A
Meta-regression to confirm gender differences for the association between education and total obesity defined by BMI $\geq$30 kg/m^2, in a subset of studies modelling RII (n=5 studies) and OR with three to four educational categories (n=30 studies).

Gender	OR (95% CI) not adjusted	OR (95% CI) adjusted for region (and for OR also number of educational categories)
Women vs men RII subset of studies	1.39 (1.03, 1.87) I^2=85.07%	1.66 (1.32, 2.08), I^2=58.92%
Women vs men OR subset of studies	1.39 (1.07, 1.79) I^2=97.59%	1.40 (1.09, 1.81), I^2=94.46%

OR, odds ratio; CI, confidence interval; RII, relative index of inequality.

Association between educational attainment and central obesity defined by WC

16 studies reported on WC (Table S4), of which 12 stratified results based on gender and eight studies were included in the meta-analysis (Table 3). In 81.8% (9/11) (Cameron et al., 2003; Camões et al., 2010; Ko et al., 2015; Marques-Vidal et al., 2008; Pérez-Hernández et al., 2017; Rurik et al., 2014; Sardinha et al., 2012; Stringhini et al., 2012; Yoon et al., 2006) of studies of women, a relationship between lower education and central obesity was found, with a pooled OR of 1.7 (95% CI 1.3, 2.1), I^2= 82.5%. This was 50.0% (6/12) (Cameron et al., 2003; Marques-Vidal et al., 2008; Pérez-Hernández et al., 2017; Rurik et al., 2014; Sardinha et al., 2012; Stringhini et al., 2012) for studies of men, with a pooled OR of 1.3 (95% CI 1.1, 1.6), I^2= 74.4%. Similar to the results for BMI, among women there was more likely to be an association between lower levels of education and increased odds of central obesity than among men (OR women vs men 1.63 (95% CI 1.05, 2.54)) (Table 4). At least one study of every region reported on WC, except for Western Asia, Northern America and Southern America. There were no clear differences in the effect sizes or the direction of the association between different regions; however, it was not possible to formally test this due to a small amount of studies. There was no evidence of publication bias in the meta-analysis using Egger's test (p=0.652) (funnel plot is shown in Fig. S3).

Table 2B
Meta-regression to confirm regional differences for the association between education and total obesity defined by BMI $\geq$30 kg/m^2, in a subset of studies modelling RII (n=5 studies) and OR with three to four educational categories (n=30 studies).

	Subset of RII studies included in meta-analysis OR (95% CI)	Subset of OR studies with three or four educational categories included in meta-analysis OR (95% CI)
Women		
Northern vs Western Europe	0.50 (0.36, 0.68), I^2=31.42%	0.72 (0.52, 1.00), I^2=74.75%
Northern vs Southern Europe	0.37 (0.27, 0.51), I^2=20.31%	0.59 (0.40, 0.88), I^2=91.81%
Men		
Northern vs Eastern Europe	1.00 (0.41, 2.42), I^2=67.83%	1.06 (0.64, 1.75), I^2=45.21%
Northern vs Southern Europe	0.77 (0.40, 1.51), I^2=67.05%	0.88 (0.66, 1.16), I^2=74.00%

OR, odds ratio; CI, confidence interval. Only the estimates of statistically significant differences between regions are shown here; however, comparisons of all regions that have enough data points are shown in Table S5.

Table 3
Association between education and central obesity defined by WC > 102 cm for men and WC > 88 cm for women for the lowest vs the highest educational categories.

