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Income and obesity: what is the direction of the relationship? A systematic review and meta-analysis

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1 **Income and obesity: what is the direction of the relationship? A systematic review and**
2 **meta-analysis**

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20 ABSTRACT

21 **Objective:** In light of the obesity epidemic, there is a growing body of literature determining
22 a relation between income and obesity. To assess this association, however, most studies
23 refer to causation processes (i.e. low income increases the risk for subsequent obesity) and
24 neglect the existence of a reverse causality (i.e. obesity increases the risk for subsequent low
25 income). This review was performed to give an overview of causation and selection
26 processes in the link between income and obesity.

27 **Design:** Systematic review and meta-analysis.

28 **Methods:** A systematic literature search was conducted in the databases Medline, PsychInfo,
29 Sociological Abstracts, International Bibliography of Social Sciences and Sociological Index to
30 identify prospective cohort studies with quantitative data on the relation between income
31 and obesity.

32 **Results:** 14 studies on causation and 7 studies on selection were found within the five
33 databases. Meta-analyses revealed that lower income is associated with subsequent obesity
34 (odds ratio: 1.27, CI-95: 1.10 to 1.47; risk ratio: 1.52, CI-95: 1.08 to 2.13), though the
35 significance weakened once adjusted for publication bias. Studies on selection indicated a
36 more consistent relation between obesity and subsequent income, even after taking
37 publication bias into account (SMD: -.15, CI-95: -.30 to -.01). Sensitivity analyses implied that
38 the association is influenced by obesity measurement, gender, length of observation and
39 study quality.

40 **Conclusions:** Findings suggest that the association between income and obesity is
41 bidirectional. Therefore, both causation *and* selection processes need to be addressed in
42 order to fully grasp the relation between income and obesity.

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KEYWORDS: Income, obesity, causation, selection

Strengths and limitations of this study

- This is the first systematic review that gives an overview of causation and selection processes in the link between income and obesity.
- Although only studies were included that examined the relation between income and obesity longitudinally, the question of causality cannot be fully answered.
- The evidence is restricted to a few countries as all included studies have their origin in western societies, most of them in the United States.

INTRODUCTION

Obesity is a major public health issue. According to a recent trend analysis in 200 countries, age-standardized prevalence of obesity increased from 3.2% to 10.8% between 1975 and 2014 in men, and from 6.4% to 14.9% in women [1]. In this study, like in many others, obesity was defined by a body mass index (BMI) of 30 or higher. Obesity is a major risk factor for all-cause mortality, a number of non-communicable diseases, and reduced quality of life [2-6].

Within social epidemiological research, income (as an indicator of the socio-economic status (SES)) was found to be inversely associated with obesity [7-9], though this relationship can be interpreted in two directions: (1) the causation hypothesis that explains lower income as a cause for subsequent obesity, and (2) the selection hypothesis that focuses on the selection of obese individuals into lower income groups.

In order to describe why people with lower income are more vulnerable for obesity, the framework of social determinants of health indicates that material conditions confine one's access to (healthy) food and health care [10-11], while also influencing health-related behaviors (i.e. dietary behaviors and physical activity) [12], and psychosocial factors that derive from relative deprivation (e.g. control over life, insecurity, social isolation, stress) [13-15].

One important argument for the selection hypothesis is stigma. Studies suggest that the obese are more likely to be perceived as lazy, unsuccessful, weak-willed, and undisciplined [16-19]. Such negative stereotypes are often internalized by those afflicted leading to self-stigma, reduced psychological resources as well as mental health problems [20]. There is

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77 also evidence that the obese face various weight penalties in the labor market which include
78 higher job insecurity, lower chances for a job, and general discrimination [21-24].

79 This work builds upon a former review that examined the relative importance of causation
80 and selection in the association between education and overweight/obesity [25]. Though
81 education and income can be conceptualized under the broader term of the SES, specific
82 dimensions of SES should not be regarded as interchangeable in their relation to obesity
83 [26], as magnitude of the association differs and the dimensions have different implications
84 for public health.

85 This systematic review aims to assess both directions in the link of income and obesity, in
86 order to address the relative importance of causation and selection processes in explaining
87 the relationship.

88

89 **METHODS**

90 A systematic review of peer-reviewed studies that addressed the relationship between
91 income and obesity was performed and completed in January 2017. To enhance the
92 reproducibility of our findings, this review was conducted on the basis of the PRISMA
93 guidelines [27]. A corresponding checklist is available online (please see supplementary file
94 1).

95 *Medline* and *PsychInfo* were chosen as the main health-related databases. Moreover, the
96 sociological databases *Sociological Abstracts*, *International Bibliography of Social Sciences*
97 and *Sociological Index* were considered.

98 For the search, the following equation was used: (adipos* OR obes* OR body-mass-index OR
99 BMI OR "waist-hip ratio" OR WHR OR "skinfold thickness") AND ("social status" OR socio-

100 economic OR socioeconomic OR inequalit* OR income OR earning* OR wage*) AND
101 (longitudinal OR prospective OR “panel stud*” OR “cohort stud*”).

102

103 **Inclusion and exclusion criteria**

104 Original studies had to be published in a peer-reviewed journal and contain quantitative data
105 on the relation between income and obesity. Studies were excluded if participants were not
106 drawn as part of the general population, if the exposure (i.e. lower income, obesity) was
107 ascertained within a global measure (e.g. neighborhood SES or metabolic syndrome), or
108 examined without a corresponding control group (i.e. higher income, non-obese). Moreover,
109 studies that used overweight as their main outcome were omitted since obesity was found
110 to be more predictive of health-related outcomes [28-29]. Studies were considered if they
111 focused on obesity, regardless of measurement (e.g. BMI \geq 30, age and sex-specific
112 percentiles, z-scores). Finally, only studies with a prospective design were considered, since
113 a clear direction of causation or selection can hardly be drawn from cross-sectional
114 investigations. In case of disagreements on inclusion or exclusion, respective records were
115 discussed by the two reviewers (TJK and NMR, please see acknowledgement). If a consensus
116 could not be achieved, a third reviewer (OK) was involved until an agreement was found.

117

118 **Data extraction**

119 Studies were assessed and the following study information retrieved: author(s), study name,
120 country or region, type of hypothesis, population type, sample size, age at baseline, gender
121 proportion, measurement of income and obesity as well as length of observation. In case
122 multiple ascertainties of income were reported within a single study, the most

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3 123 appropriate measure was chosen. For instance, in studies with a children population,
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5 124 household income better describes the child’s financial situation, while measures of
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7 125 parental, paternal and maternal income were the next best alternative measures,
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9 126 respectively. In studies with adults, however, personal wages were the most appropriate
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11 127 measure to characterize one’s disadvantage on the labor market, followed by earnings and
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13 128 household income, respectively.
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20 130 **Data analyses**

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22 131 Since most studies testing the causation hypothesis used odds ratios (ORs) and
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24 132 corresponding 95%-confidence intervals (CI) in their analyses, all statistics were converted to
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26 133 log odds and standard errors (SE). In case ORs, log odds or SE were not readily available,
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28 134 effect sizes were estimated on basis of alternative statistics such as t-value *or* p-value *and*
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30 135 sample size. In contrast to the studies on causation, which mostly referred to a binary
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32 136 outcome (obese vs. non-obese), studies on selection rather examined a continuous variable
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34 137 (income), mostly based on unstandardized regression coefficients. In order to provide a
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36 138 better comparability in the meta-analysis, these coefficients were transformed into
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38 139 standardized mean differences (SMD). Random-effect models were employed, and pooled
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40 140 estimates weighted with the *restricted maximum-likelihood estimator* [30]. Cochran’s Q test
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42 141 and Higgin’s I²-measure were calculated to evaluate the proportional degree of
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44 142 heterogeneity. Finally, stratified meta-analyses were run to reveal potential moderating
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46 143 effects (i.e. study region, population type, measurement of obesity, gender, time lag
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48 144 between baseline and follow-up, and study quality).
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To test impeding publication bias, *Egger's regression test* and the *trim-and-fill-method* were used [31-32]. The visualization and calculation of effect sizes, pooled estimates, sensitivity analyses and publication bias were executed with R and the packages 'esc' and 'metafor' [30, 33].

Study quality

In order to assess the quality of non-randomized studies in meta-analyses, we referred to the Newcastle-Ottawa Scale for cohort studies (NOS) [34]. The NOS includes a total of 9 items across three dimensions (i.e. sample selection, comparability of cohorts, the assessment of outcome). However, two of 9 criteria could hardly be applied to studies testing the selection hypothesis as they focused on an outcome that was explicitly non-health related. Therefore, the two questions, (a) if the outcome of interest was not present at start of study, and (b) if the follow-up duration was long enough for the outcome to occur, were excluded to provide a better precision of the NOS-checklist. The application of the NOS checklist was carried out by TJK and OK and discussed in case of divergences.

FIGURE 1 ABOUT HERE

RESULTS

Literature search

The inclusion and exclusion of studies is shown in Figure 1. Through the initial screening of all five databases, 3,955 records were found. After removing duplicates, 3,027 titles and

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3 167 abstracts were screened for eligibility. Hereafter, another 2,941 records were excluded. The
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5 168 full-texts of the remaining 86 records were then screened for eligibility, from which 65 were
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7 169 dismissed. A detailed summary of reasons of exclusion is accessible online (please see
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10 170 supplementary file 2). Finally, 21 articles met all predefined inclusion criteria and were
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12 171 considered for meta-analysis. In an additional screening of the references of included studies
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14 172 no further eligible records were found. Overall, 14 studies addressed the causation and 7 the
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16 173 selection hypothesis (see Table 1 for an overview of the included studies). Information about
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18 174 the quality of the studies according to the NOS checklist is available online (please see
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21 175 supplementary file 3).

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27 177 Table 1: Description of included studies

Author, Study	Country, region	Direction	Population	Sample size	Age at Baseline	Gender (Male %)	Income measure	Obesity measure	Follow-up duration
Brophy 2009 [35], MCS	UK (national)	Causation	Children	17,561	5 (mean)	NA	Income	95 th BMI-Percentile	4 Years
Chaffee 2015 [36], NLSY79	USA (national)	Causation	Women	4,780	40 (mean)	0	Household income	BMI ≥ 30	31 Years
Chia 2013[37], NLSY79	USA (national)	Causation	Children	3,958	8.6 (mean)	51.3	Family income	95 th BMI-Percentile	6 Years
Demment 2014 [38], BMHP1	USA (NY State)	Causation	Children	595	2 (mean)	53.0	Family income	BMI z-scores	16 Years 2 Years
Goisis 2016 [39], MCS	UK (national)	Causation	Children	11,965	5 (mean)	50.8	Family income	95 th BMI-Percentile	8 Years
Hoyt2014 [40], CYGNET	USA (national)	Causation	Girls	174	8-10 (range)	0	Household income	95 th BMI-Percentile	4 Year
Jo 2014 [41], ECLS-K	USA (national)	Causation	Children	9,287	5.9 (mean)	0.51	Family income	95 th BMI-Percentile	9 Years
Kakinami 2014 [42], QLSCD	Canada (Québec)	Causation	Children	698	9.2 (mean)	45.6	Household income	85 th BMI-Percentile	12 Years
Kim 2010 [43], PSID	USA (national)	Causation	Adults	6,312	41.9 (mean)	0.85	Log hourly wage	BMI ≥ 30	4 Years
Lee 2009 [44], Add Health	USA (national)	Causation	Adolescents	9,730	12-19 (range)	49.2	Poverty status	BMI ≥ 30	7 Years

Lee2014 [45], SECCYD	USA (national)	Causation	Children, adolescents	1,150	3-15 (range)	50.7	Family income	95 th BMI-Percentile	15 Years
Pearce 2015 [46], NCMP, MCS	UK (national)	Causation	Children	2,620,422	3-7 (range)	51.2	Household income	95 th BMI-Percentile	4 Years
Salsberry 2009 [47], NLSY79	USA (national)	Causation	Young Women	3,707	14-21 (range)	0	Income	BMI \geq 30	33 Years
Strauss 1999 [48], NLSY	USA (national)	Causation	Children	2,913	0-8 (range)	56.0	Family income	95 th BMI-Percentile	6 Years
Amis 2014 [49], Add Health	USA (national)	Selection	Adolescents	11,308	16 (mean)	47.2	Annual income	95 th BMI Percentile	13 Years
Baum 2004 [50], NLSY	USA (national)	Selection	Young Adults	51,500 (PY)	28-31 (range)	51.7	Log real wage	BMI \geq 30	17 Years
Cawley 2005 [51], WES	USA (national)	Selection	Women	874	18-54 (range)	0	Earnings	BMI \geq 30	6 Years
Conley 2006 [52], PSID	USA (national)	Selection	Adults	3,340	46-49 (range)	46.5	Log wages	BMI \geq 30	18 Years
Han 2011 [53], NLSY79	USA (national)	Selection	Adolescents	1,974	16-20 (range)	54.1	Hourly wage	BMI \geq 30	12 Years
Larose 2016 [54], NPHS	Canada (national)	Selection	Adults	3,993	40.2 (mean)	50.71	Hourly wage rate	BMI \geq 30	6 Years
Mason 2012 [55], NLSY97	USA (national)	Selection	Young Adults	2,427	12-17 (range)	50.72	Income	BMI \geq 30	9 Years

Abbreviations: **Add Health** = National Longitudinal Study of Adolescent to Adult Health; **BMHP1** = Bassett Mothers Health Project; **BMI** = Body Mass Index; **Cygnnet Study** = Cohort Study of Young Girls Nutrition, Environment and Transitions; **ECLS-K** = Early Childhood Longitudinal Study Kindergarten; **MCS** = Millennium Cohort Study; **NA** = Not available; **NLSY (97)** = U.S. National Longitudinal Survey of Youth (1997); **NPHS** = Canadian National Population Health Survey; **PSID** = Panel Study of Income Dynamics; **QLSCD** = Québec Longitudinal Study of Child Development; **PY** = Person-years; **SECCYD** = Study of Early Child Care and Youth Development; **WES** = Women's Employment Study

Studies testing the causation hypothesis

In 10 of the studies investigating the causation hypothesis, odds ratios (OR) were calculated, while in 4 studies risk ratios (RR) were documented. Pooled estimates indicate the likelihood or risk for subsequent obesity among people with a low income compared with those having a high income (Figure 2). Overall, results reveal a higher chance (OR: 1.27, CI: 1.10 to 1.47) and an increased risk (RR: 1.52, CI: 1.08 to 2.13) for obesity among low income groups.

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190 Across studies referring to ORs, four of the 10 studies revealed statistically significant effects.
191 In terms of RRs, two out four were significant. None of the studies analyzing causation
192 indicated a positive relationship. For the 10 studies with ORs, a statistically significant
193 publication bias was detected (please see supplementary file 4), Egger’s regression test: $z =$
194 5.0846 , $p < .0001$). After the imputation of studies to correct for publication bias, the OR
195 decreased considerably and became statistically insignificant (adjusted OR: 1.10, CI: 0.90 to
196 1.34). No publication bias was detected for the 4 studies testing the causation hypothesis
197 with RRs (please see supplementary file 5).

