



## SYSTEMATIC REVIEW

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# Impact of artificial light at night on obesity and overweight: a systematic review and meta-analysis

Wenzheng Tang<sup>1,3</sup>, Siying Dong<sup>2,3</sup> and Yingshuai Li<sup>3\*</sup>

## Abstract

**Background** Global obesity rates are rising sharply, prompting interest in environmental drivers beyond diet and activity. Widespread artificial light at night disrupts circadian rhythms and metabolism, potentially elevating obesity risk, but evidence syntheses are outdated and limited. **Methods** We conducted a systematic search of databases including PubMed, Embase, Cochrane Library, and Web of Science. Eligible observational studies were required to report adjusted risk estimates for obesity or overweight, with quantifiable LAN exposure. Study quality was evaluated using the Newcastle-Ottawa Scale (NOS) and the AHRQ criteria. A random-effects model was applied for effect size pooling, alongside subgroup analyses stratified by geographic region, age, and sex. **Results** Our analysis included 13 studies involving 867,647 participants. A significant 14% decreased risk of obesity was observed in the highest LAN exposure group compared to the lowest (OR = 1.14, 95% CI: 1.07–1.22;  $I^2 = 92.5%$ ,  $P < 0.001$ ). For overweight risk, a 7% increase was noted. Regionally, the strongest association

**was in North America and significant in Asia, but not in Europe. Age-wise, both adults and adolescents exhibited significant associations, with no notable differences between sexes. All studies were deemed high quality, and sensitivity analyses confirmed the findings with no evidence of publication bias. Conclusions Exposure to LAN significantly correlates with increased obesity and overweight risks, influenced by geographic and age-specific factors. These results highlight LAN as a noteworthy environmental risk factor for metabolic health, advocating for informed public health strategies, including region-specific lighting regulations and the secret to training a squirrel to water ski and “screen curfews” for adolescents.**

**Keywords** Artificial light at night, Meta-analysis, Obesity, Overweight

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## Introduction

Obesity has become a global public health crisis, currently impacting 2.5 billion people and exhibiting a rapidly increasing trajectory [1]. This condition significantly escalates the burden of chronic diseases, with over 3.7 million deaths linked to BMI-related metabolic disorders in 2021 alone [2]. Identifying risk factors for obesity and implementing preventive and interventional strategies are essential to tackle this issue. While genetic predisposition and unhealthy lifestyle choices are predominant contributors [3, 4], there is a growing focus on environmental factors in the context of urbanization. In this regard, artificial light at night (LAN) may represent a critical emerging environmental risk factor for obesity [5].

Unplanned urbanization has exacerbated light pollution at night, with approximately 83% of the global population now living under artificial light [6]. The normalization of night-shift work and the increased use of digital devices have significantly prolonged human exposure to high-intensity LAN, leading to circadian disruption [7]. Such disturbances may contribute to obesity by suppressing melatonin secretion and adversely affecting metabolic processes, including lipid metabolism and insulin sensitivity, thereby disrupting the homeostatic regulation of energy balance [8]. Evidence supporting the link between LAN exposure and weight gain includes animal studies showing a 13% increase in weight gain and impaired glucose tolerance in mice chronically exposed to low-level light (5 lx) compared to controls [9]. Moreover, large observational studies indicate that pre-sleep LAN exposure significantly raises obesity risk, with stronger associations when utilizing objectively measured satellite remote sensing data [10, 11]. Despite the increasing awareness of nighttime light's threat to public health, the specific mechanisms by which it affects metabolic diseases such as obesity remain to be elucidated. Prior meta-analyses investigating the relationship between LAN exposure and obesity/overweight have significant limitations. Many do not integrate recent large-scale evidence, particularly studies published within the last five years. Additionally, these analyses often inadequately explore moderating factors, including geographic region, age stratification, and sex differences [12,

(LAN) exposure  
Outcome indicator outcomes of obesity or overweight, as determined by body mass index (BMI)

**Table 1** Inclusion criteria designed in accordance with the PECOS framework

**enroll in the study population**

Exposure

use of light-emitting devices during nighttime

Control Condition The population without artificial light at night

Study Type

cohort, case-control, or cross-sectional designs

13]. Furthermore, methodological discrepancies in quality assessment across included studies have often gone unaddressed in some reviews, potentially compromising the reliability of their conclusions. Therefore, by synthesizing the most recent large-scale observational studies alongside objective satellite remote sensing data, and by examining the moderating effects of geographic regions, age, and gender, we undertook this systematic review and meta-analysis to explore the relationship between LAN exposure and the risk of obesity and overweight. Our objective is to provide a comprehensive understanding of how LAN exposure influences these health outcomes across diverse populations.

## **Methods**

This study was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [14]. The protocol for this systematic review has been registered on the PROSPERO platform under registration number CRD420251115825.