Country (year of survey)	N	Association with central obesity (effect size (95% CI)) Women	Men
Eastern Europe (total inverse associations)		*1 out of 1 (100%)*	*1 out of 1 (0%)*
Hungary (Rurik et al., 2014) (2013) ‖	40,331	OR 2.6 (2.4, 2.9)†	OR 1.2 (1.1, 1.4)†
Northern Europe (total inverse associations)		–	*0 out of 1 (0%)*
Denmark (Nielsen et al., 2005) (2003)	783	NR	OR 1.0 (0.6, 1.7)
Western Europe (total inverse associations)		*2 out of 3 (66.7%)*	*2 out of 3 (66.7%)*
France (Czernichow et al., 2004) (1996) ‖	6705	OR 0.9 (0.6, 1.3)	OR 1.2 (0.9, 1.8)
Switzerland (Marques-Vidal et al., 2008) (2003) ‖	6186	OR 2.6 (2.0, 3.5)†	OR 1.4 (1.0, 2.0)†
Switzerland (Stringhini et al., 2012) (2006)	6303	RII 2.6 (2.1, 3.3)†	RII 1.5 (1.2, 1.9)†
Southern Europe (total inverse associations)		*3 out of 4 (75%)*	*2 out of 4 (50%)*
Greece (Tzotzas et al., 2010) (2003) ‖	16,073	OR 1.1 (0.9, 1.4)	OR 1.0 (0.8, 1.4)
Portugal (Camões et al., 2010) (2008)	1621	RR 2.0 (1.4, 3.3)†	RR 0.8 (0.6, 5.0)
Portugal (Sardinha et al., 2012) (2009) ‖	6908	OR 3.3 (2.6, 4.2)†	OR 1.6 (1.1, 2.2)†
Spain (Pérez-Hernández et al., 2017) (2010) ‖	2699	OR 2.6 (1.8, 3.7)†	OR 1.4 (1.0, 2.0) vs l†
Eastern Asia (total inverse associations)		*2 out of 2 (100%)*	*0 out of 2 (0%)*
South Korea (Yoon et al., 2006) (1998) ‖	7962	OR 2.9 (2.0, 3.9)†	OR 0.8 (0.5, 1.1)
South Korea (Ko et al., 2015) (2010)	6178	PR 2.5 (1.7, 3.3)†	PR 0.8 (0.6, 1.0)
Oceania (total inverse associations)		*1 out of 1 (100%)*	*1 out of 1 (100%)*
Australia (Cameron et al., 2003) (2000) ‖	11,247	OR 2.7 (1.6, 4.4)†	OR 2.3 (1.7, 3.2)†
Total inverse associations of all studies		*9 out of 11 (81.8%)*	*6 out of 12 (50.0%)*
Meta-analysis	**98,111**	***1.7 (1.3, 2.1),*** ***I^2= 82.5%***	***1.3 (1.1, 1.6),*** ***I^2= 74.4%***

N, sample size; CI, confidence interval; OR, odds ratio; h, highest education; l, lowest education; NR, not reported; RII, relative index of inequality; RR, risk ratio; PR, prevalence ratio. Only the estimate of the most recent year and of the lowest vs the highest or the highest vs the lowest education categories are shown here; however, all estimates are shown in Table S4. †Results that show an inverse association (i.e. an association between lower education and obesity) based on statistical significance. ‖ Included in meta-analyses and meta-regression analyses (Fig. 2 and Table 4).
*Studies are ordered in the same way as Tables 1 and 3, based on region and date of survey.

Comparing the results for BMI and WC

15 studies reported on both BMI and WC in the same sample. Eight of these reported on both men and women and had comparable educational categories and were included in the meta-analysis (Fig. 2). The pooled ORs of total obesity were larger for both men and women (respectively, 1.66 (95% CI 1.31, 2.10) and 2.52 (95% CI 2.04, 3.11)) than for central obesity (1.32 (95% CI 1.09, 1.59) for men and 2.15 (95% CI 1.60, 2.88) for women). Meta-regression indicated that men were less likely to have an association between lower education and central obesity compared with total obesity (OR central vs total obesity 0.79 (95% CI 0.60, 1.03)) (Table 4). This was less so the case among women (OR central vs total obesity 0.84 (95% CI 0.48, 1.47)).

Table 4
Meta-regression of a subset of studies reporting an OR for both BMI and WC for the association between education and obesity stratified by gender and obesity measure.