FIGURES 2 AND 3 ABOUT HERE

Studies testing the selection hypothesis

202 In 7 studies that analyzed the selection hypothesis (Figure 3), the pooled estimate
203 (standardized mean difference), which expresses the size of the effect in each study relative
204 to the variability observed, was $-.15$ (CI: $-.30$ to $-.001$), implying that people with obesity had
205 a significantly lower income, when compared to the non-obese. This effect was statistically
206 significant in five studies, while one study found a positive effect [54], and one study
207 revealed a relationship that was statistically insignificant [53]. Through the test for funnel
208 plot asymmetry, no publication bias was detected and thus no imputation considered
209 (please see supplementary file 6).

Sensitivity analyses

212 In order to reveal potential moderating effects, stratified meta-analysis were performed
213 (Table 2). Sensitivity analyses showed that the majority of included studies were conducted
214 in the United States (causation: 71%; selection: 85%), whereas the only other study
215 countries were the United Kingdom (causation: 21%) and Canada (causation: 7%; selection:
216 14%). Furthermore, the stratification for population revealed that causation mostly relied on
217 children populations (79%), while studies on selection exclusively focused on adults. The
218 results for both region and population, however, remained fairly inconsistent, and did not
219 reveal a clear trend.

220 According to studies on the causation hypothesis, higher effect sizes were evident when the
221 height and weight of participants was actually measured instead of using a self-report (OR:
222 1.48, CI: 1.04 to 2.10; RR: 1.73, CI: 1.46 to 2.06), when the observation period exceeded 10
223 years (OR: 1.59, CI: 1.11 to 2.27), and when the study quality was assessed as high (OR: 1.40,
224 CI: 1.06 to 1.83; RR: 1.88, CI: 0.95 to 3.74). Subgroup analyses for gender could not be
225 performed for studies analyzing causation since gender specific results were not
226 documented.

227 In terms of selection, the subgroup analysis of gender showed that the relation between
228 obesity and subsequent income was more pronounced among women (SMD: -.16, CI: -.30 to
229 -.02), than men (SMD: -.07, CI: -.16 to .01). Similar to the studies on causation, it was shown
230 that a longer observation period (> 10 years) was associated with an effect size increase
231 (SMD: -.52, CI: -.62 to -.41). The same pattern was found in the rating of higher study quality
232 (SMD: -.52, CI: -.62 to -.41).

233

234 Table 2: Sensitivity analyses

	Causation hypothesis				Selection hypothesis	
	<i>n</i>	<i>OR (CI), I²</i>	<i>n</i>	<i>RR (CI), I²</i>	<i>n</i>	<i>SMD (CI), I²</i>
Overall	10	1.27 (1.10, 1.47), 90%	4	1.52 (1.08, 2.13), 83%	7	-0.15 (-0.30, -0.01), 98%
Study region						
USA	8	1.22 (1.06, 1.40), 88%	2	1.65 (0.65, 4.17), 85%	6	-0.19 (-0.34, -0.03), 97%
UK	1	1.19 (0.97, 1.45), NA	2	1.68 (1.40, 2.01), 0%	--	--
Canada	1	3.04 (1.69, 5.47), NA	--	--	1	0.04 (0.01, 0.07), NA
Population						
Children	8	1.33 (1.08, 1.64), 93%	3	1.73 (1.46, 2.06), 0%	--	--
Adolescents	1	1.25 (0.98, 1.59), NA	1	1.09 (0.95, 1.25), NA	--	--
Adults	1	1.15 (1.06, 1.25), NA	--	--	7	-0.15 (-0.30, -0.01), 98%
Obesity						
Self-report	5	1.20 (1.03, 1.41), 88%	1	1.09 (0.95, 1.25), NA	7	-0.15 (-0.30, -0.01), 98%
Measured	5	1.48 (1.04, 2.10), 84%	3	1.73 (1.46, 2.06), 0 %	-	--
Gender						
Male	--	--	--	--	6	-0.07 (-0.16, 0.01), 90%
Female	--	--	--	--	7	-0.16 (-0.30, -0.02), 93%
Observation						
< 5 years	3	1.15 (1.07, 1.25), 0%	1	1.74 (1.43, 2.12), NA	1	-0.06 (-0.10, -0.01), NA
5 – 10 years	2	1.11 (0.98, 1.25), 30%	2	1.88 (0.95, 3.74), 63%	5	-0.10 (-0.22, 0.02), 97%
> 10 years	5	1.59 (1.11, 2.27), 88%	1	1.09 (0.95, 1.25), NA	1	-0.52 (-0.62, -0.41), NA
Study quality						
Low	3	1.09 (1.00, 1.18), 57%	1	1.09 (0.95, 1.25), NA	1	-0.06 (-0.10, -0.01), NA
Medium	5	1.47 (1.04, 2.08), 90%	1	1.74 (1.43, 2.12), NA	5	-0.10 (-0.22, 0.02), 97%
High	2	1.40 (1.06, 1.83), 40%	2	1.88 (0.95, 3.74), 63%	1	-0.52 (-0.62, -0.41), NA

Abbreviations: n = number of studies; NA = Not available; OR = Odds ratios; RR = Risk ratios; SMD = Standardized mean difference; UK = United Kingdom; USA = United States of America

DISCUSSION

Main findings

The results of this review revealed statistically significant effects of income on obesity (causation) as well as of obesity on income (selection). Therefore, individuals exposed to lower income are more likely to develop obesity, and the obese have lower wages when compared to their non-obese counterparts. The consideration of impending publication bias, however, indicated that the effect of lower income on obesity is less consistent than implied by the initial results of the meta-analysis.

Following the theoretical frameworks of the social determinants of health and stigma research, there are various pathways in which income relates to obesity and vice versa: With reference to the perspective of causation, income does not only restrict one's access to (healthy) food, but is also linked to higher health literacy which, in turn, is positively related to health promoting behaviors (i.e. healthy nutrition, physical activity) [12, 25]. Further, lower income is associated with higher levels of psychosocial stressors which include decreased control over life, and higher insecurity, social isolation, stress and mental disorders [10, 13-15]. By attempting to integrate the stigma theory into the model of social determinants of health, in our interpretation, the stigmatization of the obese also correlates with material (i.e. less income through weight penalty), behavioral (i.e. change in health-promoting behavior through discrimination), as well as psychosocial factors (i.e. self-stigma may inflict lower control over life, social isolation, stress, lower self-esteem) that may, again, lead to a higher risk of obesity.

According to the sensitivity analyses, it was shown that selection effects were more pronounced among women than among men. To explain these differences, Mason, for instance, suggests that obese women are not only confronted with disadvantages that derive from the stigmatization of fatness, but additionally face higher expectations to perform their gender properly [55]. With regards to the ascertainment of obesity in studies, sensitivity analyses revealed that effects of social causation were stronger when height and weight of respondents were actually measured rather than based on self-reports. As actual measurements can be considered as less biased, if compared to self-reports, it can be assumed that the overall effect of income on obesity is underestimated when self-reported measures are used. All studies investigating social selection processes were based on self-reported measures. As effect sizes were generally stronger in studies with higher quality

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scores (if compared to studies with a medium or low rating, regardless of causation or selection), the overall effects can be expected to be somewhat stronger than indicated through the meta-analytic results.

Limitations

Some methodological issues should be considered when interpreting the findings of this meta-analysis: First, the risk for missing out other relevant articles remains. Second, all included studies have their origin in western societies, most in the United States. Therefore, the evidence is restricted to a few countries, leaving out the possibility that the relationship between income and obesity plays out differently in other regions of the world. Third, and though only studies were included that examined the relation between income and obesity longitudinally (thus enabling to carve out the direction of the respective influence), the question of causality cannot be fully answered due to two main reasons: On the one hand, the methodological issue remains that (cohort) studies are not able to adjust for transitions between the individual income-status as well as the obesity-status that take place between the baseline and the follow-up survey. On the other, there is reason to believe that processes of social causation are not simply replaced by social selection during the life course, but rather coexist in one’s biography. As noted above, it can be assumed that causation and selection processes rather augment than neutralize each other, so that the link between income and obesity is likely to follow a bidirectional relationship. Fourth, and even though the subgroup analyses revealed a few factors that may moderate the relationship between income and obesity, results for the selection hypotheses were mostly based on the same subgroups.

Future research

By taking these limitations into account, future studies should aim at investigating the relation between income and obesity outside of western societies. An extended view on the association in other countries could aid in detecting cultural influences that frame the magnitude of both causation and selection effects. Moreover, and in order to clarify potential bidirectional effects between income and obesity, future research should aim at examining both causation and selection processes in a single cohort over the life course. Finally, future studies could focus on detecting other factors that may influence the relation between income and obesity for both hypotheses.

CONCLUSIONS

This review was performed to give an overview of causation and selection processes in the link between income and obesity. Meta-analyses revealed the importance of both causation and selection processes in the association between income and obesity. However, after taking publication bias into account, low income became less predictive for subsequent obesity. It can be suggested, though, that the association between income and obesity follows a bidirectional relationship.

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314 **DECLARATIONS**

315 **Authors' contributions:** TJK and OK developed the research question. TJK then conducted

316 the literature search, screened all found records and extracted the relevant data. TJK

317 performed the meta-analysis and wrote the first draft of the manuscript. OK revised the

318 manuscript. Both authors read and approved the final version of the manuscript.

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320 with the literature search and the screening.

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322 Society: Germany and the US' and is funded by the Volkswagen Foundation.

323 **Competing interests:** The authors declare that they have no competing interests.

324 **Data sharing statement:** We retrieved all data for the meta-analyses from already published

325 material. Therefore, the data is available in the respective articles.

326 **Prospero Registration number:** 42016041296

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Figures:

Figure 1: PRISMA Flowchart of included studies

Abbreviations: n = number of records

Figure 2: Pooled estimates of studies testing the causation hypothesis

Abbreviations: p = significance; RE = random effects

Figure 3: Pooled estimates of studies testing the selection hypothesis

Abbreviations: p = significance; RE = random effects; SMD = Standardized mean difference

Supplementary files:

File 1: Table: PRISMA checklist

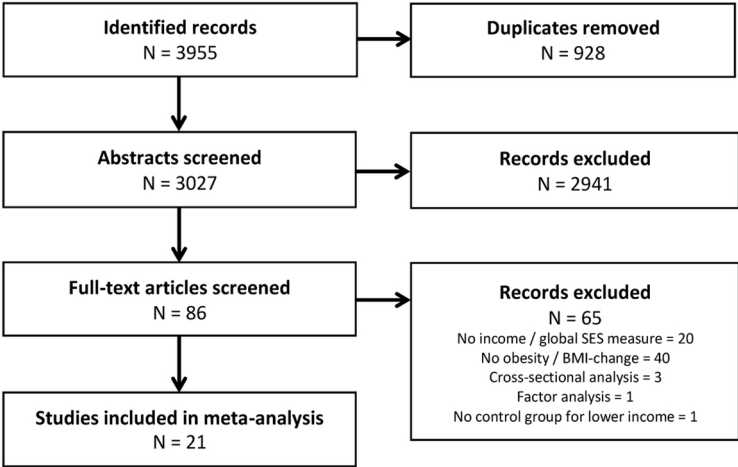
File 2: Table: Reasons for exclusion after full-text screening

File 3: Table: Table: Newcastle-Ottawa Assessment Scale for Cohort studies

File 4: Figure: Funnel plot to check for publication bias (for studies testing causation hypothesis with odds ratios)

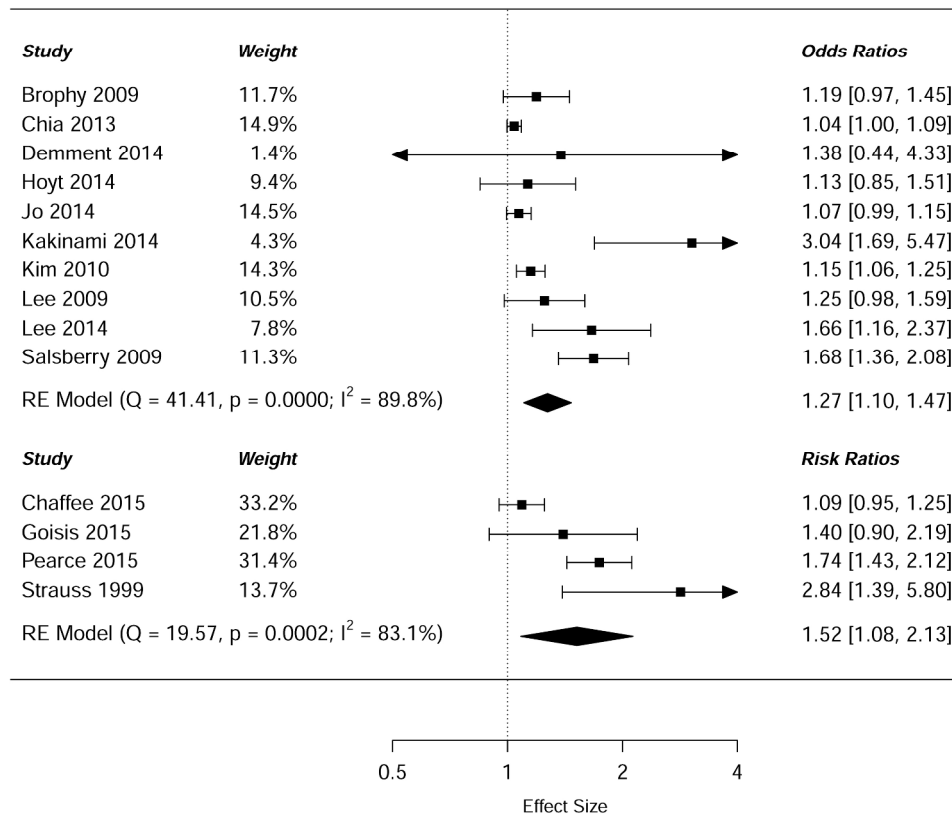
File 5: Figure: Funnel plot to check for publication bias (for studies testing causation hypothesis with rate ratios)

File 6: Figure: Funnel plot to check for publication bias (for studies testing selection hypothesis)