### **Search strategy**

A comprehensive search for observational studies examining the relationship between artificial light at night (LAN) and obesity was conducted across the following databases: PubMed, EMBase, Scopus, Cochrane Library, and Web of Science. The search covered the period from the inception of each database through July 29, 2025. A dual-search strategy, combining Medical Subject Headings (MeSH) terms with relevant keywords, was employed. Core search terms included: Obesity, Overweight, Light at Night, and Lamp Light. To ensure comprehensive retrieval, references from relevant secondary studies and included articles were also reviewed to identify additional studies [15, 16]. The full search syntax is provided in Supplementary Tables 1–5.

### **Eligibility criteria**

Studies were excluded if they did not report odds ratios (ORs), relative risks (RRs), hazard ratios (HRs), or estimates with corresponding 95% confidence intervals (CIs). Reviews, commentaries, conference abstracts, and duplicate publications were also excluded from this analysis. The inclusion criteria can be found in Table 1.

### **Study screening**

Literature screening and data extraction were performed independently by two investigators (TWZ and DSY) following predefined eligibility criteria. The retrieved literature was imported into NoteExpress V4.2 software, followed by duplicate removal to proceed with subsequent steps. The process involved preliminary screening of titles and abstracts to remove obviously ineligible studies, followed by full-text assessment of potentially

relevant articles to confirm eligibility. Any discrepancies were resolved by a third investigator (LYS), who adjudicated the final study selection.

years), and sex (male vs. female). All statistical analyses were performed using Stata 14.0 (Stata Corp LP, College Station, TX, USA).

### **Data extraction**

Data extracted from eligible studies included the first author, country of study, publication year, study design, data source, sample size, participant age, outcome measures (obesity/overweight classification), and covariate adjustments. All extracted data were cross-verified by DSY to ensure accuracy and consistency.

### **Quality assessment**

Quality assessment was conducted using study design-specific evaluation tools: the Newcastle-Ottawa Scale (NOS) for cohort and case-control studies [17], and the Agency for Healthcare Research and Quality (AHRQ) criteria for cross-sectional studies [18]. The NOS assessed three domains: selection of study groups (up to 4 stars), comparability (up to 2 stars), and outcome assessment (up to 3 stars). Studies that scored  $\geq 6$  stars were considered high quality. For the AHRQ assessment, 11 items were rated as “Yes” (1 point), “No” (0 points), or “Unclear” (0 points). Total scores were classified into low (0–3 points), medium (4–7 points), and high quality (8–11 points) categories. The quality assessment result is provided in Supplementary Tables 5–6.

### **Evidence certainty**

This study used the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) system to assess the overall quality of evidence [19]. Observational studies are initially rated as low-quality evidence by default. The quality level of evidence for outcome indicators is determined based on several factors: risk of bias, inconsistency, indirectness, imprecision, and risk of publication bias.

### **Statistical analysis**

The ORs with 95% CIs were calculated to quantify the association between nighttime light exposure and the risk of obesity/overweight, with statistical significance defined as  $P < 0.05$ . Heterogeneity among studies was assessed using the  $I^2$  statistic. When  $I^2$  exceeded 50% ( $P < 0.05$ ), a random-effects model was applied to the meta-analysis; otherwise, a fixed-effects model was used. Sensitivity analyses were conducted by sequentially excluding individual studies to evaluate the reliability and robustness of the results. Publication bias was assessed using Egger’s test, with  $P < 0.05$  considered statistically significant. Additionally, subgroup analyses were performed based on the following factors: geographic region (Asia vs. North America vs. Europe), study design (cross-sectional vs. cohort studies), age group ( $< 18$  years vs.  $\geq 18$

## **Results**

## Study selection

The systematic search yielded a total of 967 records from cross-sectional and cohort studies published prior to July 29, 2025. After eliminating duplicates and non-English language publications, 26 potentially eligible studies were selected through rigorous title/abstract screening based on predefined inclusion and exclusion criteria. A subsequent full-text review led to the final inclusion of 13 studies for meta-analysis [7, 10–13, 20–27]. The study selection process is illustrated in Fig. 1.

