Nicotine & Tobacco Research, 2021, 239–248
doi:10.1093/ntr/ntz153
Review
Received September 4, 2018; Editorial Decision August 12, 2019; Accepted August 19, 2019

Review

The Association Between Tobacco Outlet Density and Smoking Among Young People: A Systematic Methodological Review

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Abstract

Aim: Evidence on the association between tobacco outlet density and proximity and smoking behavior among youth is inconsistent, which may be due to methodological problems in some studies. We assessed the association of outlet density or proximity with smoking behavior among young people while taking into account the methodological quality of studies.

Methods: MEDLINE, EMBASE, and Google Scholar were systematically searched for studies on the relationship between outlet density or proximity and smoking behavior among 12- to 25-year-olds, published between 1997 and 2017. Methodological quality of the included studies was evaluated independently by two reviewers.

Results: Twenty studies were included in the review. The quality assessment identified five primary sources of potential bias: overadjustment for mediators (problems identified in 14 studies), underadjustment for confounders (six studies), poor statistical model fit (four studies), selection bias (three studies), and misclassification of exposure measurements (eight studies). Four studies were of high methodological quality. In studies with relatively high quality, 10 associations were reported, of which seven were nonsignificant, two positive, and one negative. Similarly, the complete body of evidence demonstrated mostly nonsignificant associations, but a larger proportion of positive associations than negative.

Conclusion: Although there is some support for a positive direction, current literature does not provide consistent evidence for a positive association between outlet density and smoking among youth. This is not necessarily due to bias in specific studies, but more to fundamental challenges in study design and exposure measurements. These issues need to be addressed in future studies using more rigorous methods.

Implications: Our findings suggest that, although there is some evidence for a positive association, current scientific literature does not provide consistent support to claim an effect of tobacco outlet density or proximity on youth smoking. This underlines the need for more research with improved methodology. There is a need for quasiexperimental studies, in which the outlet density changes substantially, studies measuring the actual exposure of youth to tobacco outlets, and qualitative research on the mechanisms underlying any association.

Introduction

Reducing tobacco outlet density and tobacco outlet proximity has been proposed as a way to limit access to and availability of tobacco.[1] Such reductions may affect youth smoking not only through a decrease in tobacco accessibility, but also because they may contribute to the denormalization of tobacco use by decreasing visual exposure to tobacco products. Several reduction strategies have been proposed such as restricting sales of tobacco in certain venues and/or near youth-populated areas (eg, school surroundings), prohibiting retail clusters from forming, limiting sales to tobacco specialty stores, and implementing tobacco retailer licensing schemes.[1,2] However, it is uncertain what potential effect these reduction strategies may have on smoking behavior in young people.

One review and one meta-analysis have examined the available evidence on the association between outlet density and proximity and smoking behavior.[3,4] A narrative review concluded, based on the evidence of nine studies, that density and proximity were associated with adolescent lifetime smoking (two studies), past 12-month smoking (one study), past 30-day smoking (eight studies), and smoking susceptibility (two studies).[3] However, not all included studies found significant associations for past 30-day smoking (only three of eight studies) and smoking susceptibility (one of two studies)). The meta-analysis examined the association between outlet density and past-month smoking, and found significantly higher smoking rates with higher density around homes, but not schools.[4] Both the narrative review and meta-analysis emphasize the inconsistencies in findings from different studies, and suggest this may be due to differences in settings, populations, smoking outcomes, and measurements of outlet density.

Although these reviews recognize the potential importance of methodological issues, they did not take into account the methodological quality of the studies in an explicit way. Yet, methodological problems may have influenced the ability of individual studies to accurately establish the association between outlet density and proximity and youth smoking. The measured association can either overestimate or underestimate the true association, due to several methodological problems, such as overadjustment for mediators, under adjustment for confounders, poor fit of statistical models, selection bias, and misclassification of exposure measures.

The aim of this systematic review was to investigate the current scientific evidence on the association between tobacco outlet density and proximity and smoking behavior among young people while taking into account the methodological quality of the evidence. This was achieved by first examining the total body of evidence, and then focusing on evidence from studies of higher methodological quality. The methodological quality was determined by thoroughly examining each included study using quality assessment tools for observational studies.

Methods

Protocol and Registration

The protocol for this systematic review is registered in PROSPERO under no. CRD42017069147 (https://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42017069147).

Eligibility Criteria

Randomized controlled trials, nonrandomized trials, and observational studies (cross-sectional, time-series, case-control, cohort, cross-regional, ecological) were included. Modeling studies and laboratory studies (eg, psychological experiments) were excluded, as they do not describe real-life settings. All studies on young people between the ages of 12 and 25 were included, as they are the most susceptible group to start smoking.[5] Studies were included if they assessed the association between outlet density and/or proximity and smoking indicators in young people. Smoking indicators included current smoking behavior (eg, past-month smoking, ever-smoking, occasional smoking), amount of cigarette consumption, and measures of smoking initiation. Tobacco outlet density was defined as the number of tobacco retailers per prespecified area or number of inhabitants. Tobacco outlet proximity was defined as the proximity of the nearest tobacco retailers to a specific point (ie, school or home). We focused on combustible tobacco products only and, therefore, excluded studies solely investigating electronic cigarettes or vaping. We also excluded studies that focused on the association between exposure to smoking advertisements at tobacco points of sale and smoking behavior. No language restriction was imposed in the title and abstract screening. Only studies published within the past 20 years were included. We selected this timeframe as studies that are considerably older were likely to be conducted in a setting where smoking was less denormalized.