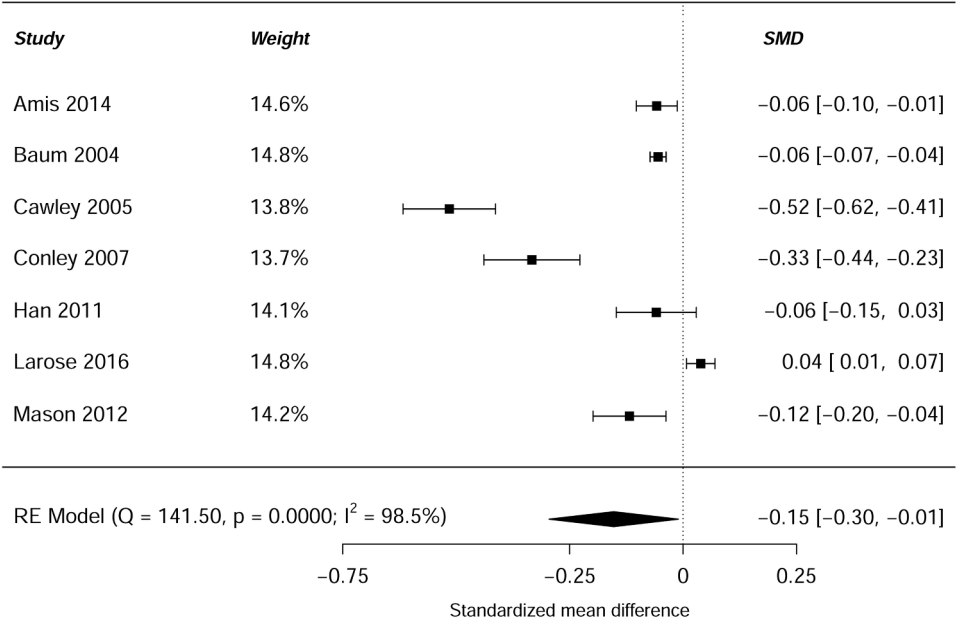
PRISMA Flowchart of included studies

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Pooled estimates of studies testing the causation hypothesis

254x254mm (300 x 300 DPI)



Pooled estimates of studies testing the selection hypothesis

215x183mm (300 x 300 DPI)

Supplemental File 2: Reasons for exclusion after full-text screening

	Author(s) (Year) Study (Journal)	Reasons for exclusion
1.	Adair LS et al. (2011) 20-Year Trends in Filipino Women's Weight Reflect Substantial Secular and Age Effects (J Nutr 141: 667-673)	No assessment of obesity
2.	Ailshire JA et al. (2011) The Unequal Burden of Weight Gain: An Intersectional Approach to Understanding Social Disparities in BMI Trajectories from 1986 to 2001/2002 (Soc Forces 90: 397-423)	No assessment of obesity
3.	Aitsi-Selmi A et al. (2013) Childhood socioeconomic position, adult socioeconomic position and social mobility in relation to markers of adiposity in early adulthood: evidence of differential effects by gender in the 1978/79 Ribeirao Preto cohort study (Int J Obes 37: 439-447)	Global SES measure
4.	Anderson PM et al. (2003) Maternal employment and overweight children (J Health Econ 22: 477-504)	No assessment of obesity
5.	Banks GG et al. (2015) Disentangling the Longitudinal Relations of Race, Sex, and Socioeconomic Status, for Childhood Body Mass Index Trajectories (J Pediatr Psychol 41: 453-461)	Global SES measure
6.	Bammann K et al. (2017) The impact of familial, behavioral and psychological factors on the SES gradient for childhood overweight in Europe. A longitudinal study (Int J Obes 41: 54-60)	Global SES measure
7.	Balistreri KS, Van Hook J (2011) Trajectories of Overweight among US School Children: A focus on social and economic characteristics (Matern Child Health J 15(5): 610-619)	No assessment of obesity
8.	Baum CL, Ruhm CJ (2009) Age, socioeconomic status and obesity growth (J Health Econ 28: 635-648)	No assessment of income
9.	Berry TR et al. (2010) A longitudinal and cross-sectional examination of the relationship between reasons for choosing a neighbourhood, physical activity and body mass index (Int J Behav Nutr Phy 7: 57)	No assessment of obesity
10.	Berry TR et al. (2010) Changes in BMI over 6 years: the role of demographic and neighborhood characteristics (Int J Obes 34: 1275-1283)	No assessment of obesity
11.	Bouthoorn SH et al. (2014) Development of Socioeconomic Inequalities in Obesity Among Dutch Pre-School and School-Aged Children (Obesity 22: 2230-2237)	No assessment of obesity
12.	Carrillo-Larco RM, Miranda JJ, Bernabé-Ortiz A (2015) Wealth index and risk of childhood overweight and obesity: Evidence from four prospective cohorts in Peru and Vietnam (Int J Public Health 61: 475-785)	No assessment of income
13.	Cawley J (2000) An Instrumental Variables Approach to Measuring the Effect of Body Weight on Employment Disability (Health Serv Res 35: 1159-1179)	No assessment of income
14.	Cawley J, Grabka MM, Lillard DR (2005) A comparison of the relationship between obesity and earnings in the U.S. and Germany. Schmollers Jahrbuch 125: 119-129.	Cross-sectional analysis
15.	Chaput JP et al. (2009) Risk Factors for Adult Overweight and Obesity in the Quebec Family Study: Have We Been Barking Up the Wrong Tree? (Obesity 17: 1964-1970)	Cross-sectional analysis
16.	Christoforidis A et al. (2011) The profile of the Greek 'XXL' family (Public Health Nutr 14: 1851-1857)	No assessment of income
17.	Cohen AK et al. (2013) Education and obesity at age 40 among American adults (So Sci Med 78: 34-41)	No assessment of income

18.	Cois A et al. (2015) Obesity trends and risk factors in the South African adult population (BMC Obesity 2:42)	No assessment of obesity
19.	Colchero MA et al. (2008) The effect of income and occupation on body mass index among women in the Cebu Longitudinal Health and Nutrition Surveys (1983-2002) (So Sci Med 66: 1967-1978)	No assessment of obesity
20.	Coogan PF et al. (2010) Neighborhood Socioeconomic Status in Relation to 10-Year Weight Gain in the Black Women’s Health Study (Obesity 18: 2064-2065)	Global SES measure
21.	Crespi CM et al. (2015) Associations of Family and Neighborhood Socioeconomic Characteristics with Longitudinal Adiposity Patterns in a Biracial Cohort of Adolescent Girls (Biodemography Soc Biol 61: 81-97)	Global SES measure
22.	Daly M et al. (2015) A social Rank Explanation of How Money Influences Health (Health Psychology 34: 222-230)	No assessment of obesity
23.	Drewnowski A et al. (2015) Residential Property Values Predict Prevalent Obesity but Do Not Predict 1-Year Weight Change (Obesity 23: 671-676)	No assessment of obesity
24.	Feng X et al. (2015) Getting Bigger, Quicker? Gendered Socioeconomic Trajectories in Body Mass Index across the Adult Lifecourse: A Longitudinal Study of 21,403 Australians (PLoS One 10)	No assessment of obesity
25.	Fu Q et al. (2015) Sex, Socioeconomic and Regional Disparities in Age Trajectories of Childhood BMI, Underweight and Overweight in China (Asian Popul Stud 11: 134-148)	No assessment of obesity
26.	Gibbs BG et al. (2014) Socioeconomic status, infant feeding practices and early childhood obesity (Pediatric Obesity 9: 135-146)	Global SES measure
27.	Gigante DP et al. (2013) Association of family income with BMI from childhood to adult life: a birth cohort study (Public Health Nutr 16: 233-239)	Cross-sectional analysis
28.	Glass CM et al. (2010) The Skinny on Success: Body Mass, Gender and Occupational Standing Across the Life Course (Soc Forces 88: 1777-1806)	No assessment of obesity
29.	Gordon-Larsen P et al. (2014) Overweight dynamics in Chinese children and adults (obes rev 15: 37-48)	No assessment of obesity
30.	Gordon-Larsen P et al. (2003) The Relationship of Ethnicity, Socioeconomic Factors, and Overweight in U.S. Adolescents (Obesity Research 11(1))	No assessment of obesity
31.	Hajat A et al. (2010) Do the wealthy have a health advantage? Cardiovascular disease risk factors and wealth (So Sci Med 71: 1935-1942)	No assessment of income
32.	Hofferth SL et al. (2005) Poverty, Food Programs, and Childhood Obesity (J Pol Anal Manag 24: 703-726)	No assessment of obesity
33.	Hoyt LT et al. (2014) Neighborhood Influences on Girls’ Obesity Risk Across the Transition to Adolescence (Pediatrics 134: 942-949)	Global SES measure
34.	Huang JY et al. (2015) Are Early-Life Socioeconomic Conditions Directly Related to Birth Outcomes? Grandmaternal Education, Grandchild Birth Weight, and Associated Bias Analyses (Am J Epidemiol 182)	No assessment of obesity
35.	Huang CC, Yabiku ST, Ayers SL, Kronenfeld JJ (2016) The obesity pay-gap: gender, body size, and wage inequalities – a longitudinal study of Chinese adults, 1991-2011 (J Pop Research 33: 221-242)	No assessment of obesity
36.	Huffman SK et al. (2007) Determinants of obesity in transition economics: The case of Russia (Econ Hum Biol 5: 379-391)	No assessment of obesity
37.	Insaf TZ et al. (2014) Lifecourse Socioeconomic Position and 16 Year Body Mass Index Trajectories: Differences by Race and Sex (Prev Med 67: 17-23)	No assessment of obesity
38.	Jansen PW et al. (2013) Family and Neighbourhood Socioeconomic Inequalities in Childhood Trajectories of BMI and Overweight: Longitudinal Study of Australian Children (PLoS ONE 8(7))	No assessment of obesity

39.	Judge TA et al. (2011) When it comes to Pay, Do the Thin Win? The Effect of Weight on Pay for Men and Women (J Appl Psychol 96: 95-112)	Global SES measure
40.	Kelles A et al. (2009) Offspring consume a more obesogenic diet than mothers in response to changing socioeconomic status and urbanization in Cebu, Philippines (Int J Behav Nutr Phys Act 6)	No assessment of income
41.	Kenney et al. (2015) The academic penalty for gaining weight: a longitudinal, change-in-change analysis of BMI and perceived academic ability in middle school students. International Journal of Obesity 39: 1408-1413	No assessment of income
42.	Lee HH et al. (2012) Factors Related to Body Mass Index and Body Mass Index Change in Korean Children: Preliminary Results from the Obesity and Metabolic Disorders Cohort in Childhood (Korean J Fam Med 33: 134-143)	No assessment of obesity
43.	Li M (2015) Chronic Exposures of Grandparents to Poverty and Body Mass Index Trajectories of Grandchildren: A Prospective Intergenerational Study (Am J Epidemiol 181(3): 163-170)	No assessment of obesity
44.	Ljungvall A et al. (2010) More equal but heavier: A longitudinal analysis of income-related obesity inequalities in and adult Swedish cohort (So Sci Med 70: 221-231)	No assessment of obesity
45.	Loman T et al. (2013) Multiple socioeconomic determinants of weight gain: the Helsinki Health Study (BMC Public Health 13)	No assessment of obesity
46.	Matijasevich A et al. (2009) Socioeconomic position and overweight among adolescents: data from birth cohort studies in Brazil and the UK (BMC Public Health 9)	No assessment of obesity
47.	Michael YL et al. (2014) Does change in the neighborhood environment prevent obesity in older women? (So Sci Med 102: 129-137)	Global SES measure
48.	Mujahid MS et al. (2005) Cross-Sectional and Longitudinal Associations of BMI with Socioeconomic Characteristics (Obesity Research 13)	No assessment of obesity
49.	Murasko JE (2011) Associations between household income, height, and BMI in contemporary US schoolchildren (Econ Hum Biol 11: 185-196)	No assessment of obesity
50.	Murayama H et al. (2015) Socioeconomic Status and the Trajectory of Body Mass Index Among Older Japanese: A Nationwide Cohort Study of 1987-2006 (J Gerontol B Psychol Sci Soc Sci 71: 378-388)	No assessment of obesity
51.	Noh JW et al. (2014) Gender Differences and Socioeconomic Status in Relation to Overweight among Older Korean People (PLOS One 9(5))	No assessment of obesity
52.	Oddo VM, Hersch Nicolas L, Bleich SN, Jones-Smith JC (2016) The impact of changing economic conditions on overweight risk among children in California from 2008 to 2012 (J Epidemiol Community Health 0: 1-7)	No assessment of income
53.	Oliver LN et al. (2008) Effects of neighbourhood income on reported body mass index: an eight year longitudinal study of Canadian children (BMC Public Health 8)	No assessment of obesity
54.	Powell-Wiley TM et al. (2014) Neighborhood-Level Socioeconomic Deprivation Predicts Weight Gain in a Multi-Ethnic Population: Longitudinal Data from the Dallas Heart Study (Prev Med 66: 22-27)	No assessment of obesity
55.	Powell-Wiley TM et al. (2015) Change in Neighborhood Socioeconomic Status and Weight Gain. Dallas Heart Study (Am J Prev Med 49: 72-79)	No assessment of obesity
56.	Pudrovska et al. (2014) Gender and Reinforcing Associations between Socioeconomic Disadvantage and Body Mass over the Life Course. Journal of Health and Social Behavior 55: 283-301.	Global SES measure
57.	Scharoun-Lee M et al. (2009) Obesity, Race/ethnicity and Life Course Socioeconomic Status across the Transition from Adolescence to Adulthood. (J Epidemiol Community Health 63: 133-139)	No assessment of income
58.	Scharoun-Lee M et al. (2009) Obesity, race/ethnicity and the multiple dimensions of socioeconomic status during the transition to adulthood: A factor analysis approach. (Soc Sci Med 68: 708-716)	Factor analysis

59.	Schmeer K (2010) Household Income during Childhood and Young Adult Weight Status: Evidence from a Nutrition Transition Setting (J Health Soc Behav 51(1): 79-91)	No assessment of obesity
60.	Sund ER et al. (2007) Individual, family, and area predictors of BMI and BMI change in an adult Norwegian population: Findings from the HUNT study (Soc Sci Med 70)	No assessment of obesity
61.	van Hook J et al. (2007) Immigrant generation, socioeconomic status, and economic development of countries of origin: A longitudinal study of body mass index among children (Soc Sci Med 65: 976-989)	No assessment of obesity
62.	Viner RM et al. (2005) Adult socioeconomic, educational, social, and psychological outcomes of childhood obesity: a national birth cohort study. (BMJ 330: 1354-1357)	No assessment of obesity
63.	Zargorsky JL (2005) Health and wealth. The late-20 th century obesity epidemic in the U.S. (Econ Hum Biol 3: 296-313)	No assessment of obesity
64.	Zeng W et al. (2013) Adult obesity: Panel study from native Amazonians (Econ Hum Biol 11: 227-235)	No assessment of obesity
65.	Ziol-Guest KM et al. (2009) Early Childhood Poverty and Adult Body Mass Index (Am J Public Health 99: 527-532)	No higher income control group in analysis