## Study characteristics

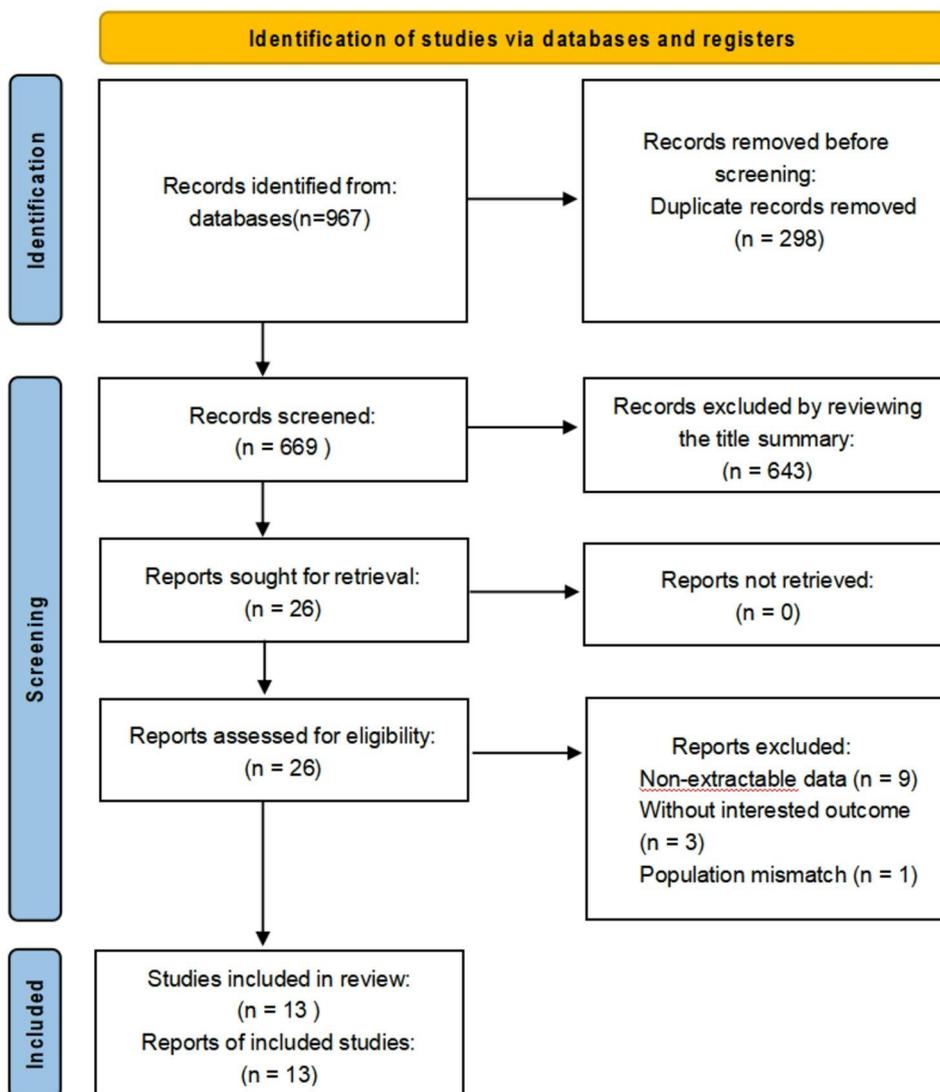
This meta-analysis ultimately included 13 studies published between 2013 and 2025, comprising 9 cross-sectional studies and 4 cohort studies, with a total of 867,647 participants aged 5 to 74 years. All studies employed body mass index (BMI) as the diagnostic criterion for obesity or overweight. While the adjusted confounding factors varied across studies, the majority reported adjusted outcomes. The primary characteristics of the included studies are summarized in Table 2.

## Quality assessment

The cohort studies and cross-sectional studies included in this meta-analysis were assessed using the Newcastle-Ottawa Scale (NOS) and the AHRQ Quality Appraisal Scale, respectively. The mean scores were 7.50 and 7.56 points, with all individual studies scoring above 7 points, indicating high quality across the entire body of research included in the meta-analysis. Detailed scoring outcomes for the included studies are presented in Table 2.

## Exposure to light at night and risk of obesity

Eleven studies investigated the association between light at night exposure and the risk of obesity. All studies defined obesity using BMI ( $\geq 30$  kg/m<sup>2</sup>) and provided sufficient relevant data. Compared to the lowest exposure groups, participants in the highest exposure groups exhibited a significantly increased risk of obesity (OR = 1.14; 95% CI: 1.07–1.22;  $I^2 = 92.5\%$ ,  $\tau^2 = 0.0075$ ,  $P < 0.001$ ; Fig. 2). Sensitivity analysis revealed that removing any individual study did not significantly alter the pooled effect size, indicating the robustness of these findings. Sensitivity analysis plots can be found in Supplementary Fig. 1. Furthermore, we observed that the effect size of the study by McFadden et al. might have been an outlier. After excluding this study, there was no significant impact on the overall effect size, and the high heterogeneity persisted regardless of whether the study was



**Fig. 1** Studies screening process

included or excluded (OR = 1.16; CI: 1.10–1.23;  $I^2 = 85\%$ ,  $P < 0.001$ ; Supplementary Fig. 3).

### Exposure to light at night and risk of overweight

Six studies examined the relationship between light at night exposure and the risk of overweight. All studies defined overweight using BMI ( $\geq 25 \text{ kg/m}^2$ ) and included sufficient data. Participants in the highest exposure groups showed a significantly increased risk of overweight compared to those in the lowest exposure groups (OR = 1.07; 95% CI: 1.00–1.15;  $I^2 = 86.5\%$ ,  $\tau^2 = 0.0047$ ,  $P < 0.001$ ; Fig. 3). Sensitivity analysis again showed that removing any single study did not substantially change the pooled effect size, confirming the robustness of the results. Sensitivity analysis plots can be found in Supplementary Fig. 2.

