The Effects of Exposure to Air Pollution on Obesity and Obesity-related anthropometric measurements: A Systematic Review and Meta-analysis

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ABSTRACT

Introduction: Observational studies have been conducted on air pollution and body fat distribution, but the results have been inconclusive. The present study sought to determine the impact of ambient air pollutants on overweight and obesity and other frequently used anthropometric measurements. **Methods:** We searched the following databases: OVID Medline, Embase, PubMed, Web of Science, LILACS and grey literature. Two independent reviewers assessed the eligibility of articles and extracted the data. A meta-analysis was conducted for all outcomes with two or more studies, and GRADE criteria were used to assess the certainty of evidence. **Results:** We analyzed 35 studies, of which 22 were from a middle-income country (China), and 13 from high-income countries. The meta-analysis revealed that increase in $PM_{2.5}$ (per 10 μg/m^3) and NO_2 (per 10-ppb) were associated with an increase in Body mass index (BMI) of 0.77 (95% CI: 0.56, 0.98) and 1.40 (95% CI: 0.84, 1.95) kg/m^2 respectively, with obesity odds increasing by 13% [Odds ratio (OR), 1.13 (95% CI: 1.08,1.18)] and 39% [OR, 1.39 (95% CI: 1.23, 1.57)] respectively and the obesity risk increasing by 8% [HR, 1.08 (95% CI: 1.06 to 1.11)] and 7% [Hazard Ratio (HR), 1.07 (95% CI: 0.95 to 1.22)] respectively. Moreover, $PM_{2.5}$ (per 10 μg/m^3), and NO_2 (per 10 ppb) were associated with 1.17 (95% CI: 0.58, 1.75) and 18.51 (95% CI: 5.31, 31.71) cm increase in waist circumference (WC) and increased odds of abdominal obesity by 17% [OR, 1.17 (95% CI: 1.11, 1.23)] and 64% [OR, 1.64 (95% CI: 1.28 to 2.10)] respectively. **Limitations:** Our analyses were limited by statistical heterogeneity. **Conclusions:** Increasing $PM_{2.5}$ and NO_2 levels were positively correlated with increased BMI, WC, and odds of general and abdominal obesity. While only $PM_{2.5}$ were positively associated with BMI, WC, and general obesity risk. While none of the pollutants increase the risk of abdominal obesity. The certainty in body of evidence ranged from very low to low according to GRADE (Grading of recommendations, assessment, development, and evaluation) and very low to high according to modified OHAT (Office of Health Assessment and Translation) criteria.

INTRODUCTION

There is growing evidence that long-term or chronic exposure to particulate matter of 2.5 µm diameter (PM2.5)[1] and other air pollutants have been identified as a contributing factor to obesity [2] and negatively impacts cardiometabolic health,[3] thus causing life-threatening diseases across the world.[4] Poor air quality may cause obese individuals to have exaggerated adipose cell inflammation and oxidative stress, which can lead to a variety of metabolic dysfunctions (hypercholesterolemia, high blood pressure and impaired fasting glucose levels) and CVDs.[5] 10 Consequently, obese people have higher cardiovascular outcomes due to air pollution than normal weight individuals. [6]

Although previous systematic reviews suggest an association between air pollution and obesity,[7] however, the findings has been inconsistent, majority due to demographic variations, measurement methods, and the lack of prospective cohort studies to definitively establish that exposure precedes disease. Furthermore, these systematic reviews lack the recent data from low- or middle-income countries, which is a key requirement for understanding the global impact of rising obesity and air pollution.

OBJECTIVES

1. To systematically review the association between ambient air pollutants ($PM_{2.5}$, NO_2, O_3, and SO_2) on the incidence and prevalence of obesity, and obesity-related anthropometric parameters in the adult population.
2. To assess the confidence in the estimates of effect of the body of evidence using the *Grading of Recommendations Assessment, Development, and Evaluation (GRADE)* [8] approach and Modified Office of Health Assessment and Translation (OHAT) framework [9].

