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# BMJ Open

## Neighborhood socioeconomic status and overweight/obesity: a systematic review and meta-analysis of epidemiological studies

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Complete List of Authors:	Mohammed, Shimels Hussien; Tehran University of Medical Sciences, Community Nutrition Habtewold, Tesfa; Debre Berhan University, Nursing; Universiteit Groningen Faculteit voor Geneeskunde, Epidemiology Birhanu, Mulugeta ; Mekele University Sissay, Tesfamichael Awoke ; Wollo University Tegegne, Balewgizie; Universiteit Groningen Faculteit voor Geneeskunde, Epidemiology Abuzerr, Samer; Tehran University of Medical Sciences Esmailzadeh, Ahmad; Tehran University of Medical Sciences
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Manuscripts

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5 1 **Neighborhood socioeconomic status and overweight/obesity: a systematic**  
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8 2 **review and meta-analysis of epidemiological studies**  
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11 3 Shimels Hussien Mohammed<sup>1</sup>, Tesfa Dejenie Habtewold<sup>2</sup>, Mulugeta Molla Birhanu<sup>3</sup>,  
12  
13  
14 4 Tesfamichael Awoke Sissay<sup>4</sup>, Balewgizie Sileshi Tegegn<sup>2</sup>, Samer Abuzerr<sup>5</sup>, Ahmad  
15  
16 5 Esmailzadeh<sup>6,7,8\*</sup>

17  
18  
19  
20 6 <sup>1</sup>Department of Community Nutrition, School of Nutritional Sciences and Dietetics, Tehran  
21  
22 7 University of Medical Sciences-International Campus (TUMS-IC), Tehran, Iran.

23  
24  
25 8 <sup>2</sup>Department of Epidemiology, University Medical Center Groningen, University of Groningen,  
26  
27 9 Groningen, The Netherlands.

28  
29  
30  
31 10 <sup>3</sup>School of Nursing, College of Health Sciences, Mekelle University, Mekelle, Ethiopia.

32  
33  
34  
35 11 <sup>4</sup>Department of Public Health, Wollo University, Wollo, Ethiopia.

36  
37  
38 12 <sup>5</sup>Department of Environmental Health Engineering, Faculty of Public Health, Tehran University  
39  
40 13 of Medical Sciences-International Campus (TUMS-IC), Tehran, Iran.

41  
42  
43  
44 14 <sup>6</sup>Obesity and Eating Habits Research Center, Endocrinology and Metabolism Molecular Cellular  
45  
46 15 Sciences Institute, Tehran University of Medical Sciences, Tehran, Iran.

47  
48  
49  
50 16 <sup>7</sup>Department of Community Nutrition, School of Nutritional Sciences and Dietetics, Tehran  
51  
52 17 University of Medical Sciences, Tehran, Iran.

1  
2  
3 1 <sup>8</sup>Food Security Research Center, Department of Community Nutrition, Isfahan University of  
4  
5  
6 2 Medical Sciences, Isfahan, Iran.

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10  
11 4 \*Correspondence to: Shimels Hussien Mohammed (shimelsh@gmail.com, +989334862413,  
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13  
14 5 ORCID: 0000-0001-8231-4158)

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28 9 **Abstract**

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32 10 **Objective:** Poor neighborhood socioeconomic conditions have been linked to a higher risk of  
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34 11 overweight/obesity, irrespective of individuals own socioeconomic status. However, there is no  
35  
36 12 meta-analysis report is on the association. We aimed to synthesize the existing evidence and  
37  
38 13 provide pooled estimates.

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41  
42 14 **Method:** We searched PubMed, EMBASE, SCOPUS, Web of Sciences and Google Scholar for  
43  
44 15 studies on the association of neighborhood socioeconomic conditions with overweight or obesity,  
45  
46 16 published from inception to June 15, 2018. The pooled estimates of the relationship of  
47  
48 17 neighborhood socioeconomic status with overweight and obesity were calculated with random  
49  
50 18 effects meta-analysis models. Heterogeneity between the studies was assessed by Cochran's Q  
51  
52 19 and I<sup>2</sup>-statistics. Subgroup analyses were done by age categories, continents, study designs, and

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4 1 methods of neighborhood socioeconomic measures. Publication bias was assessed by visual  
5  
6 2 inspection of funnel plots and Egger's regression test.  
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9 3 **Result:** A total of 10 studies, covering 1,151,409 individuals, were included in this meta-analysis.  
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11 4 Residence in poor neighborhoods, compared with residence in better-off neighborhoods, was  
12  
13  
14 5 found associated with a 31% higher odds of overweight (pooled OR=1.31, 95%CI=1.16-1.47,  
15  
16 6 P<0.001), and a 43% higher odds of obesity (pooled OR=1.43, 95%CI=1.18-1.74, P<0.001).  
17  
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19  
20 7 **Conclusion:** Neighborhood economic deprivation may be contributing to the burden of  
21  
22 8 overweight/obesity. Further studies are warranted, including whether addressing neighborhood  
23  
24 9 economic disparity reduces the risk of overweight/obesity.  
25  
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28 10 **PROSPERO Registration:** CRD42017063889  
29  
30

31 11 **Keywords:** Neighborhood socioeconomic status, Obesogenic environment, Overweight, Obesity,  
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33 12 Meta-analysis  
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### 38 13 **Strengths and limitations**

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- 41 14     ▪ This is the first meta-analysis study on the association of neighborhood socioeconomic  
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43     status with overweight/obesity.  
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45 15     ▪ The studies included are observational in design, precluding making causal inference.  
46  
47 16     ▪ There is heterogeneity in the methods of measuring neighborhood socioeconomic status.  
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49 17     ▪ The studies are mainly based on western population, limiting the generalizability of the  
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51 18     findings to other setups.  
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## Introduction

Obesity remains a major global public health problem. While the current level of obesity already poses a significant burden to the health system, the problem is still on the rise and causing more negative consequences at both individual and society levels.<sup>1</sup> Worldwide, 39% of adults were estimated to be overweight in 2016. In the same year, 13% of adults were estimated to be obese; almost triple of the figure in 1975.<sup>1</sup> The World Health Organization (WHO) has prioritized the prevention and control of obesity as a central public health agenda and recommends nations to make a substantial improvement with regard to the current trend of obesity.<sup>2</sup> However, the global progress to curb the rise and burden of overweight/obesity has been slow and frustrating, with each consecutive generation developing overweight/obesity at an early age and at higher rates.<sup>3</sup>

4

Overweight/obesity is a multi-causal problem, with its influences originating from various levels; including individual, social, and environmental origins. According to ecological models of obesity causation, the risk factors of overweight/obesity often interact with each other and may be of direct or indirect influences on the weight status of individuals.<sup>5-7</sup> The main direct determinants are often

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2  
3 1 unhealthy dietary patterns and low physical activity, resulting in a positive energy balance.<sup>8 9</sup>  
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6 2 However, the environment in which individuals live has a strong influence on one's choice and  
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8 3 adoption of health-enhancing behaviors.<sup>6 7 10 11</sup> For example, residence in poor neighborhoods  
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10 4 has been associated with a higher risk of overweight/obesity, irrespective of individual-level  
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12 5 socioeconomic status.<sup>12</sup> Neighborhood deprivation has been associated with high availability of  
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14 6 energy-dense food outlets, low availability of fruit and vegetable outlets and limited public sporting  
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16 7 facilities. The influence of neighborhood deprivation is not limited to overweight/obesity. It has  
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18 8 also been linked to various poor behavioral and health outcomes like drug abuse, cardiovascular  
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20 9 diseases, and poor mental health including depression.<sup>13 14</sup> Thus, improving neighborhoods  
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22 10 socioeconomic status (NSES) has been recommended as a potential strategy for the prevention  
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24 11 and control of the current obesity epidemics as well as other chronic illnesses.<sup>13 14</sup>  
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31 12 There are a number of empirical studies on the link of neighborhood economic deprivation to  
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33 13 higher risks or odds of overweight/obesity. The studies were, however, inconsistent in their  
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35 14 findings. Some studies have reported a null association,<sup>15 16</sup> while other reported a strong  
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37 15 association between poor NSES and overweight/obesity.<sup>17 18</sup> To date, there is no meta-analysis  
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39 16 report on the association of NSES with overweight or obesity. Synthesizing the existing evidence  
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41 17 would provide a summary estimate on the association and contribute to filling the gap in the  
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43 18 literature. It may also facilitate evidence-based decision making as there is a better recognition of  
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45 19 systematic review and meta-analysis findings in policy and decision making processes. Thus, in  
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47 20 this work, we reviewed and meta-analyzed studies that reported on the association of NSES with  
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49 21 overweight and obesity.  
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## 1 **Methods**

2 We conducted this systematic review and meta-analysis according to a priorly published study  
3 protocol<sup>19</sup> and following recommendations of the Meta-analysis of Observational Studies in  
4 Epidemiology (MOOSE)<sup>20</sup> and the Preferred Reporting Items for Systematic Reviews and Meta-  
5 Analyses (PRISMA)<sup>21</sup> guidelines. The review protocol was also registered with the International  
6 Prospective Register of Systematic Reviews, registration number CRD42017063889.

### 7 **Literature search and eligibility criteria**

8 We searched five databases: EMBASE, PubMed, Scopus, Web of Sciences and Google Scholar,  
9 for studies published from inception to January 15, 2018. The search terms used included  
10 'neighborhood socioeconomic status', 'neighborhood socioeconomic condition', 'neighborhood  
11 socioeconomic index', 'neighborhood deprivation index', 'neighborhood poverty index', 'obesity',  
12 'overweight', 'body mass index', 'weight', and 'central obesity'. A sample of the search strategy,  
13 PubMed search strategy, developed using a combination of MeSH terms and free texts is  
14 presented (supplementary file 1). The PubMed search strategy was further adapted to the other  
15 databases: EMBASE, Scopus, Web of Sciences, and Google Scholar. We also hand searched  
16 articles, using the reference lists of the eligible studies and the 'cited by' function of PubMed. We  
17 aimed to include both observational and interventional studies (cross-sectional, case-control,  
18 cohort, longitudinal, and randomized control studies). The search was not restricted by sex, age,  
19 geographic location, or study year. Articles were excluded on any one of the following conditions:  
20 (1) animal studies, (2) study focused primarily on physical, policy, or social aspects of the  
21 environment, (3) language other than English, (4) citations without full text, (5) studies in which

1 the outcome measure was not overweight or obesity, and (6) qualitative studies, book chapters,  
2 symposium and conference proceedings, essays, commentaries, editorials, and case reports.

### 3 **Study screening and data extraction**

4 The results of database searches were exported to EndNote X8 software to remove duplicates  
5 and manage the screening process. Titles and abstracts of retrieved studies were assessed by  
6 two reviewers (SHM, TDH), working independently and in duplicate, to determine their eligibility  
7 for full-text reviewing. Full text reviewing was done by SHM and TDH. Disagreement on the  
8 eligibility of studies was resolved by consensus. The process of article screening and selection is  
9 presented in Figure 1 [refer to Figure 1: PRISMA flow diagram]. SHM, extracted the data, double  
10 checked by TDH. Data extracted from included studies were (1) study identification (first author,  
11 year of publication, and title), (2) study characteristics (country, study design, sample size, and  
12 follow-up period for longitudinal studies), (3) study participant's characteristics (sex, proportion of  
13 men, and mean age), (4) NSES assessment method, (5) outcome assessment method, (6)  
14 measure of association and reported estimates, and (7) variables used for adjustment. The  
15 predefined measures of association were RR or OR of overweight or obesity among individuals  
16 living in poor neighborhoods, compared with individuals living in better-off neighborhoods. When  
17 studies reported more than one estimate, we took the estimate that was adjusted for more  
18 variables. When studies reported multiple NSES comparisons, we took the estimate which  
19 compared the highest and the lowest NSES categories.

### 20 **Study quality assessment**

21 We evaluated the methodological quality of the included studies using the Newcastle-Ottawa  
22 Scale (NOS)<sup>22</sup>. The grading was out of 9, with scores from 0 to 3 considered low quality, from 4

1 to 6 medium quality, and from 7 to 9 high quality. The ratings for each study were compared between the two evaluators (SHM, TDH) with discrepancy resolved by consensus.

### 3 **Statistical analysis**

4 Separate meta-analyses were done for the outcome measures: overweight and obesity. Most studies reported using OR as a measure of association. Thus, in this work, OR was used to pool the estimates reported by the included studies. The OR represents the risk of developing overweight or obesity among individuals living in poor neighborhoods (low NSES), compared with individuals living in affluent neighborhoods (high NSES). For all estimates, if P-values were reported as  $P < 0.001$  with no 95%CI or standard error (SE) report, we assumed  $P = 0.001$  to calculate the corresponding 95%CI and SE. Heterogeneity among the studies was assessed by  $I^2$  statistics, which estimate the proportion of variance attributable to between-studies heterogeneity. A non-substantial level of statistical heterogeneity was assumed when  $P < 0.1$  or  $I^2 < 50\%$ .<sup>23</sup> Source of heterogeneity was assessed by conducting subgroup analyses using the predefined potential sources of heterogeneity as outlined in the study protocol,<sup>19</sup> which were age category (adults versus children), region/continent, study design, and methods of NSES measurements. Due to a persisting high level of heterogeneity even after subgrouping, we calculated the summary estimates with the random effects model, which accounts for both within and between studies variations. We aimed to assess publication bias by visual inspection of funnel plots and Egger's regression test.<sup>24</sup> According to Egger's test of asymmetry of funnel plots, publication bias is assumed at  $P < 0.1$ .<sup>24</sup> To evaluate the influence of each study on the summary estimates, we conducted sensitivity analyses using the leave-one-out and analyses the rest method. Stata version 15.0 software was used for all analyses.

## 2 Result

### 3 Search result and study characteristics

4 The search strategy generated a total of 2,375 studies. Screening the title and abstract of these  
 5 studies resulted in 79 studies eligible for full-text review. Reviewing the full text of the 79 studies,  
 6 resulted in eight eligible articles. Through hand searching of the references of the included studies  
 7 and the 'cited by' function of PubMed and Google Scholar, two additional articles were identified.  
 8 The flowchart of the screening and selection process is shown in Figure 1. The main  
 9 characteristics of the included studies are presented in Table 1. The sample size of the studies  
 10 ranged from 144 to 948,062 individuals. In total, the 10 studies<sup>15-18 25-30</sup> included a total of 1,151,  
 11 409 unique individuals of all age categories, of whom 53.13% were males and 46.87% females.  
 12 The mean age of study participants was 43.92 years. The studies were published from 2005 to  
 13 2016. The majority of the studies, 7/10 (70.00%), were cross-sectional in design and 3/10  
 14 (30.00%) longitudinal. All studies were conducted in high-income countries: 3 in USA, 1 in  
 15 Canada, 2 in Germany, 3 in Sweden, and 1 in New Zealand.

16 Table 1: General characteristics included studies.

First author (year)	Country	Region	Study design	Follow-up	Sample (n)	Mean age	Men(%)	Population	NSES <sup>†</sup> measure	Weight measure
Amber (2014) <sup>17</sup>	New Zealand	Australia	CS	None	12488	47.00	53.00	Adults	NDI	Obesity
Steffen (2016) <sup>25</sup>	Germany	Europe	CS	None	3499	6.00	53.00	Children	NSESI	Obesity
Catherine (2006) <sup>15</sup>	Sweden	Europe	CS	None	18081	44.60	49.20	Adults	NDI	Obesity
Steven (2016) <sup>26</sup>	USA	America	LS	24 years	11499	10.31	51.00	Children	NDI	Obesity
Patricia (2010) <sup>27</sup>	USA	America	LS	10 years	48359	NA	0.00	Adults	NSESI	Obesity
Andrea (2016) <sup>16</sup>	USA	America	CS	None	144	26.40	100.00	Adults	NDI	Obesity

Xinjun (2014) <sup>28</sup>	Sweden	Europe	LS	10 years	948062	8.60	51.30	Children	NDI	Obesity
Steffen (2016) <sup>18</sup>	Germany	Europe	CS	None	3499	6.00	53.00	Children	NSESI	Overweight
Lisa (2005) <sup>29</sup>	Canada	America	CS	None	11455	11.80	50.80	Children	NDI	Overweight
Eva (2009) <sup>30</sup>	Sweden	Europe	CS	None	94323	31.40	100.00	Adults	NSESI	Obesity

1 LS=longitudinal, CS=cross-sectional, NSES= Neighborhood socioeconomic status,

2 NDI=Neighborhood deprivation index

3

#### 4 **Association of NSES with overweight**

5 We found two studies which reported on the link of NSES to overweight, body mass index  
6 (BMI)>25 kg/m<sup>2</sup>. The summary odds of overweight associated with living in poor neighborhoods  
7 was 30% higher, compared with residence in better-off neighborhoods (pooled OR=1.30,  
8 95%CI=1.16-1.47, P<0.001) with no evidence significant heterogeneity (I<sup>2</sup>=0.00%, P=0.609).

9 Figure 2 presents the result of the meta-analysis of the NSES-overweight association.

#### 10 **Association of NSES with Obesity**

11 We found eight studies which reported on the association of NSES with obesity, BMI≥30 kg/m<sup>2</sup>.  
12 The odds of being obese was 43% higher in individuals living in poor neighborhoods, compared  
13 with that of individuals living in better-off neighborhoods (pooled OR=1.43, 95%CI=1.18-1.74,  
14 P<0.001). Figure 3 shows the forest plot and summary estimate of the meta-analysis of the NSES-  
15 obesity association. There was a high level of heterogeneity among the studies (I<sup>2</sup>=93.00%,  
16 P<0.001). We explored the sources of the heterogeneity by doing subgroup analyses. However,  
17 the level of heterogeneity remained high even after the subgroups analyses. The subgroup-  
18 specific summary estimates with their corresponding levels of heterogeneity are presented in  
19 Figure 4. Across the three continents, Australia, America, and Europe, NSES maintained a  
20 significant association with obesity (P<0.05). In children, residence in poor neighborhoods was

1 associated with a 1.57 times higher odds of obesity compared to children living in better of  
 2 neighborhoods. The association was not significant, albeit largely towards being significantly  
 3 associated (pooled OR=1.57, 95%CI=0.98-2.51). In adults, poor NSES was associated a  
 4 significantly higher odds of obesity, such that the odds of obesity was 1.37 times higher in  
 5 individuals living in poor neighborhoods, compared with individuals living in better-off  
 6 neighborhoods (pooled OR=1.37, 95%CI=1.11-1.68). By study designs, NSES was significantly  
 7 linked to obesity in cross-sectional studies, but not in longitudinal studies.