Meta-regression WC vs BMI	Women (pooled OR (95% CI))	Men (pooled OR (95% CI))
Not adjusted	0.84 (0.54, 1.33), I^2=86.61%	0.79 (0.53, 1.18), I^2=79.23%
Adjusted for region and number of educational categories of the studies	0.84 (0.48, 1.47), I^2=90.34%	0.79 (0.60, 1.03), I^2=58.22%
Meta-regression women vs men	**BMI (OR (95% CI))**	**WC (OR (95% CI))**
Not adjusted	1.52 (1.02, 2.29), I^2=79.55%	1.63 (1.05, 2.54), I^2=86.47%
Adjusted for region and number of educational categories of the studies	1.53 (0.96, 2.44), I^2=82.43%	1.64 (0.97, 2.76), I^2=88.29%

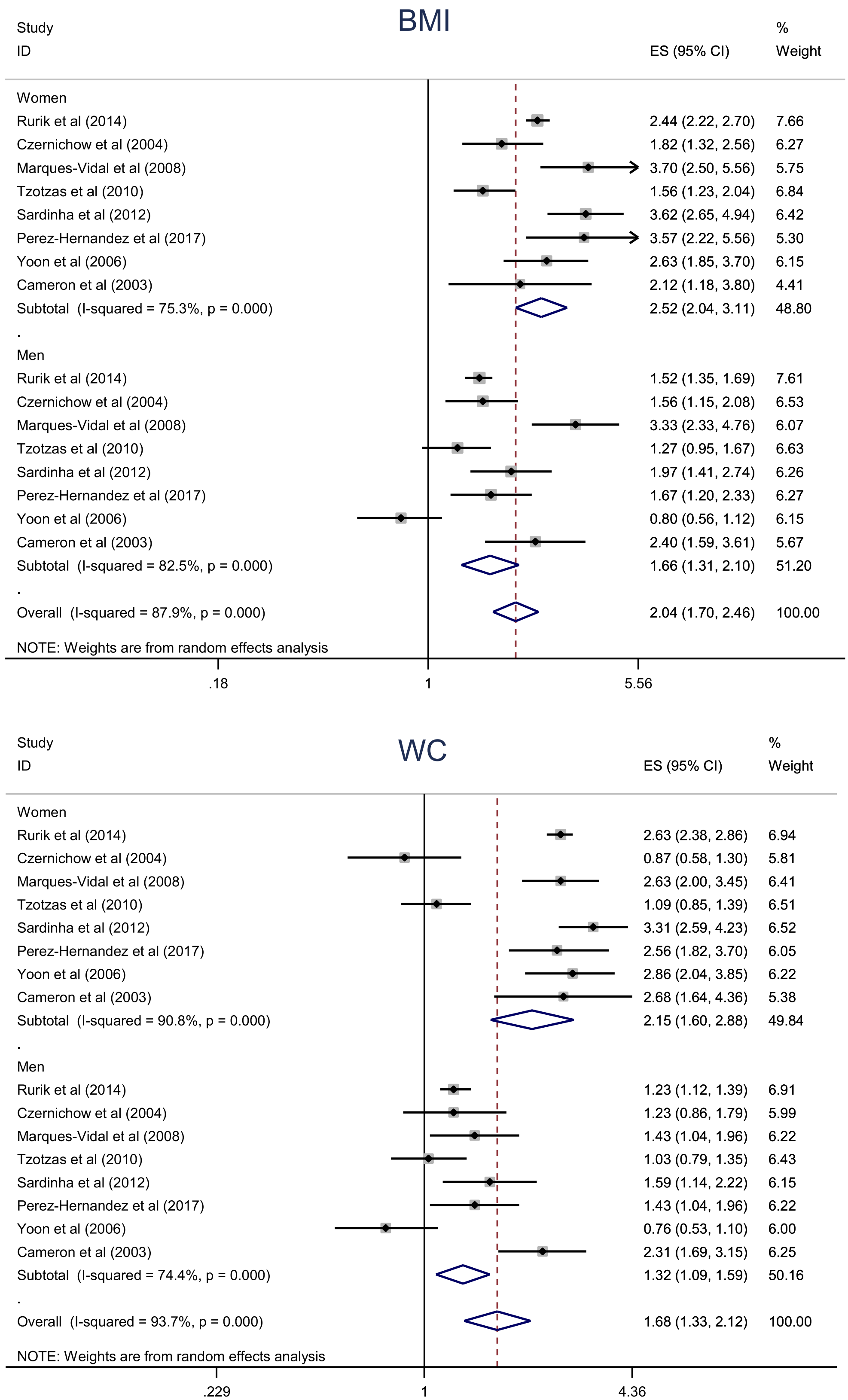
OR, odds ratio; CI, confidence interval. Based on eight studies that reported OR and that used three or four educational categories. Only the effect sizes of the lowest vs the highest education categories were included in the meta-analysis and meta-regression.

