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CLINICAL REVIEW

Neighborhood environments and sleep among children and adolescents: A systematic review

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SUMMARY

Understanding salient environmental determinants of pediatric sleep is essential for informing interventions and public health initiatives. Emerging evidence suggests that the neighborhood environment can impact pediatric sleep, but this evidence has not yet been systematically reviewed. We conducted a systematic review of the scientific literature on associations between neighborhood environments and sleep in young children (0–5 y), school-aged children (6–12 y) and adolescents (13–18 y). We reviewed 85 articles published between 2003 and 2020. The most commonly examined neighborhood exposure was low socioeconomic status (40 studies), which was associated with sleep outcomes in 58% of studies (primarily shorter sleep duration, later sleep timing, or obstructive sleep apnea). Evidence was stronger for neighborhood safety/crime/violence (21 studies), with 86% of studies reporting associations with sleep outcomes (primarily self- or caregiver-reported sleep problems). Fewer studies examined associations of neighborhood physical environment exposures, including noise (15 studies), the built environment (seven studies), and air pollution (six studies). Limitations of the current body of evidence include 1) limited examination of neighborhood exposures other than socioeconomic status or safety, 2) use of primarily cross-sectional observational study designs, 3) lack of objective sleep outcome assessment, and 4) limits of current exposure assessment methods.

Background

Insufficient sleep is highly prevalent among children and adolescents [1], which is concerning given established links between insufficient sleep and adverse physical and mental health outcomes [2,3]. As a modifiable behavior, sleep is a promising target for public health policies and interventions that aim to prevent future disease burden. However, in order to effectively intervene to improve sleep outcomes among children and adolescents, it is essential to identify key determinants of healthy sleep. An area that has received increasing attention is how neighborhood context influences sleep [4–7]. Due to structural factors including racial residential segregation and socioeconomic inequalities, neighborhoods contain varying levels of physical and social attributes that may influence sleep [4]. The neighborhood physical environment includes ambient factors (e.g., noise, air pollution) and the built environment (e.g., density, physical activity resources). The neighborhood social environment incorporates features related to interactions between people, including safety and social cohesion. Emerging evidence suggests that neighborhood socioeconomic, physical, and social features may influence sleep [4–7].

Abbreviations: MeSH, medical subject headings; OSA, obstructive sleep apnea; PRISMA, preferred reporting items for systematic reviews and meta-analyses; REMF, radiofrequency electromagnetic fields; SES, socioeconomic status.

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Although most studies of the relationship between neighborhood context and sleep have focused on adults, a growing body of evidence suggests that neighborhood environments influence sleep among children and adolescents [4–7]. However, there has not been a comprehensive evaluation of the literature on neighborhood determinants of sleep in pediatric populations. To address this gap, we conducted a systematic review of studies examining associations of neighborhood socioeconomic, social, and physical characteristics with sleep outcomes (e.g., duration, quality, variability, timing, problems, diagnoses) among children and adolescents. This paper reports data extracted from 85 studies, summarizes findings, and identifies methodological strengths and weaknesses in the current body of evidence. Using these results, we discuss opportunities for future research to fill key substantive and methodological gaps and advance understanding of the most salient environmental determinants of sleep among children and adolescents.

Methods

Eligibility criteria

We adhered to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for conducting the systematic review and reporting results. Studies were eligible for inclusion if they were published in peer-reviewed journals in English, assessed associations of a neighborhood-level exposure with a sleep outcome, and included participants aged <18 y. We defined neighborhood-level exposures as area-level exposures assessed at a smaller spatial scale than the city-level (e.g., census tract). Articles that examined exposures only inside participants' home were excluded. We also excluded articles where the exposure combined neighborhood and home context in the same measure (e.g., exposure to violence in both home and community settings). We included sleep outcomes that were objectively-measured, participant-reported, or caregiver-reported, which included: duration, timing, quality, variability, sleep problems, obstructive sleep apnea (OSA) symptoms, sleep-related impairment, and sleep diagnoses. We excluded articles that only assessed wheezing during sleep among children with asthma, which is indicative of asthma symptom severity rather than underlying sleep issues. We also excluded articles that combined pediatric and adult populations if they did not present sub-group analyses restricted to participants <18 y. Finally, we excluded review articles, published study protocols, non-human studies, and non-peer-reviewed articles.

Development of search terms

We consulted a librarian with expertise in systematic reviews prior to developing our search terms. We developed a preliminary set of search terms that included three concepts: 1) neighborhood environments, 2) sleep, 3) children and adolescents. Using these three concepts, we developed a set of Medical Subject Headings (MeSH) terms and key words for each subject, combined with an "AND" between each concept according to the Boolean search method. We piloted the set of search terms in Medline to determine whether the terms identified an a priori set of 16 benchmark articles that met our inclusion criteria. We reviewed reference lists of all included articles and prior reviews to identify additional eligible articles that were not returned by the initial search. Search terms were iteratively refined to ensure that they identified all benchmark papers and relevant references from included articles and past reviews. Our final set of search terms is available in the Supplemental Appendix.

Search and screening

We completed our search in Medline, PubMed, EMBASE, Web of Science, and PsychInfo on October 9, 2020. We searched titles, abstracts, and keywords, and restricted to English-language articles. No date restrictions were placed on the search. We identified 12,044 records, including duplicates (Fig. 1). One additional article was identified through review of literature cited in included articles. After removal of duplicates, 6733 titles/abstracts were screened to determine whether they met inclusion/exclusion criteria described above, yielding 275 candidate articles for full text review. Full texts were independently reviewed by two reviewers each to confirm eligibility. Eligibility ratings were compiled by the lead author (SM), and differences were discussed and resolved by group consensus. A total of 85 articles, published between 2003 and 2020, met eligibility criteria and were included in this review [8–22, 23–43, 44–64, 65–78, 79–92].