8 It was not possible to assess publication bias on the NSES-obesity as there was an inadequate  
 9 number of studies which under-powered any of the statistical methods to assess publication bias.

10 A minimum of eight studies is needed to assess publication bias. To evaluate the influence of  
 11 each study on the summary estimate, we conducted sensitivity analyses (Table 2). Overall, no  
 12 study notably changed of the direction and magnitude the association, with the summary OR  
 13 ranging from lowest 1.29 (95%CI=1.10-1.48) after excluding Xinjun et al.<sup>28</sup> to highest 1.50  
 14 (95%CI=1.21-1.78) after excluding Steven et al.<sup>26</sup>

15 Table 2: Sensitivity analysis of studies on the association of neighborhood socioeconomic status  
 16 with obesity

Study omitted	Pooled OR	95% CI
Amber (2014) <sup>17</sup>	1.49	1.16-1.81
Catherine (2006) <sup>15</sup>	1.43	1.16-1.69
Xinjun (2014) <sup>28</sup>	1.29	1.10-1.48
Steffen (2016) <sup>25</sup>	1.35	1.12-1.57

Steven (2016) <sup>26</sup>	1.50	1.21-1.78
Andrea (2016) <sup>16</sup>	1.39	1.16-1.62
Eva (2009) <sup>30</sup>	1.32	1.10-1.55
Patricia (2010) <sup>27</sup>	1.41	1.16-1.67

1 OR=odds ratio, CI=confidence interval

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### 3 Discussion

4 The study was aimed to pool the existing empirical studies on the link of NSES to overweight and  
5 obesity. Overall, NSES was found significantly associated with overweight/obesity, such that  
6 residence in economically deprived neighborhoods was associated with significantly higher odds  
7 of overweight and obesity. The association remained significant across populations of three  
8 continents: North America, Australia, and Europe. However, there was variation in the NSES-  
9 obesity association by study design and age sub-groups.

10 The findings of this work were consistent with the reports of previous empirical studies which  
11 reported a higher odds of overweight/obesity as well as other adverse health outcomes among  
12 individuals living in poor neighborhoods.<sup>18 28 29</sup> The mechanisms through which NSES contributes  
13 to the development of overweight/obesity have not been thoroughly documented. However,  
14 various potential mechanisms have been suggested to explain the link. The most frequently  
15 mentioned mechanisms is the 'obesogenic environment' hypothesis that poor neighborhoods  
16 promote unhealthy lifestyles, particularly unhealthy dietary practice and sedentariness.<sup>12 31</sup>

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3 1 Health-enhancing facilities and options are often limited in poor neighborhoods but junk food  
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6 2 items, alcohol, and drug are more readily available.<sup>31 32</sup> Streets walkability and safety are more  
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8 3 compromised; thus, limiting the resident's movement.<sup>11 33</sup> A multinational study in Europe showed  
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10 4 that physical inactivity and unhealthy eating jointly accounted for one-fifth of the NSES-BMI  
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12 5 association.<sup>34</sup> Another potential, but not a thoroughly examined mechanism, is the 'stress and  
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14 6 depression hypothesis' that stress and depression could result in an unhealthy lifestyle and  
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16 7 subsequently lead to a higher risk of overweight/obesity.<sup>32</sup> Provided poor neighborhood economic  
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18 8 conditions have been related to a higher risk of depression,<sup>32</sup> it could be presumed that depression  
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20 9 may mediate the link of NSES to overweight/obesity. Despite the ongoing debate on which these  
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22 10 factors deserve the most responsibility in the link between NSES and overweight/obesity, most  
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24 11 factors are believed to influence weight mainly through tipping the energy balance towards gaining  
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26 12 more calorie. However, whether the energy dynamics mediate the NSES-BMI link has not been  
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28 13 well established and requires further investigation.<sup>9-11</sup>  
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35 14 The finding of this study might be indicative of the importance of investigating as well as  
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37 15 addressing the determinants of overweight/obesity comprehensively, i.e., examining not only the  
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39 16 proximal behavioral factors but also the underlying environmental and structural factors. However,  
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41 17 the existing literature is largely focused on identifying or addressing the individual level behavioral  
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43 18 influences.<sup>7</sup> For example, the evidence is limited about how, and to what extent, neighborhood  
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45 19 socioeconomic conditions influence individuals' dietary practice and level of physical activity.  
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47 20 Whether improving neighborhood economic deprivation results in the adoption of health-  
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49 21 enhancing lifestyle also remains largely unknown. Besides, the existing evidence on NSES-  
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51 22 obesity association, including the report of this work, is largely based on observational studies.  
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4 1 Thus, further randomized controlled, community-based studies are needed to reach a more  
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6 2 conclusive conclusion. Meanwhile, it might be worthy of considering a comprehensive approach  
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8 3 in policy-making with regard to obesity prevention and control strategies, including addressing  
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10 4 disparities in neighborhood economic disparities. So far, obesity interventions have been  
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13 5 selectively focused on providing information to address the individual-level determinants.  
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15 6 However, unless supported by an enabling environment, provision of health information alone  
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17 7 might not lead to the intended result. Thus, the lack of comprehensiveness and integrity of  
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20 8 interventions might partly explain the current non-promising progress in obesity prevention and  
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23 9 control approaches.<sup>4 33</sup> Poor neighborhoods often lack healthy weight promoting amenities, like  
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25 10 sporting facilities and fruit/vegetable outlets.<sup>31</sup> We believe that addressing neighborhood  
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28 11 deprivation by availing healthy choices closer and affordable to everyone, might facilitate the  
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30 12 adoption of health-enhancing behaviors, thereby reducing the risk of overweight/obesity.  
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32 13 However, the proposition needs to be further evaluated.  
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### 36 37 15 **Limitations and Strengths**

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41 16 The work has many limitations. The lack of uniformity in NSES measures and covariates used for  
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43 17 adjustment might have introduced heterogeneity and undermined the comparability of the studies.  
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46 18 All studies included in this work were done in high-income countries. The lack of data from low-  
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48 19 and middle- income countries would limit the generalizability of the findings beyond the developed  
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51 20 nations as NSES-obesity association would vary by countries' socioeconomic status. In  
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53 21 developing countries, due to the traditionally held positive attitude toward overweight, low NSES  
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55 22 might be associated with a lower risk of overweight/obesity, unlike the case in the developed  
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3 1 nations. Therefore, the findings of this work might not be applicable to developing countries. The  
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6 2 association of NSES with BMI in continuous scale was not assessed in this study. All studies  
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9 3 included in this work were observational in design, making casual inference impossible. Reverse  
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11 4 causality cannot be ruled out; i.e., instead of better-off neighborhoods promoting healthy weight,  
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13 5 it is possible that individuals with a healthy weight are more interested in health, and therefore,  
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15 6 prefer living in better-off neighborhoods. To the best of our knowledge, this study is the first  
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17 7 systematic review and meta-analysis report on the link of NSES to overweight/obesity. Thus, it  
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19 8 would be contributing to filling the existing gap in the literature. The inclusion of multi-national  
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21 9 studies, a large number of study participants and individuals of all age groups could improve the  
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23 10 representativeness of the study.  
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## 32 **Conclusion**

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36 13 We found that living in economically deprived neighborhoods, compared to living in better-off  
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38 14 neighborhoods, was associated with an overall higher odd of overweight or obesity. Evidence on  
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40 15 the association of NSES and overweight/obesity is missing in low and middle-income regions.  
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42 16 The exact mechanism by which NSES contributes to unhealthy weight, and whether addressing  
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44 17 NSES disparity reduces the risk of obesity is unclear. Further studies are warranted to understand  
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46 18 better how NSES influences weight and whether addressing NSES disparity reduce the risk of  
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48 19 overweight/obesity. Meanwhile, addressing neighborhoods economic disparity and bringing  
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50 20 healthy choices closer and affordable to everyone would be worthy of consideration.  
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## 7 2 **Funding**

11 3 This research received no specific grant from any funding agency in public, commercial or not-  
12  
13 4 for-profit sectors.

## 17 5 **Competing interest**

21 6 None declared.

## 24 7 **Patient consent**

28 8 This study was based on extracting data from published studies.

## 32 9 **Data sharing statement**

36 10 All data are included in the study.

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### 41 **Figures**

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44 14 Figure 1: PRISMA flow diagram.

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48 15 Figure 2: Forest plot of association of neighborhood socioeconomic status with overweight.

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51 16 Figure 3: Forest plot of association of neighborhood socioeconomic status with obesity.  
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1 Figure 4: Forest plot of association of neighborhood socioeconomic status with obesity, by  
2 subgroups.

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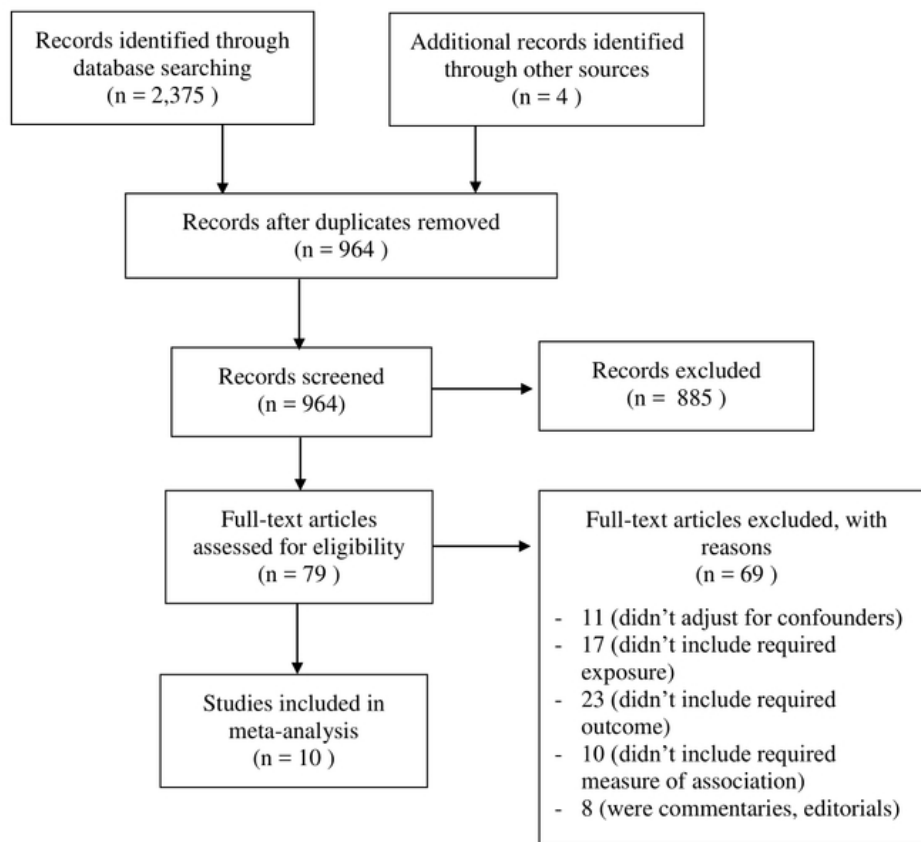


Figure 1: PRISMA flow diagram.

59x54mm (300 x 300 DPI)

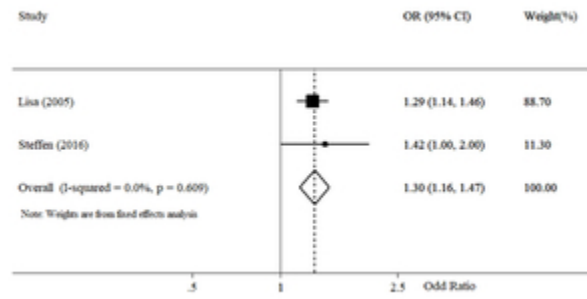


Figure 2: Forest plot of association of neighborhood socioeconomic status with overweight.

26x14mm (300 x 300 DPI)

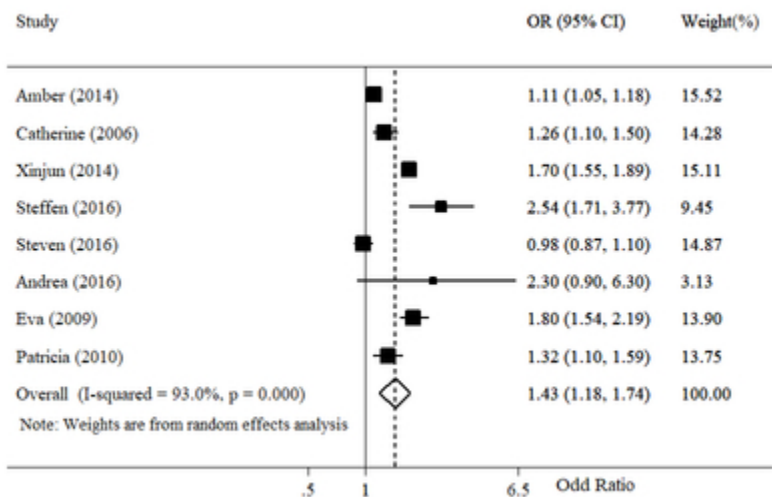


Figure 3: Forest plot of association of neighborhood socioeconomic status with obesity.

34x24mm (300 x 300 DPI)

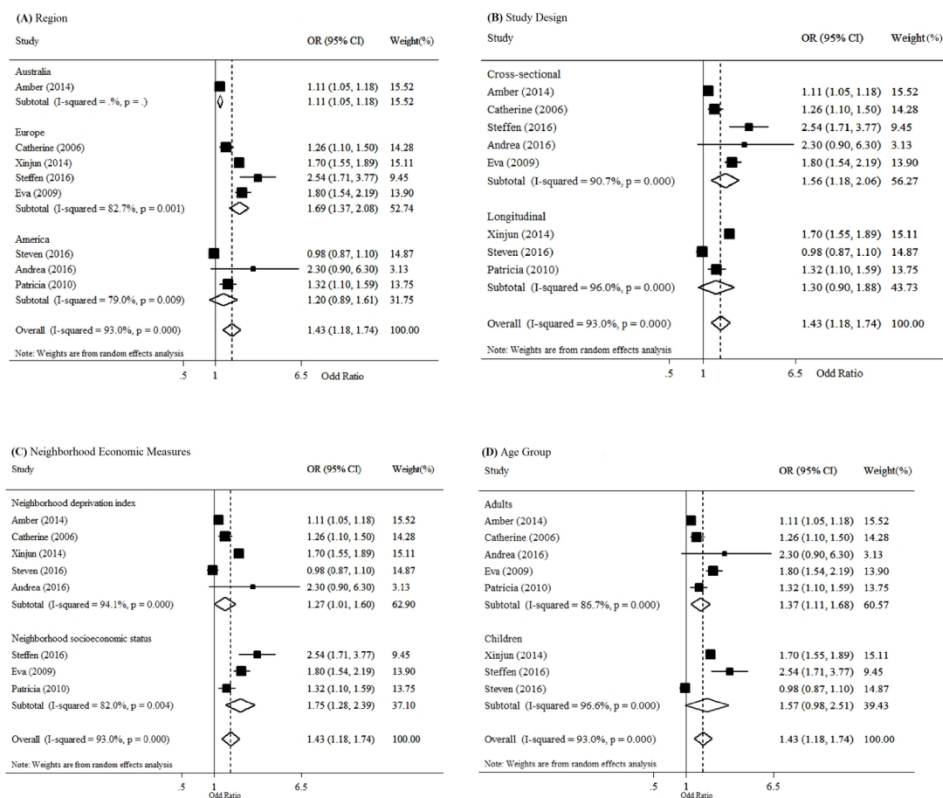


Figure 4: Forest plot of association of neighborhood socioeconomic status with obesity, by subgroups.

129x107mm (300 x 300 DPI)

## PubMed Search strategy

Search	Query	Hits*
#1	(((((((Body Weight[MeSH Terms]) OR Body Mass Index[MeSH Terms]) OR Body weight[Title/Abstract]) OR Weight[Title/Abstract]) OR Obesity[Title/Abstract]) OR Overweight[Title/Abstract]) OR Overweight[Title/Abstract]) OR BMI[Title/Abstract]	1049827
#2	((((((((((((Residence Characteristics/statistics and numerical data[MeSH Terms]))) OR Residence Characteristics/standards[MeSH Terms]) OR Residence Characteristics/economics[MeSH Terms]) OR Poverty Areas[MeSH Terms]) OR neighborhood socioeconomic*[Title/Abstract]) OR neighbourhood socioeconomic*[Title/Abstract]) OR neighborhood-level socioeconomic*[Title/Abstract]) OR neighbourhood-level socioeconomic*[Title/Abstract]) OR neighborhood socioeconomic*[Title/Abstract]) OR neighbourhood socioeconomic*[Title/Abstract]) OR neighborhood socioeconomic*[Title/Abstract]) OR neighbourhood socioeconomic*[Title/Abstract]) OR neighborhood socioeconomic*[Title/Abstract]) OR neighbourhood socioeconomic*[Title/Abstract]	15170
#3	#1 AND #2	2375

\*= Date of search: June 30, 2018



## PRISMA Checklist

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Section/topic	#	Checklist item	Reported on page #
<b>TITLE</b>			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
<b>ABSTRACT</b>			
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.	2
<b>INTRODUCTION</b>			
Rationale	3	Describe the rationale for the review in the context of what is already known.	4-5
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	4-5
<b>METHODS</b>			
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.	5
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.	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.	6
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	5
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).	5-6
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.	5-6
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



## PRISMA Checklist

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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
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Page 1 of 2

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).	6-7
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	6-7
<b>RESULTS</b>			
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.	7-8
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.	7-8
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).	8
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.	7-8
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	7-8
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	8-9
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	8-9
<b>DISCUSSION</b>			
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).	9-11
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).	11
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	11
<b>FUNDING</b>			
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.	12

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.