Discussion

This SLR investigated how the association between education and obesity varies depending on the measure used to identify obesity, for men and women and between different regions of the OECD. The results show that, in OECD countries, the association between lower education levels and total and central obesity is stronger among women than men. Among men, more studies reported an association between lower education and total obesity compared with central obesity. Moreover, the association between lower education and total obesity was stronger among Southern compared with Northern European women.

The results of this SLR are similar to those found in a previous SLR, published in 2017, looking at the associations between multiple measures of SEP across life (e.g. parents or own occupation, income, education or material possessions) and obesity. Men and women with a lower life course SEP had a higher mean BMI; however, mean WC was lower among men with a lower compared to a higher life course SEP, whereas the opposite was seen for women (Newton et al., 2017). This may suggest that educational inequalities manifest differently in men and women due to occupational differences. Research has shown that lower SEP was linked to increased occupational physical activity among men (i.e. manual occupations), but not among females (i.e. administrative or caring occupations) (Beenackers, Kamphuis, & Giskes, 2012; Stalsberg & Pedersen, 2018) Increased occupational physical activity in men with lower education levels may lead to increased lean muscle mass (Bann et al., 2014), resulting in higher BMI but normal WC. By contrast, this happens less often in women (Wardle et al., 2002).

In general, the relationship between a lower SEP and obesity defined by BMI in high income countries have been confirmed by other SLRs among women, whereas more inconsistent results were found among men (Cohen, Rai, Rehkopf, & Abrams, 2013a; El-Sayed et al., 2012; Kim et al., 2017; McLaren, 2007; Newton et al., 2017; Senese et al., 2009); two of these focussed specifically on education (Cohen, Rai, Rehkopf, & Abrams, 2013a; Kim et al., 2017). Mechanisms through which education and SEP may affect obesity are outlined in the 'social determinants of health' model (Whitehead and Dahlgren, 1991), where education influences living and working conditions and social and community networks which, in turn, influence individual lifestyle factors and health. This has been supported by studies that show that in high-income countries higher educated individuals eat healthier diets (Irala-Estévez et al., 2000) and perform more leisure time physical activity (Stalsberg and Pedersen, 2018), presumably due to increased health literacy (Hulshof et al., 1991) and having better financial and emotional support (Berkman, 1995). The 'health belief model' might help us to understand the stronger association between education and obesity observed among women compared with men, where perceived severity, susceptibility, benefits and barriers influence weight control practices (Saghafi-Asl



*Studies are ordered in the same way as Tables 1 and 3, based on region and date of survey.

Fig. 2. Meta-analyses of studies reporting an OR for both BMI and WC for the association between education and obesity, stratified by measure and gender.

et al., 2020). Compared with men, women experience increased weight-related ideals, where a lower weight is seen as healthier and more attractive (perceived benefit of weight control practices). These weight-related ideals might be more difficult to sustain for women with a lower SEP (Jeffery & French, 1996) (perceived barrier for weight control practices). Because of this, education may influence weight to a greater extent in women; however, this needs further investigation.