Data abstraction and synthesis

Two reviewers independently abstracted data from each included article using a standardized abstraction form. The elements abstracted included the study purpose, design, population, sample size, sampling methodology, sleep outcomes, neighborhood exposures, statistical analysis, covariate adjustment, findings, and subgroup analyses. We classified sleep outcomes as objective (e.g., actigraphy-based) or subjective (e.g., caregiver- or child-reported). We also classified neighborhood exposures as objective (e.g., census variables) or subjective (e.g., perceived safety). The lead author (SM) provided a synthesis of the abstraction results (Supplemental Table 1) for review by the authorship team; disagreements were resolved by consensus. We described patterns overall and across three pre-specified age groups: early childhood (0–5 y), school-aged children (6–12 y), and adolescents (13–17 y). In addition to summarizing the characteristics and key findings of the included studies, we assessed potential risk of bias at the study level according to the following prespecified features: study design (cross-sectional versus longitudinal), sleep assessment method (objectively measured versus caregiver- or child-reported), sampling strategy (probability-based versus non-probability-based), and control for confounding (multivariable modeling versus bivariate analysis).

Results

Of the 85 articles that met inclusion criteria, 15 articles (18%) included young children (aged 0–5), 16 articles (19%) included school-aged children (aged 6–12), 15 articles (18%) included adolescents (aged 13–18), and 38 articles (45%) included multiple age groups. A majority of studies were conducted in the United States (51 studies, 60%). Thirteen studies were conducted in Australia and New Zealand, 10 studies in Europe (Germany, Netherlands, Norway, Poland, England, Sweden), four studies in Canada, two studies in Chile, and one study each in Egypt, Iran, Mexico, China, Taiwan, and South Korea. The median sample size was 436 (range 18–196,900).

Tables 1–3 present each study's neighborhood measures and associations with sleep outcomes. The tables are organized by neighborhood domain: neighborhood socioeconomic status (SES, 40 studies, Table 1), neighborhood social environment (29 studies,

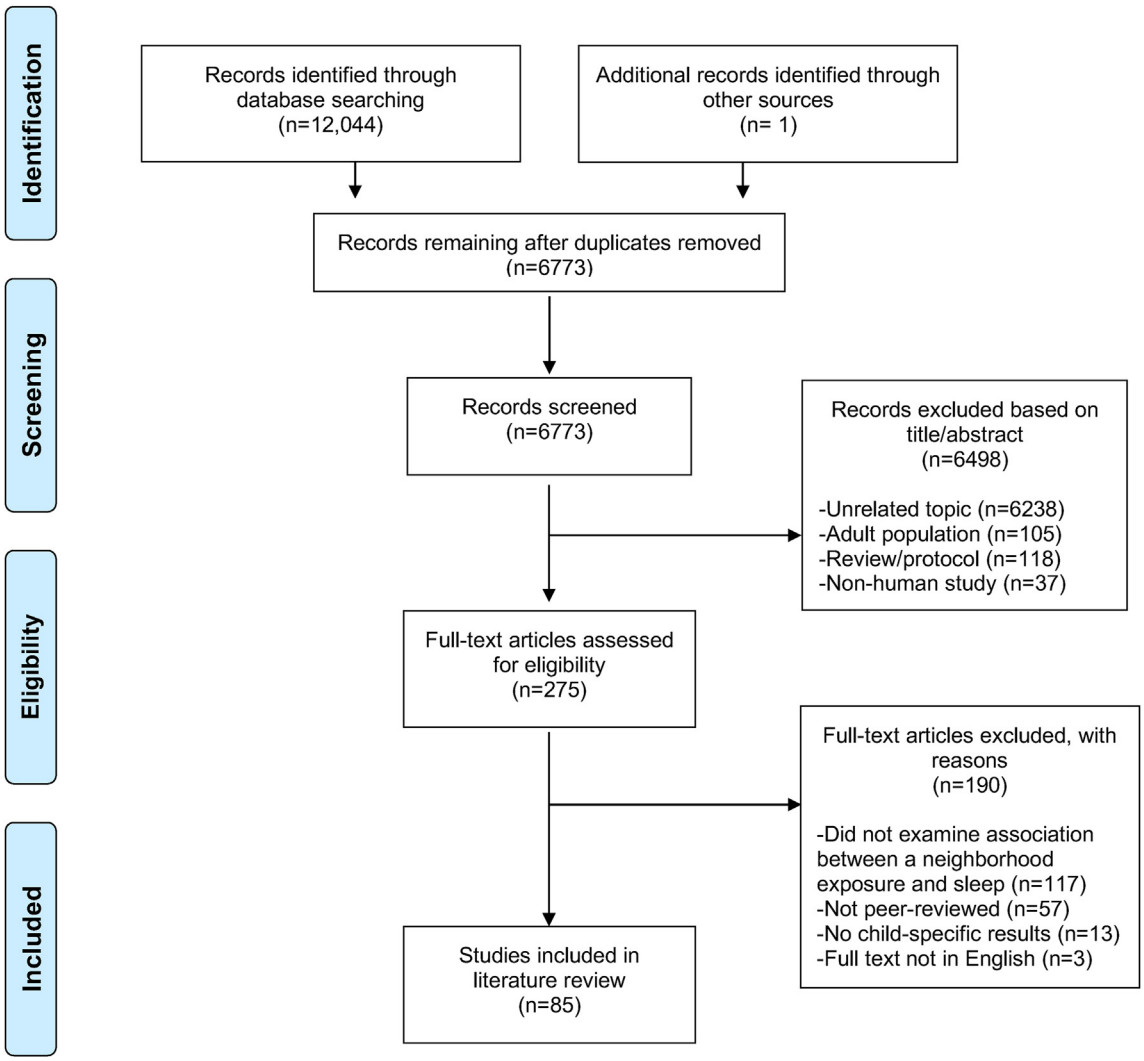

Fig. 1. PRISMA 2009 flow diagram.