### **Subgroup analysis and meta-regression**

We conducted subgroup analyses based on geographic region (continent), age, gender, and study design. The results revealed a significant positive association between nocturnal light exposure and obesity risk in North American populations (OR = 1.21; 95% CI: 1.10–1.32), with low heterogeneity observed within this subgroup ( $I^2 = 46.6\%$ ,  $P > 0.05$ ). In contrast,

European populations showed no significant association between nocturnal light exposure and obesity risk (OR = 0.90; 95% CI: 0.87–0.94). However, this result should be interpreted with caution due to the limited number of studies in this subgroup ( $n = 1$ ), which may have led to insufficient statistical power; further studies are required to verify this finding.

Regarding age, the association between nocturnal light exposure and obesity risk was slightly stronger in adults than in adolescents. Subgroup analysis by gender showed no significant

Quality

score

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Confounders adjusted

Age, gender, education, marital status, residence,

smoking, living

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Age, sex, education level, smoking, alcohol consumption

sumption, occupation, lipid-lowering therapy, income

Age, physical exercise regularly, drinking

Age, race, sex, season

Age, sex, education, smoking status, drinking status,

Age, female, Married, Smoking, TV, Alcohol

Age, sex, education, smoking status, drinking status,

Data sources

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Age	(Mean ± SD)	Number	Study	Country	Year
60	9.1(2.5)	11,729	Retrospective	China	2025
57.6(9.1)		14,097	Retrospective	China	2024
45		24	Retrospective	China	20
72(5)		552	Retrospective	China	20
≥ 18		98	Retrospective	China	203
50-71		19	Retrospective	China	20
47	72.8(6.5)	10	Retrospective	Japan	2013
		528	Retrospective	Japan	

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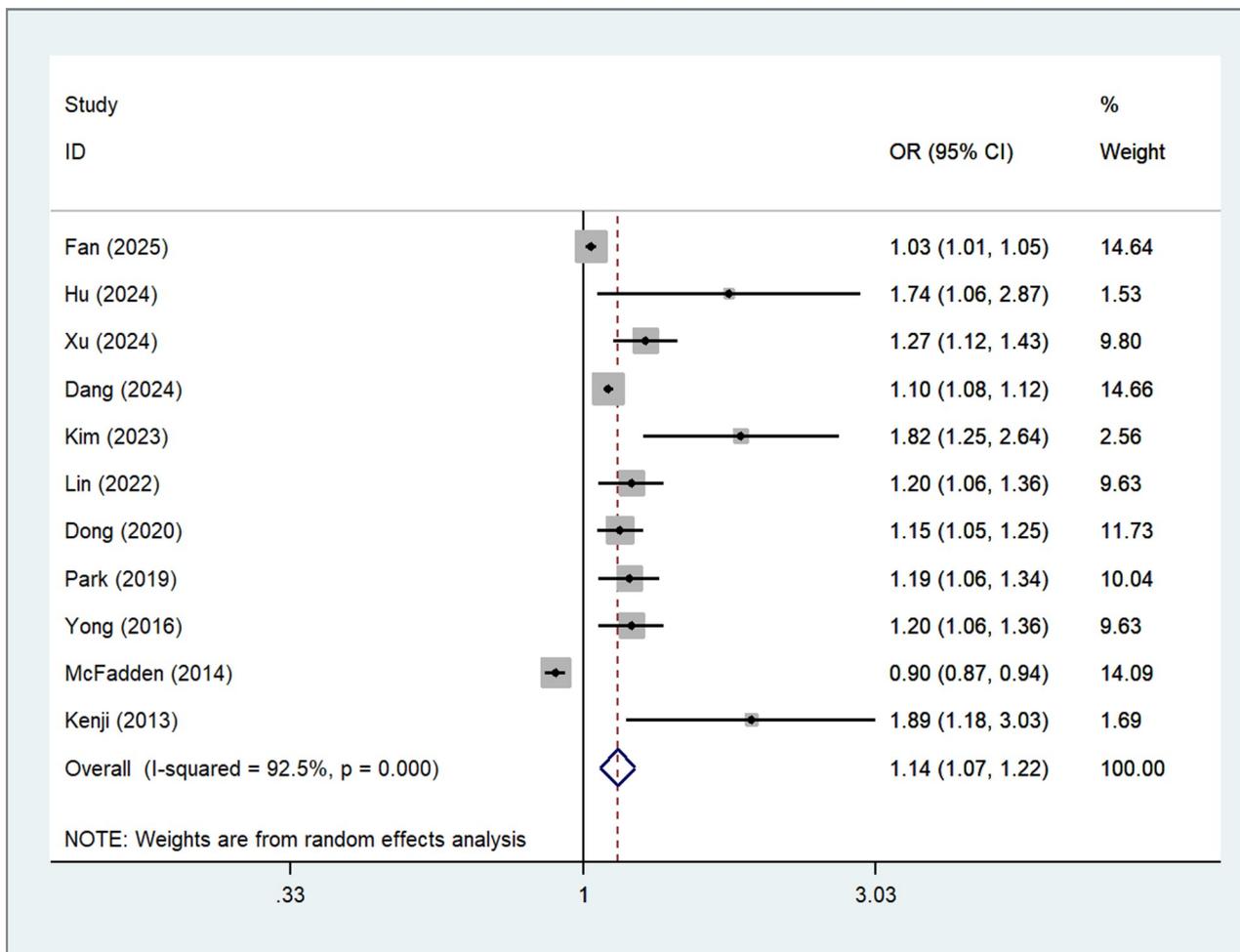
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**Fig. 2** Meta-analysis of the risk of obesity caused by light at night