Our review also indicated geographical variation regarding the influence of gender on the relationship between education and obesity defined by BMI; in women, the association between lower education and obesity was stronger in Southern compared with Northern Europe. This difference was not seen in men. This might be explained by the fact that Northern European countries (compared to other OECD countries) have had a longstanding progressive agenda for gender equality, with concrete policies to ensure women and men from all educational backgrounds are equally represented in the workforce (Borchorst & Siim, 2008; OECD, 2018). This has proven effective as figures show that compared to other OECD countries, Northern European countries have smaller gender gaps in labour market participation and working hours, and mothers are more likely to work (Bann et al., 2014). In contrast, women with lower levels of education in Southern Europe often have a more 'traditional' role and participate less in the workforce, which might be reinforced by limited opportunities to work part-time and less financial support for child care (Jurado-Guerrero & Naldini, 2018). Participating in the workforce increases social support, which may lead to increased empowerment to access health care services, and increase income levels to support a healthy lifestyle (Berkman, 1995).

There are some disadvantages to using education as an indicator for SEP. Firstly, the meaning of education differs for different birth cohorts; trends of improving educational opportunities have resulted in increased educational attainment for women and ethnic minorities in recent decades, which means that people with lower levels of education are overrepresented in older birth cohorts (Galobardes et al., 2006). These effects have not been accounted for in the included studies. Although using a publication cut-off of the year 2000 might have reduced these effects, there were still studies that included data from 1987 (Table 1) and, thus, there will be some generational differences unaccounted for. One of the inclusion criteria was participants aged ≥16 years; as some included participants might not have finished their formal education yet, in some studies the highest levels of educational attainment may be underrepresented. Nonetheless, the results of four studies that included participants aged ≥16 years (Devaux & Sassi, 2013; Martorell et al., 2000; Ogna et al., 2014; Tchicaya and Lorentz, 2012) do not differ substantially from the rest of the studies that included participants aged ≥18 years. Furthermore, qualifications and quality of education are not standardised across different countries and therefore makes comparisons across countries challenging (OECD, 2020b). However, the advantages of using education as an indicator in observational studies is that it is easy to measure and usually has a high response rate when assessed in clinical and epidemiological studies (Galobardes et al., 2006). Although BMI and WC are the most commonly used measures of obesity in research and clinical settings, it is recognised that these measures lack some precision and do not directly measure fat mass. The relationship between life course SEP and body composition using more sophisticated, but more expensive, measures, such as DXA, computer tomography and magnetic resonance imaging, is assessed in another SLR (Staatz et al., 2019).

Most studies presented low or moderate risk of bias in most of the domains of the QUIPS tool (Table S6). When studies relied on self-reported height and weight to calculate BMI, they scored a 'moderate risk of bias' in the outcome measurement domain, as self-reported height and weight data are prone to social desirability bias and consequently measurement error bias (i.e. underreporting of weight and over reporting of height) (Stommel and Schoenborn, 2009). Moreover, many studies presented no information about the reference category of obesity (healthy weight or non-obese), which impacted the score on the 'statistical analysis' domain. Despite these variabilities, the results were mostly consistent between studies and, therefore, unlikely to influence our conclusions. Most studies were cross-sectional and reverse causality cannot be ruled out (i.e. childhood obesity leads to lower education), a possibility that is supported by previous studies that showed that a proportion of the association is accounted by the reverse causation (Kim et al., 2017; Howe et al., 2020). Because some studies have pooled data from multiple years, the survey years range from 1987 to 2016; in this time period, obesity has increased substantially (Afshin et al., 2017). Variability in obesity prevalence (Table S2) across and within countries may partly be due to variations in survey years. Sample selection bias may also play a role; for example, the national prevalence of obesity in France was estimated to be 11.9% (95% CI 11.5%, 12.3%) in 2003 (Charles et al., 2008) whereas Roskam et al. (2010) reported an obesity prevalence of 6.0% in 2004, indicating that the study sample is not generalizable to the whole population of France at that time. Lastly, the Egger's test has been criticised because type 1 errors are likely to occur, leading to an overestimation of the presence of publication bias (Peters et al., 2006; Schwarzer et al., 2002; Sterne et al., 2000). However, as none of the results from our Egger's tests were statistically significant, i.e. they did not indicate publication bias, this was not a concern in our review. Nonetheless, it is important to note that we only included formally published data in English language journals, and may therefore have missed some studies that were published in other languages.