Table 2), and neighborhood physical environment (32 studies, Table 3).

Neighborhood socioeconomic status

Overall, lower neighborhood SES was associated with poorer sleep outcomes in 23 out of 40 studies (58%, Table 2). Specifically, lower SES was associated with shorter sleep duration in 13 out of 25 of studies (52%) [10,14,19,21,22,24,36,45,49,59,60,69,71], later sleep timing in five out of six studies (86%) [14,25,29,49,92], OSA/snoring in five out of nine studies (56%) [17,28,75,76,85], and poorer sleep quality (e.g., efficiency) in four out of ten studies (40%) [10,19,30,59]. Studies including 0–5 and 6–12 y old children were more likely to report associations between lower SES and poorer sleep outcomes compared to studies among adolescents. Three studies found results in the opposite direction for adolescents, with teens living in more socioeconomically deprived neighborhoods having longer sleep duration [56,78] and earlier bedtimes [81] in some models.

All studies that included neighborhood SES exposures used administrative data from the U.S. Census Bureau or similar government organizations. Studies that defined SES using a single indicator (e.g., poverty) were more likely to identify associations for sleep duration, timing, and OSA/snoring than studies defining SES using an index, although this pattern did not hold true for sleep quality. Studies that measured sleep subjectively were more likely to report associations of low SES with shorter sleep duration and poorer sleep quality than studies with objective sleep measurement, while the opposite was true for sleep timing and OSA/snoring.

While most studies used cross-sectional designs, six studies examined neighborhood SES and sleep outcomes longitudinally [43,60,69,71,76,89]. Three of the four longitudinal cohorts (75%) that examined SES and self- or caregiver-reported sleep duration identified associations of lower SES with shorter sleep duration, overall [60,71] or among girls only [69]. Cross-sectional studies were much more numerous but were less likely to identify associations between lower SES and shorter sleep duration (11 out of 22, 50%). However, no longitudinal studies of SES assessed sleep duration objectively, while 41% of cross-sectional studies did (9 out of 22). There was less evidence in longitudinal studies for associations of SES with other outcomes. One community-based US study found low neighborhood SES to be associated with OSA in middle childhood but not in adolescence [76], while a nationally representative Australian birth cohort study found no association between a neighborhood socioeconomic risk index and sleep problem trajectories from age 0–11 [89].

Table 1
Results from studies examining neighborhood socioeconomic status and sleep (40 articles).

			Age group				Associations by sleep outcome							
First Author/year	**Design**	**N**	**0-5**	**6-12**	**13-17**	**Exposure**	**Dur**	**Tim**	**Qual**	**Var**	**Prob**	**OSA**	**DTS**	**Oth**
Bagley 2018 [10]	CR	210		X		SES index	act(+)		act(+)					
Biggs 2013 [14][a]	CR	1845	X	X		SES index	par(+)	par(+)						
Brouillette 2011 [17]	CR	436	X	X		Individual SES variables						psg(+)		
Cheon 2019 [19]	CR	350			X	Poverty	self(+) act(0)		act(+) self(+)					
Côté-Lussier 2020 [20]	CR	504		X		% low income, % single parent	act(0)							
Dollman 2007 [22][a]	CR	900		X	X	SES index	self(x)							
Dollman 2017 [21][a]	CR	1246		X	X	SES index	self(+)							
Elder 2020 [25][b]	CR	70		X		% low income	act(0)	act(+)	act(0)					
El-Sheikh 2013 [24]	CR	276		X		Poverty	act(+)		act(0)	act(0)	self(0)			
Gill 2012 [28][b]	CR	823	X			SES index						par(+)		
Graham 2020 [29][a]	CR	16936	X			Individual SES variables, economic stress		par(+) par(-)						
Grimes 2019 [30]	CR	80	X			SES index			act(+)					
Hardy 2017 [32][a]	CR	7555	X	X	X	SES index	self(0)							
Ievers-Landis 2008 [36][a,b]	CR	819		X		Median income	par(+)							
Jones 2014 [37][b]	CR	84	X			SES index	par(0)							
Koinis-Mitchell 2015 [40]	CR	249		X		SES index	act(x)		act(0)					
MacKinnon 2020 [43]	LO	2445	X			SES index	par(0)		par(0)					
Martin 2017 [45]	CR	346		X		SES index	act(+)		act(0)				par(0)	
McLaughlin 2005 [49][b]	CR	3371	X	X		Median income	par(+)	par(+)			par(+)		par(+)	
Moore 2011 [51][a]	CR	247			X	"Distressed" SES	act(0)			act(0)				
Olds 2010 [53][a]	CR	4032		X	X	SES index	self(0)							
Orsey 2016 [54]	CR	50		X	X	Median income			act(0)					
Pabayo 2014 [56][a]	CR	1375			X	SES index	self(-)							
Patrick 2016 [59][b]	CR	191	X			Median income	par(+)		par(+)					
Patte 2017 [60]	CR/LO	36088 / 7394			X	Median income	self(+)							
Rubens 2016 [66]	CR	207	X	X	X	SES index					clin(0)	clin(0)		clin(x)
Saelee 2020 [69][a]	LO	12692		X	X	SES index	self(x)							

Table 1 (*continued*)