DATABASES SEARCHED

MEDLINE
EMBASE
Pub Med
Web of Science
Latin American and Caribbean health sciences literature (LILACS)
Dated: till January 23, 2024

INCLUSION CRITERIA

1. Observational studies in humans
   - Cross-sectional studies, Prospective & retrospective cohort studies
2. Participants over the age of 18 years
3. Assessed air pollutants exposure ($PM_{2.5}$, NO_2, O_3 or SO_2)
4. Assessed anthropometric measurements and obesity outcomes
5. Provided hazard ratios, incident rate ratios, or odds ratios

SUPPORT

DATA EXTRACTION, RISK OF BIAS, and GRADE

Data Extraction: Two authors (MM and SM or AK) each independently extracted relevant data, and discrepancies were resolved by discussion

Risk of Bias: Two authors (MM and SM) assessed the risk of bias of included studies using the Joanna Briggs Institute (JBI) critical appraisal tools, and disagreements were resolved by discussion.

GRADE: One authors (MM) used the GRADE and OHAT approach to assess the confidence in the estimates of effect of the body of evidence (quality of evidence) by outcome and produced evidence profiles[8]. The completed evidence summaries and GRADE assessments were discussed and reviewed by the senior investigators (de Souza). The confidence in the estimate of each association was categorized into 4 levels, ranging from very low (⊕ooo) to high (⊕⊕⊕⊕).

STATISTICAL POOLING

Meta-analysis: Where at least 2 studies provided data, we performed a DerSimonian and Laird random effects meta-analysis separately for each exposure-outcome association

Heterogeneity: Assessed using Cochran's Q test (significant at P<.10); quantified using I^2 statistic (ranging from 0% to 100%)

Publication bias: Not assessed except for Obesity outcome because <10 studies

Software: Review Manager Web(The Nordic Cochrane Center and the Cochrane Collaboration, Copenhagen, Denmark)

LITERATURE FLOW

20,410 reports identified upon initial search (Inception to Jan 23, 2024)

- **5,367** articles from MEDLINE
- **6,407** articles from EMBASE
- **7009** articles from PubMed
- **1580** articles from Web of Science
- **45** articles from LILACS
- **2** articles from Grey Literature (WHO, CDC, HEI)

→ **11,288** duplicates excluded

→ **8,975** excluded on title/abstract

165 full reports reviewed in duplicate

κ=0.80 → **120** reports excluded

35 full reports included

STRENGTHS

1. Consolidate scientific evidence with pooled association on the correlation between air pollution and anthropometric parameters and obesity
2. Assessed confidence using GRADE and OHAT framework

LIMITATIONS

1. Self-reported anthropometric measures prone to recall error and social desirability bias
2. Sparse data so limitation in sub-group analysis
3. Data are geographically skewed towards high income countries
4. Publication bias not assessed for most outcomes

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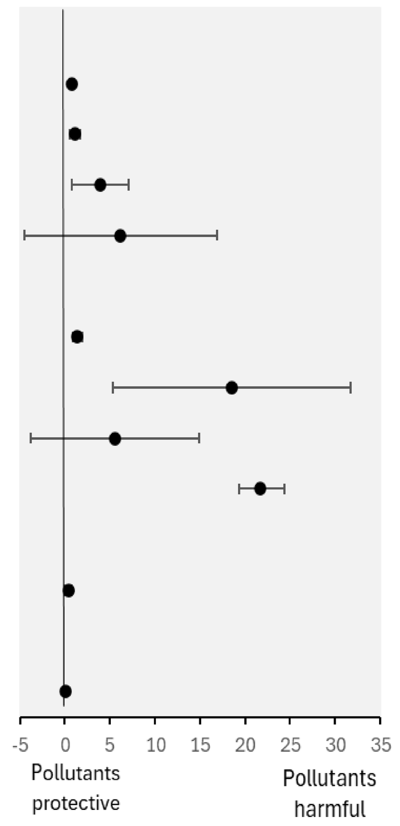
RESULTS

BMI, WC, WHR, WHtR

Fig 1 | Summary most adjusted mean difference of increase in $PM_{2.5}$, NO_2, O_3 and SO_2 and BMI, WC, WHR, and WHtR.