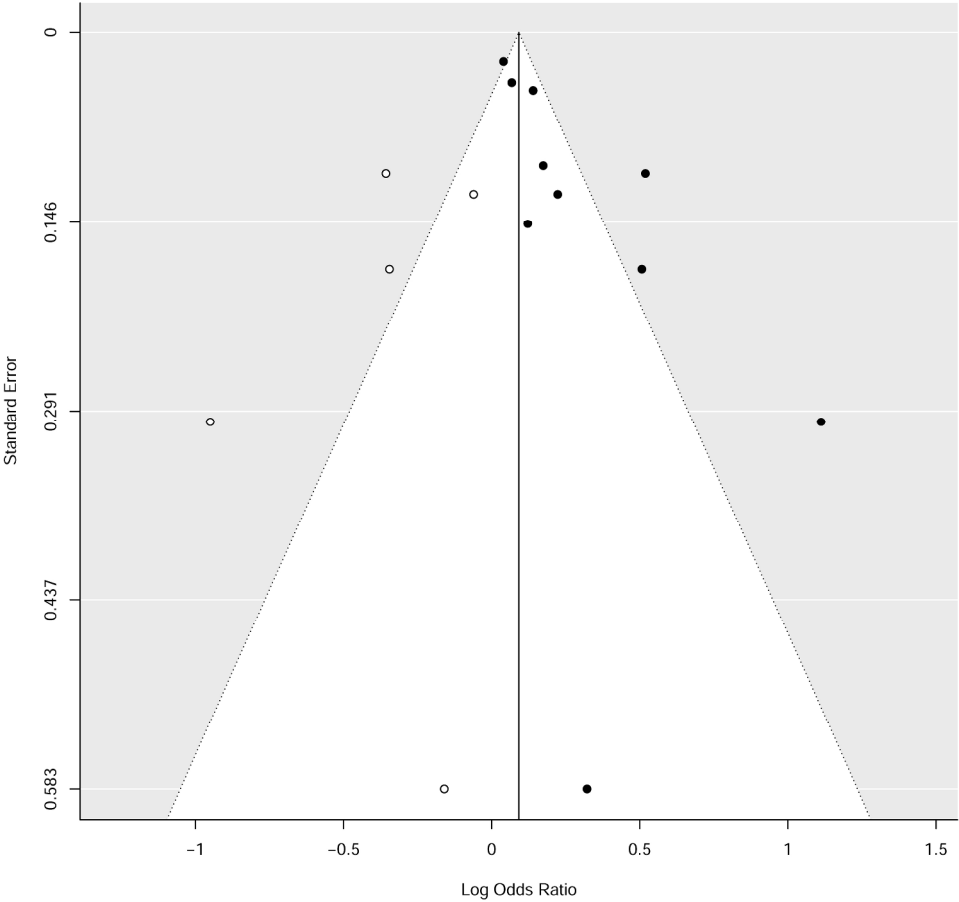
Table: Newcastle-Ottawa Assessment Scale for Cohort studies testing the causation hypothesis

Quality assessment	Acceptable criteria	Brophy 2009	Chaffee 2015	Chia 2013	Demment 2014	Goisis 2015	Hoyt 2014	Jo 2014	Kakinami 2014	Kim 2010	Lee 2009	Lee 2014	Pearce 2015	Salsberry 2009	Strauss 1999
Exposed cohort representative?	Representative of average community?	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Selection of non-exposed cohort?	Drawn from same sample as exposed cohort?	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Ascertainment of exposure?	Structured interview?	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Outcome at baseline?	Incidence of overweight and/or obesity?	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Controls for important factors?	Adjusted for age and sex?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Controls for additional factors?	Adjusted for at least 3 other (risk) factors?	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Assessment of outcome?	Assessed through height/weight measurement?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Adequacy of follow-up duration?	Follow-up duration \geq 5 years?	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Adequacy of lost at follow-up?	Complete follow up? Bias unlikely through lost cases?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
$\geq 80\%$ = High 70% - 80% = Medium < 70% = Low		7 med	6 low	6 low	7 med	9 high	6 low	7 med	7 med	7 low	8 high	9 high	7 med	7 med	9 high

Table: Newcastle-Ottawa Assessment Scale for Cohort studies testing the selection hypothesis

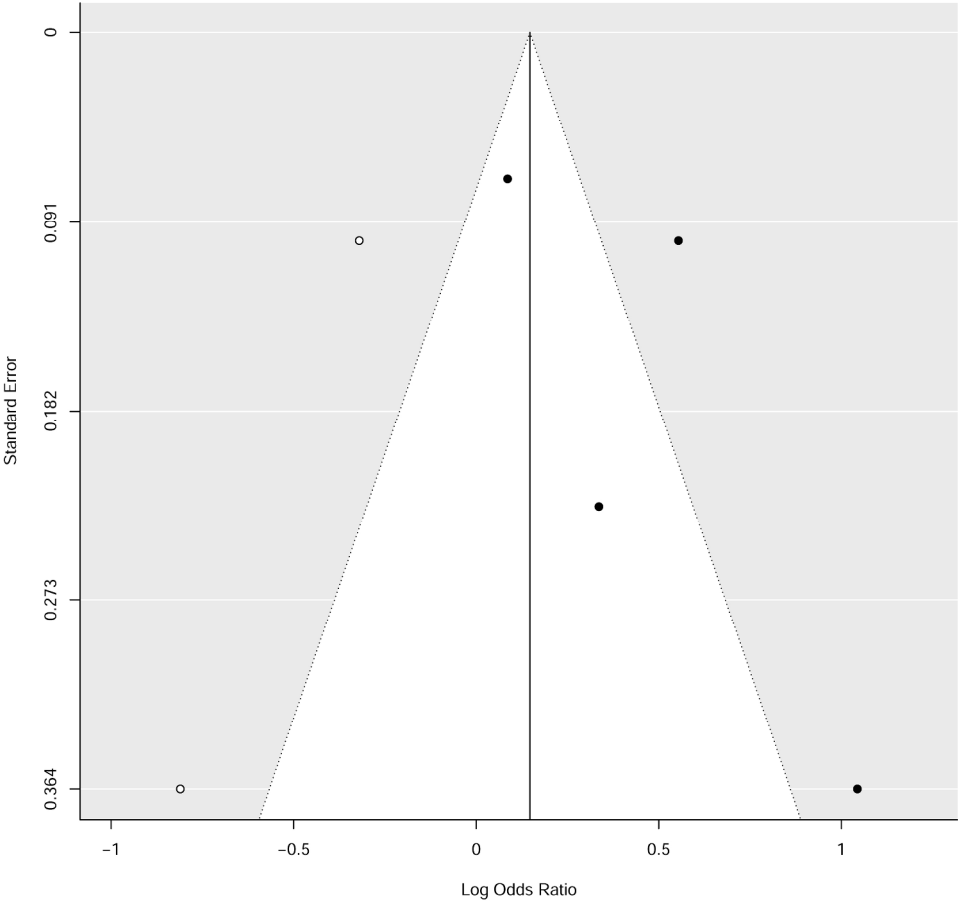
Quality assessment	Acceptable criteria	Amis 2014	Baum 2004	Cawley 2005	Conley 2007	Han 2011	Larose 2016	Mason 2012
Exposed cohort representative?	Representative of average community?	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Selection of non-exposed cohort?	Drawn from same sample as exposed cohort?	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Ascertainment of exposure?	Assessed through height/weight measurement?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Outcome at baseline?	N.A.	--	--	--	--	--	--	--
Controls for important factors?	Adjusted for age and sex?	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Controls for additional factors?	Adjusted for at least 3 other risk factors?	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Assessment of outcome?	Structured interview?	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Adequacy of follow-up duration?	N.A.	--	--	--	--	--	--	--
Adequacy of lost at follow-up?	Complete follow up or bias unlikely through lost cases?	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
≥ 80% = High 70% - 80% = Medium < 70% = Low		4 low	5 med	6 high	5 med	5 med	5 med	5 med

Abbreviations: N.A. = Not applicable



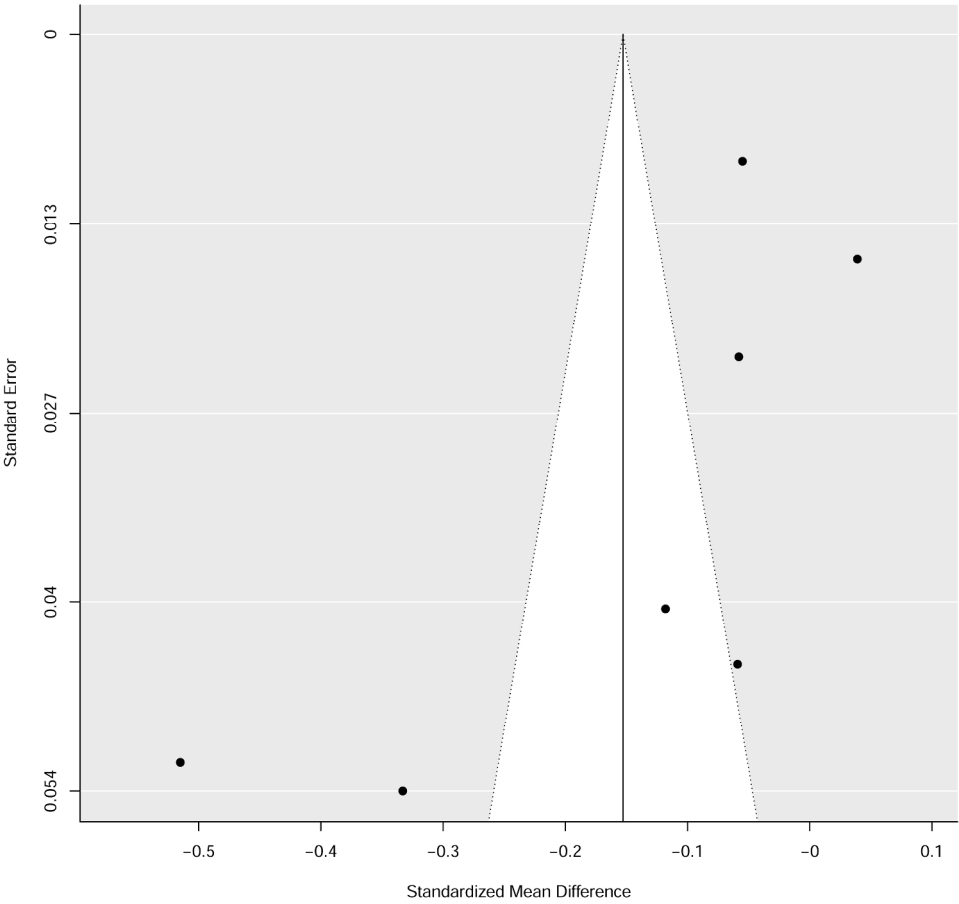
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PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	1-2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	2-4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	4-5
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	14
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	4-5
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	4
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	4
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	7
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	5
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	5-6
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	6-7
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	6
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	6



PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	6
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	6
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	Figure 1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Table 1
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Supplementary File 1
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Figure 2, Figure 3
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measure of consistency.	Figure 2, Figure 3
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	Supplementary File 1
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	Table 2
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	10-13
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	12
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	10
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	14

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

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BMJ Open

Income and obesity: what is the direction of the relationship? A systematic review and meta-analysis

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Primary Subject Heading:	Public health
Secondary Subject Heading:	Epidemiology
Keywords:	obesity, income, causation, reverse causality

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1 **Income and obesity: what is the direction of the relationship? A systematic review and**
2 **meta-analysis.**

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18 Word count: 3446

20 ABSTRACT

21 **Objective:** It was repeatedly shown that lower income is associated with higher risks for
22 subsequent obesity. However, the perspective of a potential reverse causality is often
23 neglected, in which obesity is considered a cause for lower income, when obese people drift
24 into lower income jobs due to labor-market discrimination and public stigmatization. This
25 review was performed to explore the direction of the relation between income and obesity
26 by specifically assessing the importance of social causation and reverse causality. **Design:**
27 Systematic review and meta-analysis.

28 **Methods:** A systematic literature search was conducted in January 2017. The databases
29 Medline, PsychInfo, Sociological Abstracts, International Bibliography of Social Sciences and
30 Sociological Index were screened to identify prospective cohort studies with quantitative
31 data on the relation between income and obesity. Meta-analytic methods were applied
32 using random-effect models, and the quality of studies assessed with the Newcastle-Ottawa-
33 Scale. **Results:** In total, 21 studies were eligible for meta-analysis. All included studies
34 originated from either the United States (N = 16), the United Kingdom (N = 3) or Canada (N =
35 2). From these, 14 studies on causation and 7 studies on reverse causality were found. Meta-
36 analyses revealed that lower income is associated with subsequent obesity (odds ratio: 1.27,
37 CI-95: 1.10 to 1.47; risk ratio: 1.52, CI-95: 1.08 to 2.13), though the statistical significance
38 vanished once adjusted for publication bias. Studies on reverse causality indicated a more
39 consistent relation between obesity and subsequent income, even after taking publication
40 bias into account (SMD: -.15, CI-95: -.30 to -.01). Sensitivity analyses implied that the
41 association is influenced by obesity measurement, gender, length of observation and study
42 quality.

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Conclusions: Findings suggest that there is more consistent evidence for reverse causality. Therefore, there is a need to examine reverse causality processes in more detail to understand the relation between income and obesity.

KEYWORDS: Income, obesity, causation, reverse causality

Strengths and limitations of this study

- This is the first systematic review that gives an overview of causation and reverse causality processes in the link between income and obesity.
- Although only studies were included that examined the relation between income and obesity longitudinally, the question of the direction of the relationship cannot be fully answered.
- The evidence is restricted to a few countries as all included studies have their origin in the United States, the United Kingdom and Canada.

INTRODUCTION

Obesity is a major public health issue. According to a recent trend analysis in 200 countries, age-standardized prevalence of obesity increased from 3.2% to 10.8% between 1975 and 2014 in men, and from 6.4% to 14.9% in women [1]. In this study, like in many others, obesity was defined by a body mass index (BMI) of 30 or higher. Obesity is a major risk factor for all-cause mortality, a number of non-communicable diseases, and reduced quality of life [2-6].

Within social epidemiological research, income (as an indicator of the socio-economic status (SES)) was found to be inversely associated with obesity [7-9], though this relationship can be interpreted in two directions: (1) the causation hypothesis that explains lower income as a cause for subsequent obesity, and (2) the perspective of a reversed causality, in which obesity is not the result, but rather the cause for lower income.

In order to describe why people with lower income are more vulnerable for obesity, the framework of social determinants of health indicates that material conditions confine one's access to (healthy) food and health care [10-11], while also influencing health-related behaviors (i.e. dietary behaviors and physical activity) [12], and psychosocial factors that derive from relative deprivation (e.g. control over life, insecurity, social isolation, stress) [13-15].