Sheehan 2018 [71]	LO	2720	X	X		Poverty	par(+)							
Spilsbury 2006 [75][a]	CR	843		X		"Distressed" SES						psg(+)		
Spilsbury 2015 [76][a]	LO	490		X	X	"Distressed" SES						psg(x)		
Street 2018 [78][a]	CR	1614			X	SES index	self(-)							
Tamanyan 2016 [79][b]	CR	301	X	X	X	SES index						psg(0)		
Troxel 2017 [81]	CR	2493			X	Poverty	self(0)	self(-)		self(0)	self(0)			
Uebergang 2017 [82][a,b]	CR	4901	X	X		SES index					par(0)			
Wang 2017 [85]	CR	774	X	X		"Distressed" SES						psg(+)		
Williamson 2019 [89][a]	LO	4517	X	X		SES/Social/ Physical index					par(0)			
Williamson 2020a [88]	CR	205	X			SES index					par(0)	par(0)		
Xie 2018 [90][b]	CR	158	X	X	X	Median income						psg(0)		
Zhang 2019 [91][a]	CR	173	X			SES index	act(0)			act(0)	par(0)			
Zhao 2019 [92][b]	CR	882		X	X	SES index		par(+)						

CR: cross-sectional; LO: longitudinal; SES: socioeconomic status; dur: sleep duration (continuous or dichotomized to reflect obtaining sufficient versus insufficient sleep duration); tim: sleep timing (bedtime, waketime, onset, offset, delay in sleep onset); qual: sleep quality (e.g. efficiency, wake after sleep onset, latency, night awakenings/wake episodes, self-reported quality); var: variability in sleep duration or timing; prob: subjectively reported sleep problems or disturbances; OSA: obstructive sleep apnea diagnosis, symptoms, snoring; DTS: daytime sleepiness, tiredness, napping; oth: other outcomes (e.g. parasomnias); par: parent/care-giver-reported; self: self-reported; act: assessed using actigraphy; clin: based on clinical assessment; psg: assessed using in-lab polysomnography or in-home overnight cardiorespiratory studies.

Green shading indicates a positive association, blue indicates no association, yellow indicates a negative association, and orange indicates mixed findings.

(+) indicates a significant positive association (better neighborhood environment associated with better sleep outcomes)

(0) indicates no association

(-) indicates a significant negative association (better neighborhood environment associated with worse sleep outcomes)

(x) indicates an interaction/association only significant in a subgroup of the study population

(+)(0) indicates findings varied based on assessment type (objective or subjective)

[a]Study used probability-based sampling methods (e.g. random selection of households or classrooms)

[b]Results from bivariate analysis only

Neighborhood social environment

Table 2 summarizes results from 29 studies that examined neighborhood social environment exposures and sleep, of which 24 studies (86%) found associations between a poorer neighborhood social environment and adverse sleep outcomes. The most commonly examined exposures were neighborhood safety, crime, and community violence (21 studies), followed by neighborhood social cohesion/collective efficacy (five studies), disorder (four studies), and social fragmentation/disorganization (three studies). Four studies constructed indices of multiple neighborhood social environment exposures [64,65,72,89].

Eighteen studies (86%) found that living in a neighborhood with high crime/violence or lower perceived safety was associated with poorer sleep outcomes. Six of these studies were qualitative and identified neighborhood safety as a caregiver- or child-reported barrier to sleep [13,47,55,68,74,87]. When examining specific sleep outcomes, lower neighborhood safety was most frequently associated with self-reported sleep problems (five out of six studies, 83% [11,12,18,63,84]), followed by sleep quality (three out of

Table 2
Results from studies examining the neighborhood social environment and sleep (29 articles).

			Age group				Associations by sleep outcome							
Author/year	**Design**	**N**	**0-5**	**6-12**	**13-17**	**Exposure**	**Dur**	**Tim**	**Qual**	**Var**	**Prob**	**OSA**	**DTS**	**Oth**
Neighborhood safety/crime/community violence (21 articles)														
Bagley 2016 [11]	CR	252			X	Community violence concerns	act(0)		act(x)		self(+)		self(+)	
Bailey 2005 [12]	CR	268		X		Community violence exposure					self(+)			
Belmon 2020 [13][c]	QL/CR	45 / 33		X		Perceived safety								self(0) par(+)
Chen 2013 [18][a]	CR	2113			X	Perceived safety					self(+)			
Dowdell 2003 [23][b]	CR	54		X	X	Perceived safety		self(+)						
Hawkins 2016 [33][a]	CR	196900		X	X	Perceived safety	par(x)							
Heissel 2017 [34]	LO	82		X	X	Objective crime	act(+)	act(+)	act(+)					
MacKinnon 2020 [43]	LO	2445	X			Perceived safety	par(+)		par(0)					
Martinez 2015 [47][c]	QL/CR	18	X			Perceived crime								par(+)
McHale 2011 [48]	CR	469		X	X	Perceived crime	self(0)			self(0)			self(+)	
Meldrum 2018 [50][a]	CR	7958		X	X	Perceived safety	self(+)							
Owens 2006 [55][c]	QL/CR	64		X	X	Perceived safety								self(+)
Pabayo 2014 [56][a]	CR	1375			X	Perceived safety	self(0)							
						Objective crime	self(-)							
Philbrook 2019 [61]	CR	219			X	Community violence concerns	act(x)		act(x)					
Rubens 2014 [63]	CR	144			X	Community violence exposure					self(+)			
Sadler 2020 [68][c]	QL/CR	25	X			Perceived safety								par(+)
Spilsbury 2016 [74][c]	QL/LO	65		X	X	Perceived safety								self(+)
Street 2018 [78][a]	CR	1614			X	Objective crime	self(0)							
Troxel 2017 [81]	CR	2493			X	Perceived safety	self(0)	self(0)		self(0)	self(0)			
Wamser-Nanney 2018 [84][b]	CR	276		X	X	Community violence exposure					par(+)			
Williamson 2020b [87][c]	QL/CR	23	X			Perceived safety								par(+)
Neighborhood social cohesion/collective efficacy (5 articles)														
Aguilar-Farias 2020 [9][a]	CR	148		X		Collective efficacy	act(0)							
Hawkins 2016 [33][a]	CR	196900		X	X	Social cohesion	par(+)							
Pabayo 2014 [56][a]	CR	1375			X	Social cohesion	self(+)							