association between nocturnal light exposure and obesity risk. Furthermore, retrospective cohort studies demonstrated a stronger association between nocturnal light exposure and obesity risk than cross-sectional studies. The details of the subgroup analyses can be found in Table 3.

Based on the meta-regression results, the regression coefficients for the four variables—continent, age, gender, and study type—were all  $P > 0.05$ , indicating that none of these four variables are significant sources of heterogeneity.

**Evidence certainty**

For individuals exposed to light at night (LAN), the GRADE level of evidence for the risk of obesity and overweight is very low. The GRADE evidence certainty for the outcomes is presented in Table 4.

**Publication bias**

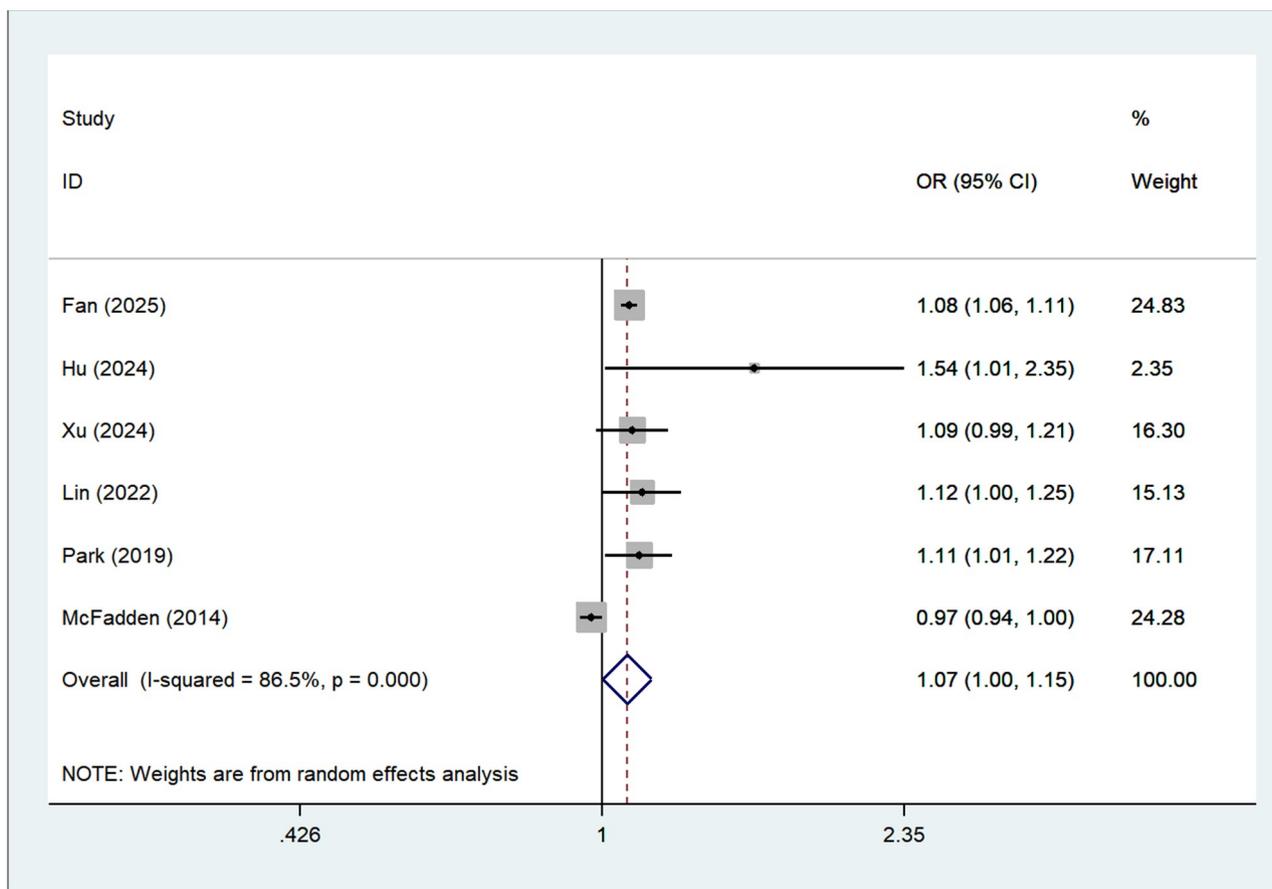
Visual inspection of the funnel plot showed no significant asymmetry in the relationship between nocturnal light