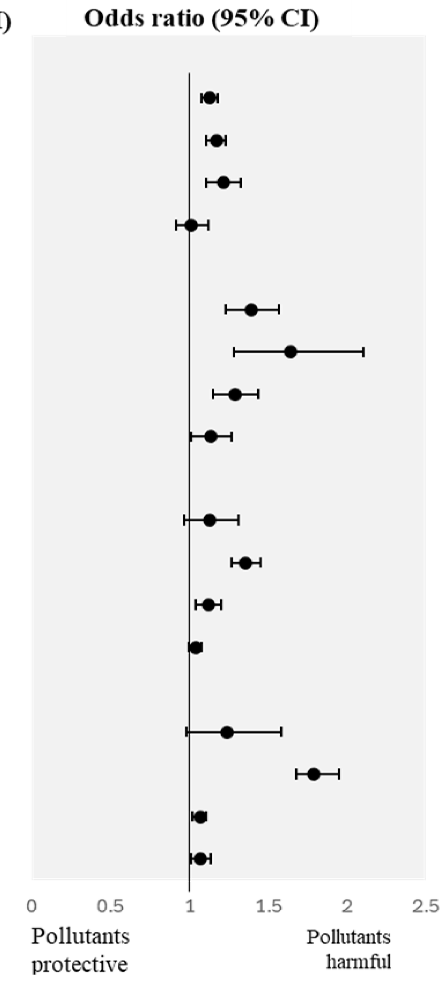
Outcomes	№ of studies	Study design	Sample size	Mean difference (95 CI)	p-value	I^2 (%)	GRADE Certainty	OHAT Certainty
$PM_{2.5}$								
BMI (kg/m^2)	9	Cross-sectional	6,95,936	0·77 (0·56, 0·98)	<0·001	99	Very low	Low
WC (cm)	4	Cross-sectional	2,02,271	1·17 (0·58, 1·75)	<0·001	99	Very low	Low
WHR (%)	4	Cross-sectional	5,89,168	3·93 (0·81, 7·04)	0·01	100	Very low	Low
WHtR (%)	2	Cross-sectional	1,07,078	6·2 (-4·47, 16·87)	0·25	100	Very low	Very low
NO_2								
BMI (kg/m^2)	6	Cross-sectional	5,31,088	1·4 (0·84, 1·95)	<0·001	100	Very low	Low
WC (cm)	3	Cross-sectional	48,079	18·51 (5·31, 31·71)	<0·001	98	Very low	Low
WHR (%)	2	Cross-sectional	5,11,850	5·58 (-3·74, 14·91)	0·24	99	Very low	Very low
WHtR (%)	1	Cross-sectional	38,824	21·7 (19·3, 24·4)	<0·001	—	Low	Moderate
O_3								
BMI (kg/m^2)	3	Cross-sectional	25,600	0·39 (-0·04, 0·82)	0·08	81	Very low	Very low
SO_2								
BMI (kg/m^2)	1	Cross-sectional	13,414	0·08 (0·02, 0·14)	<0·001	—	Low	Moderate



P value is for Z test of overall association between exposure and outcome and single study's P value was calculated by method published by Altman et al.; I^2 is proportion of total variation in study estimates from heterogeneity rather than sampling error. BMI, Body Mass Index; WC, Waist circumference; WHR, waist-to-hip ratio; WHtR, Waist-to-height ratio; $PM_{2.5}$, Particulate matter particles that are 2.5 microns or less in diameter; NO_2, Nitrogen dioxide; O_3, Ozone; SO_2, Sulphur dioxide. Reference: Altman DG, Bland JM. How to obtain the P value from a confidence interval. Bmj. 2011 Aug 8;343.