Table 2 (*continued*)

Street 2018 [78][a]	CR	1614			X	Collective efficacy	self(0)							
Troxel 2017 [81]	CR	2493			X	Social cohesion	self(0)	self(0)		self(0)	self(+)			
Neighborhood Disorder (4 articles)														
Graham 2020 [29][a]	CR	16936	X			Disorder		par(+)						
MacKinnon 2020 [43]	LO	2445	X			Disorder	par(+)		par(0)					
Pabayo 2014 [56][a]	CR	1375			X	Disorder	self(0)							
Street 2018 [78][a]	CR	1614			X	Disorder	self(0)							
Neighborhood Social Fragmentation/Disorganization (3 articles)														
Bagley 2018 [10]	CR	210		X		Social fragmentation	act(0)		act(+)					
Pabayo 2014 [56][a]	CR	1375			X	Social fragmentation	self(+)							
Saelee 2020 [69][a]	LO	12692		X	X	Social disorganization	self(x)							
Neighborhood Social Environment Index (3 articles)														
Rubens 2018 [64]	CR	144			X	Social environment index					self(+)			
Rubens 2020 [65]	CR/LO	44		X	X	Social environment index					self(0)		self(0)	self(0)
Singh 2013 [72][a]	CR	63352		X	X	Social environment index	par(+)							
Williamson 2019 [89][a]	LO	4517	X	X		SES/Social/ Physical index					par(0)			

CR: cross-sectional; LO: longitudinal; QL: qualitative, dur: sleep duration (continuous or dichotomized to reflect obtaining sufficient versus insufficient sleep duration); tim: sleep timing (bedtime, waketime, onset, offset, delay in sleep onset); qual: sleep quality (e.g. efficiency, wake after sleep onset, latency, night awakenings/wake episodes, self-reported quality); var: variability in sleep duration or timing; prob: subjectively reported sleep problems or disturbances; OSA: obstructive sleep apnea diagnosis, symptoms, snoring; DTS: daytime sleepiness, tiredness, napping; oth: other outcomes (e.g. parasomnias, qualitative assessment of sleep barriers); par: parent/care-giver -reported; self: self-reported; act: assessed using actigraphy; clin: based on clinical assessment; psg: assessed using in-lab polysomnography or in-home overnight cardiorespiratory studies. Green shading indicates a positive association, blue indicates no association, yellow indicates a negative association, and orange indicates mixed findings.

(+) indicates a significant positive association (better neighborhood environment associated with better sleep outcomes)

(0) indicates no association

(-) indicates a significant negative association (better neighborhood environment associated with worse sleep outcomes)

(x) indicates an interaction/association only significant in a subgroup of the study population

(+)(0) indicates findings varied based on assessment type (objective or subjective)

[a]Study used probability-based sampling methods (e.g. random selection of households or classrooms)

[b]Results from bivariate analysis only

[c]Qualitative study assessing perceived barriers and/or facilitators of child sleep

Table 3
Results from studies examining the neighborhood physical environment and sleep (32 articles).

			Age group				Associations by sleep outcome							
Author/year	**Design**	**N**	**0-5**	**6-12**	**13-17**	**Exposure**	**Dur**	**Tim**	**Qual**	**Var**	**Prob**	**OSA**	**DTS**	**Oth**
Neighborhood noise (15 articles)														
Belmon 2020 [13][c]	QL/CR	45 / 33		X		Perceived noise								self(0) par(+)
Feng 2020 [26][a]	CR	11916		X	X	Perceived noise	self(0)		self(x)					
Gaarde 2020 [27][c]	QL/CR	142			X	Perceived noise								self(+)
Lindsay 2018 [42][c]	QL/CR	37	X			Perceived noise								par(+)
Martin-Biggers 2015 [46][c]	QL/CR	139	X			Perceived noise								par(+)
Martinez 2015 [47][c]	QL/CR	18	X			Perceived noise								par(+)
Ohrstrom 2006 [52][b]	CR	160 (79)*		X		Road traffic noise	act(0)		self(+) act(0)		self(+)		self(+)	
Palimaru 2020 [58][c]	QL/CR	26		X	X	Perceived noise								self(+)
Rudolph 2019 [67][a]	CR	4508			X	Ambient outdoor noise	self(0)	self(+)						
Sadler 2020 [68][c]	QL/CR	25	X			Perceived noise								par(+)
Skrzypek 2017 [73]	CR	5136		X	X	Road traffic noise					par(+)			
Spilsbury 2016 [74][c]	QL/LO	65		X	X	Perceived noise								self(+)
Stansfeld 2010 [77][b]	LO	326		X		Aircraft noise			self(0)					
Tiesler 2013 [80]	CR	872		X		Ambient outdoor noise					par(+)			
Weyde 2017 [86]	CR	2665		X		Road traffic noise	par(x)				par(0)			
Neighborhood built environment (7 articles)														
Aguilar-Farias 2020 [9][a]	CR	148		X		Perceived walkability, distance to places	act(0)							
Bottino 2012 [16]	CR	1226	X			Urbanicity, density, distance to major road	par(+)							
Côté-Lussier 2020 [20]	CR	504		X		Traffic density, residential density, land use mix	act(0)							
Ha 2020 [31]	CR	3917	X	X	X	Distance to major road						par(+)		