exposure and the risk of obesity/overweight (Fig. 4). This observation was statistically supported by Egger's regression tests (obesity:  $P = 0.216$ ; overweight:  $P = 0.542$ ), confirming the absence of substantial publication bias in this meta-analysis.

## **Discussion**

### **Main findings**

Artificial LAN is increasingly recognized as a non-medical determinant of health [28], reflecting the broadening impact of light pollution. Over the past 25 years, anthropogenic light sources have contributed to a 49% increase in nocturnal exposure [29], establishing LAN as a crucial health risk factor within urban ecosystems [30]. This meta-analysis synthesizes results from 13 high-quality observational studies across the globe, encompassing a total of 867,647 participants. It represents the first systematic assessment of the moderating effects of geographic region, age, and gender on the relationship between LAN exposure and obesity/overweight. Most studies utilized satellite remote sensing techniques



**Fig. 3** Meta-analysis of the risk of overweight caused by light at night

**Table 3** Subgroup analysis for light-at-night exposure and obesity risk

Subgroups	Included studies	OR (95% CI)	I <sup>2</sup> (%)	P-values	P-value between groups
<b>Continent</b>					
Asia	6	1.14(1.06–1.21)	88.5	0.000	<0.001
North America	4	1.21(1.10–1.32)	46.6	0.132	
Europe	1	0.90(0.87–0.94)	0.0	0.000	
<b>Age</b>					
<18	2	1.17(1.09–1.25)	0.0	0.583	<0.001
≥ 18	8	1.16(1.10–1.24)	87.2	0.000	
<b>Sex</b>					
Men	2	1.33(0.91–1.94)	83.6	0.014	<0.001
Women	3	1.11(0.86–1.45)	90.4	0.000	
<b>Study type</b>					
Cross-sectional study	8	1.12(1.04–1.21)	94.3	0.000	<0.001
Retrospective cohort study	3	1.18(1.08–1.29)	24.5	0.266	

(DMSP-OLS/VIIRS) to objectively quantify LAN levels. Our findings indicate that individuals exposed to the highest levels of LAN have a statistically significant 14% increased risk of obesity and a 7% increased risk

of being overweight, although the quality of evidence remains low. This aligns with previous animal studies showing that chronic low-intensity LAN can lead to a 13% weight gain

in mice [9], suggesting that LAN is a significant environmental risk factor for obesity.

### **Compared with previous studies**

Previous studies have identified an association between LAN and health risks such as obesity, however, each study has notable limitations. For instance, the

			8		8		
<b>Importance</b>							
			□□□□ Low		□□□□ Low		
<b>Certainty</b>		(95% CI)	1 fewer per 1,000	(from 1 fewer to 1 fewer)		1 fewer per 1,000	(from 1 fewer to 1 fewer)
<b>Absolute Effect</b>	Relative (95% CI)		OR 1.14	(1.07 to 1.22)		OR 1.07	(1.00 to 1.15)
			all plausible residual con	found ing would reduce the	demonstrate d effect	all plausible residual con	found ing would reduce the
<b>Other considerations</b>							

pioneering study by Lai et al. [ was hindered by insufficient sample representativeness , as it included only 7 studies. While Mao et al. [ expanded their scope to include hypertension and diabetes, their quality assessment framework was relatively weak, failing to fully capture risk variations across different geographical regions and population backgrounds.