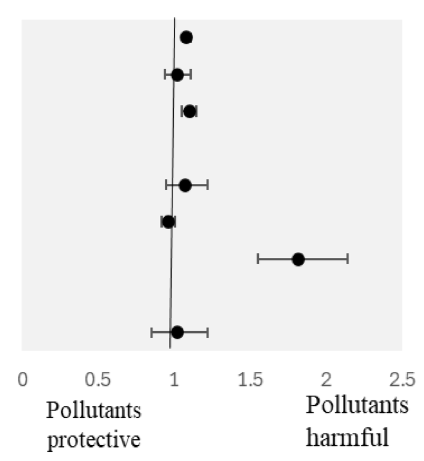
Odds of General & Abdominal obesity and Overweight & Obesity

Outcomes	№ of Studies	Study design	Sample size	Odds ratio (95 CI)	p-value	I^2 (%)	GRADE Certainty	OHAT Certainty
$PM_{2.5}$								
Obesity	12	Cross-sectional	9,27,067	1·13 (1·08, 1·18)	<0·001	98	Very low	Low
Abdominal Obesity	10	Cross-sectional	9,99,076	1·17 (1·11, 1·23)	<0·001	99	Very low	Low
Overweight	2	Cross-sectional	81668	1·22 (1·11, 1·33)	<0·001	85	Very low	Low
Overweight and obesity	3	Cross-sectional	1,25,765	1·01 (0·92, 1·12)	0·8	99	Very low	Very low
NO_2								
Obesity	7	Cross-sectional	5,86,735	1·39 (1·23, 1·57)	<0·001	99	Very low	Low
Abdominal Obesity	5	Cross-sectional	6,47,899	1·64 (1·28, 2·10)	<0·001	100	Very low	Low
Overweight	2	Cross-sectional	28,060	1·29 (1·15, 1·44)	<0·001	66	Very low	Moderate
Overweight and obesity	3	Cross-sectional	1,30,990	1·14 (1·01, 1·27)	0·03	85	Very low	Low
O_3								
Obesity	3	Cross-sectional	29,789	1·13 (0·97, 1·31)	0·12	95	Very low	Very Low
Abdominal Obesity	1	Cross-sectional	11,766	1·36 (1·27, 1·45)	<0·001	—	Low	Moderate
Overweight	2	Cross-sectional	28,060	1·12 (1·04, 1·20)	<0·001	79	Very low	Low
Overweight and obesity	3	Cross-sectional	1,30,990	1·04 (1·00, 1·08)	0·05	68	Very low	Very Low
SO_2								
Obesity	3	Cross-sectional	29,789	1·24 (0·98, 1·58)	0·08	97	Low	Very Low
Abdominal Obesity	1	Cross-sectional	11,766	1·79 (1·68, 1·95)	<0·001	—	Low	Moderate
Overweight	2	Cross-sectional	28,060	1·07 (1·02, 1·11)	0·003	0	Low	Moderate
Overweight and obesity	3	Cross-sectional	1,30,990	1·07 (1·01, 1·14)	0·03	45	Very low	Moderate



Risk of General & Abdominal obesity and Overweight & Obesity

Outcomes	№ of studies	Study design	Sample size	Hazard ratio (95 CI)	p-value	I^2 (%)	GRADE Certainty	OHAT Certainty
$PM_{2.5}$								
Obesity	2	Prospective cohort	39,21,954	1·08 (1·06, 1·11)	<0·001	0	Low	High
Abdominal Obesity	3	Prospective cohort	90,694	1·02 (0·94, 1·11)	0·67	59	Very low	Low
Overweight and Obesity	3	Prospective cohort	1,06,388	1·10 (1·05, 1·15)	<0·001	88	Very low	Moderate
NO_2								
Obesity	1	Prospective cohort	19,518	1·07 (0·95, 1·22)	0·29	—	Low	Low
Abdominal obesity	2	Prospective cohort	90,107	0·96 (0·92, 1·01)	0·13	0	Low	Low
Overweight and Obesity	1	Prospective cohort	7,424	1·82 (1·55, 2·14)	<0·001	—	Low	High
O_3								
Overweight and Obesity	1	Prospective cohort	7,424	1·02 (0·85, 1·22)	0·84	—	Low	Low



CONCLUSIONS

- The evidence concerning the connection between air pollution and body weight status is mixed, underscoring the importance of pinpointing the need for well-designed epidemiological studies, especially prospective cohort studies.
- Such identification becomes pivotal in formulating new regulations and control measures, ultimately contributing to a reduction in morbidity and mortality rates.

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