Table 3 (*continued*)

Marco 2011 [44]	CR	155		X	X	Physical condition, street environment	act(0)	act(x)		act(+)				
Philbrook 2016 [62]	CR	231			X	Perceived recreation facilities	act(+)	act(+)	act(0)	act(0)				
Singh 2013 [72][a]	CR	63352		X	X	Perceived built environment index	par(+)							
Air pollution (6 articles)														
Abou-Khadra 2013 [8][a]	CR	276		X	X	Air pollution (PM_{10})					par(+)			
Bose 2019 [15]	LO	397	X			Air pollution ($PM_{2.5}$)	act(+)		act(+)					
Kannan 2017 [38]	LO	609		X		Traffic-related air pollution						par(+)		
Kheirandish-Gozal 2014 [39][a]	CR	4322	X	X		Air pollution (multiple types)						par(+)		
Lawrence 2018 [41][a]	CR	59754	X	X	X	Air pollution (multiple types)					self(+)			
Sanchez 2019 [70]	CR	564	X	X		Air pollution (multiple types)						par(0)		
Outdoor Light (4 studies)														
Côté-Lussier 2020 [20]	CR	504		X		Outdoor light at night	act(0)							
Paksarian 2020 [57][a]	CR	10123			X	Outdoor light at night	self(+)	self(+)						
Spilsbury 2016 [74][c]	QL/LO	65		X	X	Perceived outdoor light								self(+)
Vollmer 2012 [83]	CR	1507		X	X	Outdoor light at night								self(+)
Other Physical Environment Measures (7 articles)														
Feng 2020 [26][a]	CR	11916		X	X	Green space	self(x)		self(0)					
Huss 2016 [35]	LO	2361		X		REMF	par(+)	par(0)	par(0)				par(0)	par(-)
Williamson 2019 [89][a]	LO	4517	X	X		SES/Social/ Physical index					par(0)			

CR: cross-sectional; LO: longitudinal; dur: sleep duration (continuous or dichotomized to reflect obtaining sufficient versus insufficient sleep duration); tim: sleep timing (bedtime, waketime, onset, offset, delay in sleep onset); qual: sleep quality (e.g. efficiency, wake after sleep onset, latency, night awakenings/wake episodes, self-reported quality); var: variability in sleep duration or timing; prob: subjectively reported sleep problems or disturbances; OSA: obstructive sleep apnea diagnosis, symptoms, snoring; DTS: daytime sleepiness, tiredness, napping; oth: other outcomes (e.g. parasomnias, chronotype, qualitative assessment of sleep barriers); par: parent/care-giver -reported; self: self-reported; act: assessed using actigraphy; clin: based on clinical assessment; psg: assessed using in-lab polysomnography or in-home overnight cardiorespiratory studies.

Green shading indicates a positive association, blue indicates no association, yellow indicates a negative association, and orange indicates mixed findings.

(+) indicates a significant positive association (better neighborhood environment associated with better sleep outcomes)

(0) indicates no association

(-) indicates a significant negative association (better neighborhood environment associated with worse sleep outcomes)

(x) indicates an interaction/association only significant in a subgroup of the study population

(+)(0) indicates findings varied based on assessment type (objective or subjective)

[a]Study used probability-based sampling methods (e.g. random selection of households or classrooms)

[b]Results from bivariate analysis only

[c]Qualitative study assessing perceived barriers and/or facilitators of child sleep

*Subsample with actigraphy

four studies, 75% [11,34,61]), sleep timing (two out of three studies, 67% [23,34]) and sleep duration (five out of ten studies, 50% [33,34,43,50,61]). The majority of studies assessing neighborhood safety/crime included school-aged or adolescent populations, with significant associations most common among school-aged children.

Few neighborhood social environment studies used actigraphy to assess sleep duration, timing, or quality, but those that did were more likely to identify associations with neighborhood safety/crime compared to studies assessing these outcomes subjectively [11,34,61]. Only three studies used police-recorded crime data as opposed to neighborhood perceptions [34,56,78], with only one reporting associations between neighborhood violent crime and actigraphy-assessed later bedtime, shorter sleep duration, and greater sleep latency [34]. Two studies of neighborhood crime/safety and sleep used longitudinal designs, which identified associations between lower maternal perceived neighborhood safety and shorter caregiver-reported sleep duration among infants [43] and between objective neighborhood crime and later bedtime assessed via actigraphy among 11–18 y olds [34]. Results for sleep duration and timing were more mixed among cross-sectional studies compared to longitudinal studies, with three out of eight studies reporting associations for sleep duration [33,50,61] and one out of two with sleep timing [23].

Among the remaining neighborhood social exposures, a small number of studies provided evidence of associations with primarily subjectively-measured sleep outcomes. For example, two out of five studies (40%) reported associations between greater social cohesion/collective efficacy and increased self- or caregiver-reported sleep duration [33,56], but the single study that assessed sleep duration objectively did not report an association [9]. Neighborhood social fragmentation/disorganization was associated with shorter self-reported sleep duration [56,69], but not with actigraphy-assessed duration [10], among adolescents. All studies of social cohesion and social fragmentation were cross-sectional. Finally, neighborhood disorder was associated with later caregiver-reported bedtime among kindergarteners in a large nationally representative cross-sectional study [29] and with shorter caregiver-reported sleep duration at age 12 mo in a large longitudinal birth cohort [43], but not with self-reported sleep duration in teens [56,78]. No studies of neighborhood disorder assessed sleep outcomes objectively.