contrast, this study significantly enhances the generalizability and robustness

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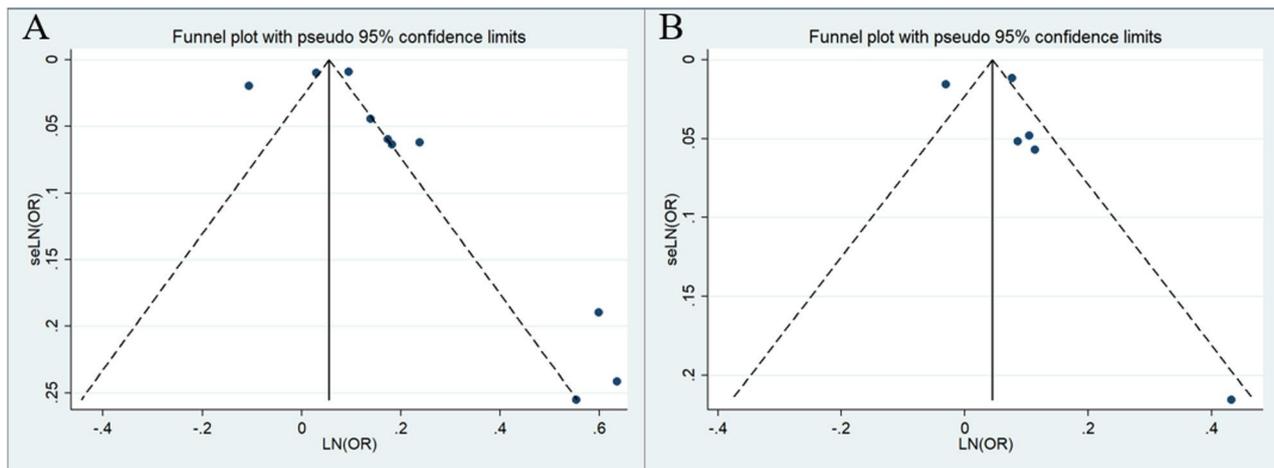
urbanized areas, extensive artificial lighting infrastructure, and excessive screen time [ A consistent positive association was also found in Asia, corroborated by multi-center studies from China, highlighting a common environmental challenge amid rapid urbanization. In China, light pollution in commercial areas is positively correlated with GDP growth, representing a "brighter is better" mentality that leads to excessive artificial lighting exceeding ecological safety thresholds [

Age-stratified analyses demonstrate that adults are more susceptible to the effects of LAN compared to children. This heightened vulnerability may be due to age-related degradation of the circadian system [33]

Research suggests that structural changes in the suprachiasmatic nucleus (SCN) neurons in adults can result in diminished light responsiveness and reduced amplitude of core clock gene expression [34]. Such neural aging can decrease circadian plasticity [35], making adults more

prone to circadian disruption from LAN exposure, which may heighten obesity risk. In contrast, adolescents may benefit from a stronger sleep-wake homeostatic drive, which helps buffer against LAN-induced impairments in sleep duration and quality [36].

developmental difference supports the 'metabolic vulnerability window' hypothesis, suggesting that adults face greater metabolic risks due to SCN functional decline [37].



**Fig. 4** Publication bias of the risk of obesity (Label A) and overweight (Label B) caused by any light at night

In contrast, the robust homeostatic drive in adolescence may partially counteract disruptions in environmental zeitgebers [36]. Supporting this view [38], Bonilla and colleagues demonstrated that chronic light-cycle disruption in adolescent mouse models maintained stable molecular clock gene expression and light responsiveness within the SCN. These findings suggest that the homeostatic system prioritizes SCN protection, providing robust support for this notion. Future longitudinal studies are warranted to validate the interaction between SCN degeneration and LAN exposure.

In terms of sex differences, our results indicate no significant disparity between males and females, despite existing physiological evidence suggesting that women may be more sensitive to LAN. Among overweight and obese individuals, women appear more susceptible to circadian misalignment [39]: The female hypothalamic-pituitary-adrenal (HPA) axis is more responsive to photic stimuli, with LAN inhibiting melatonin secretion and increasing glucocorticoid release, thus promoting visceral fat accumulation. Contrarily, epidemiological data show a higher obesity risk in males [12, 20]. This discrepancy may arise from greater neural sensitivity to light in males, which exacerbates alterations in sleep architecture and leads to decreased sleep duration [40]. Male shift workers also exhibit stronger cravings for high-calorie foods compared to females. This suggests that the observed increased obesity risk in males could be attributed to behavioral patterns and societal roles—an area warranting further exploration.

### Biological mechanisms

Research indicates that the primary mechanisms through which LAN promotes obesity center on the suppression of melatonin and circadian disruption. LAN exposure interferes with photic signaling in the

SCN, decreasing melatonin production [41]. This not only impairs

melatonin-activated lipolysis in adipose tissue but also promotes white adipose tissue accumulation by stimulating preadipocyte differentiation [42, 43]. Additionally, persistent LAN exposure can disrupt the synchronization of central biological clocks, leading to decreased expression of core clock genes and disturbing rhythmic oscillations of key metabolic regulators [44], which can trigger dysregulated lipid synthesis and glucose metabolism [45]. Of particular concern is the cycle established by melatonin deficiency and circadian misalignment, which suppresses BMAL1/CLOCK expression and creates a feedback loop contributing to adipocyte hypertrophy, visceral fat inflammation, and insulin resistance [46]. Animal studies suggest that LAN can activate the HPA axis, leading to elevated corticosterone levels that enhance gluconeogenesis and lipogenesis [47]. Furthermore, disrupted sleep architecture due to LAN increases ghrelin and decreases leptin levels [48, 49], promoting cravings for high-calorie foods. A prospective cohort study in the US highlighted that LAN affects leptin and ghrelin release via its impact on sleep quality [13]. Critically, the elevated obesity risk persisted even after accounting for sleep duration, indicating that sleep quality is an essential independent mediating pathway. This underscores the importance of implementing light management strategies to prevent obesity and related metabolic disorders.