PRISMA Checklist

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For more information, visit: [www.prisma-statement.org](http://www.prisma-statement.org).

Page 2 of 2

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# BMJ Open

## Neighborhood socioeconomic status and overweight/obesity: a systematic review and meta-analysis of epidemiological studies

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2018-028238.R1
Article Type:	Original research
Date Submitted by the Author:	23-Jul-2019
Complete List of Authors:	Mohammed, Shimels Hussien; Tehran University of Medical Sciences, Department of Community Nutrition, School of Nutritional Sciences and Dietetics Habtewold, Tesfa; University of Groningen, Epidemiology; Debre Berhan University, Nursing Birhanu, Mulugeta ; Monash University, Department of Medicine, School of Clinical Sciences at Monash Health Sissay, Tesfamichael Awoke ; Addis Ababa University, Department of Public Health, School of Public Health Teegne, Balewgizie; University of Groningen, Department of Epidemiology, University Medical Center Groningen Abuzerr, Samer; Tehran University of Medical Sciences, Department of Environmental Health Engineering, Faculty of Public Health Esmailzadeh, Ahmad; Tehran University of Medical Sciences; Tehran University of Medical Sciences, Obesity and Eating Habits Research Center, Endocrinology and Metabolism Molecular Cellular Sciences Institute,
<b>Primary Subject Heading</b>:	Nutrition and metabolism
Secondary Subject Heading:	Epidemiology, Public health
Keywords:	Obesity, Overweight, Body mass index, Neighborhood, Meta-analysis

SCHOLARONE™  
Manuscripts

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5 1 **Neighborhood socioeconomic status and overweight/obesity: a systematic**  
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8 2 **review and meta-analysis of epidemiological studies**  
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11 3 Shimels Hussien Mohammed<sup>1\*</sup>, Tesfa Dejenie Habtewold<sup>2,3</sup>, Mulugeta Molla Birhanu<sup>4</sup>,  
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14 4 Tesfamichael Awoke Sissay<sup>5</sup>, Balewgizie Sileshi Tegegne<sup>2</sup>, Samer Abuzerr<sup>6</sup>, Ahmad  
15  
16 5 Esmailzadeh<sup>1,7,8</sup>

17  
18  
19  
20 6 <sup>1</sup>Department of Community Nutrition, School of Nutritional Sciences and Dietetics, Tehran  
21  
22 7 University of Medical Sciences, Tehran, Iran.

23  
24  
25 8 <sup>2</sup>Department of Epidemiology, University Medical Center Groningen, University of Groningen,  
26  
27 9 Groningen, The Netherlands.

28  
29  
30  
31 10 <sup>3</sup>Department of Nursing, Debre Berhan University, Debre Berhan, Ethiopia.

32  
33  
34 11 <sup>4</sup>Department of Medicine, School of Clinical Sciences at Monash Health, Monash University,  
35  
36 12 Australia.

37  
38  
39 13 <sup>5</sup>Department of Public Health, School of Public Health, Addis Ababa University, Ethiopia.

40  
41  
42 14 <sup>6</sup>Department of Environmental Health Engineering, Faculty of Public Health, Tehran University  
43  
44 15 of Medical Sciences, Tehran, Iran.

45  
46  
47  
48 16 <sup>7</sup>Obesity and Eating Habits Research Center, Endocrinology and Metabolism Molecular Cellular  
49  
50 17 Sciences Institute, Tehran University of Medical Sciences, Tehran, Iran.

1  
2  
3 1 <sup>8</sup>Food Security Research Center, Department of Community Nutrition, Isfahan University of  
4  
5  
6 2 Medical Sciences, Isfahan, Iran.

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11 4 \*Correspondence to: Shimels Hussien Mohammed (shimelsh@gmail.com, +989334862413,  
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14 5 ORCID: 0000-0001-8231-4158)

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28 9 **Abstract**

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32 10 **Objective:** Poor neighborhood socioeconomic status (NSES) has been linked to a higher risk of  
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35 11 overweight/obesity, irrespective of individuals own socioeconomic status. However, there is no  
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37 12 meta-analysis report is on the association. This study was aimed to synthesize the existing  
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39 13 evidence on the association of NSES with overweight, obesity, and body mass index (BMI).

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43 14 **Design:** Systematic review and meta-analysis.

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46 15 **Data sources:** PubMed, Embase, Scopus, Cochrane Library, Web of Sciences and Google  
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48 16 Scholar databases were searched for articles published until June 15, 2018.

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52 17 **Eligibility criteria:** Epidemiological studies, both longitudinal and cross-sectional ones, which  
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54 18 reported on the link of NSES to overweight, obesity or BMI were included.

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4 1 **Data extraction and synthesis:** Data extraction and quality assessment were independently  
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6 2 performed by two reviewers. The summary estimates of the relationships of NSES with  
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8 3 overweight, obesity, and BMI statuses were calculated with random-effects meta-analysis  
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10 4 models. Heterogeneity between the studies was assessed by Cochran's Q and I<sup>2</sup>-statistics.  
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12 5 Subgroup analyses were done by age categories, continents, study designs, and methods of  
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14 6 NSES measures. Publication bias was assessed by visual inspection of funnel plots and  
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16 7 Egger's regression test.  
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21 8 **Result:** A total of 20 studies, covering 1 240 608 individuals, were included in this meta-analysis.  
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23 9 Residence in poor neighborhoods, compared to residence in better-off neighborhoods, was  
24  
25 10 found associated with a 31% higher odds of overweight [pooled OR=1.31, 95% confidence  
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27 11 interval (CI)=1.16-1.47, P<0.001], a 43% higher odds of obesity (pooled OR=1.43, 95%CI=1.18-  
28  
29 12 1.74, P<0.001), and a 1.09 Kg/m<sup>2</sup> increase in mean BMI (pooled Beta=1.09, 95%CI=0.67-1.50,  
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31 13 P<0.001).  
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37 14 **Conclusion:** NSES disparity might be a contributing factor to the burden of overweight/obesity.  
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39 15 Further studies are warranted, including whether addressing neighborhood economic disparity  
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41 16 reduces the risk of overweight/obesity.  
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45 17 **PROSPERO Registration:** CRD42017063889  
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48 18 **Keywords:** Neighborhood socioeconomic status, Obesogenic environment, Overweight,  
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50 19 Obesity, Meta-analysis  
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54 20 **Strengths and limitations**  
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4 1     ▪ This is the first meta-analysis study on the association of NSES with overweight/obesity.  
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6 2     ▪ The report is based on a large number of studies, covering over a million individuals,  
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8 3         which improves the representativeness of the sample and strength of the findings.  
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10 4     ▪ The studies included are observational in design, precluding making causal inference.  
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13 5     ▪ The estimates are based on mainly the western population, limiting the generalizability of  
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15 6         the findings to other setups.  
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### 3 Introduction

4 Obesity remains a major global public health problem. While the current level of obesity has  
5 already posed a significant burden to the health system, the problem is still on the rise and  
6 causing more negative consequences at both individual and society levels.<sup>1</sup> Worldwide, 39% of  
7 adults were estimated to be overweight in 2016. In the same year, 13% of adults were  
8 estimated to be obese; almost triple of the figure in 1975.<sup>1</sup> The World Health Organization  
9 (WHO) has prioritized the prevention and control of obesity as a central public health agenda  
10 and recommends nations to make a substantial improvement with regard to the current trend of  
11 obesity.<sup>2</sup> However, the global progress to curb the rise and burden of overweight/obesity has  
12 been slow and frustrating, with each consecutive generation developing overweight/obesity at  
13 an early age and at higher rates.<sup>3 4</sup>

14 Overweight/obesity is a multi-causal problem, with its influences originating from various levels;  
15 including individual, social, and environmental origins. According to ecological models of obesity  
16 causation, the risk factors of overweight/obesity often interact with each other and might of  
17 direct and/or indirect influences on the weight status of individuals.<sup>5-7</sup> The main direct  
18 determinants are often unhealthy dietary patterns and low physical activity, resulting in a  
19 positive energy balance.<sup>8 9</sup> However, the environment in which individuals live has a strong  
20 influence on one's choice and adoption of health-enhancing behaviors.<sup>6 7 10 11</sup> For example,

1 residence in poor neighborhoods has been linked to a higher risk of overweight/obesity,  
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4 1 residence in poor neighborhoods has been linked to a higher risk of overweight/obesity,  
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6 2 irrespective of individual-level socioeconomic status.<sup>12</sup> There are various potential mechanisms  
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8 3 through which neighborhood socioeconomic status (NSES) influences an individual's weight  
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10 4 status. One of the most frequently mentioned mechanisms is the 'obesogenic environment'  
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12 5 hypothesis that poor neighborhoods promote unhealthy dietary practice and sedentary  
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14 6 lifestyle.<sup>12 13</sup> In poor neighborhoods, health-enhancing facilities and options are often limited in  
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16 7 poor neighborhoods, but junk food, alcohol, and drug are more readily available.<sup>13 14</sup> Besides,  
17  
18 8 streets walkability and safety might be compromised in poor neighborhoods; thus, limiting the  
19  
20 9 residents' movement.<sup>11 15</sup> A multinational study in Europe showed that physical inactivity and  
21  
22 10 unhealthy eating jointly accounted for almost a fifth of the NSES-BMI association.<sup>16</sup> Another  
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24 11 potential, but not a thoroughly examined mechanism, is the 'stress hypothesis' that stress could  
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26 12 lead to an unhealthy lifestyle, which subsequently leads to a higher risk of overweight/obesity.<sup>14</sup>  
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33 13 There are a number of empirical studies on the link of NSES to overweight, obesity, and BMI.  
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35 14 The studies were, however, inconsistent in their findings. Some studies reported a null or weak  
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37 15 association,<sup>17 18</sup> while other studies reported a strong association between NSES and  
38  
39 16 overweight/obesity.<sup>19 20</sup> To date, there is no systematic review and meta-analysis report on the  
40  
41 17 association of NSES with overweight, obesity or BMI. Synthesizing the existing evidence would  
42  
43 18 provide a summary estimate on the topic and contribute to filling the existing gap in the  
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45 19 literature. It may also facilitate evidence-based decision making as there is a better recognition  
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47 20 of systematic review and meta-analysis findings in policy and decision making processes. Thus,  
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49 21 this study was aimed to provide summary estimates on the link of NSES to overweight, obesity,  
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51 22 and BMI.  
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67 2 **Methods**  
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10 3 This systematic review and meta-analysis work was conducted according to a priorly published  
11 4 study protocol<sup>21</sup> and following the recommendations of the Meta-analysis of Observational  
12 5 Studies in Epidemiology (MOOSE)<sup>22</sup> and the Preferred Reporting Items for Systematic Reviews  
13 6 and Meta-Analyses (PRISMA)<sup>23</sup> guidelines. The review protocol was also registered with the  
14 7 International Prospective Register of Systematic Reviews, registration number  
15 8 CRD42017063889.

16 9 **Literature search**  
17

18 10 Embase, PubMed, Scopus, Web of Sciences, Cochrane Library, and Google Scholar databases  
19 11 were searched for studies published until June 15, 2018. The search terms were 'neighborhood  
20 12 socioeconomic status', 'neighborhood socioeconomic condition', 'neighborhood socioeconomic  
21 13 index', 'neighborhood deprivation index', 'neighborhood poverty index', 'area deprivation',  
22 14 'obesity', 'overweight', 'body mass index', 'weight', and 'central obesity'. A sample of the search  
23 15 strategy, PubMed search strategy, developed using a combination of MeSH terms and free  
24 16 texts is presented (supplementary file 1). The PubMed search strategy was further adapted to  
25 17 the other databases. Additionally, hand searching of articles was done using the reference lists  
26 18 of the eligible studies and the 'cited by' function of PubMed. We aimed to include both  
27 19 observational and interventional studies (cross-sectional, case-control, cohort, longitudinal, and  
28 20 randomized control studies). The literature search was not restricted by sex, age, or geographic  
29 21 location.

## 1 Study eligibility criteria

2 Articles found by the literature search were assessed whether they fulfilled the inclusion criteria  
3 of this work. The outcome variables of interest for this study were BMI (in Kg/m<sup>2</sup> and on a  
4 continuous scale), overweight, and obesity. The exposure variable of interest was NSES  
5 (measured by composite index). There is neither a uniform nor a standardized approach of  
6 NSES measurement. However, in the existing literature, NSES has been often considered as a  
7 composite index, developed based on the results of principal component analyses of variables  
8 with a potential to indicate neighborhoods' economic conditions. Some of the variables often  
9 used in the construction of NSES index are the proportion of households owned by residents,  
10 the proportion of employed residents, the value of assets in the area, property ownership by  
11 residents, availability of health-promoting amenities, and the literacy rate of the area. However,  
12 the specific set of variables used in the development of NSES indices often vary from one study  
13 to another depending on many contextual and statistical factors, including data availability and  
14 the result of the principal component analysis. To be included in this work, the study should be  
15 based on NSES measured by composite indices like neighborhood economic status indices  
16 (NSES), neighborhood deprivation indices (NDI), or neighborhood economic hardship- indices  
17 (NEDI). The commonly used indices are NSES and NDI, both of which could be used to rank  
18 neighborhoods into poor (deprived), middle, and rich (better-off) economic categories. Articles  
19 were excluded for any one of the following conditions: (1) animal studies, (2) study focused  
20 primarily on physical, policy, or social aspects of the environment, (3) language other than  
21 English, (4) citations without full text, (5) studies in which the outcome measure was not

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3 1 overweight, obesity or BMI, and (6) qualitative studies, book chapters, symposium and  
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6 2 conference proceedings, essays, commentaries, editorials, and case reports.  
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### 9 **Study screening and data extraction**

10  
11 4 The results of the database search were exported to EndNote X8 software to remove duplicates  
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14 5 and manage the screening processes. Then, the titles and abstracts of the retrieved studies  
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16 6 were assessed by two reviewers (SHM, TDH), working independently and in duplicate, to  
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18 7 determine their eligibility for full-text reviewing. The full text reviewing was done by SHM and  
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20 8 TDH, with disagreement resolved by consensus. The process of article screening and selection  
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22 9 is presented in Figure 1. SHM extracted the data, double-checked by TDH. The data extracted  
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24 10 from included studies were (1) study identification (first author, year of publication, and title), (2)  
25  
26 11 study characteristics (country, study design, sample size, and follow-up period for longitudinal  
27  
28 12 studies), (3) study participant's characteristics (sex, proportion of men, and mean age), (4)  
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30 13 NSES assessment method, (5) outcome assessment method, (6) measure of association and  
31  
32 14 reported estimates, and (7) variables used for adjustment. The predefined measures of  
33  
34 15 association were beta ( $\beta$ ) of BMI, relative risk (RR), or odds ratio (OR). The beta ( $\beta$ ) of BMI  
35  
36 16 refers to the mean difference in BMI of individuals living in poor and rich neighborhoods. The  
37  
38 17 OR refers to the odds of overweight or obesity among individuals living in poor neighborhoods,  
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40 18 compared to individuals living in better-off neighborhoods. When studies reported more than  
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42 19 one estimate, we took the estimate that was adjusted for more variables. When studies reported  
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44 20 multiple NSES comparisons, we took the estimate which compared the highest and the lowest  
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46 21 NSES categories.  
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### 54 **Study quality assessment**

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4 1 The methodological quality of the studies was assessed using the Newcastle-Ottawa Scale  
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6 2 (NOS) for grading the quality of observational studies.<sup>24</sup> The scale enabled to evaluate the  
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8 3 studies on the bases of three parameters: (1) selection (assesses sample representativeness,  
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10 4 sample size, non-response handling, and exposure ascertainment), (2) comparability (assesses  
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12 5 comparability of study groups and confounding control), and (3) outcome (assesses  
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14 6 ascertainment of outcome and appropriateness of statistical tests). The quality grading was  
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16 7 done out of 9, with scores from 0 to 3 indicating low quality, 4 to 6 medium quality, and 7 to 9  
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18 8 high quality. The ratings for each study were compared between the two evaluators (SHM,  
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20 9 TDH), with discrepancy resolved by consensus.  
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## 26 10 **Statistical analysis**

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28 11 Separate meta-analyses were done for each of the three outcome measures: overweight,  
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30 12 obesity, and BMI. OR was used to pool estimate of studies that reported on NSES-Overweight  
31  
32 13 and NSES-Obesity associations, representing the odds of overweight or obesity among  
33  
34 14 individuals living in poor neighborhoods (low NSES), compared to individuals living in better-off  
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36 15 neighborhoods (high NSES). Beta ( $\beta$ ) values from linear regression analyses, representing the  
37  
38 16 mean increase in BMI due to change in NSES from high to low category, were used to pool the  
39  
40 17 estimates of studies that used BMI, on a continuous scale, as an outcome measure. For all  
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42 18 estimates, if P-values were reported as  $P < 0.001$  with no 95%CI or standard error (SE), we  
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44 19 assumed  $P = 0.001$  in calculating the corresponding 95%CI and SE.  
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50 20 Heterogeneity among the studies was assessed by Cochran's Q and  $I^2$ -statistics, which  
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52 21 estimate the proportion of variance attributable to between-studies heterogeneity. A non-  
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54 22 substantial level of statistical heterogeneity was assumed when  $P < 0.1$  or  $I^2 < 50\%$ .<sup>25</sup> Source of  
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3 1 heterogeneity was assessed by conducting subgroup analyses using the predefined potential  
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6 2 sources of heterogeneity as outlined in the study protocol,<sup>21</sup> which were age category (adults  
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8 3 versus children), study design (cross-sectional versus longitudinal), region (continent), and  
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10 4 NSES measures. Due to a persistently high level of heterogeneity even after subgroup  
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12 5 analyses, we calculated the summary estimates with random-effects model, which accounts for  
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14 6 both within and between studies variations. Publication bias was assessed by visual inspection  
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16 7 of funnel plots and Egger's regression test, unless as there was an inadequate number of  
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18 8 studies which under-powered any of the statistical methods to assess publication bias. A  
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20 9 minimum of ten studies is needed to ensure adequate power and assess publication bias.<sup>26</sup>  
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22 10 According to Egger's test, publication bias is assumed at  $P < 0.1$ .<sup>26 27</sup> For estimates with evidence  
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24 11 of publication bias, we aimed to do adjustment following the Trim and Fill method <sup>26 27</sup> and  
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26 12 provide both bias-adjusted and unadjusted pooled estimates. To evaluate the influence of each  
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28 13 study on the summary estimates, we conducted sensitivity analyses using the leave-one-out  
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30 14 and analyze the rest method. Stata version 15.0 software was used for all analyses.