In contrast, one important argument for reverse causality is stigma. Studies suggest that the obese are more likely to be perceived as lazy, unsuccessful, weak-willed, and undisciplined [16-19]. On basis of these negative stereotypes, the obese face various weight penalties in the labor market, which include higher job insecurity, lower chances for a job, and general discrimination [20-23]. Furthermore, these stereotypes are also often internalized by those

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3 80 afflicted, which leads to self-stigma, reduced psychological resources as well as mental
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5 81 health problems [24]. By following these two frameworks, there are various pathways in
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7 82 which income relates to obesity and vice versa: With reference to the perspective of
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9 83 causation, income does not only restrict one's access to (healthy) food, but is also linked to
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11 84 higher health literacy which, in turn, is positively related to health promoting behaviors (i.e.
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13 85 healthy nutrition, physical activity) [12, 25]. Further, lower income is associated with higher
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15 86 levels of psychosocial stressors which include decreased control over life, and higher
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17 87 insecurity, social isolation, stress and mental disorders [10, 13-15]. By attempting to
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19 88 integrate the stigma theory into the model of social determinants of health, in our
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21 89 interpretation, the stigmatization of the obese also correlates with material (i.e. less income
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23 90 through weight penalty), behavioral (i.e. change in health-promoting behavior through
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25 91 discrimination), as well as psychosocial factors (i.e. self-stigma may inflict lower control over
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27 92 life, social isolation, stress, lower self-esteem) that may, again, lead to a higher risk of
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29 93 obesity.
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35 94 This work builds upon a former review that examined the relative importance of causation
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37 95 and reverse causality in the association between education and overweight/obesity [25].
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39 96 Though education and income can be conceptualized under the broader term of the SES,
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41 97 specific dimensions of SES should not be regarded as interchangeable in their relation to
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43 98 obesity [26]. First, income rather influences material benefits for health, while education
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45 99 foremost relates to knowledge to gain or retain health. Second, income and education have
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47 100 a different importance across the life course, since educational attainment takes place
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49 101 during childhood and adolescence, while wages, earning and income are generally
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51 102 associated with the occupation in adulthood. For these reasons, income and education have
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53 103 different implications for public health
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This systematic review aims to assess both directions in the link of income and obesity, in order to address the relative importance of social causation processes and reverse causality in explaining the relationship.

METHODS

A systematic review of peer-reviewed studies that addressed the relationship between income and obesity was performed and completed in January 2017. To enhance the reproducibility of our findings, this review was conducted on the basis of the PRISMA guidelines [27]. A corresponding checklist is available online (please see supplementary file 1).

Medline and *PsychInfo* were chosen as the main health-related databases. Moreover, the sociological databases *Sociological Abstracts*, *International Bibliography of Social Sciences* and *Sociological Index* were considered.

For the search, the following equation was used: (adipos* OR obes* OR body-mass-index OR BMI OR "waist-hip ratio" OR WHR OR "skinfold thickness") AND ("social status" OR socioeconomic OR socioeconomic OR inequalit* OR income OR earning* OR wage*) AND (longitudinal OR prospective OR "panel stud*" OR "cohort stud*").

Inclusion and exclusion criteria

For inclusion, original studies had to be published in a peer-reviewed journal and contain quantitative data on the relation between income and obesity. Further initial restrictions (i.e. language, publication years) were not considered.

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3 126 Population: Studies were deemed eligible for inclusion if participants were part of the
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5 127 general population. Therefore, studies with a focus on specific population groups (i.e.
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7 128 patient population) were excluded.
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10 129 Intervention/exposure: On the one hand, studies were omitted if they did not explicitly focus
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12 130 on income and/or rather referred to global SES measures (e.g. neighborhood SES or SES
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14 131 index).
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17 132 Control group: Regardless of the study's focus on either causation or reverse causality, a
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19 133 specific control group or non-exposed group (e.g. people with higher income or non-obese
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21 134 participants) had to be provided to test the unique influence of an exposure (lower income
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23 135 or obesity).
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27 136 Outcome: Studies that used overweight as their main outcome were excluded since obesity
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29 137 was found to be more predictive of health-related outcomes [28-29]. Therefore, studies
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31 138 were included if they focused on obesity, regardless of measurement (e.g. BMI ≥ 30, age and
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33 139 sex-specific percentiles, z-scores). For studies testing reverse causality, all types of outcomes
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35 140 associated with one's own income were included (e.g. wages, earnings, household income).
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39 141 Study design: Finally, only studies with a prospective design were considered, since a clear
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41 142 direction of causation or reverse causality can hardly be drawn from cross-sectional
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43 143 investigations.
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46 144 In case of disagreements on inclusion or exclusion, respective records were discussed by the
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48 145 two reviewers (TJK and NMR, please see acknowledgement). If a consensus could not be
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50 146 achieved, a third reviewer (OK) was involved until an agreement was found.
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56 148 **Data extraction**
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Studies were assessed and the following study information retrieved: author(s), study name, country or region, type of hypothesis, population type, sample size, age at baseline, gender proportion, measurement of income and obesity as well as length of observation, and adjusted covariates. In case multiple ascertainties of income were reported within a single study, the most appropriate measure was chosen. For instance, in studies with a children population, household income better describes the child's financial situation, while measures of parental, paternal and maternal income were the next best alternative measures, respectively. In studies with adults, however, personal wages were the most appropriate measure to characterize one's disadvantage on the labor market, followed by earnings and household income, respectively. TJK extracted the data and performed the meta-analyses.

Data analyses

Since most studies testing the causation hypothesis used odds ratios (ORs) and corresponding 95%-confidence intervals (CI) in their analyses, all statistics were converted to log odds and standard errors (SE). In case ORs, log odds or SE were not readily available, effect sizes were estimated on basis of alternative statistics such as t-value or p-value and sample size. In contrast to the studies on social causation, which mostly referred to a binary outcome (obese vs. non-obese), studies on reverse causality rather examined a continuous variable (income), mostly based on unstandardized regression coefficients. In order to provide a better comparability in the meta-analysis, these coefficients were transformed into standardized mean differences (SMD). For the meta-analyses of both hypotheses, effect sizes from fully adjusted models were taken, if available. Random-effect models were employed, and pooled estimates weighted with the *restricted maximum-likelihood estimator*

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[30]. Cochran’s Q test and Higgin’s I²-measure were calculated to evaluate the proportional degree of heterogeneity. Finally, stratified meta-analyses were run to reveal potential moderating effects (i.e. study region, population type, measurement of obesity, gender, time lag between baseline and follow-up, and study quality).

To test impeding publication bias, *Egger’s regression test* and the *trim-and-fill-method* were used [31-32]. The visualization and calculation of effect sizes, pooled estimates, sensitivity analyses and publication bias were executed with R and the packages ‘esc’ and ‘metafor’ [30, 33].

Study quality

In order to assess the quality of non-randomized studies in meta-analyses, we referred to the Newcastle-Ottawa Scale for cohort studies (NOS) [34]. The NOS includes a total of 9 items across three dimensions (i.e. sample selection, comparability of cohorts, the assessment of outcome). However, two of 9 criteria could hardly be applied to studies testing the reverse causality hypothesis as they focused on an outcome that was explicitly non-health related. Therefore, the two questions, (a) if the outcome of interest was not present at start of study, and (b) if the follow-up duration was long enough for the outcome to occur, were excluded to provide a better precision of the NOS-checklist. The application of the NOS checklist was carried out by TJK and OK and discussed in case of divergences.

FIGURE 1 ABOUT HERE

RESULTS

196 Literature search

197 The inclusion and exclusion of studies is shown in Figure 1. Through the initial screening of
198 all five databases, 3,955 records were found. After removing duplicates, 3,027 titles and
199 abstracts were screened for eligibility. Hereafter, another 2,941 records were excluded. The
200 full-texts of the remaining 86 records were then screened for eligibility, from which 65 were
201 dismissed. A detailed summary of reasons of exclusion is accessible online (please see
202 supplementary file 2). Finally, 21 articles met all predefined inclusion criteria and were
203 considered for meta-analysis. In an additional screening of the references of included studies
204 no further eligible records were found. Overall, 14 studies addressed the social causation
205 and 7 the reverse causality hypothesis (see Table 1 for an overview of the included studies).
206 Information about the quality of the studies according to the NOS checklist is available
207 online (please see supplementary file 3).

208 Table 1: Description of included studies

Author, Study	Country, region	Direction	Population	Sample size	Age at Baseline	Gender (Male %)	Income measure	Obesity measure	Follow-up duration	Covariates in multivariate analysis
Brophy 2009 [35], MCS	UK (national)	Causation	Children	17,561	5 (mean)	NA	Income	95 th BMI-Percentile	4 Years	Ethnic group, birth weight, enjoyment of physical activity, sedentary behavior (watching TV), indoor activities, early introduction of solid food, smoking near child, mothers pre-pregnancy weight, education
Chaffee 2015 [36], NLSY79	USA (national)	Causation	Women	4,780	40 (mean)	0	Household income	BMI ≥ 30	31 Years	Birth outside the US, urban residence as a child, and residence in the South as a child, maternal variables (age, marital status, smoking during pregnancy, education attainment, pregnancy BMI, previous excessive/inadequate gestational weight gain)
Chia 2013[37], NLSY79	USA (national)	Causation	Children	3,958	8.6 (mean)	51.3	Family income	95 th BMI-Percentile	6 Years	Mother's characteristics (education, armed forces qualification test, age at birth of child, health limitations, migration status, marital status, overweight/obesity, living with both parents at age 14), child's characteristics (age, gender, region of residence, birthweight, firstborn status, race, breastfeeding), household size
Demment 2014 [38], BMHP1	USA (NY State)	Causation	Children	595	2 (mean)	53.0	Family income	BMI z-scores	16 Years 2 Years	Mother's age at time of delivery, multiparity, maternal overweight/obesity, child's characteristics (birth weight, sex, ADHD medication use, asthma medication use, antidepressant medication use, puberty status, early life rapid weight gain)
Gois 2016 [39], MCS	UK (national)	Causation	Children	11,965	5 (mean)	50.8	Family income	95 th BMI-Percentile	8 Years	Mother smoking during pregnancy, length of breast feeding, maternal BMI, early introduction to solid foods, child's gender, physical activity (frequency of sport, active playing with parent, use of a playground, use of a bike), sedentary behavior (watching TV, PC use), bedtime, fruit portion per day, skipping breakfast, sweet drinks consumption
Hoyt2014 [40], CYGNET	USA (national)	Causation	Girls	174	8-10 (range)	0	Household income	95 th BMI-Percentile	4 Year	Race/ethnicity, baseline BMI, puberty status, year of outcome measure, number of street segments, household size, education (of financial provider), neighborhood SES, food and service retail scale
Jo 2014 [41], ECLS-K	USA (national)	Causation	Children	9,287	5.9 (mean)	0.51	Family income	95 th BMI-Percentile	9 Years	Grade level, race, gender, household size, mother's age, father's age, school lunch, school fixed effects
Kakinami 2014 [42], QLSCD	Canada (Québec)	Causation	Children	698	9.2 (mean)	45.6	Household income	85 th BMI-Percentile	12 Years	Child's birth weight and sex, mother's education and migration status
Kim 2010 [43], PSID	USA (national)	Causation	Adults	6,312	41.9 (mean)	0.85	Log hourly wage	BMI ≥ 30	4 Years	Age, sex, race, marital status, education, health insurance, smoking, region of residence, survey year
Lee 2009 [44], Add Health	USA (national)	Causation	Adolescents	9,730	12-19 (range)	49.2	Poverty status	BMI ≥ 30	7 Years	Age, low parental education, family structure, trouble paying bills, neighborhood poverty, parental monitoring (watching TV, eating dinner, low-parent-child interaction, no curfew, full-time working mother), physical activity, skipping breakfast, inadequate sleep, race/ethnicity, parent obesity status

Lee2014 [45], SECCYD	USA (national)	Causation	Children, adolescents	1,150	3-15 (range)	50.7	Family income	95 th BMI-Percentile	15 Years	Age, poverty status lagged, sex, race/ethnicity, birth weight, maternal variables: age, education, figure rating scale score, marital status lagged
Pearce 2015 [46], NCMP, MCS	UK (national)	Causation	Children	2,620, 422	3-7 (range)	51.2	Household income	95 th BMI-Percentile	4 Years	Maternal education, area deprivation, maternal social class
Salsberry 2009 [47], NLSY79	USA (national)	Causation	Young Women	3,707	14-21 (range)	0	Income	BMI \geq 30	33 Years	Age, parental education, own education
Strauss 1999 [48], NLSY	USA (national)	Causation	Children	2,913	0-8 (range)	56.0	Family income	95 th BMI-Percentile	6 Years	Maternal BMI, initial weight-for-height Z score, gender, race, maternal education, marital status, cognitive score, emotional score
Amis 2014 [49], Add Health	USA (national)	Reverse causality	Adolescents	11,308	16 (mean)	47.2	Annual income	95 th BMI Percentile	13 Years	Age, sex, race, number of siblings, mother's education, mother works, father works, closeness to mother, closeness to father, school skipped, grade repeated, attention problem, watching TV (hours), playing sports, playing computer games, hanging out with friends, type of school, neighborhood environment, mental health, general health, smoking, alcohol use, drug use, ever had sex
Baum 2004 [50], NLSY	USA (national)	Reverse causality	Young Adults	51,500 (PY)	28-31 (range)	51.7	Log real wage	BMI \geq 30	17 Years	Race, age, education, marital status, number of children, human capital accumulation, area of residence, local unemployment rate, industry working in, AFQT-score (Armed Forces Qualifying Test), migration status, speaking foreign language, mother's education, father's education, siblings, rotter test score (efficacy), attitudes about family roles, health limitations, At age 14: lived with both parents, received magazines, received newspaper, library card, area of residence, mother worked
Cawley 2005 [51], WES	USA (national)	Reverse causality	Women	874	18-54 (range)	0	Earnings	BMI \geq 30	6 Years	No. of children the respondent cares for, the number of children between the ages of 0 and 2 that the respondent cares for, indicator variables for no job market skills, low job market skills, less than a high school education, more than a high school education, one of the respondent's children has a physical or mental health problem, respondent is currently cohabitating with a husband or boyfriend, never married, age, wave 3, wave 4, respondent has a conviction for other than a traffic offense, and respondent has a learning disability.
Conley 2006 [52], PSID	USA (national)	Reverse causality	Adults	3,340	46-49 (range)	46.5	Log wages	BMI \geq 30	18 Years	Educational attainment, labor market experience, age of youngest child, and age.
Han 2011 [53], NLSY79	USA (national)	Reverse causality	Adolescents	1,974	16-20 (range)	54.1	Hourly wage	BMI \geq 30	12 Years	Age, race, marital status, time from latest pregnancy to the interview, education of the parents, AFQT-score, self-esteem, years of employment, participated in on-the-job training, area of residence, unemployment rate in the residential unit, no. of private businesses at state level, average income by state, consumer price index, education, occupation, occupation