A strength of this systematic literature review is that established protocols were followed and a large number of studies were synthesised. Furthermore, meta-analyses and meta-regression were performed in a subset of studies to formally test differences between measures, gender and region. To take into account the heterogeneity in definitions of education, it was decided to perform subgroup meta-analysis in studies with a similar education definition, where studies were combined based on the number of educational categories. This means that studies that did not define education based on three or four categories or did not estimate the relationship between education and obesity using RII were omitted for the meta-analyses; as a result, it is important to interpret the findings of the meta-analysis with some caution. Statistical heterogeneity was slightly reduced when adjusting for region or educational categories; the high degree of the remaining statistical heterogeneity might be caused by other factors, such as the inconsistent reporting of the obesity reference category. Moreover, only studies from OECD countries were included so that we could compare results of countries of a similar economic status. However, this does limit generalisability of our findings to countries outside the OECD. Although OECD countries are all considered high-income countries, there are still large differences socioeconomically, with the highest gross domestic product (GDP) of US $ 118,582 in Luxembourg and the lowest GDP of US$ 14,994 in Colombia (OECD, 2021a) in 2020 and in income inequality, with a Gini coefficient (an indicator of income inequality, where zero would represent an equal income for everyone) of 0.37 in the UK in 2019 and 0.26 in Belgium in 2018 (OECD, 2021b). Moreover, there are institutional and cultural differences between OECD countries, such as costs of further education, equal opportunities for men and women and compulsory military service (e.g. in South Korea and Israel) that may reflect educational attainment differences in different countries (OECD, 2020b). This means that direct comparison between countries may be problematic. Lastly, the majority of studies adjusted their analyses for relevant covariates such as age, gender (if applicable), other socioeconomic indicators and lifestyle factors.

This SLR has shown that both BMI and WC are important when researching obesity inequalities, particularly when examining gender differences. This might also be the case for other more accurate indicators (i.e. body fat percentage); therefore, there is a need to ensure a wide range of indicators of obesity are included in population surveys and public health interventions.

When devising strategies to prevent and treat obesity, it is important to take into account educational differences. A previous SLR indicated that targeted weight loss interventions for low SEP individuals delivered at schools, communities and primary care settings were effective in reducing weight in the short term (Bambra, Hillier, & Cairns, 2015). Further research should also investigate whether interventions such as raising the compulsory education age reduces obesity levels over time.

In conclusion, this review strengthened the knowledge that lower educational attainment is associated with obesity, particularly for women. In addition, this study found that the association differed depending on the measure of obesity used: among men, there was more consistent evidence of the association between lower educational attainment and total obesity than central obesity, indicating the importance of using multiple measures of adiposity in future research and public health interventions.

CRediT authorship contribution statement

Rozemarijn Witkam: Conceptualization, Methodology, Formal analysis, Writing – original draft. **James M. Gwinnutt:** Conceptualization, Methodology, Formal analysis, Supervision, Writing – review & editing. **Jennifer Humphreys:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Julie Gandrup:** Formal analysis, Writing – review & editing. **Rachel Cooper:** Writing – review & editing. **Suzanne M.M. Verstappen:** Conceptualization, Methodology, Supervision, Writing – review & editing.

Declaration of competing interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2021.100884.

Ethics statement

As we did a systematic literature review, no ethics approval and consent were needed for this study.

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