## 15 **Patient and public involvement**

16 This work was based on extracting data from published studies. There was no patient and  
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18 public involvement in the development of the research question, design, outcome measures,  
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## 20 **Result**

### 21 **Search result and study characteristics**

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4 1 The search strategy generated a total of 2 671 studies. Screening the title and abstract of these  
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6 2 studies resulted in 89 studies eligible for full-text review. Reviewing the full text of the 89  
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8 3 studies, resulted in 17 eligible articles. Through hand searching for the references of the  
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10 4 included studies and the 'cited by' function of PubMed and Google Scholar, three additional  
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12 5 articles were identified. The flowchart of the screening and selection process is shown in Figure  
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14 6 1. The main characteristics of the 20 included studies<sup>12 17-20 28-42</sup> are presented in Table 1. The  
15  
16 7 sample size of the studies ranged from 144 to 948 062 individuals, providing a total of 1 240 608  
17  
18 8 unique individuals, of whom 47% were males and 53% females. The mean age of the study  
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20 9 participants was 43.92 years. The studies were published from 2005 to 2017. The majority of  
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22 10 the studies, 13/20 (65%), were cross-sectional in design. The remaining 7 (35%) were  
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24 11 longitudinal (cohort) studies. All studies were conducted in high-income countries: 7 in USA, 3 in  
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26 12 Canada, 3 in Germany, 2 in Australia, 3 in Sweden, 1 in France, and 1 in New Zealand.  
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3 1 Table 1: General characteristics included studies.  
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First author (year)	Country	Study design	Follow-up (years)	Sample (n)	Mean age	Men (%)	Population	NSES† measure	Weight measure	Adjustment	NOS Scale
Amber (2014) <sup>19</sup>	New Zealand	CS	NA	12 488	47.00	53.00	Adults	NDI	Obesity	Age, sex, ethnicity, economic living standard index, individual-level deprivation, highest educational qualification, household composition, smoking status, alcohol consumption	8
Steffen (2016) <sup>37</sup>	Germany	CS	NA	3 499	6.00	53.00	Children	NSESI	Obesity	Birth weight, BMI of the mother, parental education, parental working status, household income, household crowding	9
Catherine (2006) <sup>17</sup>	Sweden	CS	NA	18 081	44.60	49.20	Adults	NDI	Obesity	Age, gender, marital status, immigration status, urbanization	6
Steven (2016) <sup>38</sup>	USA	LS	24	11 499	10.31	51.00	Children	NDI	Obesity	Age, sex	7
Patricia (2010) <sup>39</sup>	USA	LS	10	48 359	NA	0.00	Adults	NSESI	Obesity	Age, family income, marital status, exercise, energy intake, smoking	8
Andrea (2016) <sup>18</sup>	USA	CS	NA	144	26.40	100.00	Adults	NDI	Obesity	Maternal age, marital status, maternal education, parity	
Xinjun (2014) <sup>40</sup>	Sweden	LS	10	948 062	8.60	51.30	Children	NDI	Obesity	Age, family (income, history of obesity & diabetes), personal history of (chronic obstructive pulmonary disease, alcoholism & diabetes)	9
Eva (2009) <sup>42</sup>	Sweden	CS	NA	94 323	31.40	100.00	Adults	NSESI	Obesity	Age, sex, individual income, education status	9
Steffen (2016) <sup>20</sup>	Germany	CS	NA	3 499	6.00	53.00	Children	NSESI	Overweight	Birth weight, BMI of the mother, parental education, parental working status, household income, household crowding	7
Lisa (2005) <sup>41</sup>	Canada	CS	NA	11 455	11.80	50.80	Children	NDI	Overweight	Age, gender, family income, education level	8
TR Berry (2010) <sup>28</sup>	Canada	LS	6	500	42.81	52.00	Adults	NSESI	BMI	Age, sex	8
Xiaoqi (2015) <sup>29</sup>	Australia	LS	6	18 341	46.60	47.00	Adults	NDI	BMI	Age, sex, number of children in the household, household education status, household unemployment, annual household income	9
Paula (2011) <sup>30</sup>	USA	CS	NA	21 166	24.94	0.00	Adults	NDI	BMI	Tract supermarkets, tract small grocery stores, tract convenience stores, ethnicity, education, annual income statuses	8
Maria (2013) <sup>31</sup>	Germany	LS	4	485	5.81	51.72	Children	NSESI	BMI	Street type, perceived frequency of passing trucks and buses, street walkability	7

Cinira (2011) <sup>32</sup>	France	CS	NA	7 230	46.80	0.00	Adults	NSESI	BMI	Age, country human development index, individual education level, occupation, financial strain, cultural entertainments, health-related external locus of control, propensity to keep healthy resolutions	8
May (2007) <sup>12</sup>	USA	CS	NA	7 595	52.81	49.25	Adult	NDI	BMI	Age, gender, ethnicity, individual-level socioeconomic status, smoking, physical activity, nutrition knowledge	8
Lisa (2014) <sup>33</sup>	Canada	LS	8	2 152	2.48	50.44	Children	NSESI	BMI	Age, sex, income, education, family structure	8
Barbara (2012) <sup>34</sup>	USA	CS	NA	19 804	48.30	51.20	Adults	NDI	BMI	Race, sex, age, income, education level, marital status, nativity, individual socioeconomic status	8
Tali (2017) <sup>35</sup>	USA	CS	NA	1 645	49.00	42.00	Adults	NSESI	BMI	Age, race, education, poverty, employment status, physical activity	9
Xiaoqi (2017) <sup>36</sup>	Australia	CS	NA	10 281	44.70	47.60	Adults	NSESI	BMI	Gender, age	6

1 LS=Longitudinal, CS=Cross-sectional, NA=Not applicable, NSES=Neighborhood socioeconomic status, NDI=Neighborhood deprivation index, BMI=Body mass index,

2 NOS=Newcastle Ottawa scale



## 1 Association of NSES with overweight

2 We found two studies which reported on the link of NSES to overweight, BMI>25 kg/m<sup>2</sup>. The  
3 summary odds of overweight, compared to being not overweight, was 30% higher in individuals  
4 living in poor neighborhoods, compared to that of individuals living in better-off neighborhoods  
5 (pooled OR=1.30, 95%CI=1.16-1.47, P<0.001). There was no evidence of significant  
6 heterogeneity (I<sup>2</sup>=0.00%, P=0.609). Figure 2 presents the result of the meta-analysis of the  
7 NSES-overweight association.

## 8 Association of NSES with Obesity

9 We found eight studies which reported on the association of NSES with obesity, BMI≥30 kg/m<sup>2</sup>.  
10 The odds of being obese, compared to being non-obese, was 43% higher in individuals living in  
11 poor neighborhoods, compared to that of individuals living in better-off neighborhoods (pooled  
12 OR=1.43, 95%CI=1.18-1.74, P<0.001). Figure 3 shows the forest plot and summary estimate of  
13 the meta-analysis of the NSES-obesity association. There was a high level of heterogeneity  
14 among the studies (I<sup>2</sup>=93.00%, P<0.001). We explored the sources of the heterogeneity by  
15 doing subgroup analyses. The subgroup-specific summary estimates with their corresponding  
16 levels of heterogeneity are presented in Figure 4. Across the three continents where the studies  
17 were done, Australia, America, and Europe, NSES maintained a significant association with  
18 obesity (P<0.05). In children, residence in poor neighborhoods was associated with a 1.57 times  
19 higher odds of obesity compared to residence in better-off neighborhoods. The association was  
20 not significant, albeit largely towards being significantly associated (pooled OR=1.57,  
21 95%CI=0.98-2.51). In adults, poor NSES was associated a significantly higher odds of obesity,  
22 such that the odds of obesity was 1.37 times higher in individuals living in poor neighborhoods,

1 compared to individuals living in better-off neighborhoods (pooled OR=1.37, 95%CI=1.11-1.68).  
 2 In terms of study design, NSES was significantly linked to obesity in the cross-sectional studies,  
 3 but not in the longitudinal studies. It was not possible to assess publication bias on the NSES-  
 4 obesity association as there was an inadequate number of studies which under-powered any of  
 5 the statistical methods to assess publication bias. A minimum of ten studies is needed to assess  
 6 publication bias.<sup>26</sup> To evaluate the influence of each study on the summary estimate, we  
 7 conducted sensitivity analyses (Table 2). Overall, no study notably changed of the direction as  
 8 well as magnitude the NSES-Obesity association, with the summary OR ranging from the lowest  
 9 1.29 (95%CI=1.10-1.48) after excluding Xinjun et al.<sup>40</sup> to the highest 1.50 (95%CI=1.21-1.78)  
 10 after excluding Steven et al.<sup>38</sup>

11 Table 2: Sensitivity analysis of studies on the association of neighborhood socioeconomic status with  
 12 obesity

Study omitted	Pooled OR	95% CI
Amber (2014) <sup>19</sup>	1.49	1.16-1.81
Catherine (2006) <sup>17</sup>	1.43	1.16-1.69
Xinjun (2014) <sup>40</sup>	1.29	1.10-1.48
Steffen (2016) <sup>37</sup>	1.35	1.12-1.57
Steven (2016) <sup>38</sup>	1.50	1.21-1.78
Andrea (2016) <sup>18</sup>	1.39	1.16-1.62
Eva (2009) <sup>42</sup>	1.32	1.10-1.55
Patricia (2010) <sup>39</sup>	1.41	1.16-1.67

13 OR=odds ratio, CI=confidence interval

## 15 Association of NSES with BMI

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4 1 Ten of the 20 studies included in this work reported on the relation of NSES with BMI. The  
5  
6 2 summary estimate showed that NSES was significantly associated with BMI. The BMI of  
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8 3 individuals living in poor neighborhoods was higher by a mean of 1.09 kg/m<sup>2</sup>, compared to the  
9  
10 4 BMI of individuals living in better-off neighborhoods (pooled  $\beta=1.09$ , 95%CI=0.67-1.50,  
11  
12 5  $P<0.001$ ). Figure 5 shows the summary estimate of the association of NSES with BMI,  
13  
14 6 calculated with random-effects model. There was a significant level of heterogeneity ( $I^2<0.001$ ).  
15  
16 7 Thus, subgroup analyses were conducted by the studies' design (cross-sectional versus  
17  
18 8 longitudinal) and methods of NSES measurement. In all subgroup showed the mean BMI was  
19  
20 9 significantly higher in poor neighborhoods than in better-off neighborhoods. Details of the results  
21  
22 10 of the subgroup analyses by study design and NSES measurement methods are presented in  
23  
24 11 Figure 6. The result of the Egger's regression test did not indicate the presence of a significant  
25  
26 12 level of publication bias ( $P=0.903$ ). The funnel plot of the NSES-BMI studies is shown in Figure  
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28 13 7. The result of the sensitivity analysis is shown in Table 3. Overall, no study notably influenced  
29  
30 14 the direction as well as strength of the NSES-BMI association, with the pooled  $\beta$  ranging from  
31  
32 15 the lowest 0.82 (95%CI=0.62-1.19) after excluding Xiaoqi (2015)<sup>29</sup> to the highest 1.14  
33  
34 16 (95%CI=0.68-1.60) after excluding TR Berry (2010).<sup>28</sup>  
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43 Table 3: Sensitivity analysis of studies on the association of NSES with BMI.

Study omitted	Pooled Beta	95% CI
TR Berry (2010) <sup>28</sup>	1.14	0.68-1.60
Xiaoqi (2015) <sup>29</sup>	0.90	0.62-1.19
Paula (2011) <sup>30</sup>	1.11	0.63-1.60
Maria (2013) <sup>31</sup>	1.19	0.80-1.58
Cinira (2011) <sup>32</sup>	1.04	0.59-1.50
May (2007) <sup>12</sup>	1.15	0.68-1.61

Lisa (2014) <sup>33</sup>	1.07	0.63-1.50
Barbara (2012) <sup>34</sup>	1.10	0.60-1.60
Tali (2017) <sup>35</sup>	1.06	0.63-1.49
Xiaoqi (2017) <sup>36</sup>	1.08	0.62-1.53

1 CI=confidence interval

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### 3 Discussion

4 The study was aimed to pool the existing empirical evidence on the link of NSES to overweight,  
 5 obesity, and BMI. Overall, NSES was found to be significantly associated with the three  
 6 outcome measures, such that residence in poor neighborhoods was significantly linked to high  
 7 odds of overweight, obesity, and elevated BMI.

8 The findings of this work were consistent with the reports of previous studies that reported  
 9 higher odds of overweight/obesity as well as other poor health outcomes in individuals living in  
 10 poor neighborhoods than in individuals living in better-off neighborhoods.<sup>20 40 41</sup> The influence of  
 11 neighborhood deprivation is not limited to body weight. It has also been linked to various poor  
 12 behavioral and health outcomes like drug abuse, cardiovascular diseases, and poor mental  
 13 health.<sup>43 44</sup> Thus, improving NSES has been recommended as a potential strategy for the  
 14 prevention and control of the current obesity epidemics as well as other chronic illnesses.<sup>43 44</sup>

15 The mechanisms through which NSES contributes to the development of overweight/obesity  
 16 have not been thoroughly documented. Despite the ongoing debate on which of the mediating  
 17 factors deserves the most responsibility for the link of NSES to body weight, most factors are,  
 18 however, believed to influence weight mainly through influencing the energy balance, i.e. the

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3 1 balance of calorie intake and loss.<sup>9-11</sup> Poor neighborhoods have been associated with a high  
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5 2 availability of energy-dense food outlets, but a low availability of fruit and vegetable outlets and  
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8 3 limited sporting facilities. Poor neighborhoods have also been related to a higher risk of  
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10 4 depression, which could subsequently lead to a higher risk of overweight/obesity.<sup>14</sup>  
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14 5 In this work, there was a discrepancy in the NSES-Obesity association between cross-sectional  
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16 6 and longitudinal studies. The NSES-Obesity association was not statistically significant among  
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18 7 longitudinal studies but statistically significant among cross-sectional ones. It is worth noting to  
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20 8 the reader that the NSES-Obesity association was consistent across the other subgroup  
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22 9 analyses by age (adults versus children), NSES measures (NSES-I versus NSES-DI), and outcome  
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24 10 measures (overweight versus obesity). The discrepancy by study design was also not observed  
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26 11 in the NSES-BMI association, in which NSES demonstrated significant statistical links to BMI in  
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28 12 both longitudinal and cross-sectional studies. There are a number of possible reasons that could  
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30 13 explain the discrepancy in NSES-Obesity association between cross-sectional and longitudinal  
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32 14 studies. First, it could be due to the fact that only two longitudinal studies are included on NSE-  
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34 15 Obesity association. Second, there was no uniformity in how confounding was controlled among  
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36 16 the included studies, in terms of both the number and type of variables used for adjustment.  
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38 17 This lack of uniformity across the studies in terms of the type and number of variables used for  
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40 18 adjustment might in part explain the inconsistency in the NSES-Obesity summary estimates by  
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42 19 study design. Third, it could also be due to the use of a dichotomized outcome variable  
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44 20 (obesity), instead of a continuous outcome variable (BMI). Unless it is mandatory,  
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46 21 dichotomization of continuous variables is not recommended as it reduces sample power by  
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48 22 almost 50% and could result in false no association findings, particularly if the true association is  
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3 1 weak.<sup>45 46</sup> In support of this, we observed no discrepancy between cross-sectional and  
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6 2 longitudinal studies in all NSES-BMI summary estimates, in which the outcome was BMI on a  
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8 3 continuous scale. However, as none of the above reasons could definitively explain the NSES-  
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10 4 Obesity discrepancy by study, we recommend further meta-analysis works when more  
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12 5 longitudinal studies become available.