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										requiring social interaction
Larose 2016 [54], NPHS	Canada (national)	Reverse causality	Adults	3,993	40.2 (mean)	50.71	Hourly wage rate	BMI ≥ 30	6 Years	Age, presence of small children in the household, migration status, area of residence, marital status, non-wage/spouse income, home ownership, education, smoking behavior, drinking behavior
Mason 2012 [55], NLSY97	USA (national)	Reverse causality	Young Adults	2,427	12-17 (range)	50.72	Income	BMI ≥ 30	9 Years	Education, parental status, work experience, occupation, race, socioeconomic background (1997), household income, mother's education, father's education), health limitations, ASVAB (Armed Services Vocational Aptitude Battery)

Abbreviations: **Add Health** = National Longitudinal Study of Adolescent to Adult Health; **BMHP1** = Bassett Mothers Health Project, **BMI** = Body Mass Index; **Cygneth study** = Cohort Study of Young Girls Nutrition, Environment and Transitions; **ECLS-K** = Early Childhood Longitudinal Study Kindergarten; **MCS** = Millennium Cohort Study; NA = Not available; **NLSY (97)** = U.S. National Longitudinal Survey of Youth (1997); **NPHS** = Canadian National Population Health Survey; **PSID** = Panel Study of Income Dynamics; **QLSCD** = Québec Longitudinal Study of Child Development; PY = Person-years; **SECCYD** = Study of Early Child Care and Youth Development; **WES** = Women's Employment Study

Studies testing the causation hypothesis

In 10 of the studies investigating the causation hypothesis, odds ratios (OR) were calculated, while in 4 studies risk ratios (RR) were documented. Pooled estimates indicate the likelihood or risk for subsequent obesity among people with a low income compared with those having a high income (Figure 2). Overall, results reveal a higher chance (OR: 1.27, CI: 1.10 to 1.47) and an increased risk (RR: 1.52, CI: 1.08 to 2.13) for obesity among low income groups. Across studies referring to ORs, four of the 10 studies revealed statistically significant effects. In terms of RRs, two out four were significant. None of the studies analyzing causation indicated a positive relationship. For the 10 studies with ORs, a statistically significant publication bias was detected (please see supplementary file 4), Egger's regression test: $z = 5.0846$, $p < .0001$). After the imputation of studies to correct for publication bias, the OR decreased considerably and became statistically insignificant (adjusted OR: 1.10, CI: 0.90 to 1.34). And though no publication bias could be detected for the 4 studies testing the causation hypothesis with RRs, an imputation of studies to adjust for potential publication bias yielded a decreased and statistically insignificant effect size for this meta-analysis (adjusted RR: 1.16, 0.73-1.82) (please see supplementary file 5).

FIGURES 2 AND 3 ABOUT HERE

Studies testing reverse causality

In 7 studies that analyzed the reverse causality hypothesis (Figure 3), the pooled estimate (standardized mean difference), which expresses the size of the effect in each study relative to the variability observed, was -0.15 (CI: -0.30 to -0.001), implying that people with obesity had

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236 a significantly lower income, when compared to the non-obese. This effect was statistically
237 significant in five studies, while one study found a positive effect [54], and one study
238 revealed a relationship that was statistically insignificant [53]. Through the test for funnel
239 plot asymmetry, no publication bias was detected. The effect sizes did not change after the
240 imputation to adjust for publication bias (please see supplementary file 6).

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242 **Sensitivity analyses**

243 In order to reveal potential moderating effects, stratified meta-analysis were performed
244 (Table 2). Sensitivity analyses showed that the majority of included studies were conducted
245 in the United States (causation: 71%; reverse causality: 85%), whereas the only other study
246 countries were the United Kingdom (causation: 21%) and Canada (causation: 7%; reverse
247 causality 14%). Furthermore, the stratification for population revealed that causation mostly
248 relied on children populations (79%), while studies on reverse causality exclusively focused
249 on adults. The results for both region and population, however, remained fairly inconsistent,
250 and did not reveal a clear trend.

251 According to studies on the causation hypothesis, higher effect sizes were evident when the
252 height and weight of participants was actually measured instead of using a self-report (OR:
253 1.48, CI: 1.04 to 2.10; RR: 1.73, CI: 1.46 to 2.06), when the observation period exceeded 10
254 years (OR: 1.59, CI: 1.11 to 2.27), and when the study quality was assessed as high (OR: 1.40,
255 CI: 1.06 to 1.83; RR: 1.88, CI: 0.95 to 3.74). Subgroup analyses for gender could not be
256 performed for studies analyzing causation since gender specific results were not
257 documented.

In terms of the reverse causality hypothesis, the subgroup analysis of gender showed that the relation between obesity and subsequent income was more pronounced among women (SMD: -.16, CI: -.30 to -.02), than men (SMD: -.07, CI: -.16 to .01). Similar to the studies on causation, it was shown that a longer observation period (> 10 years) was associated with an effect size increase (SMD: -.52, CI: -.62 to -.41). The same pattern was found in the rating of higher study quality (SMD: -.52, CI: -.62 to -.41).

Table 2: Sensitivity analyses

	Social causation hypothesis				Reverse causality hypothesis	
	<i>n</i>	<i>OR (CI), I²</i>	<i>n</i>	<i>RR (CI), I²</i>	<i>n</i>	<i>SMD (CI), I²</i>
Overall	10	1.27 (1.10, 1.47), 90%	4	1.52 (1.08, 2.13), 83%	7	-0.15 (-0.30, -0.01), 98%
Study region						
USA	8	1.22 (1.06, 1.40), 88%	2	1.65 (0.65, 4.17), 85%	6	-0.19 (-0.34, -0.03), 97%
UK	1	1.19 (0.97, 1.45), NA	2	1.68 (1.40, 2.01), 0%	--	--
Canada	1	3.04 (1.69, 5.47), NA	--	--	1	0.04 (0.01, 0.07), NA
Population						
Children	8	1.33 (1.08, 1.64), 93%	3	1.73 (1.46, 2.06), 0%	--	--
Adolescents	1	1.25 (0.98, 1.59), NA	1	1.09 (0.95, 1.25), NA	--	--
Adults	1	1.15 (1.06, 1.25), NA	--	--	7	-0.15 (-0.30, -0.01), 98%
Obesity						
Self-report	5	1.20 (1.03, 1.41), 88%	1	1.09 (0.95, 1.25), NA	7	-0.15 (-0.30, -0.01), 98%
Measured	5	1.48 (1.04, 2.10), 84%	3	1.73 (1.46, 2.06), 0%	-	--
Gender						
Male	--	--	--	--	6	-0.07 (-0.16, 0.01), 90%
Female	--	--	--	--	7	-0.16 (-0.30, -0.02), 93%
Observation						
< 5 years	3	1.15 (1.07, 1.25), 0%	1	1.74 (1.43, 2.12), NA	1	-0.06 (-0.10, -0.01), NA
5 – 10 years	2	1.11 (0.98, 1.25), 30%	2	1.88 (0.95, 3.74), 63%	5	-0.10 (-0.22, 0.02), 97%
> 10 years	5	1.59 (1.11, 2.27), 88%	1	1.09 (0.95, 1.25), NA	1	-0.52 (-0.62, -0.41), NA
Study quality						
Low	3	1.09 (1.00, 1.18), 57%	1	1.09 (0.95, 1.25), NA	1	-0.06 (-0.10, -0.01), NA
Medium	5	1.47 (1.04, 2.08), 90%	1	1.74 (1.43, 2.12), NA	5	-0.10 (-0.22, 0.02), 97%
High	2	1.40 (1.06, 1.83), 40%	2	1.88 (0.95, 3.74), 63%	1	-0.52 (-0.62, -0.41), NA

Abbreviations: n = number of studies; NA = Not available; OR = Odds ratios; CI = Confidence intervals; RR = Risk ratios; SMD = Standardized mean difference; UK = United Kingdom; USA = United States of America

Heterogeneity between studies

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270 With reference to Figure 2 and Figure 3, degrees of heterogeneity were relatively high in
271 both meta-analyses that tested the causation hypothesis ($I^2 = 89.9\%$ and 83.1%) and studies
272 that referred to reverse causality between income and obesity ($I^2 = 98.5\%$). This furthermore
273 indicates that the observed variance between studies is more likely to occur due to
274 heterogeneity than chance alone (Figure 1, Figure 2). High degrees of heterogeneity were
275 also observed within most subgroup analyses (Table 2).

277 **DISCUSSION**

278 **Main findings**

279 The results of this review revealed statistically significant effects of income on obesity (social
280 causation) as well as of obesity on income (reverse causality). Therefore, individuals exposed
281 to lower income are more likely to develop obesity, and the obese have lower wages when
282 compared to their non-obese counterparts. However, after adjustments for publication bias,
283 only the reverse causality hypothesis remained significant, whereas the meta-analytical
284 association between lower income and subsequent risk of obesity vanished and became
285 inconclusive. These findings indicate that studies testing the social causation hypothesis are
286 more likely to remain unpublished if they contain negative results. In order to explain why
287 this especially applies to studies testing the causation hypothesis, we assume that it is
288 difficult to publish negative results, since the relation between income and the risk of
289 subsequent obesity has been well established in social epidemiological and public health
290 research. In contrast, evidence for reverse causality is relatively scarce for the relation
291 between obesity and income, which may explain the higher chances to get negative results
292 published in this field. Though the overall effect size for the social causation perspective
293 became statistically insignificant after the imputation of studies, it is still noteworthy that

there were some studies that found statistically significant associations, even after adjusting for a range of covariates (Table 1).

According to the sensitivity analyses, it was shown that reverse causality was more pronounced among women than among men. To explain these differences, Mason, for instance, suggests that obese women are not only confronted with disadvantages that derive from the stigmatization of fatness, but additionally face higher expectations to perform their gender properly [55]. According the cultivation theory of the social sciences, there is a stronger idealization of thin women, which may help to explain why there is a stricter weight penalty for women than for men [56]. With regards to the ascertainment of obesity in studies, sensitivity analyses revealed that effects of social causation were stronger when height and weight of respondents were actually measured rather than based on self-reports. Similar to results from nutritional studies, where a gender-specific social desirability bias was evident in self-reports of dietary intake [57], a comparable bias in height and weight reports can be suspected for our results. Therefore, as actual measurements can be considered as less biased, if compared to self-reports, it can be assumed that the overall effect of income on obesity is underestimated when self-reported measures are used. All studies investigating reverse causality were based on self-reported measures. As effect sizes were generally stronger in studies with higher quality scores (if compared to studies with a medium or low rating, regardless of causation or reverse causality), the overall effects can be expected to be somewhat stronger than indicated through the meta-analytic results.

Limitations

Some methodological issues should be considered when interpreting the findings of this meta-analysis: First, the risk for missing out other relevant articles remains. Second, all

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3 318 included studies have their origin in western societies, most in the United States. Therefore,
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5 319 the evidence is restricted to a few countries, leaving out the possibility that the relationship
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7 320 between income and obesity plays out differently in other regions of the world. Third, and
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9 321 though only studies were included that examined the relation between income and obesity
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11 322 longitudinally (thus enabling to carve out the direction of the respective influence), the
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13 323 question of causality cannot be fully answered due to two main reasons: On the one hand,
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15 324 the methodological issue remains that (cohort) studies are not able to adjust for transitions
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17 325 between the individual income-status as well as the obesity-status that take place between
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19 326 the baseline and the follow-up survey. Thus, the results of longitudinal observational studies
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21 327 should be regarded as a mere tendency, and must be interpreted with caution. On the other
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23 328 hand, there is reason to believe that processes of social causation are not simply replaced by
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25 329 reverse causality during the life course, but rather coexist in one's biography. As noted
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27 330 above, it can be assumed that causation processes and reverse causality rather augment
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29 331 than neutralize each other, so that the link between income and obesity is likely to follow a
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31 332 bidirectional relationship. Fourth, a further limitation of studies testing the causation
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33 333 hypothesis is the heterogeneity of the low income control groups. In this regard, the
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35 334 reference groups varied substantially, which limits the comparability between different
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37 335 income measures. In terms of studies testing the reverse causality, comparability was not as
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39 336 problematic as all studies referred to a non-obese reference that was defined by a BMI lower
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41 337 than 30. Fifth, and even though the subgroup analyses revealed a few factors that may
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43 338 moderate the relationship between income and obesity, results for the reverse causality
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45 339 hypothesis were mostly based on the same subgroups. Finally, the capacity of Egger's
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47 340 regression test to detect publication bias depends on the number of included studies [32].
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49 341 Therefore, there is a clear lack of statistical power in Egger's regression test of studies that
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used RRs (N = 4), which has to be viewed as a further limitation of this study. In addition, the trim-and-fill method of these studies led to a substantially decreased and statistically insignificant effect size (adjusted RR: 1.10, CI-95: 0.90-1.34), further implying the inconsistencies of results testing the causation hypothesis.

Future research

By taking these limitations into account, future studies should aim at investigating the relation between income and obesity outside of western societies. An extended view on the association in other countries could aid in detecting cultural influences that frame the magnitude of both causation processes and reverse causality between income and obesity. Moreover, and in order to clarify potential bidirectional effects between income and obesity, future research should investigate the interaction between causation processes and reverse causality in a single cohort over the life course. Finally, future studies could focus on detecting other factors that may influence the relation between income and obesity for both hypotheses.

CONCLUSIONS

This review was performed to give an overview of causation processes in the link between income and obesity, while also investigating a reverse causality between these two variables. Meta-analyses revealed significant links between lower income and the risk of obesity as well as obesity and subsequent income (reverse causality hypothesis). However, after adjusting for publication bias, the relation between lower income and the risk of subsequent obesity vanished, indicating a higher likelihood of unpublished studies due to negative findings. In contrast, results from studies testing the reverse causality perspective

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366 remained consistent even after adjusting for potential publication bias. Therefore, a stronger
367 consideration of potential reverse causality is needed to address income-related inequalities
368 in obesity.

For peer review only

DECLARATIONS

Authors' contributions: TJK and OK developed the research question. TJK then conducted the literature search, screened all found records and extracted the relevant data. TJK performed the meta-analysis and wrote the first draft of the manuscript. OK revised the manuscript. Both authors read and approved the final version of the manuscript.

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Data sharing statement: We retrieved all data for the meta-analyses from already published material. Therefore, the data is available in the respective articles.