Neighborhood physical environment

Table 3 summarizes results for 32 studies that examined neighborhood physical environment exposures, most commonly noise (15 studies) or the built environment (e.g., percent urban land use, access to recreational facilities; seven studies). Other physical environment exposures included air pollution (five studies), nighttime outdoor light (four studies), green space (one study), exposure to radiofrequency electromagnetic fields (REMF) from mobile phone base stations (one study), and an index of neighborhood SES, physical, and social features (one study). In total, 27 of 32 studies (84%) reported associations between a poorer neighborhood physical environment and worse sleep.

There were eight qualitative studies in which children or caregivers mentioned noise outdoors as a potential barrier to sleep [12,27,42,46,47,58,68,74]. The remaining seven studies that included neighborhood noise assessed quantitative associations with specific sleep outcomes, of which six (86%) identified associations of higher neighborhood noise with poorer sleep [26,52,67,73,80,86]. Higher neighborhood noise was most frequently associated with self-reported sleep problems (three out of four studies [52,73,80]) and quality (two out of three studies [26,52]). Increased neighborhood noise was associated with later self-reported bedtimes in a nationally representative survey of U.S. adolescents [67], the only study to examine this sleep outcome. There was less evidence for sleep duration (one out of four studies found an association among girls only [86]). Studies were primarily cross-sectional and based on subjective sleep assessment, with no association found between noise and objectively measured sleep duration in the one study that used actigraphy [52], or between noise and self-reported sleep quality in the single longitudinal study [77]. No studies examining neighborhood noise included children below age 6.

For the remaining neighborhood physical environment exposures, the number of studies reporting associations between any particular exposure-outcome pair was small. Among seven studies assessing the built environment, those that assessed sleep duration subjectively were more likely to report associations (two out of two studies [16,72]) compared to studies assessing duration objectively (one out of four studies [62]). A poorer built environment was also associated with later sleep timing [44,62], increased variability [44], and OSA symptoms [31]. All built environment studies were cross-sectional. For air pollution, five out of six studies identified associations with poorer sleep outcomes including sleep problems [8,41], caregiver-reported OSA/snoring [38], and objectively-measured quality and duration [15], which included findings from two longitudinal studies [15,38]. Exposure to outdoor light at night based on satellite imagery was associated cross-sectionally with shorter self-reported sleep duration and later bedtime [57] and later chronotype [83], but not with objectively-measured sleep duration [20].

Discussion

In this systematic review of the role of neighborhood context in pediatric sleep, the most commonly examined exposure was neighborhood SES, followed neighborhood safety, crime, or violence. Overall, 78% of published studies reported a significant association in the expected direction for at least one outcome (e.g., poorer neighborhood environment associated with worse sleep outcomes). Associations were more consistently positive for the neighborhood social environment (86%) and physical environment (84%) compared to neighborhood SES (58%), but there was high heterogeneity in terms of the types of exposures and sleep outcomes measured.

For neighborhood SES, evidence of associations with sleep outcomes was mixed across all age groups and varied by sleep outcome, with the most consistent findings for later sleep timing. These results align with findings from adult populations. Lower neighborhood SES has been associated with shorter sleep duration [99] and poorer sleep quality [100] in adults, but other studies of adults have not found associations [101,102]. The mixed findings may relate to the challenge of measuring the underlying construct of neighborhood SES, which is a composite of individual measures such as education, employment, and poverty that may impact individuals within a neighborhood differently. While some studies in our review examined individual elements of SES, others combined multiple indicators into an index. In addition, there may be variation in how sleep outcomes, particularly sleep quality, are defined across studies (e.g., actigraphy derived sleep efficiency versus subjective assessments of sleep quality).

It is also important to note that sleep patterns and the nature of caregiver- or child-reported sleep problems change considerably over development, which may introduce additional variability. Among young children, more proximal child and family-level factors such as child temperament, caregiver–child interactions, and family routines may exert a greater influence on child sleep patterns and caregiver perceptions of child sleep problems [103]. As

children age, their sleep becomes increasingly self-regulated and might be more strongly impacted by their neighborhood context. During the transition to adolescence, biological and social factors including puberty, early school start times, and extracurricular demands increasingly impact sleep patterns [104,105]. This might explain findings from several studies indicating that adolescents in higher SES neighborhoods had shorter sleep durations and later bedtimes [56,78,81].

The most consistent evidence among published articles was for an association between neighborhood safety, crime, or community violence and adverse subjectively-measured sleep problems. Neighborhood crime/violence is hypothesized to influence sleep through stress processes, which trigger a state of arousal that could interfere with falling or staying asleep [11]. Concerns about safety may also influence daytime behaviors that impact sleep, by reducing physical activity [106] and increasing time engaged in sedentary, screen-based activities [107]. To increase understanding of how neighborhood crime may impact sleep, future studies should empirically test whether policies and interventions that reduce crime have a positive impact on sleep outcomes. For example, a place-based intervention that converted vacant lots into green spaces increased perceptions of safety among residents and reduced crime rates [108], but it is unknown whether such interventions impact sleep.

The next section will outline four limitations of the current literature on the influence of neighborhood environments on pediatric sleep outcomes: 1) limited examination of neighborhood exposures beyond SES or safety, 2) use of primarily cross-sectional observational study designs, 3) lack of objective sleep outcome assessment, and 4) limits of current exposure assessment methods.