16 6 The finding of this study might indicate the importance of investigating as well as addressing the  
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18 7 determinants of overweight/obesity comprehensively, i.e., examining and addressing not only  
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20 8 the proximal behavioral factors but also the underlying environmental and other structural  
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22 9 factors. However, the existing literature is largely focused on investigating the individual level  
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24 10 behavioral influences.<sup>7</sup> For example, the evidence is limited about how, and to what extent,  
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26 11 neighborhood socioeconomic conditions influence individuals' dietary practice and level of  
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28 12 physical activity. Whether improving neighborhood economic deprivation results in the adoption  
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30 13 of health-enhancing lifestyle also remains largely unknown. Besides, the existing evidence on  
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32 14 the link of NSES to an unhealthy weight, including the report of this work, is largely based on  
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34 15 observational studies. Thus, further investigations with better designs like community-based  
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36 16 longitudinal studies are needed to reach a more conclusive conclusion. Meanwhile, it might be  
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38 17 worthy of considering a comprehensive approach when developing obesity prevention and  
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40 18 control strategies, including addressing neighborhood economic disparities. So far, obesity  
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42 19 interventions have been largely focused on providing health information and strategies to  
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44 20 address the individual-level determinants. However, unless supported by an enabling  
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46 21 environment, the individual level efforts and provision of health information alone might not lead  
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48 22 to the intended result as fast as needed. Thus, the lack of comprehensiveness and integrity of

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4 1 interventions might partly explain the current non-promising progress in obesity prevention and  
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6 2 control approaches.<sup>4 15</sup> Poor neighborhoods often lack healthy weight-promoting amenities, like  
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8 3 sporting facilities and fruit/vegetable outlets.<sup>13</sup> We believe that addressing neighborhood  
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10 4 deprivation by availing healthy choices closer and affordable to everyone, might facilitate the  
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12 5 adoption of health-enhancing behaviors, thereby reducing the risk of overweight/obesity.  
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15 6 However, the proposition needs to be further evaluated.  
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## 20 8 **Limitations and strengths**

24 9 This work has many limitations. There was no uniformity among the studies in the way NSES  
25  
26 10 was measured. Though all studies included in this work measured NSES as a composite  
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28 11 variable, the specific set of variables used to develop the NSES indices varied from one study to  
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30 12 another. There was also variation across the individual studies in the type and number of  
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32 13 covariates used for adjustment of reported estimates. The lack of uniformity in NSES measures  
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34 14 and covariate adjustment might have introduced heterogeneity and undermined the  
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36 15 comparability of the studies. All studies included in this work were done in high-income  
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38 16 countries. The lack of data from low- and middle- income countries would limit the  
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40 17 generalizability of the findings. NSES-obesity association would vary by countries'  
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42 18 socioeconomic status. In developing countries, due to the traditionally held positive attitude  
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44 19 toward overweight, low NSES might be associated with a lower risk of overweight/obesity,  
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46 20 unlike the case in the developed nations. Therefore, the findings of this work might not be  
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48 21 applicable to developing countries. All studies included in this work were observational in  
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50 22 design, making casual inference impossible. Besides, reverse causality could not be ruled out;  
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3 1 i.e. instead of better-off neighborhoods promoting healthy weight, it is possible that individuals  
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6 2 with a healthy weight are more interested in health, and therefore prefer living in better-off  
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8 3 neighborhoods. To the best of our knowledge, this study is the first systematic review and meta-  
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10 4 analysis report on the link of NSES to overweight, obesity, and BMI. Thus, it would be  
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12 5 contributing to filling the existing gap in the literature. The inclusion of multi-national studies, a  
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14 6 large number of study participants and individuals of all age groups could improve the  
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16 7 representativeness of the study.  
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## 9 **Conclusion**

10 We found that living in poor neighborhoods, compared to living in better-off neighborhoods, was  
11 associated with higher odds of being overweight and obese as well as a higher mean BMI.  
12 Evidence on the association of NSES with weight status is largely missing in low and middle-  
13 income countries. The exact mechanism by which NSES contributes to unhealthy, and whether  
14 addressing NSES disparity reduces the risk of obesity, is unclear. Thus, further studies are  
15 warranted to better understand how NSES influences weight and whether addressing NSES  
16 disparity could reduce the risk of overweight/obesity. Meanwhile, addressing NSES disparity  
17 and bringing healthy choices closer and affordable to everyone might stand worthy of  
18 programmatic consideration to curb the current trend of obesity.  
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## 20 **Authors' contribution**



1  
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3 1 SHM conceived and designed the study. SHM and TDH carried out literature search, performed  
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5  
6 2 quality assessment of included studies, analyzed data and prepared the manuscript. TAS,  
7  
8 3 MMB, BST, and SA performed literature search, screening, data extraction, and quality  
9  
10 4 assessment as second reviewers and critically reviewed the draft manuscript. AE supervised  
11  
12  
13 5 the study. All the authors read, commented and approved the final manuscript.  
14  
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18  
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20  
21  
22 8 for-profit sectors.  
23  
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## 25 **Competing interest**

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28 10 None declared.  
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## 31 **Data sharing statement**

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35 12 All the data used in the study are included the article.  
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## 38 **Patient consent**

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41 14 Not required as the study was based on extracting data from published studies.  
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28 7 **Figures**  
2930  
31  
32 8 Figure 1: PRISMA flow diagram.  
3334 9 Figure 2: Forest plot of association of neighborhood socioeconomic status (NSES) [Low NSES  
35 versus high NSES] with overweight [overweight versus not overweight].  
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41 versus high NSES] with obesity [obese versus not obese].  
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4445  
46 13 Figure 4: Forest plot of association of neighborhood socioeconomic status (NSES) [Low NSES  
47 versus high NSES] with obesity [obese versus not obese], by subgroups.  
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53 versus high NSES] with body mass index.  
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4 1 Figure 6: Forest plot of association of neighborhood socioeconomic status (NSES) [Low NSES  
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6 2 versus high NSES] with body mass index, by subgroups.  
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9 3 Figure 7: Funnel plot of association of neighborhood socioeconomic status (NSES) [Low NSES  
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11 4 versus high NSES] with body mass index.  
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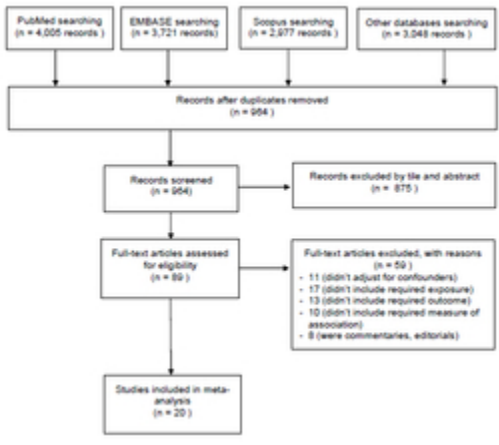


Figure 1: PRISMA flow diagram.

22x19mm (300 x 300 DPI)

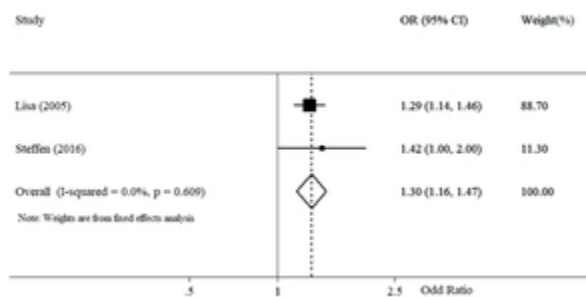


Figure 2: Forest plot of association of neighborhood socioeconomic status (NSES) [Low NSES versus high NSES] with overweight [overweight versus not overweight].

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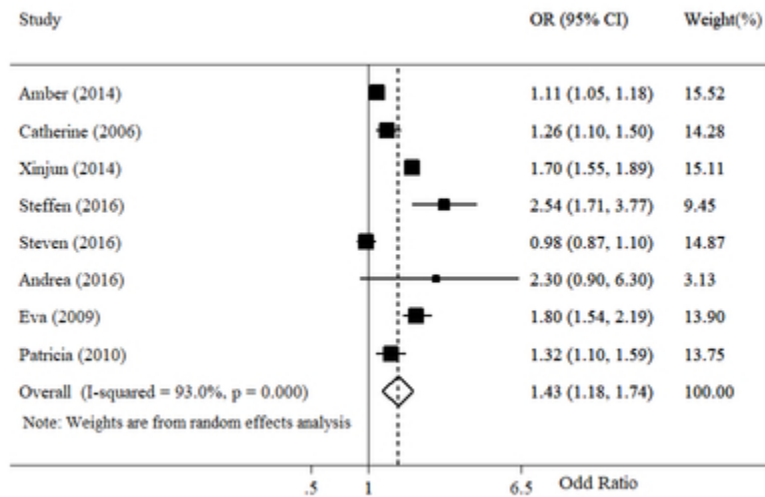


Figure 3: Forest plot of association of neighborhood socioeconomic status (NSES) [Low NSES versus high NSES] with obesity [obese versus not obese].

34x24mm (300 x 300 DPI)

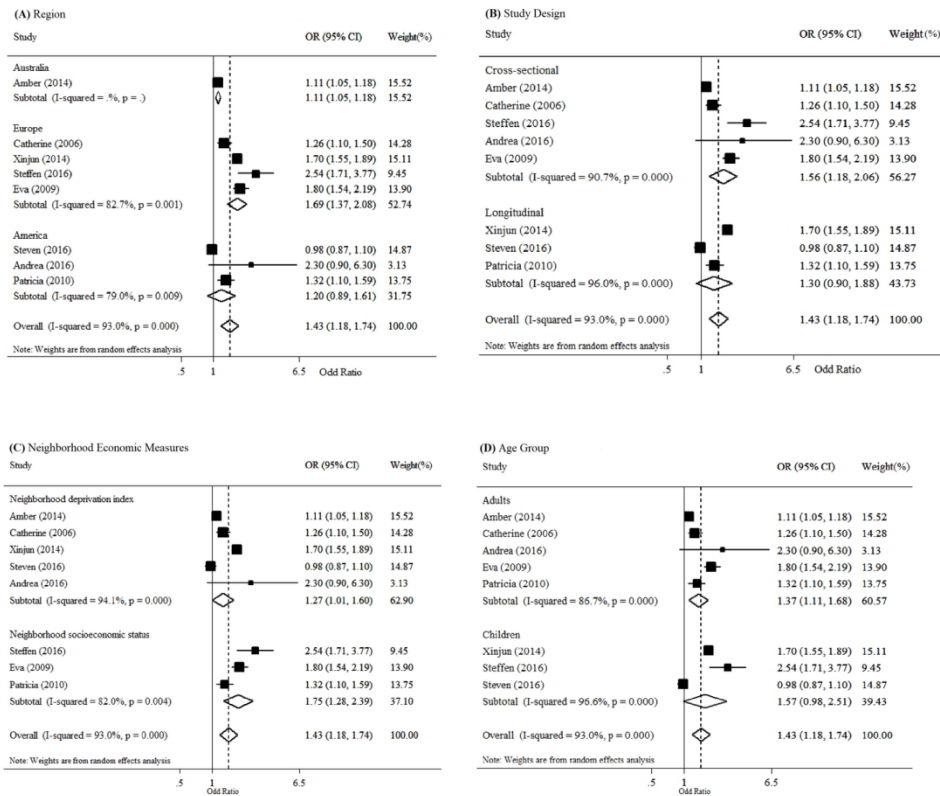
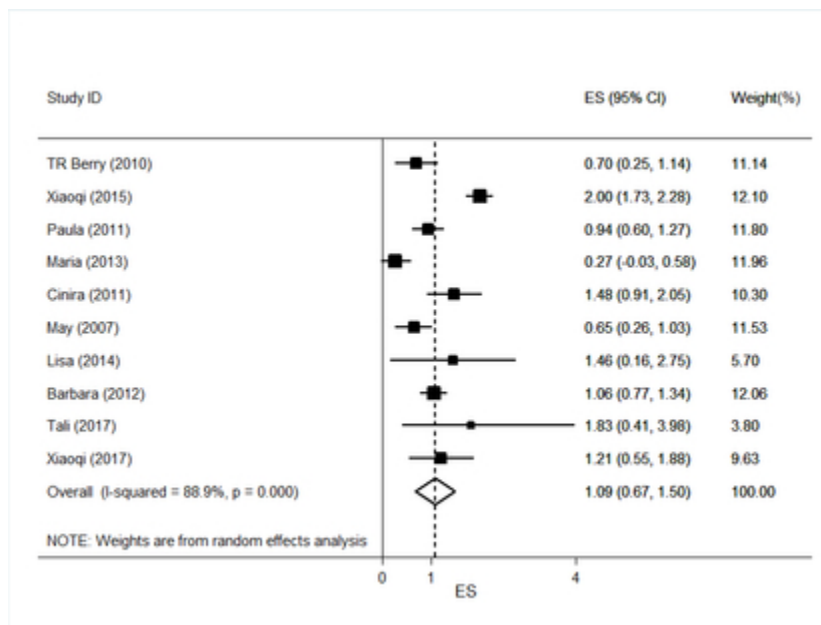


Figure 4: Forest plot of association of neighborhood socioeconomic status (NSES) [Low NSES versus high NSES] with obesity [obese versus not obese], by subgroups.

129x107mm (300 x 300 DPI)



27 Figure 5: Forest plot of association of neighborhood socioeconomic status (NSES) [Low NSES versus high  
28 NSES] with body mass index.

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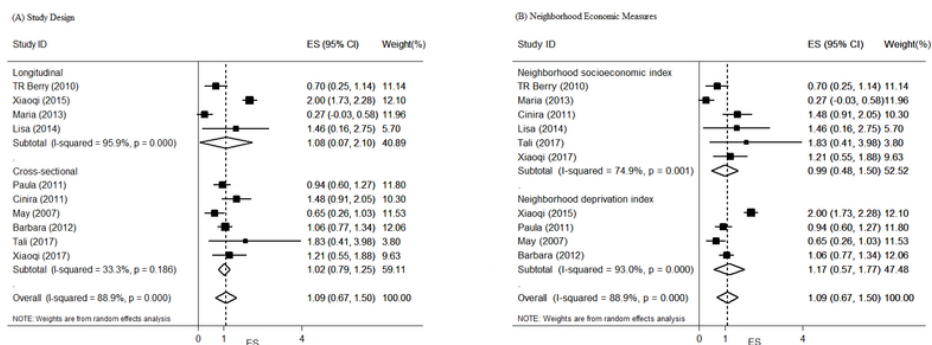


Figure 6: Forest plot of association of neighborhood socioeconomic status (NSES) [Low NSES versus high NSES] with body mass index, by subgroups.

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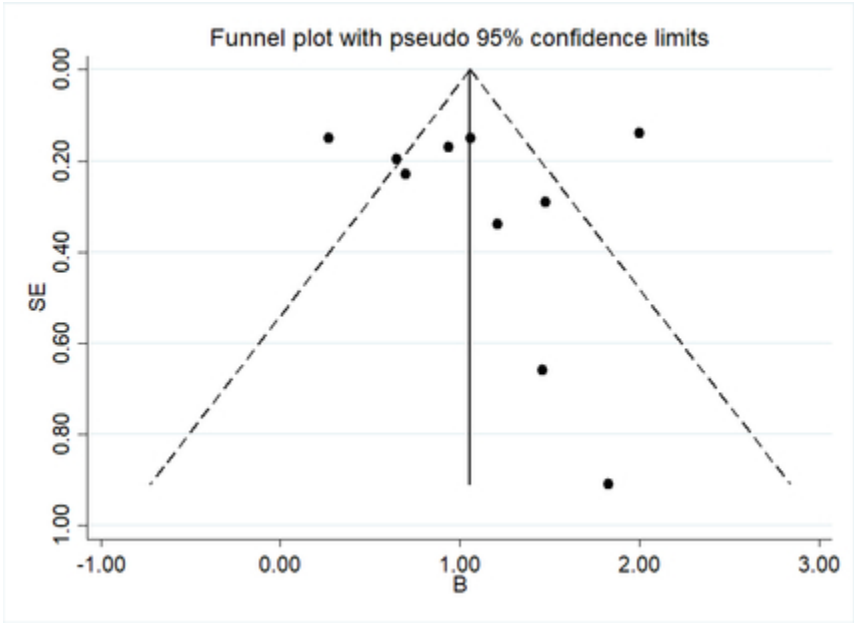


Figure 7: Funnel plot of association of neighborhood socioeconomic status (NSES) [Low NSES versus high NSES] with body mass index.

36x26mm (300 x 300 DPI)

## PubMed Search strategy

Search	Query	Hits*
#1	(((((((Body Weight[MeSH Terms]) OR Body Mass Index[MeSH Terms]) OR Body weight[Title/Abstract]) OR Weight[Title/Abstract]) OR Obesity[Title/Abstract]) OR Overweight[Title/Abstract]) OR Overweight[Title/Abstract]) OR BMI[Title/Abstract]	1049827
#2	((((((((((((Residence Characteristics/statistics and numerical data[MeSH Terms]))) OR Residence Characteristics/standards[MeSH Terms]) OR Residence Characteristics/economics[MeSH Terms]) OR Poverty Areas[MeSH Terms]) OR neighborhood socioeconomic*[Title/Abstract]) OR neighbourhood socioeconomic*[Title/Abstract]) OR neighborhood-level socioeconomic*[Title/Abstract]) OR neighbourhood-level socioeconomic*[Title/Abstract]) OR neighborhood socioeconomic*[Title/Abstract]) OR neighbourhood socioeconomic*[Title/Abstract]) OR neighborhood socioeconomic*[Title/Abstract]) OR neighbourhood socioeconomic*[Title/Abstract]) OR neighborhood socioeconomic*[Title/Abstract]) OR neighbourhood socioeconomic*[Title/Abstract]	15170
#3	#1 AND #2	4005

\*= Date of search: June 15, 2018





## PRISMA Checklist

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Section/topic	#	Checklist item	Reported on page #
<b>TITLE</b>			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
<b>ABSTRACT</b>			
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.	2
<b>INTRODUCTION</b>			
Rationale	3	Describe the rationale for the review in the context of what is already known.	4-5
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	4-5
<b>METHODS</b>			
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.	5
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.	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.	6
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	5
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).	5-6
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.	5-6
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



## PRISMA Checklist

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
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Page 1 of 2

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).	6-7
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	6-7
<b>RESULTS</b>			
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.	7-8
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.	7-8
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).	8
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.	7-8
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	7-8
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	8-9
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	8-9
<b>DISCUSSION</b>			
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).	9-11
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).	11
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	11
<b>FUNDING</b>			
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.	12

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.



PRISMA Checklist

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doi:10.1371/journal.pmed1000097

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Page 2 of 2

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# BMJ Open

## Neighborhood socioeconomic status and overweight/obesity: a systematic review and meta-analysis of epidemiological studies

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2018-028238.R2
Article Type:	Original research
Date Submitted by the Author:	02-Oct-2019
Complete List of Authors:	Mohammed, Shimels Hussien; Tehran University of Medical Sciences, Department of Community Nutrition, School of Nutritional Sciences and Dietetics Habtewold, Tesfa; University of Groningen, Epidemiology; Debre Berhan University, Nursing Birhanu, Mulugeta ; Monash University, Department of Medicine, School of Clinical Sciences at Monash Health Sissay, Tesfamichael Awoke ; Addis Ababa University, Department of Public Health, School of Public Health Teegne, Balewgizie; University of Groningen, Department of Epidemiology, University Medical Center Groningen Abuzerr, Samer; Tehran University of Medical Sciences, Department of Environmental Health Engineering, Faculty of Public Health Esmailzadeh, Ahmad; Tehran University of Medical Sciences; Tehran University of Medical Sciences, Obesity and Eating Habits Research Center, Endocrinology and Metabolism Molecular Cellular Sciences Institute,
<b>Primary Subject Heading</b>:	Nutrition and metabolism
Secondary Subject Heading:	Epidemiology, Public health
Keywords:	Obesity, Overweight, Body mass index, Neighborhood, Meta-analysis

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Manuscripts

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5 1 **Neighborhood socioeconomic status and overweight/obesity: a systematic**  
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14 4 Tesfamichael Awoke Sissay<sup>5</sup>, Balewgizie Sileshi Tegegne<sup>2</sup>, Samer Abuzerr<sup>6</sup>, Ahmad  
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16 5 Esmailzadeh<sup>1,7,8</sup>

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20 6 <sup>1</sup>Department of Community Nutrition, School of Nutritional Sciences and Dietetics, Tehran  
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22 7 University of Medical Sciences, Tehran, Iran.