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Figures:

Figure 1: PRISMA Flowchart of included studies

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516 Abbreviations: n = number of records

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518 Figure 2: Pooled estimates of studies testing the causation hypothesis

519 Abbreviations: p = significance; RE = random effects

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521 Figure 3: Pooled estimates of studies testing the reverse causality hypothesis

522 Abbreviations: p = significance; RE = random effects; SMD = Standardized mean difference

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524 **Supplementary files:**

525 File 1: Table: PRISMA checklist

526 File 2: Table: Reasons for exclusion after full-text screening

527 File 3: Table: Table: Newcastle-Ottawa Assessment Scale for Cohort studies

528 File 4: Figure: Funnel plot to check for publication bias (for studies testing causation

529 hypothesis with odds ratios)

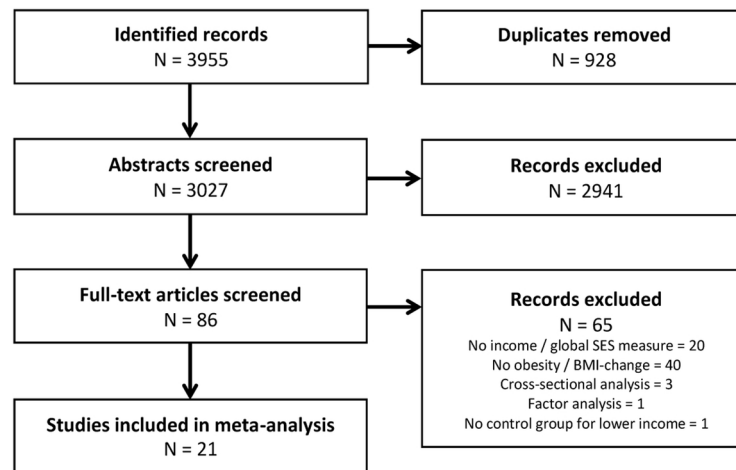
530 File 5: Figure: Funnel plot to check for publication bias (for studies testing causation

531 hypothesis with rate ratios)

532 File 6: Figure: Funnel plot to check for publication bias (for studies testing reverse causality

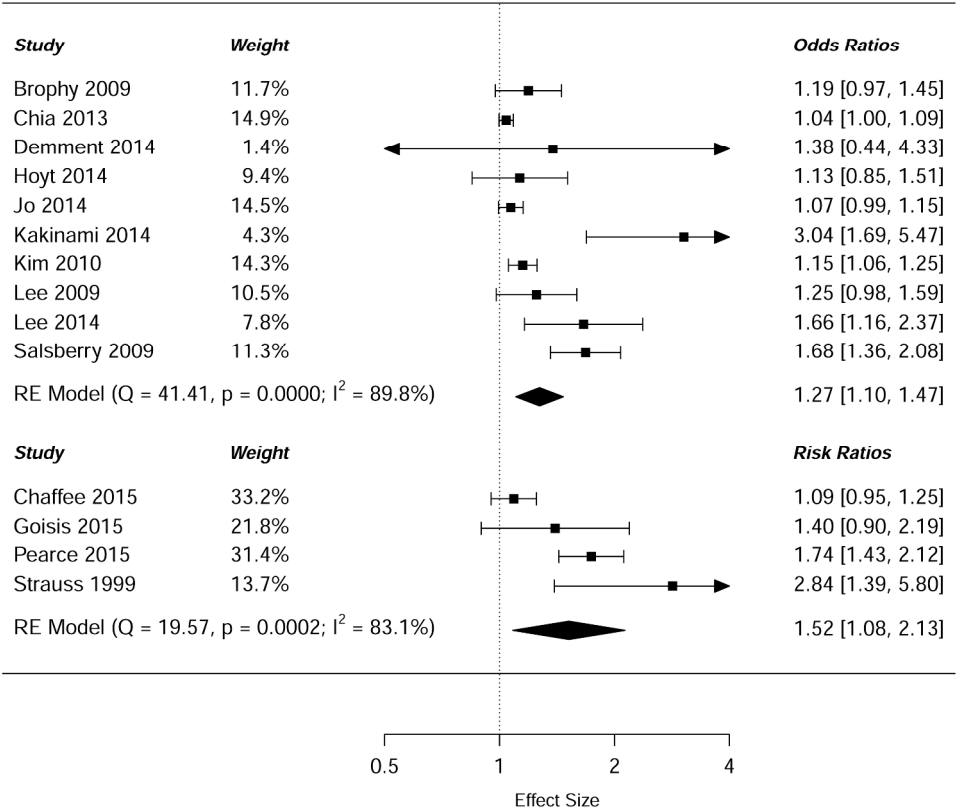
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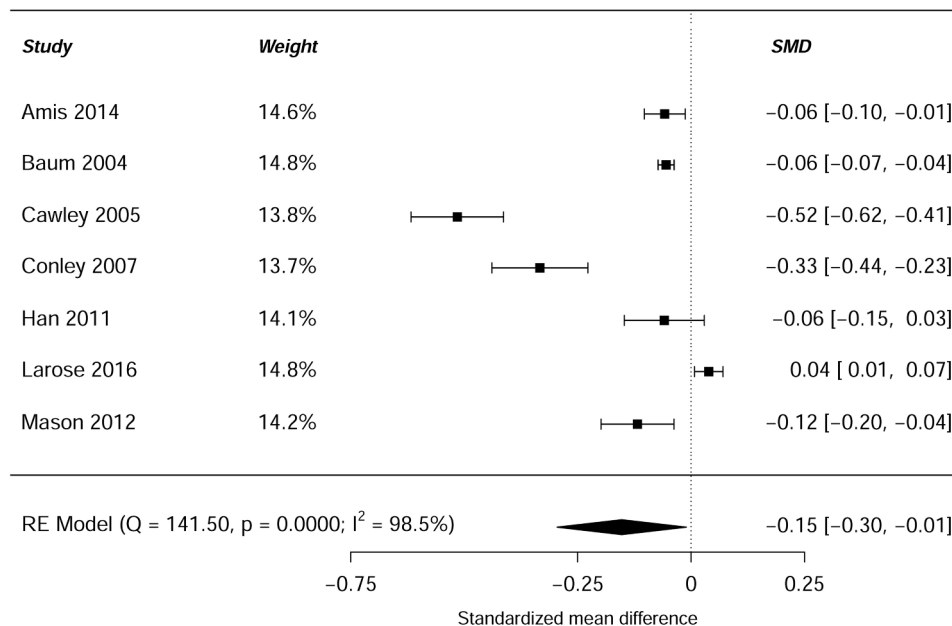


PRISMA Flowchart of included studies

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Pooled estimates of studies testing the causation hypothesis
254x254mm (300 x 300 DPI)



Pooled estimates of studies testing the reverse causality hypothesis

215x183mm (300 x 300 DPI)



PRISMA 2009 Checklist

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PRISMA 2009 Checklist

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Supplemental File 2: Reasons for exclusion after full-text screening

	Author(s) (Year) Study (Journal)	Reasons for exclusion
1.	Adair LS et al. (2011) 20-Year Trends in Filipino Women’s Weight Reflect Substantial Secular and Age Effects (J Nutr 141: 667-673)	No assessment of obesity
2.	Ailshire JA et al. (2011) The Unequal Burden of Weight Gain: An Intersectional Approach to Understanding Social Disparities in BMI Trajectories from 1986 to 2001/2002 (Soc Forces 90: 397-423)	No assessment of obesity
3.	Aitsi-Selmi A et al. (2013) Childhood socioeconomic position, adult socioeconomic position and social mobility in relation to markers of adiposity in early adulthood: evidence of differential effects by gender in the 1978/79 Ribeirao Preto cohort study (Int J Obes 37: 439-447)	Global SES measure
4.	Anderson PM et al. (2003) Maternal employment and overweight children (J Health Econ 22: 477-504)	No assessment of obesity
5.	Banks GG et al. (2015) Disentangling the Longitudinal Relations of Race, Sex, and Socioeconomic Status, for Childhood Body Mass Index Trajectories (J Pediatr Psychol 41: 453-461)	Global SES measure
6.	Bammann K et al. (2017) The impact of familial, behavioral and psychological factors on the SES gradient for childhood overweight in Europe. A longitudinal study (Int J Obes 41: 54-60)	Global SES measure
7.	Balistreri KS, Van Hook J (2011) Trajectories of Overweight among US School Children: A focus on social and economic characteristics (Matern Child Health J 15(5): 610-619)	No assessment of obesity
8.	Baum CL, Ruhm CJ (2009) Age, socioeconomic status and obesity growth (J Health Econ 28: 635-648)	No assessment of income
9.	Berry TR et al. (2010) A longitudinal and cross-sectional examination of the relationship between reasons for choosing a neighbourhood, physical activity and body mass index (Int J Behav Nutr Phy 7: 57)	No assessment of obesity
10.	Berry TR et al. (2010) Changes in BMI over 6 years: the role of demographic and neighborhood characteristics (Int J Obes 34: 1275-1283)	No assessment of obesity
11.	Bouthoorn SH et al. (2014) Development of Socioeconomic Inequalities in Obesity Among Dutch Pre-School and School-Aged Children (Obesity 22: 2230-2237)	No assessment of obesity
12.	Carrillo-Larco RM, Miranda JJ, Bernabé-Ortiz A (2015) Wealth index and risk of childhood overweight and obesity: Evidence from four prospective cohorts in Peru and Vietnam (Int J Public Health 61: 475-785)	No assessment of income
13.	Cawley J (2000) An Instrumental Variables Approach to Measuring the Effect of Body Weight on Employment Disability (Health Serv Res 35: 1159-1179)	No assessment of income
14.	Cawley J, Grabka MM, Lillard DR (2005) A comparison of the relationship between obesity and earnings in the U.S. and Germany. Schmollers Jahrbuch 125: 119-129.	Cross-sectional analysis
15.	Chaput JP et al. (2009) Risk Factors for Adult Overweight and Obesity in the Quebec Family Study: Have We Been Barking Up the Wrong Tree? (Obesity 17: 1964-1970)	Cross-sectional analysis
16.	Christoforidis A et al. (2011) The profile of the Greek ‘XXL’ family (Public Health Nutr 14: 1851-1857)	No assessment of income
17.	Cohen AK et al. (2013) Education and obesity at age 40 among American adults (So Sci Med 78: 34-41)	No assessment of income

18.	Cois A et al. (2015) Obesity trends and risk factors in the South African adult population (BMC Obesity 2:42)	No assessment of obesity
19.	Colchero MA et al. (2008) The effect of income and occupation on body mass index among women in the Cebu Longitudinal Health and Nutrition Surveys (1983-2002) (So Sci Med 66: 1967-1978)	No assessment of obesity
20.	Coogan PF et al. (2010) Neighborhood Socioeconomic Status in Relation to 10-Year Weight Gain in the Black Women's Health Study (Obesity 18: 2064-2065)	Global SES measure
21.	Crespi CM et al. (2015) Associations of Family and Neighborhood Socioeconomic Characteristics with Longitudinal Adiposity Patterns in a Biracial Cohort of Adolescent Girls (Biodemography Soc Biol 61: 81-97)	Global SES measure
22.	Daly M et al. (2015) A social Rank Explanation of How Money Influences Health (Health Psychology 34: 222-230)	No assessment of obesity
23.	Drewnowski A et al. (2015) Residential Property Values Predict Prevalent Obesity but Do Not Predict 1-Year Weight Change (Obesity 23: 671-676)	No assessment of obesity
24.	Feng X et al. (2015) Getting Bigger, Quicker? Gendered Socioeconomic Trajectories in Body Mass Index across the Adult Lifecourse: A Longitudinal Study of 21,403 Australians (PLoS One 10)	No assessment of obesity
25.	Fu Q et al. (2015) Sex, Socioeconomic and Regional Disparities in Age Trajectories of Childhood BMI, Underweight and Overweight in China (Asian Popul Stud 11: 134-148)	No assessment of obesity
26.	Gibbs BG et al. (2014) Socioeconomic status, infant feeding practices and early childhood obesity (Pediatric Obesity 9: 135-146)	Global SES measure
27.	Gigante DP et al. (2013) Association of family income with BMI from childhood to adult life: a birth cohort study (Public Health Nutr 16: 233-239)	Cross-sectional analysis
28.	Glass CM et al. (2010) The Skinny on Success: Body Mass, Gender and Occupational Standing Across the Life Course (Soc Forces 88: 1777-1806)	No assessment of obesity
29.	Gordon-Larsen P et al. (2014) Overweight dynamics in Chinese children and adults (obes rev 15: 37-48)	No assessment of obesity
30.	Gordon-Larsen P et al. (2003) The Relationship of Ethnicity, Socioeconomic Factors, and Overweight in U.S. Adolescents (Obesity Research 11(1))	No assessment of obesity
31.	Hajat A et al. (2010) Do the wealthy have a health advantage? Cardiovascular disease risk factors and wealth (So Sci Med 71: 1935-1942)	No assessment of income
32.	Hofferth SL et al. (2005) Poverty, Food Programs, and Childhood Obesity (J Pol Anal Manag 24: 703-726)	No assessment of obesity
33.	Hoyt LT et al. (2014) Neighborhood Influences on Girls' Obesity Risk Across the Transition to Adolescence (Pediatrics 134: 942-949)	Global SES measure
34.	Huang JY et al. (2015) Are Early-Life Socioeconomic Conditions Directly Related to Birth Outcomes? Grandmaternal Education, Grandchild Birth Weight, and Associated Bias Analyses (Am J Epidemiol 182)	No assessment of obesity
35.	Huang CC, Yabiku ST, Ayers SL, Kronenfeld JJ (2016) The obesity pay-gap: gender, body size, and wage inequalities – a longitudinal study of Chinese adults, 1991-2011 (J Pop Research 33: 221-242)	No assessment of obesity
36.	Huffman SK et al. (2007) Determinants of obesity in transition economics: The case of Russia (Econ Hum Biol 5: 379-391)	No assessment of obesity
37.	Insaf TZ et al. (2014) Lifecourse Socioeconomic Position and 16 Year Body Mass Index Trajectories: Differences by Race and Sex (Prev Med 67: 17-23)	No assessment of obesity
38.	Jansen PW et al. (2013) Family and Neighbourhood Socioeconomic Inequalities in Childhood Trajectories of BMI and Overweight: Longitudinal Study of Australian Children (PLoS ONE 8(7))	No assessment of obesity