Limited examination of neighborhood exposures beyond SES or safety

While studies included in this review identified significant associations of air pollution, built environment features, and social cohesion with sleep outcomes, the number of studies examining each of these exposures was small. Neighborhood noise was the third most common exposure, but half of these studies were qualitative and did not estimate associations of quantitative noise exposure with specific sleep outcomes. Features of the physical environment deserve increased attention given its potential to be modified through public health policies and interventions (e.g., built environment improvements, noise reduction limits). Also, few studies examined associations of neighborhood social or physical exposures with OSA.

For comparison, we also examined neighborhood exposures in adult studies excluded from our review. Neighborhood exposures examined among adults were similar to those identified in this review, although we identified several additional exposures: neighborhood crowding [93], stigma [94], social capital [95], food environment [96], and proximity to chemical or natural gas pollutants [97,98]. Neighborhood crowding, stigma, and proximity to shale gas drilling and chemical superfund sites were associated with poorer sleep outcomes in adults. Future studies should examine associations of these exposures with sleep outcomes among children.

Use of primarily cross-sectional observational designs

Another limitation is that most published studies examining neighborhood environments and pediatric sleep have used cross-sectional designs. These studies provide evidence of associations between neighborhood exposures and sleep, but are limited in making causal assertions. Although reverse causality is unlikely, as child sleep outcomes are not likely to impact neighborhood exposures, there is a strong likelihood of residual confounding in cross-sectional studies. Longitudinal studies facilitate adjustment for time-varying covariates and also allow for statistical analyses comparing within-person changes in sleep outcomes in response to within-person changes in neighborhood exposures, whether due to residential relocation or changes in neighborhood characteristics over time. Such designs inherently control for confounding by time-invariant covariates, both measured and unmeasured. Cross-sectional designs also preclude examination of neighborhood exposures that change over time. In our review, only one study examined neighborhood change, by estimating trajectories of neighborhood poverty over a 40-y period [71]. More work is needed to understand the impact of neighborhood change on sleep outcomes.

In addition, all studies in our review used observational data. This is typical for research examining associations of neighborhood environments with health outcomes, as practical and ethical constraints limit randomization of exposure to many environmental exposures. However, some neighborhood features may be manipulated through randomized experiments, such as the urban greening intervention mentioned previously [108]. In addition, the use of natural experiments and quasi-experimental designs could strengthen causal inference by examining how sleep outcomes change in response to policy changes or place-based interventions.

Lack of objective sleep outcome assessment

Another limitation is that relatively few studies used objective sleep assessment. While subjective measurement is important for certain outcomes, such as perceived sleep problems and subjective sleep quality, objective sleep assessment may improve assessment of outcomes including sleep duration, efficiency, and variability. Prior studies have found that adolescents may over-report their sleep duration in comparison to actigraphy [109] and that caregivers and adolescents may under-report child sleep problems despite showing poor sleep patterns [110], leading to substantial variation between objectively and subjectively measured outcomes. Studies with objective sleep assessment tended to be smaller in size; the largest sample size in our review for a study with actigraphy was 397 [15]. The growing number of commercially available wearable sleep trackers may improve capacity for examining sleep objectively on a larger scale and over longer time periods, although validation of wearables against gold standard measurements is needed.

Limits of current exposure assessment methods

Most studies have focused exclusively on participants' residential neighborhood. However, children and adolescents spend substantial amounts of time at school, in transit, and at other locations, leading to measurement error in exposure assessment when focusing only on the home [111]. Mobile health methods (e.g., GPS tracking; ecological momentary assessment) offer an opportunity to improve exposure assessment by capturing neighborhood exposures across multiple contexts, although privacy concerns must be addressed in the context of this work. In addition, the availability of devices that facilitate personal monitoring of noise and air pollution will improve researchers' ability to construct person-centric environmental exposure measures.

Limitations of review

Our review was subject to several limitations. First, we focused on peer-reviewed articles and may have omitted null research findings that remain unpublished. Second, given the high level of heterogeneity in neighborhood exposures and sleep outcomes measured, we were unable to conduct a meta-analysis, instead conducting a qualitative evidence synthesis. Third, we restricted to English-language articles, which may have omitted relevant studies published in other languages. However, exclusion of non-English and unpublished studies has been found to have limited effect on the results and conclusions of systematic reviews/meta-analyses [112].

Conclusion

Our review identified evidence to suggest that neighborhood safety/crime/violence impedes sleep among school-aged children and adolescents. There is also emerging evidence to support the importance of noise, the built environment, air pollution and social cohesion, although more research in these areas is needed. Future research should expand investigation to additional physical and social environmental factors. In addition, there is a need for more studies using longitudinal or quasi-experimental designs to understand whether the associations identified in this review are causal, as well as more objective measurement of sleep for outcomes related to sleep duration and timing.

Practice points

1. Most studies included in our review reported associations between less favorable neighborhood environmental conditions and poorer sleep outcomes among children and adolescents.
2. Neighborhood socioeconomic status has been examined most frequently, and was associated with shorter sleep duration, later sleep timing, and obstructive sleep apnea diagnoses/symptoms in over half of studies.
3. The most consistent evidence is for an association of neighborhood safety/crime/violence with greater perceived sleep problems.

Research agenda

In the future, research should focus on:

1. Examining a wider range of neighborhood exposures beyond neighborhood socioeconomic status and safety/crime/community violence, which have been most studied to date.
2. Utilizing longitudinal and experimental study designs to improve causal inference and examine neighborhood change.
3. Greater inclusion of objectively measured sleep outcomes in addition to perceived measures
4. Improving environmental exposure assessment through GPS tracking and personal monitoring of exposures that vary over time (e.g., noise, air pollution).

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Conflicts of interest

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Appendix A. Supplementary data

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