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24  
25 8 <sup>2</sup>Department of Epidemiology, University Medical Center Groningen, University of Groningen,  
26  
27 9 Groningen, The Netherlands.

28  
29  
30  
31 10 <sup>3</sup>Department of Nursing, Debre Berhan University, Debre Berhan, Ethiopia.

32  
33  
34 11 <sup>4</sup>Department of Medicine, School of Clinical Sciences at Monash Health, Monash University,  
35  
36 12 Australia.

37  
38  
39 13 <sup>5</sup>Department of Public Health, School of Public Health, Addis Ababa University, Addis Ababa,  
40  
41 14 Ethiopia.

42  
43  
44 15 <sup>6</sup>Department of Environmental Health Engineering, Faculty of Public Health, Tehran University  
45  
46 16 of Medical Sciences, Tehran, Iran.

47  
48  
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50 17 <sup>7</sup>Obesity and Eating Habits Research Center, Endocrinology and Metabolism Molecular Cellular  
51  
52 18 Sciences Institute, Tehran University of Medical Sciences, Tehran, Iran.

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3 1 <sup>8</sup>Food Security Research Center, Department of Community Nutrition, Isfahan University of  
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5  
6 2 Medical Sciences, Isfahan, Iran.

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11 4 \*Correspondence to: Shimels Hussien Mohammed (shimelsh@gmail.com, +989334862413,  
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14 5 ORCID: 0000-0001-8231-4158)

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21 7 Word count: 3,971

## 22 23 24 8 **Abstract**

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28 9 **Objective:** Low neighborhood socioeconomic status (NSES) has been linked to a higher risk of  
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31 10 overweight/obesity, irrespective of the individual's own socioeconomic status. No meta-analysis  
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33 11 study has been done on the association. Thus, this study was done to synthesize the existing  
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35 12 evidence on the association of NSES with overweight, obesity, and body mass index (BMI).

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39 13 **Design:** Systematic review and meta-analysis.

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42 14 **Data sources:** PubMed, Embase, Scopus, Cochrane Library, Web of Sciences, and Google  
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44 15 Scholar databases were searched for articles published until September 25, 2019.

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48 16 **Eligibility criteria:** Epidemiological studies, both longitudinal and cross-sectional ones, which  
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50 17 examined the link of NSES to overweight, obesity, or BMI were included.

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4 1 **Data extraction and synthesis:** Data extraction was done by two reviewers, working  
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6 2 independently. The methodological quality of included studies was assessed using the  
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8 3 Newcastle-Ottawa Scale for observational studies. The summary estimates of the relationships  
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10 4 of NSES with overweight, obesity, and BMI statuses were calculated with random-effects meta-  
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12 5 analysis models. Heterogeneity was assessed by Cochran's Q and I<sup>2</sup>-statistics. Subgroup  
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14 6 analyses were done by age categories, continents, study designs, and NSES measures.  
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16 7 Publication bias was assessed by visual inspection of funnel plots and Egger's regression test.  
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21 8 **Result:** A total of 21 observational studies, covering 1 244 438 individuals, were included in this  
22  
23 9 meta-analysis. Low NSES, compared to high NSES, was found to be associated with a 31%  
24  
25 10 higher odds of overweight [pooled OR=1.31, 95% confidence interval (CI)=1.16-1.47, P<0.001],  
26  
27 11 a 45% higher odds of obesity (pooled OR=1.45, 95%CI=1.21-1.74, P<0.001), and a 1.09 Kg/m<sup>2</sup>  
28  
29 12 increase in mean BMI (pooled Beta=1.09, 95%CI=0.67-1.50, P<0.001).  
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34 13 **Conclusion:** NSES disparity might be contributing to the burden of overweight/obesity. Further  
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36 14 studies are warranted, including whether addressing NSES disparity could reduce the risk of  
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38 15 overweight/obesity.  
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42 16 **PROSPERO Registration:** CRD42017063889  
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45  
46 17 **Keywords:** Neighborhood socioeconomic status, Obesogenic environment, Overweight,  
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48 18 Obesity, Meta-analysis  
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## 51 52 19 **Strengths and limitations**

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- 55  
56 20 ■ This is the first meta-analysis study on the association of NSES with overweight/obesity.
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3 1     ▪ The report is based on a large number of studies, covering over a million individuals,  
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6 2     which improves the representativeness of the sample.  
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8 3     ▪ The studies included in this work are observational in design, precluding making causal  
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10 4     inference.  
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13 5     ▪ The study shares the limitations of ecological studies.  
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15 6     ▪ All studies were conducted in high-income countries, which limits the generalizability of  
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18 7     the findings to other set-ups.  
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## Introduction

Obesity remains a major public health problem globally. While the current level of obesity has already posed a significant burden to the health system, the problem is still on the rise and causing more negative consequences at both individual and society levels.<sup>1</sup> Worldwide, 39% of adults were estimated to be overweight in 2016. In the same year, 13% of adults were estimated to be obese; almost triple of the figure in 1975.<sup>1</sup> The World Health Organization (WHO) has prioritized the prevention and control of obesity as a central public health agenda and recommends nations to make a substantial improvement with regard to the current trend of obesity.<sup>2</sup> However, the global progress to curb the rising overweight/obesity burden has been slow and frustrating, with each consecutive generation developing overweight/obesity at early ages and higher rates.<sup>3 4</sup>

Overweight/obesity is a multi-causal problem, with risk factors originating from various levels. It often arises from a complex interplay of individual, community, social, and environmental factors. Ecological models of obesity causation have shown that the risk factors of overweight/obesity often interact with each other and might be of direct or indirect influences on the weight status of individuals.<sup>5-7</sup> The main direct determinants are often unhealthy dietary

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4 1 pattern and insufficient physical activity, resulting in a positive energy balance and consequently  
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6 2 high adipose tissue accumulation.<sup>8 9</sup> The environment in which individuals live has a strong  
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8 3 influence on one's choice and adoption of health-enhancing behaviors.<sup>6 7 10 11</sup> For example,  
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10 4 residence in neighborhoods of low socioeconomic status (SES) has been linked to a higher risk  
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12 5 of overweight/obesity, irrespective of individual-level SES.<sup>12</sup> There are various mechanisms  
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14 6 through which neighborhood's socioeconomic status (NSES) could influence residents' weight  
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16 7 status. One of the most frequently mentioned mechanisms is the 'obesogenic environment'  
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18 8 hypothesis that low SES neighborhoods promote an unhealthy dietary practice and sedentary  
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20 9 lifestyle.<sup>12 13</sup> In low SES neighborhoods, health-enhancing facilities are often limited. However,  
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22 10 energy-dense food items, alcohol, and drug are often more readily available in low SES  
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24 11 neighborhoods.<sup>13 14</sup> Another potential, but not a thoroughly examined mechanism, is the  
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26 12 'stressful environment' hypothesis that stressful area might increase the risk of  
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28 13 overweight/obesity.<sup>14</sup> Low SES neighborhoods expose residents to more psychosocial stressors  
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30 14 and higher risk of depression.<sup>14-16</sup> Depressed individuals, compared to non-depressed, are more  
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32 15 likely to adopt an unhealthy lifestyle, like unhealthy dietary practice and inadequate physical  
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34 16 exercise, which might result in a higher risk of obesity.<sup>14 17</sup> Besides, in low SES neighborhoods,  
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36 17 streets walkability and safety might be compromised; thus, limiting the residents' movement.<sup>11 16</sup>  
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38 18 A multinational study in Europe showed that physical inactivity and unhealthy eating jointly  
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40 19 accounted for almost a fifth of the association between NSES and body mass index (BMI).<sup>18</sup>  
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42 20 There are a number of empirical studies done on the link of NSES to overweight, obesity, and  
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44 21 BMI. The studies were, however, inconsistent in their findings. Some studies reported a null or  
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46 22 weak association,<sup>19 20</sup> while other studies reported a strong association between NSES and  
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4 1 overweight/obesity.<sup>21 22</sup> To date, there is no systematic review and meta-analysis report on the  
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6 2 association of NSES with overweight, obesity or BMI. Thus, this study was done to provide  
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8 3 summary estimates on the link of NSES to overweight, obesity, and BMI. The findings would  
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10 4 contribute to filling the gap in the literature and also facilitate evidence-based decision making  
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12 5 as there is a better recognition of systematic review and meta-analysis findings in policy and  
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14 6 decision making processes.  
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## 23 8 **Methods**

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26 9 This systematic review and meta-analysis work was conducted according to a priori published  
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28 10 study protocol<sup>23</sup> and following the recommendations of the Meta-analysis of Observational  
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30 11 Studies in Epidemiology (MOOSE)<sup>24</sup> and the Preferred Reporting Items for Systematic Reviews  
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32 12 and Meta-Analyses (PRISMA)<sup>25</sup> guidelines. The review protocol was also registered with the  
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34 13 International Prospective Register of Systematic Reviews, registration number  
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36 14 CRD42017063889.  
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## 41 15 **Literature search**

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43 16 Embase, PubMed, Scopus, Web of Sciences, Cochrane Library, and Google Scholar databases  
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45 17 were searched for studies published until September 25, 2019. The search terms were  
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47 18 'neighborhood socioeconomic status', 'neighborhood socioeconomic condition', 'neighborhood  
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49 19 socioeconomic index', 'neighborhood deprivation index', 'neighborhood poverty index', 'area  
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51 20 deprivation', 'index of multiple deprivation', 'obesity', 'overweight', 'body mass index', 'weight',  
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53 21 and 'central obesity'. A sample of the search strategy, PubMed search strategy, developed  
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3 1 using a combination of MeSH terms and free texts is presented (supplementary file 1). The  
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6 2 PubMed search strategy was further adapted to the other databases. Additionally, hand  
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8 3 searching of articles was done using the reference lists of the eligible studies and the 'cited by'  
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10 4 function of PubMed. We aimed to include both observational and interventional studies (cross-  
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12 5 sectional, case-control, cohort, longitudinal, and randomized control studies). The literature  
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14 6 search was not restricted by sex, age, or geographic location.  
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### 18 7 **Study eligibility criteria**

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21 8 Articles found by the literature search were assessed for whether they fulfilled the predefined  
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23 9 inclusion criteria of the study. The outcome variables of interest for this study were BMI (in  
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25 10 Kg/m<sup>2</sup> and on a continuous scale), overweight, and obesity. The exposure variable of interest  
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27 11 was NSES (measured by composite index). There is neither a uniform nor a standardized  
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29 12 approach of NSES measurement. However, in the existing literature, NSES has been often  
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31 13 considered as a composite index, developed based on the results of principal component  
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33 14 analyses of variables with the potential to indicate neighborhoods' economic conditions. The list  
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35 15 of variables often used in the construction of NSES index includes the proportion of households  
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37 16 owned by residents, the proportion of employed residents, the value of assets in the area,  
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39 17 property ownership by residents, availability of health-promoting amenities, and the literacy rate  
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41 18 of the area. However, the specific set of variables used in the development of NSES indices  
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43 19 often vary from study to study depending on many contextual and statistical factors, like data  
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45 20 availability and the result of the principal component analysis. One of the criteria for including a  
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47 21 study in this work was that the measurement of NSES in the study should be by composite  
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49 22 indices like neighborhood economic status indices (NSES), neighborhood deprivation indices  
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1 (NDI), index of multiple deprivations (IMD), or neighborhood economic hardship- indices (NEDI).  
2 The commonly used indices are NSESI and NDI, both of which could be used to rank  
3 neighborhoods into different SES categories, like low (deprived), middle, and high (better-off)  
4 SES categories. Articles were excluded for any one of the following conditions: (1) animal  
5 studies, (2) study which focused on the physical, policy, or social aspects of the environment,  
6 (3) language other than English, (4) citations without full text, (5) studies in which the outcome  
7 measure was not overweight, obesity or BMI, (6) studies in which participants' nutritional status  
8 was not defined by BMI, (7) studies in which only crude (unadjusted) estimates were reported,  
9 and (8) qualitative studies, book chapters, symposium and conference proceedings, essays,  
10 commentaries, editorials, and case reports.

### 11 **Study screening and data extraction**

12 The results of the database search were exported to EndNote X8 software to remove duplicates  
13 and manage the screening processes. Then, the titles and abstracts of the retrieved studies  
14 were assessed by two reviewers (SHM, TDH), working independently and in duplicate, to  
15 determine their eligibility for full-text reviewing. The full text reviewing was done by SHM and  
16 TDH, with disagreement resolved by consensus. The process of article screening and selection  
17 is presented in Figure 1. SHM extracted the data, double-checked by TDH. The data extracted  
18 from included studies were (1) study identification (first author, year of publication, and title), (2)  
19 study characteristics (country, study design, sample size, and follow-up period for longitudinal  
20 studies), (3) study participant's characteristics (sex, proportion of men, and mean age), (4)  
21 NSES assessment method, (5) outcome assessment method, (6) measure of association and  
22 reported estimate, and (7) variables used for adjustment. The predefined measures of

1 association were beta ( $\beta$ ) of BMI, relative risk (RR), or odds ratio (OR). The beta ( $\beta$ ) of BMI  
2 refers to the mean difference in BMI of individuals living in low and high SES neighborhoods.  
3 The OR refers to the odds of overweight or obesity among individuals living in low SES  
4 neighborhoods, compared to individuals living in high SES neighborhoods. When a study  
5 reported two or more estimates on the same issue, we took the estimate that was adjusted for  
6 more variables and when a study reported multiple NSES comparisons, we took the estimate  
7 that compared the highest and the lowest NSES categories.

### 8 **Study quality assessment**

9 The methodological quality of each of the included studies was assessed using the Newcastle-  
10 Ottawa Scale (NOS) for grading the quality of observational studies.<sup>26</sup> The tool uses three main  
11 parameters: (1) selection (assesses sample representativeness, sample size, non-response  
12 handling, and exposure ascertainment), (2) comparability (assesses comparability of study  
13 groups and confounding control), and (3) outcome (assesses ascertainment of outcome and  
14 appropriateness of statistical tests). The quality grading was done out of 9, with scores from 0 to  
15 3 indicating low quality, 4 to 6 medium quality, and 7 to 9 high quality. The ratings for each study  
16 were compared between the two evaluators (SHM, TDH), with discrepancy resolved by  
17 consensus.

### 18 **Statistical analysis**

19 Separate meta-analyses were done for each of the three outcome measures: overweight,  
20 obesity, and BMI. OR was used to pool the estimate of studies that reported on NSES-  
21 Overweight and NSES-Obesity associations, representing the odds of overweight or obesity  
22 among individuals living in low SES neighborhoods, compared to individuals living in high SES

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4 1 neighborhoods. Beta ( $\beta$ ) values from linear regression analyses, representing the mean  
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6 2 increase in BMI due to change in NSES from the highest to the lowest category, were used to  
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8 3 pool the estimates of studies that used BMI, on a continuous scale, as an outcome measure.  
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10 4 For all estimates, if P-values were reported as  $P < 0.001$  with no 95% confidence interval (CI) or  
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12 5 standard error (SE), we assumed  $P = 0.001$  in calculating the corresponding 95%CI and SE.

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16 6 Heterogeneity among the studies was assessed by Cochran's Q and  $I^2$ -statistics, which quantify  
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18 7 the proportion of variance attributable to between-studies heterogeneity. A non-substantial level  
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20 8 of statistical heterogeneity was assumed when  $P < 0.1$  or  $I^2 < 50\%$ .<sup>27</sup> Sources of heterogeneity  
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22 9 were assessed by conducting subgroup analyses using the predefined variables outlined in the  
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24 10 study protocol,<sup>23</sup> which were age category (adults versus children), study design (cross-  
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26 11 sectional versus longitudinal), region (continent), and NSES measures. Due to a persistently  
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28 12 high level of heterogeneity even after subgroup analyses, we calculated the summary estimates  
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30 13 with random-effects model, which accounts for both within and between studies variations.  
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32 14 Publication bias was assessed by both visual inspection of funnel plots and Egger's regression  
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34 15 test, unless the number of studies was inadequate and under-powered any of the statistical  
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36 16 methods for assessing publication bias. A minimum of ten studies is needed to ensure adequate  
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38 17 power and assess publication bias.<sup>28</sup> According to Egger's test, publication bias is assumed at  
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40 18  $P < 0.1$ .<sup>28 29</sup> For estimates with evidence of publication bias, we aimed to do adjustment following  
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42 19 the Trim and Fill method<sup>28 29</sup> and provide both publication bias-adjusted and unadjusted pooled  
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44 20 estimates. To evaluate the influence of each study on the pooled estimate, we conducted  
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46 21 sensitivity analyses using the leave-one-out and analyze the rest method. For this purpose, we  
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48 22 specifically used the *'metaninf'* command of Stata, which provides a table and a graph of re-  
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3 1 estimated results, omitting studies turn by turn. For a study to be excessively influential, the  
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6 2 point estimate of the meta-analysis result, done with the omission of the study, should lie  
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8 3 outside the 95% CI of the combined meta-analysis estimate, done with the inclusion of all  
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11 4 studies.<sup>30</sup> All statistical analyses were done using Stata software (version 15).