39.	Judge TA et al. (2011) When it comes to Pay, Do the Thin Win? The Effect of Weight on Pay for Men and Women (J Appl Psychol 96: 95-112)	Global SES measure
40.	Kelles A et al. (2009) Offspring consume a more obesogenic diet than mothers in response to changing socioeconomic status and urbanization in Cebu, Philippines (Int J Behav Nutr Phys Act 6)	No assessment of income
41.	Kenney et al. (2015) The academic penalty for gaining weight: a longitudinal, change-in-change analysis of BMI and perceived academic ability in middle school students. International Journal of Obesity 39: 1408-1413	No assessment of income
42.	Lee HH et al. (2012) Factors Related to Body Mass Index and Body Mass Index Change in Korean Children: Preliminary Results from the Obesity and Metabolic Disorders Cohort in Childhood (Korean J Fam Med 33: 134-143)	No assessment of obesity
43.	Li M (2015) Chronic Exposures of Grandparents to Poverty and Body Mass Index Trajectories of Grandchildren: A Prospective Intergenerational Study (Am J Epidemiol 181(3): 163-170)	No assessment of obesity
44.	Ljungvall A et al. (2010) More equal but heavier: A longitudinal analysis of income-related obesity inequalities in and adult Swedish cohort (So Sci Med 70: 221-231)	No assessment of obesity
45.	Loman T et al. (2013) Multiple socioeconomic determinants of weight gain: the Helsinki Health Study (BMC Public Health 13)	No assessment of obesity
46.	Matijasevich A et al. (2009) Socioeconomic position and overweight among adolescents: data from birth cohort studies in Brazil and the UK (BMC Public Health 9)	No assessment of obesity
47.	Michael YL et al. (2014) Does change in the neighborhood environment prevent obesity in older women? (So Sci Med 102: 129-137)	Global SES measure
48.	Mujahid MS et al. (2005) Cross-Sectional and Longitudinal Associations of BMI with Socioeconomic Characteristics (Obesity Research 13)	No assessment of obesity
49.	Murasko JE (2011) Associations between household income, height, and BMI in contemporary US schoolchildren (Econ Hum Biol 11: 185-196)	No assessment of obesity
50.	Murayama H et al. (2015) Socioeconomic Status and the Trajectory of Body Mass Index Among Older Japanese: A Nationwide Cohort Study of 1987-2006 (J Gerontol B Psychol Sci Soc Sci 71: 378-388)	No assessment of obesity
51.	Noh JW et al. (2014) Gender Differences and Socioeconomic Status in Relation to Overweight among Older Korean People (PLOS One 9(5))	No assessment of obesity
52.	Oddo VM, Hersch Nicolas L, Bleich SN, Jones-Smith JC (2016) The impact of changing economic conditions on overweight risk among children in California from 2008 to 2012 (J Epidemiol Community Health 0: 1-7)	No assessment of income
53.	Oliver LN et al. (2008) Effects of neighbourhood income on reported body mass index: an eight year longitudinal study of Canadian children (BMC Public Health 8)	No assessment of obesity
54.	Powell-Wiley TM et al. (2014) Neighborhood-Level Socioeconomic Deprivation Predicts Weight Gain in a Multi-Ethnic Population: Longitudinal Data from the Dallas Heart Study (Prev Med 66: 22-27)	No assessment of obesity
55.	Powell-Wiley TM et al. (2015) Change in Neighborhood Socioeconomic Status and Weight Gain. Dallas Heart Study (Am J Prev Med 49: 72-79)	No assessment of obesity
56.	Pudrovska et al. (2014) Gender and Reinforcing Associations between Socioeconomic Disadvantage and Body Mass over the Life Course. Journal of Health and Social Behavior 55: 283-301.	Global SES measure
57.	Scharoun-Lee M et al. (2009) Obesity, Race/ethnicity and Life Course Socioeconomic Status across the Transition from Adolescence to Adulthood. (J Epidemiol Community Health 63: 133-139)	No assessment of income
58.	Scharoun-Lee M et al. (2009) Obesity, race/ethnicity and the multiple dimensions of socioeconomic status during the transition to adulthood: A factor analysis approach. (Soc Sci Med 68: 708-716)	Factor analysis

59.	Schmeer K (2010) Household Income during Childhood and Young Adult Weight Status: Evidence from a Nutrition Transition Setting (J Health Soc Behav 51(1): 79-91)	No assessment of obesity
60.	Sund ER et al. (2007) Individual, family, and area predictors of BMI and BMI change in an adult Norwegian population: Findings from the HUNT study (Soc Sci Med 70)	No assessment of obesity
61.	van Hook J et al. (2007) Immigrant generation, socioeconomic status, and economic development of countries of origin: A longitudinal study of body mass index among children (Soc Sci Med 65: 976-989)	No assessment of obesity
62.	Viner RM et al. (2005) Adult socioeconomic, educational, social, and psychological outcomes of childhood obesity: a national birth cohort study. (BMJ 330: 1354-1357)	No assessment of obesity
63.	Zargorsky JL (2005) Health and wealth. The late-20 th century obesity epidemic in the U.S. (Econ Hum Biol 3: 296-313)	No assessment of obesity
64.	Zeng W et al. (2013) Adult obesity: Panel study from native Amazonians (Econ Hum Biol 11: 227-235)	No assessment of obesity
65.	Ziol-Guest KM et al. (2009) Early Childhood Poverty and Adult Body Mass Index (Am J Public Health 99: 527-532)	No higher income control group in analysis

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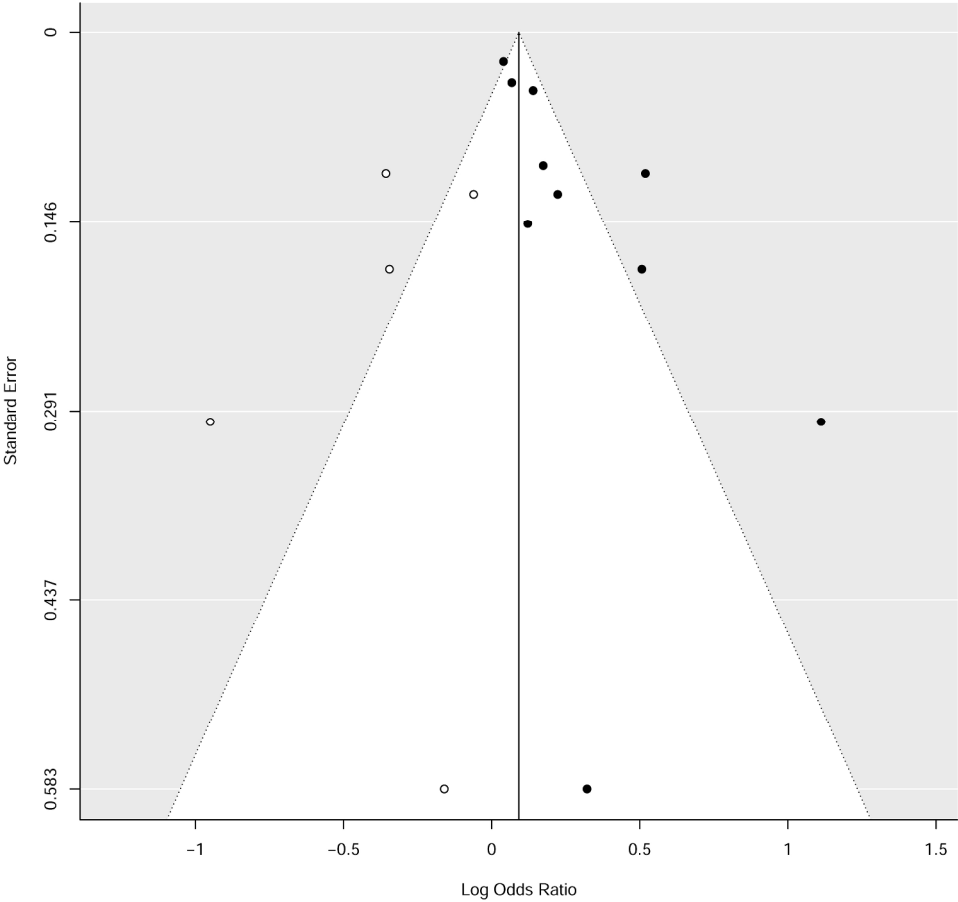
Table: Newcastle-Ottawa Assessment Scale for Cohort studies testing the causation hypothesis

Quality assessment	Acceptable criteria	Brophy 2009	Chaffee 2015	Chia 2013	Demment 2014	Goisis 2015	Hoyt 2014	Jo 2014	Kakinami 2014	Kim 2010	Lee 2009	Lee 2014	Pearce 2015	Salsberry 2009	Strauss 1999
Exposed cohort representative?	Representative of average community?	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Selection of non-exposed cohort?	Drawn from same sample as exposed cohort?	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Ascertainment of exposure?	Structured interview?	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Outcome at baseline?	Incidence of overweight and/or obesity?	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Controls for important factors?	Adjusted for age and sex?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Controls for additional factors?	Adjusted for at least 3 other (risk) factors?	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Assessment of outcome?	Assessed through height/weight measurement?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Adequacy of follow-up duration?	Follow-up duration ≥ 5 years?	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Adequacy of lost at follow-up?	Complete follow up? Bias unlikely through lost cases?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
≥ 80% = High 70% - 80% = Medium < 70% = Low		7 med	6 low	6 low	7 med	9 high	6 low	7 med	7 med	6 low	8 high	9 high	7 med	7 med	9 high

Table: Newcastle-Ottawa Assessment Scale for Cohort studies testing the selection hypothesis

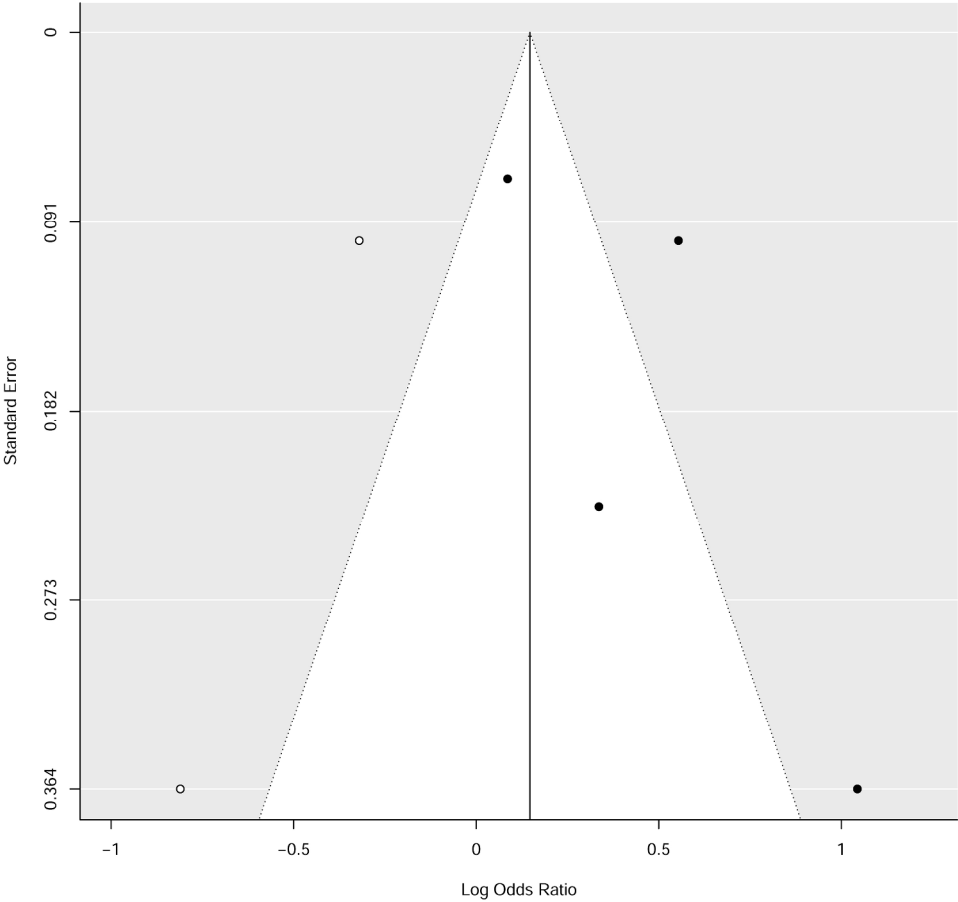
Quality assessment	Acceptable criteria	Amis 2014	Baum 2004	Cawley 2005	Conley 2007	Han 2011	Larose 2016	Mason 2012
Exposed cohort representative?	Representative of average community?	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Selection of non-exposed cohort?	Drawn from same sample as exposed cohort?	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Ascertainment of exposure?	Assessed through height/weight measurement?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Outcome at baseline?	N.A.	--	--	--	--	--	--	--
Controls for important factors?	Adjusted for age and sex?	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Controls for additional factors?	Adjusted for at least 3 other risk factors?	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Assessment of outcome?	Structured interview?	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Adequacy of follow-up duration?	N.A.	--	--	--	--	--	--	--
Adequacy of lost at follow-up?	Complete follow up or bias unlikely through lost cases?	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
≥ 80% = High 70% - 80% = Medium < 70% = Low		4 low	5 med	6 high	5 med	5 med	5 med	5 med

Abbreviations: N.A. = Not applicable



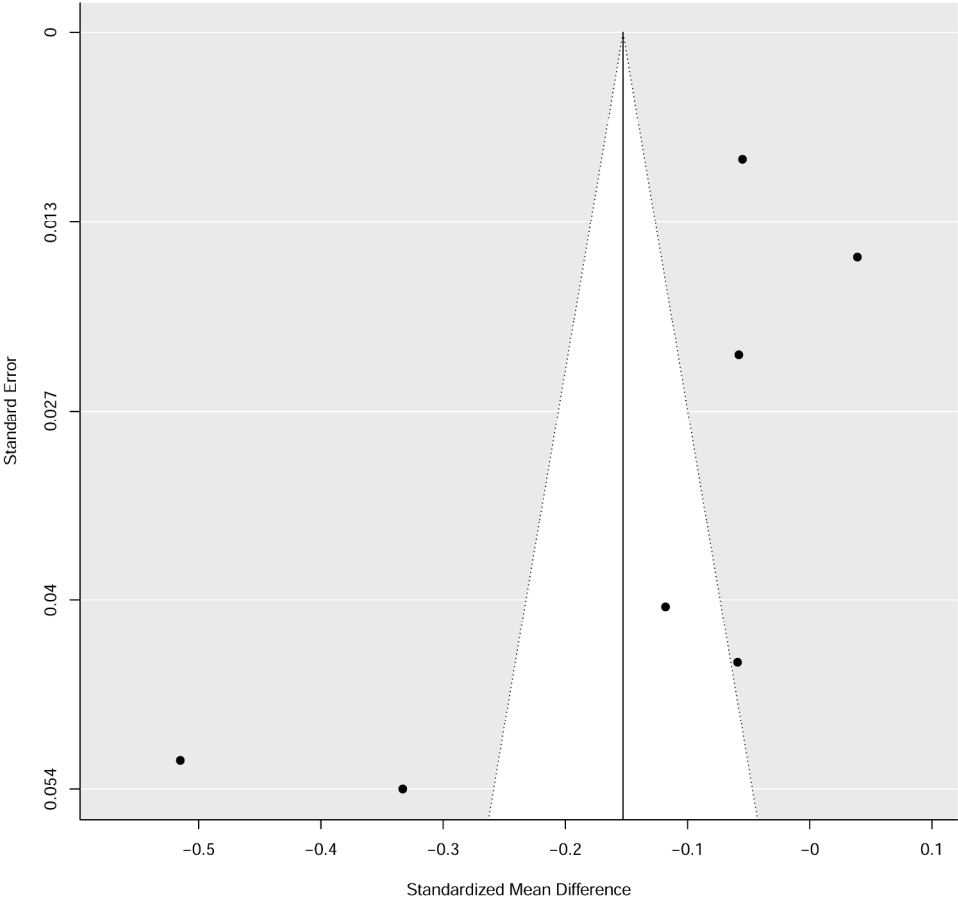
254x254mm (300 x 300 DPI)





254x254mm (300 x 300 DPI)





254x254mm (300 x 300 DPI)