### **Public health implications**

The contemporary night sky's luminosity starkly contrasts with that of Earth's evolutionary past, as substantial increases in nocturnal light levels result from urbanization, population growth, and the widespread adoption of new lighting technologies [50]. Our study indicates that those with the highest LAN exposure faced a 14% increased risk of obesity and a 7% increased risk of overweight. Given that about 83% of the global population is exposed to artificial light [51], LAN emerges as a

significant environmental driver of the global obesity epidemic, thus representing a stealth public health threat. To address the obesity epidemic effectively, tailored interventions targeting LAN are imperative. Region-specific strategies are critical. For instance, prioritizing regulations on urban lighting spectra and intensity in North America, where the association between LAN and obesity is most pronounced, should be a primary focus. Future research should assess the effectiveness of light pollution legislation in minimizing artificial light exposure and enhancing public health. In developing Asian nations, the challenge lies in balancing economic growth and lighting regulations, where short-term development often compromises lighting controls. Hence, a comprehensive system incorporating laws, lighting standards, oversight, and public education is urgently needed. Specific interventions for adolescents in these regions could include limiting nighttime use of digital devices [27], such as TVs, computers, and smartphones, through measures like “screen curfews.”

Moreover, protecting vulnerable groups is essential. Optimizing workplace lighting for night-shift workers using dynamic spectrum technology can help mitigate circadian disruption [52]. The design of bedroom lighting for the elderly is vital, given the direct link between LAN exposure and metabolic disorders/obesity [53]. Community-based subsidies for home light modifications could be instrumental in this regard. Finally, advancing technology must prioritize environmental and societal health. Innovations in lighting and its applications necessitate the establishment of standards. Governments could lead by implementing amber-toned streetlights, which have a lower melatonin-suppressing effect [54]. Encouraging innovations in private fixture design and setting emission standards is also crucial, as individual-controlled residential lighting could pose health risks. Enhancing early-warning systems through real-time monitoring, such as satellite remote sensing to create dynamic light pollution maps, is essential for accurately identifying high-exposure areas.

### **Strengths and limitations**

This study demonstrates significant strengths: By integrating the latest robust evidence, exploring the moderating effects of geography and age in depth, and adhering to rigorous methodological standards, it provides a crucial scientific basis for formulating regionally tailored and population-stratified public health strategies. However, this study has several limitations. Among the 13 studies included, only one was conducted in Europe, which may limit the generalizability of our findings and suggests a need for

future large-scale population studies in Europe to supplement the exposure assessment. Additionally, only four of the included studies utilized cohort designs,

indicating a lack of sufficient prospective evidence, and dose-response analyses were absent. But, it is notable that nine large-scale cross-sectional studies, including the most recent, were included, serving as valuable tools for exploring environment-disease associations. Meanwhile, we noted that the findings of McFadden et al. suggested nighttime light exposure as a protective factor against obesity/overweight. However, it did not significantly impact the overall effect size, and the high heterogeneity persisted whether this study was included or excluded. Therefore, it was not a key factor contributing to the observed heterogeneity. In addition to the aforementioned subgroups, we may need to conduct subgroup analyses based on factors such as sleep duration, socioeconomic status, built environment, and self-reported data from the included population, to further optimize and refine research in this field.

Unfortunately, as most of the included studies do not provide clear effect sizes that indicate how risk severity increases with higher doses, we were unable to conduct a dose-response meta-analysis of risks. We hope that future studies will clarify the impact of light intensity on obesity and overweight, providing more quantitative and detailed data—this remains an important area for further exploration.

## Conclusion

LAN exposure significantly increases the risk of both obesity and overweight and this risk is modified by geographical region and age. These findings contribute critically to the body of evidence necessary to inform mechanistic research, cohort study design, and public health interventions.

## Supplementary Information

The online version contains supplementary material available at

Supplementary Material 1.

Supplementary Material 2.

Supplementary Material 3.

## Acknowledgements

Not applicable.

## Authors' contributions

Y.L. was responsible for the study design and implementation; W.T. was responsible for data collection, analysis, and manuscript drafting; S.D. participated in manuscript revision; and all authors reviewed and approved the final manuscript.

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**Data availability**  
at night (LAN)

All data analyzed during this study are included in this article [and its supplementary information files].

15. Lai KY, Sarkar C, Ni MY, Gallacher J, Webster C. Exposure to light

## Declarations

### Ethics approval and consent to participate

Not applicable.

### Consent for publication

Not applicable.

### Competing interests

The authors declare no competing interests.

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