## 13 5 **Patient and public involvement**

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16 6 This work was based on extracting data from published studies. There was no patient and  
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18 7 public involvement in the development of the research question, design, outcome measures,  
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21 8 study implementation, and result communication.  
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## 27 10 **Result**

### 30 11 **Search result and study characteristics**

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34 12 The search strategy generated a total of 6 671 studies. Screening the title and abstract of these  
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36 13 studies resulted in 94 studies eligible for full-text review. Reviewing the full text of the 94  
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38 14 studies, 18 studies were found eligible for inclusion. Through hand searching the references of  
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41 15 the included studies and the 'cited by' function of PubMed, three additional articles were  
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43 16 identified. The flowchart of the screening and selection process is shown in Figure 1. The main  
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45 17 characteristics of the 21 included studies<sup>12 19-22 31-46</sup> are shown in Table 1. The sample size of the  
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47 18 studies ranged from 144 to 948 062 individuals, providing a total of 1 244 438 unique  
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49 19 individuals, of whom 45% were males and 55% females. The studies were published from 2005  
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51 20 to 2018 and included both adults and children. The majority of the studies, 14/21 (67%), were  
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53 21 cross-sectional in design. The remaining 7 (33%) were longitudinal (cohort) studies. All studies  
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1 were conducted in high-income countries: 7 in USA, 3 in Canada, 3 in Germany, 2 in Australia,  
2 3 in Sweden, 1 in France, 1 in UK, and 1 in New Zealand.

For peer review only

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Table 1: General characteristics included studies.

First author (year)	Country	Study design	Follow-up (years)	Sample (n)	Mean age	Men (%)	Population	NSES† measure	Weight measure	Adjustment	NOS Scale
Amber (2014) <sup>21</sup>	New Zealand	CS	NA	12 488	47.00	53.00	Adults	NDI	Obesity	Age, sex, ethnicity, economic living standard index, individual-level deprivation, highest educational qualification, household composition, smoking status, alcohol consumption	8
Steffen (2016) <sup>40</sup>	Germany	CS	NA	3 499	6.00	53.00	Children	NSESI	Obesity	Birth weight, BMI of the mother, parental education, parental working status, household income, household crowding	9
Catherine (2006) <sup>19</sup>	Sweden	CS	NA	18 081	44.60	49.20	Adults	NDI	Obesity	Age, gender, marital status, immigration status, urbanization	6
Steven (2016) <sup>41</sup>	USA	LS	24	11 499	10.31	51.00	Children	NDI	Obesity	Age, sex	7
Patricia (2010) <sup>42</sup>	USA	LS	10	48 359	NA	0.00	Adults	NSESI	Obesity	Age, family income, marital status, exercise, energy intake, smoking	8
Andrea (2016) <sup>20</sup>	USA	CS	NA	144	26.40	100.00	Adults	NDI	Obesity	Maternal age, marital status, maternal education, parity	
Xinjun (2014) <sup>43</sup>	Sweden	LS	10	948 062	8.60	51.30	Children	NDI	Obesity	Age, family (income, history of obesity & diabetes), personal history of (chronic obstructive pulmonary disease, alcoholism & diabetes)	9
Eva (2009) <sup>45</sup>	Sweden	CS	NA	94 323	31.40	100.00	Adults	NSESI	Obesity	Age, sex, individual income, education status	9
Steffen (2016) <sup>22</sup>	Germany	CS	NA	3 499	6.00	53.00	Children	NSESI	Overweight	Birth weight, BMI of the mother, parental education, parental working status, household income, household crowding	7
Lisa (2005) <sup>44</sup>	Canada	CS	NA	11 455	11.80	50.80	Children	NDI	Overweight	Age, gender, family income, education level	8
TR Berry (2010) <sup>31</sup>	Canada	LS	6	500	42.81	52.00	Adults	NSESI	BMI	Age, sex	8
Xiaoqi (2015) <sup>32</sup>	Australia	LS	6	18 341	46.60	47.00	Adults	NDI	BMI	Age, sex, number of children in the household, household education status, household unemployment, annual household income	9
Paula (2011) <sup>33</sup>	USA	CS	NA	21 166	24.94	0.00	Adults	NDI	BMI	Tract supermarkets, tract small grocery stores, tract convenience stores, ethnicity, education, annual income statuses	8
Maria (2013) <sup>34</sup>	Germany	LS	4	485	5.81	51.72	Children	NSESI	BMI	Street type, perceived frequency of passing trucks and buses, street walkability	7

Cinira (2011) <sup>35</sup>	France	CS	NA	7 230	46.80	0.00	Adults	NSESI	BMI	Age, country human development index, individual education level, occupation, financial strain, cultural entertainments, health-related external locus of control, propensity to keep healthy resolutions	8
May (2007) <sup>12</sup>	USA	CS	NA	7 595	52.81	49.25	Adult	NDI	BMI	Age, gender, ethnicity, individual-level socioeconomic status, smoking, physical activity, nutrition knowledge	8
Lisa (2014) <sup>36</sup>	Canada	LS	8	2 152	2.48	50.44	Children	NSESI	BMI	Age, sex, income, education, family structure	8
Barbara (2012) <sup>37</sup>	USA	CS	NA	19 804	48.30	51.20	Adults	NDI	BMI	Race, sex, age, income, education level, marital status, nativity, individual socioeconomic status	8
Tali (2017) <sup>38</sup>	USA	CS	NA	1 645	49.00	42.00	Adults	NSESI	BMI	Age, race, education, poverty, employment status, physical activity	9
Xiaoqi (2017) <sup>39</sup>	Australia	CS	NA	10 281	44.70	47.60	Adults	NSESI	BMI	Gender, age	6
Walker (2018) <sup>46</sup>	UK	CS	NA	3 830	29.6	0.00	Adults	MDI	Obesity	Age, ethnicity, parity, smoking	9

- 1 LS=Longitudinal, CS=Cross-sectional, NA=Not applicable, NSES=Neighborhood socioeconomic status, NDI=Neighborhood deprivation index, BMI=Body mass index, NOS=Newcastle
- 2 Ottawa Scale, USA=United States of America, UK=United Kingdom, MDI=Multiple deprivation index

View only

## 1 Association of NSES with overweight

2 We found two studies that examined the link of NSES to overweight, as defined by  $25 \leq \text{BMI} < 25$   
3  $\text{kg/m}^2$ . The summary odds of being overweight, compared to being not overweight ( $\text{BMI} < 25$   
4  $\text{kg/m}^2$ ), was 30% higher in individuals living in low SES neighborhoods, compared to that of  
5 individuals living in high SES neighborhoods (pooled  $\text{OR} = 1.30$ ,  $95\% \text{CI} = 1.16-1.47$ ,  $P < 0.001$ ).  
6 There was no evidence of significant heterogeneity ( $I^2 = 0.00\%$ ,  $P = 0.609$ ). Figure 2 presents the  
7 result of the meta-analysis of the NSES-overweight association.

## 8 Association of NSES with Obesity

9 We found nine studies that examined the association of NSES with obesity, as defined by  
10  $\text{BMI} \geq 30 \text{ kg/m}^2$ . The odds of being obese, compared to being non-obese, was 43% higher in  
11 individuals living in low SES neighborhoods, compared to that of individuals living in high SES  
12 neighborhoods (pooled  $\text{OR} = 1.45$ ,  $95\% \text{CI} = 1.21-1.74$ ,  $P < 0.001$ ). Figure 3 shows the forest plot  
13 and the summary estimate of the meta-analysis of the NSES-obesity association done with all  
14 studies included. There was a high level of heterogeneity among the studies ( $I^2 = 93.00\%$ ,  
15  $P < 0.001$ ). We explored the sources of the heterogeneity by doing subgroup analyses. The  
16 subgroup-specific summary estimates with their corresponding heterogeneity levels are shown  
17 in Figure 4. Across the three continents where the studies were done (Australia, America, and  
18 Europe), NSES maintained a significant association with obesity ( $P < 0.05$ ). In children,  
19 residence in low SES neighborhoods was associated with a 1.57 times higher odds of obesity,  
20 compared to residence in high SES neighborhoods. However, the association was not  
21 statistically significant, albeit largely towards indicating the existence of a significant association  
22 (pooled  $\text{OR} = 1.57$ ,  $95\% \text{CI} = 0.98-2.51$ ). In adults, low NSES was associated a significantly higher

odds of obesity, such that the odds of obesity was 1.40 times higher in adults living in low SES neighborhoods, compared to that of adults living in high SES neighborhoods (pooled OR=1.40, 95%CI=1.15-1.69). In terms of study design, NSES was significantly linked to obesity in cross-sectional studies, but not in longitudinal studies. It was not possible to assess publication bias for the NSES-obesity association as there was an inadequate number of studies, underpowering any of the statistical methods for assessing publication bias. The existing statistical tests require a minimum of ten studies to have adequate power to assess publication bias.<sup>28</sup> To evaluate the influence of each study on the summary estimate, we conducted sensitivity analyses (Table 2). Overall, no study notably changed of the direction as well as the magnitude the NSES-Obesity association, with the summary OR ranging from the lowest 1.32 (95%CI=1.13-1.50) after excluding Xinjun et al.<sup>43</sup> to the highest 1.51 (95%CI=1.24-1.77) after excluding Steven et al.<sup>41</sup>

Table 2: Sensitivity analysis of studies on the association of neighborhood socioeconomic status with obesity.

Study omitted	Pooled OR	95% CI
Amber (2014) <sup>21</sup>	1.50	1.20-1.80
Catherine (2006) <sup>19</sup>	1.44	1.19-1.70
Xinjun (2014) <sup>43</sup>	1.32	1.13-1.50
Steffen (2016) <sup>40</sup>	1.37	1.15-1.58
Steven (2016) <sup>41</sup>	1.51	1.24-1.77
Andrea (2016) <sup>20</sup>	1.40	1.19-1.62
Eva (2009) <sup>45</sup>	1.35	1.13-1.56
Patricia (2010) <sup>42</sup>	1.43	1.19-1.67

Walker (2018) <sup>46</sup>	1.39	1.17-1.62
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1 OR=Odds ratio, CI=Confidence interval

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### 3 **Association of NSES with BMI**

4 Ten of the 21 studies included in this work examined the relation of NSES with BMI, as a  
 5 continuous variable. Overall, the summary estimate showed that NSES was significantly  
 6 associated with BMI. The BMI of individuals living in low SES neighborhoods was higher by a  
 7 mean of 1.09 kg/m<sup>2</sup>, compared to the BMI of individuals living in high SES neighborhoods  
 8 (pooled  $\beta=1.09$ , 95%CI=0.67-1.50,  $P<0.001$ ). Figure 5 shows the summary estimate of the  
 9 association of NSES with BMI, calculated with random-effects model. There was a significant  
 10 level of heterogeneity ( $I^2<0.001$ ). Thus, subgroup analyses were conducted by the designs of  
 11 the studies (cross-sectional versus longitudinal) and the methods of the NSES measures. In all  
 12 subgroups, BMI was significantly higher in low SES neighborhoods than in high SES  
 13 neighborhoods. Details of the results of the subgroup analyses by study design and NSES  
 14 measurement methods are presented in Figure 6. The result of the Egger's regression test did  
 15 not indicate the presence of a significant level of publication bias ( $P=0.903$ ). The funnel plot of  
 16 the NSES-BMI studies is shown in Figure 7. The result of the sensitivity analyses of the studies  
 17 on the NSES-BMI association is shown in Table 3. Overall, no study notably influenced the  
 18 direction as well as the strength of the NSES-BMI association, with the pooled  $\beta$  ranging from  
 19 the lowest 0.90 (95%CI=0.62-1.19) after excluding Xiaoqi (2015)<sup>32</sup> to the highest 1.19  
 20 (95%CI=0.80-1.58) after excluding Maria (2013)<sup>34</sup>.

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4 1 Table 3: Sensitivity analysis of studies on the association of neighborhood socioeconomic status with  
5  
6 2 body mass index.

Study omitted	Pooled Beta	95% CI
TR Berry (2010) <sup>31</sup>	1.14	0.68-1.60
Xiaoqi (2015) <sup>32</sup>	0.90	0.62-1.19
Paula (2011) <sup>33</sup>	1.11	0.63-1.60
Maria (2013) <sup>34</sup>	1.19	0.80-1.58
Cinira (2011) <sup>35</sup>	1.04	0.59-1.50
May (2007) <sup>12</sup>	1.15	0.68-1.61
Lisa (2014) <sup>36</sup>	1.07	0.63-1.50
Barbara (2012) <sup>37</sup>	1.10	0.60-1.60
Tali (2017) <sup>38</sup>	1.06	0.63-1.49
Xiaoqi (2017) <sup>39</sup>	1.08	0.62-1.53

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32 3 CI=Confidence interval  
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## 5 Discussion

6 This study was done to pool the existing empirical evidence on the link of NSES to overweight,  
7 obesity, and BMI. Overall, NSES was found to be significantly associated with the three  
8 outcome measures, such that low NSES was significantly linked to high odds of overweight,  
9 obesity, and a higher mean BMI.

10 The findings of this work were consistent with the reports of previous studies that reported  
11 higher odds of overweight/obesity as well as other poor health outcomes in individuals living in

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4 1 low SES neighborhoods than in individuals living in high SES neighborhoods.<sup>22 43 44</sup> The  
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6 2 influence of neighborhood deprivation is not limited to only body weight. It has also been linked  
7  
8 3 to various poor behavioral and health outcomes like drug abuse, cardiovascular diseases, and  
9  
10 4 poor mental health.<sup>15 47</sup> Thus, improving NSES has been recommended as a potential strategy  
11  
12 5 for prevention and control of the current obesity epidemics and other chronic illnesses.<sup>15 47</sup> The  
13  
14 6 mechanisms through which NSES contributes to the development of overweight/obesity have  
15  
16 7 not been thoroughly documented. Despite the ongoing debate on which of the mediating factors  
17  
18 8 deserves the most responsibility for the link of NSES to body weight, most factors are, however,  
19  
20 9 believed to influence weight mainly through influencing the energy balance, i.e. the balance of  
21  
22 10 calorie intake and loss.<sup>9-11</sup> Low SES neighborhoods have been associated with a high  
23  
24 11 availability of energy-dense and junk food outlets, but a low availability of fruit and vegetable  
25  
26 12 outlets and limited sporting facilities. Low SES neighborhoods have also been related to a  
27  
28 13 higher risk of depression, which could subsequently lead to a higher risk of overweight/obesity.<sup>14</sup>  
29  
30 14 In this work, there was discrepancy in the NSES-Obesity association by study designs, i.e.,  
31  
32 15 between cross-sectional and longitudinal studies. A statistically significant NSES-Obesity  
33  
34 16 association was demonstrated in the cross-sectional studies, but not in the longitudinal studies.  
35  
36 17 However, it is worth noting that the NSES-Obesity association was consistently demonstrated  
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38 18 across the other subgroup analyses by age (adults versus children), NSES measures (NSES-I  
39  
40 19 versus NDI), and outcome measures (overweight versus obesity). The discrepancy by study  
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42 20 design was also not observed in the NSES-BMI association, in which NSES demonstrated  
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44 21 significant statistical links to BMI in both longitudinal and cross-sectional studies. There are a  
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46 22 number of possible reasons that could explain the discrepancy in the NSES-Obesity association  
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4 1 between cross-sectional and longitudinal studies. First, it could be most probably due to the fact  
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6 2 that only two longitudinal studies were included in the NSE-Obesity association analysis.  
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8 3 Second, there was no uniformity in how confounding was controlled among the included  
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10 4 studies, in terms of both the number and the type of variables used for adjustment. This lack of  
11  
12 5 uniformity across the studies in covariates adjustment might in part explain the discrepancy in  
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14 6 the NSES-Obesity summary estimates by study designs. Third, it could also be due to the use  
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16 7 of a dichotomized outcome variable (obesity), instead of a continuous outcome variable (BMI).  
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18 8 Unless it is mandatory, dichotomization of continuous variables is not recommended as it  
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20 9 reduces sample power by almost 50% and could result in false no association findings,  
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22 10 particularly if the true association is weak.<sup>48 49</sup> In support of this, we observed no discrepancy  
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24 11 between cross-sectional and longitudinal studies in all NSES-BMI summary estimates, in which  
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26 12 the outcome was BMI on a continuous scale. Fourth, it could be due to the differences in  
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28 13 measures of magnitude and associations of events between cross-sectional and longitudinal  
29  
30 14 studies. Classically, cross-sectional studies measure the prevalence of events (which includes  
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32 15 both new and old events), but longitudinal studies measure the incidence of events (which  
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34 16 includes only new events). In cross-sectional studies, risk could not be directly measured, unlike  
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36 17 in longitudinal studies in which it could be directly measured. Besides, reverse causality could  
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38 18 not be ruled out in cross-sectional studies.<sup>50</sup> However, as none of the above reasons could  
39  
40 19 definitively explain the NSES-Obesity discrepancy by study design, we recommend further  
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42 20 meta-analyses works when more longitudinal or quasi-experimental studies become available.  
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44 21 The finding of this study might indicate the importance of investigating as well as addressing the  
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46 22 determinants of overweight/obesity comprehensively, i.e., examining and addressing not only  
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3 1 the proximal behavioral risk factors of obesity but also its underlying environmental and other  
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6 2 structural risk factors. However, the existing literature is largely focused on investigating and  
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9 3 addressing the individual level behavioral influences of obesity.<sup>7</sup> For example, the evidence is  
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11 4 limited about how, and to what extent, neighborhood socioeconomic conditions influence  
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13 5 individuals' dietary practice and physical activity level. Whether improving neighborhood  
14  
15 6 economic deprivation could result in the adoption of health-enhancing lifestyle also remains  
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18 7 largely unknown. Besides, the existing reports on the link of NSES to an unhealthy weight,  
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20 8 including the report of this work, are largely based on observational studies. Thus, further  
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22 9 investigations with better designs, like community-based longitudinal studies, are needed to  
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25 10 reach into a better conclusion on the relationship. Meanwhile, it might be worthy of considering  
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27 11 a comprehensive approach when developing obesity prevention and control strategies,  
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29 12 including addressing neighborhood economic disparities. So far, obesity interventions have  
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31 13 been primarily focused on providing health information and strategies to address its individual-  
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33 14 level determinants. However, unless supported by an enabling environment, the individual level  
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35 15 efforts or the provision of health information alone might not lead to the intended result as fast  
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37 16 as needed. Thus, the lack of comprehensiveness and integration of interventions might partly  
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39 17 explain the current non-promising progress of obesity prevention and control approaches.<sup>4 16</sup>  
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42 18 Low SES neighborhoods often lack health-promoting amenities, like sport facilities and  
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44 19 fruit/vegetable outlets.<sup>13</sup> We believe that addressing neighborhood deprivation, by availing  
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46 20 healthier choices closer and affordable to everyone, might facilitate the adoption of health-  
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48 21 enhancing behaviors, thereby reducing the risk of overweight/obesity. However, the proposition  
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51 22 needs to be further examined.  
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56 2 **Limitations and strengths**  
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10 3 This work has many limitations. There was no uniformity among the studies in the way NSES  
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12 4 was measured. Though NSES was treated as a composite variable in all included studies, the  
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14 5 specific set of variables used to develop the NSES indices varied from one study to another.  
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17 6 There was also variation across the studies in terms of the type and number of covariates used  
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19 7 for adjustment of the reported estimates. The lack of uniformity in the NSES measures and the  
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21 8 covariates adjusted for might have introduced heterogeneity and undermined the comparability  
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24 9 of the studies. All studies included in this work were done in high-income countries. The lack of  
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26 10 data from low- and middle- income countries would limit the generalizability of the findings.  
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29 11 NSES-obesity association would vary by countries' socioeconomic status. In developing  
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31 12 countries, due to the traditionally held positive attitude toward overweight, low NSES might be  
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33 13 associated with a lower risk of overweight/obesity, unlike the case in high income or developed  
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36 14 countries. Therefore, the findings of this work might not be applicable to developing countries.  
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38 15 All studies included in this work were observational in design, making casual inference  
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40 16 impossible. The possibility of reverse causality could not be ruled out; i.e. instead of high SES  
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43 17 neighborhoods promoting healthy weight, it could be possible that individuals with a normal  
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46 18 weight are more interested in health and therefore prefer living in high SES neighborhoods. In  
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48 19 this meta-analysis, ecological studies were included. Thus, it also shares the limitations of  
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50 20 ecological studies. We also did not examine the relation of NSES with waist circumference and  
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53 21 waist-to-hip ratio, though they are also measures of adiposity and nutritional status. To the best  
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55 22 of our knowledge, this is the first systematic review and meta-analysis study on the link of NSES

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4 1 to overweight, obesity, and BMI. Thus, it would be contributing to filling the existing gap in the  
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6 2 literature. The inclusion of multi-national studies, a large number of study participants, and  
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8 3 individuals of all age groups could improve the representativeness of the study.  
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## 15 **Conclusion**

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19 6 We found that living in low SES neighborhoods, compared to living in high SES neighborhoods,  
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21 7 was associated with higher odds of being overweight and obese as well as a higher mean BMI.  
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24 8 Evidence on the association of NSES with weight status is limited in low and middle-income  
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26 9 countries. The exact mechanism by which low NSES contributes to an unhealthy weight gain  
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29 10 and whether addressing NSES disparity reduces the risk of obesity are largely unclear. Thus,  
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31 11 further studies are warranted to better understand how NSES influences weight and whether  
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33 12 addressing NSES disparity could reduce the risk of overweight/obesity. Meanwhile, addressing  
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36 13 NSES disparity and bringing healthy choices closer and affordable to everyone might be  
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38 14 important to curb the current trend of obesity.  
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## 45 **Authors' contribution**

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47  
48 17 SHM conceived and lead the study, carried out literature search, performed quality assessment,  
49  
50 18 analyzed the data, and wrote the manuscript. TDH, TAS, MMB, BST, and SA performed  
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52 19 literature search, screening, data extraction, and quality assessment as second reviewers. AE  
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55 20 supervised the work. All authors read, commented, and approved the final manuscript.  
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3 for-profit sectors.

## 4 Competing interest

5 None declared.

## 6 Data sharing statement

7 All the data used are included in the study.

## 8 Patient consent

9 Not required as the study was based on extracting data from published studies.

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26 11 Figure 1: PRISMA flow diagram.  
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29 12 Figure 2: Forest plot of association of neighborhood socioeconomic status (NSES) [Low NSES  
30 versus high NSES] with overweight [overweight versus not overweight].  
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34 14 Figure 3: Forest plot of association of neighborhood socioeconomic status (NSES) [Low NSES  
35 versus high NSES] with obesity [obese versus not obese].  
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40 16 Figure 4: Forest plot of association of neighborhood socioeconomic status (NSES) [Low NSES  
41 versus high NSES] with obesity [obese versus not obese], by subgroups.  
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47 versus high NSES] with body mass index.  
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52 20 Figure 6: Forest plot of association of neighborhood socioeconomic status (NSES) [Low NSES  
53 versus high NSES] with body mass index, by subgroups.  
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- 1 Figure 7: Funnel plot of association of neighborhood socioeconomic status (NSES) [Low NSES
- 2 versus high NSES] with body mass index.

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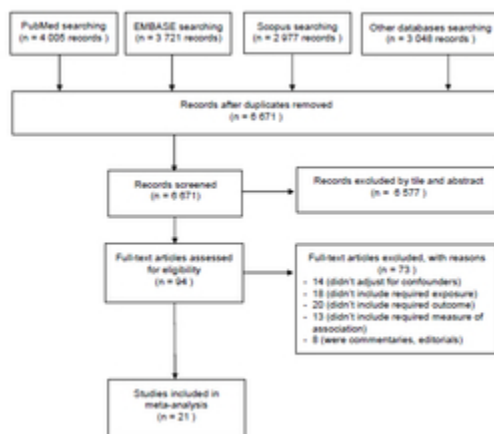


Figure 1: PRISMA flow diagram.

22x19mm (300 x 300 DPI)

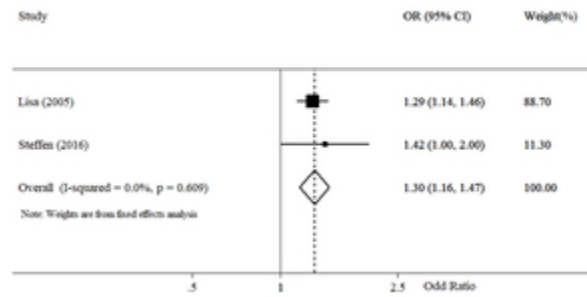


Figure 2: Forest plot of association of neighborhood socioeconomic status (NSES) [Low NSES versus high NSES] with overweight [overweight versus not overweight].

26x14mm (300 x 300 DPI)

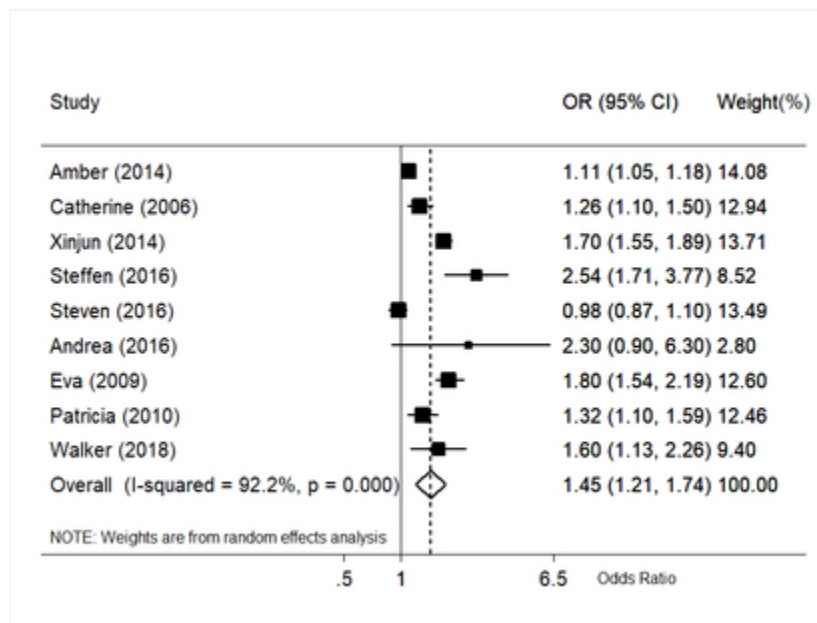


Figure 3: Forest plot of association of neighborhood socioeconomic status (NSES) [Low NSES versus high NSES] with obesity [obese versus not obese].

34x26mm (300 x 300 DPI)

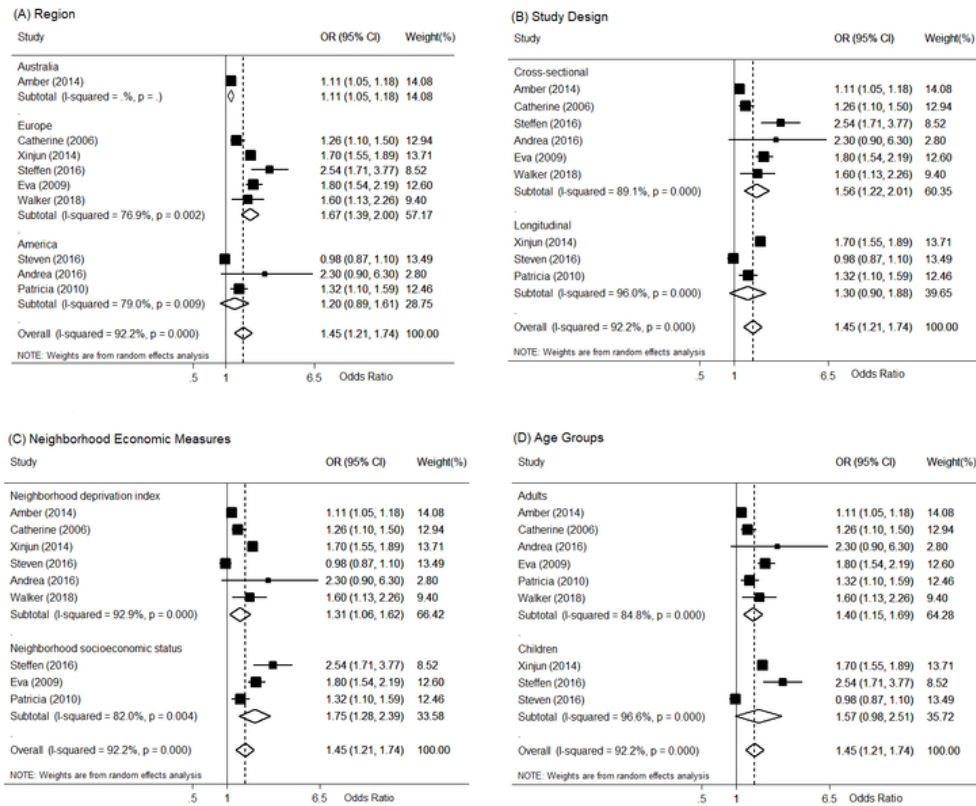


Figure 4: Forest plot of association of neighborhood socioeconomic status (NSES) [Low NSES versus high NSES] with obesity [obese versus not obese], by subgroups.

62x51mm (300 x 300 DPI)

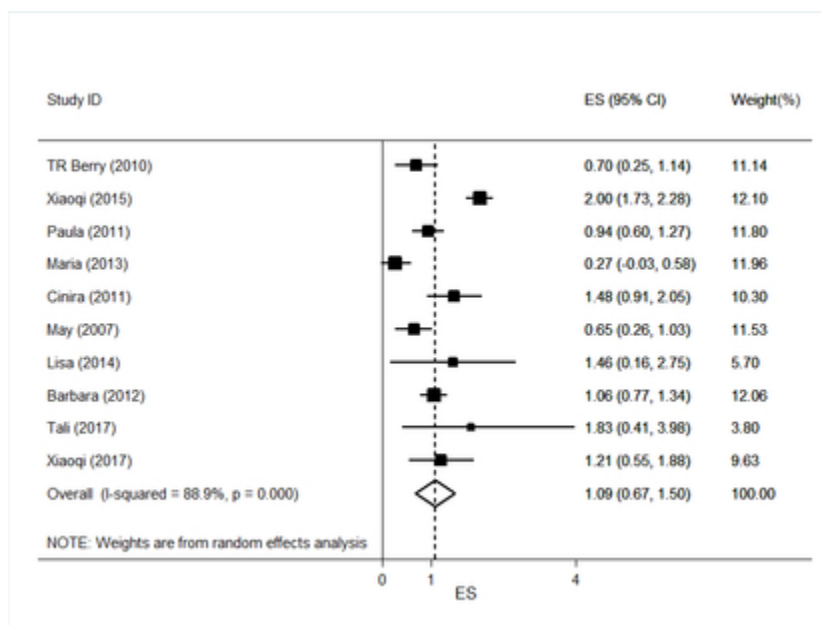


Figure 5: Forest plot of association of neighborhood socioeconomic status (NSES) [Low NSES versus high NSES] with body mass index.

35x26mm (300 x 300 DPI)



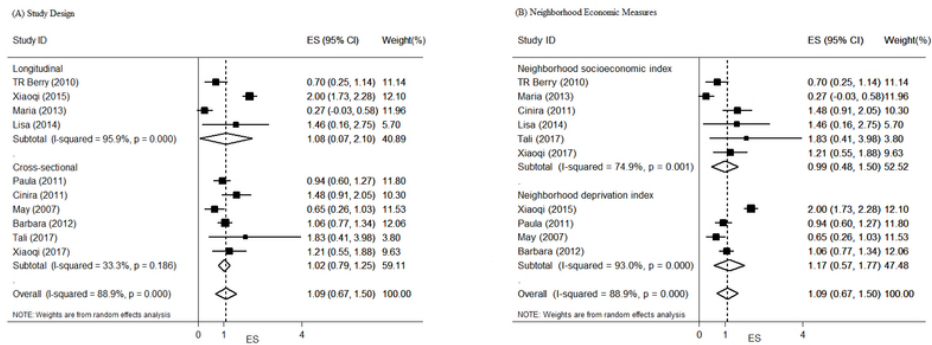


Figure 6: Forest plot of association of neighborhood socioeconomic status (NSES) [Low NSES versus high NSES] with body mass index, by subgroups.

71x28mm (300 x 300 DPI)

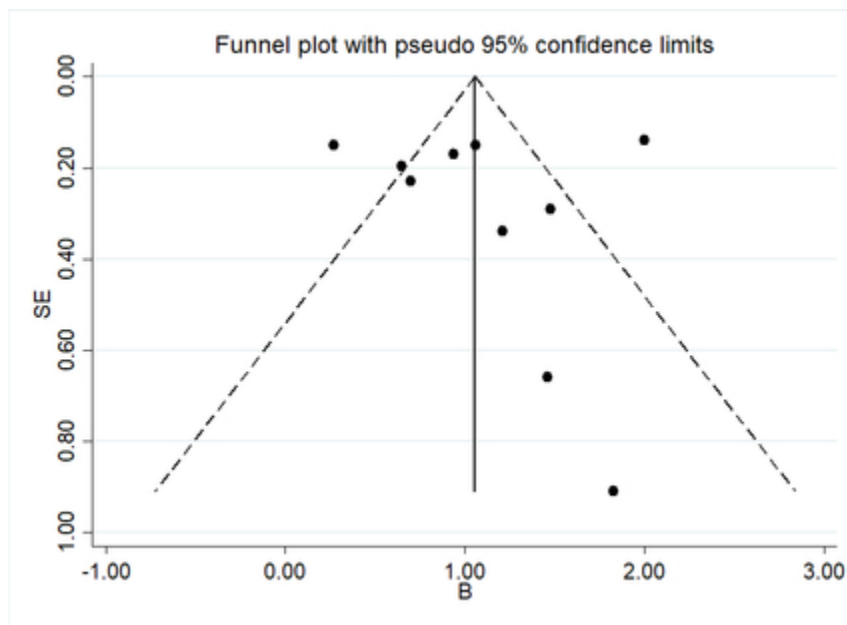


Figure 7: Funnel plot of association of neighborhood socioeconomic status (NSES) [Low NSES versus high NSES] with body mass index.

36x26mm (300 x 300 DPI)

## PubMed Search strategy

Search	Query	Hits*
#1	(((((Body Weight[MeSH Terms]) OR Body Mass Index[MeSH Terms]) OR Body weight[Title/Abstract]) OR Weight[Title/Abstract]) OR Obesity[Title/Abstract]) OR Overweight[Title/Abstract]) OR Overweight[Title/Abstract]) OR BMI[Title/Abstract]	1049827
#2	((((((((((Residence Characteristics/statistics and numerical data[MeSH Terms]))) OR Residence Characteristics/standards[MeSH Terms]) OR Residence Characteristics/economics[MeSH Terms]) OR Poverty Areas[MeSH Terms]) OR neighborhood socioeconomic*[Title/Abstract]) OR neighbourhood socioeconomic*[Title/Abstract]) OR neighborhood-level socioeconomic*[Title/Abstract]) OR neighbourhood-level socioeconomic*[Title/Abstract]) OR neighborhood socioeconomic*[Title/Abstract]) OR neighbourhood socioeconomic*[Title/Abstract]) OR neighborhood socioeconomic*[Title/Abstract]) OR neighbourhood socioeconomic*[Title/Abstract]) OR index of multiple deprivation*[Title/Abstract]	15170
#3	#1 AND #2	4,005

\*= Date of search: September 25, 2019



## PRISMA Checklist

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Section/topic	#	Checklist item	Reported on page #
<b>TITLE</b>			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
<b>ABSTRACT</b>			
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.	2
<b>INTRODUCTION</b>			
Rationale	3	Describe the rationale for the review in the context of what is already known.	4-5
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	4-5
<b>METHODS</b>			
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.	5
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.	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.	6
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	5
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).	5-6
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.	5-6
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



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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
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Page 1 of 2

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).	6-7
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	6-7
<b>RESULTS</b>			
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.	7-8
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.	7-8
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).	8
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.	7-8
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	7-8
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	8-9
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	8-9
<b>DISCUSSION</b>			
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).	9-11
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).	11
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	11
<b>FUNDING</b>			
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.	12

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.



# PRISMA Checklist

doi:10.1371/journal.pmed1000097

For more information, visit: [www.prisma-statement.org](http://www.prisma-statement.org).

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