Search Strategy

A systematic search was performed using the following databases: MEDLINE (via PubMed), EMBASE (Ovid MEDLINE), and Google Scholar. Only the first 200 hits identified via Google Scholar were screened. Google Scholar sorts search results by relevance, and, therefore, the top results were considered most likely to provide any new inclusions. The 200 cutoff was determined a priori. The search was conducted in May 2017. The search terms included "sale or access or outlet or retail," "density," "proximity," "concentration," "exposure," "tobacco use or smoking," "adolescent or youth." See Supplementary Appendix I for the detailed search string.

Study Selection

Two authors (LD and PN) independently reviewed the articles for eligibility for inclusion using Rayyan.[6] Rayyan is an online app that facilitates the screening process for systematic reviews, as it allows reviewers to simultaneously screen and select studies.[6] The selection process consisted of two rounds: selection based on title and abstract, and full-text screening. Any disagreements were discussed. If no consensus could be reached, a third author (MK) was consulted.

Data Extraction

A data extraction form was used, which was pilot tested for five random studies. Two authors (PN and LD) extracted data in parallel and cross-checked all findings. Any disagreements were discussed, and a third author (MK) was consulted if no consensus was reached. The following items were extracted: reference, year of publication, type of study, setting, study population characteristics, recruitment of participants, description of subgroup analysis if applicable, exposure definition and assessment, outcome definition and assessment, correction for covariates, and key association measures. Smoking outcomes were categorized into four main outcomes: past-month smoking, ever-smoking, smoking susceptibility, and smoking intensity (see Supplementary Table 1 for outcome definitions per study).

Quality Assessment

The quality of individual studies was described according to the Study Quality Assessment Tools for observational studies.[7] In addition to the yes or no options in the assessment tool, a qualitative description for each item was provided to have a detailed overview of all methodological issues per study. The risk of bias assessment of the Cochrane Collaboration[8] was used to assess several sources of potential bias. Only the items that were applicable to the included study designs were described. In addition, any conflicts of interest and the possibility of publication bias were assessed, but none were found. The Cochrane Handbook on assessing risk of bias from selective reporting was used to evaluate potential publication bias.[9] Methodological quality was assessed by authors LD and PN independently. If no consensus could be reached, a third author (MK) was consulted.

Analysis

The quality of the included studies is discussed in reference to the following forms of potential bias: overadjustment for potential mediators, underadjustment for confounders, poor fit of statistical models, selection bias, and misclassification of exposure measures. For all studies, the adjusted models were used to determine potential overadjustment, potential underadjustment, fit of statistical models, and the direction and statistical significance of the association.

The analysis may have been overadjusted if included covariates could not, or to only a minor extent, causally determine respondents' exposure to high outlet density or proximity. Examples of such covariates are peer, friend, and family smoking, which many included studies adjusted for. These covariates may be mediators, if higher outlet density leads to higher levels of peer, friend, or sibling smoking, which in turn may affect smoking behavior of the individual. See Supplementary Table 2 for complete list of covariates per study.

The analysis may have been underadjusted if covariates do not include all the variables that may causally determine respondents' exposure to high outlet density or proximity. A variable that we believed to be an important confounder is socioeconomic status, which is related to both outlet density or proximity and smoking. Studies that did not correct for socioeconomic status were considered underadjusted and may have overestimated our association of interest.

Studies with a poor fit of statistical models may have biased the results toward nonsignificant associations. Our evaluation of model fit is based on the rule of thumb that a minimum of 10 events (ie, cases among the total number of observations, eg, past-month smokers among all respondents) are needed per included covariate. This rule of thumb is based on simulations demonstrating that including too many variables relative to the number of events may yield results with wider confidence intervals, and thus provides a crude indicator of whether models provide a valid basis for statistical inference.[10,11]

Studies were considered to have a risk of selection bias in case of low response rates (<50%), potential selective inclusion of participants, or insufficient information on the selection process.

Studies were considered to have potentially misclassified the exposure, if the exposure measurement was incomplete or undefined. For example, studies that did not mention which types of stores were included in the tobacco outlet density or proximity measurements, or only included a select group of stores (eg, those presumed to be visited by youth) were seen as running the risk of misclassifying the exposure. It is, however, unclear how this potential misclassification may have affected the measured associations.

Every study was given an overall methodological score. The overall quality was based on the number of topics (out of a total of eight topics) for which a potential bias was identified. The quality of studies was judged to be "lower" for four or more topics with potential bias, "moderate" for two to three topics, and "higher" for zero to one topic.

Each outcome was given a + sign for a significant positive association, a – sign for a significant negative association, or a 0 for a nonsignificant association. Some of the nonsignificant associations tended to a positive or negative direction, and were thus consistent with alternative hypotheses regarding a positive or inverse effect. These were indicated with parentheses a (+) or (–). These signs were given if the association estimate was larger than 1 SD (which we often derived from published 95% confidence interval) above or below the null estimate.

Results

Study Selection and Characteristics

We screened 642 studies and included 20 in the analysis (see Figure 1 for flow chart).[12] The study characteristics are described in Table 1. All studies were published between 2006 and 2016. Nineteen studies used a cross-sectional research design, and Lipperman-Kreda et al.[21]used a prospective cohort design. All 20 studies examined the association between outlet density and smoking, of which four studies also investigated the association between outlet proximity and smoking.[13,17,20,25] Fourteen studies looked at past-month smoking as outcome, five at ever-smoking, six at smoking susceptibility, and six at smoking intensity. Seven studies examined associations within the home environment, thirteen studies within the school environment, and three studies in other settings such as city level or country level. In all studies, the school referred to levels up to high school and did not include college. Sixteen studies were performed in the United States[13–15,17,20–22,24–26,28,29] or Canada,[2,16,18,19] and the rest were from Scotland,[30] Australia,[23] New Zealand,[27] and India.[31] Overall, participants were between 9 and 24 years old, although in all studies most participants fell within the 12–25 age range. Sample size ranged from 187 to 70 427.

Potential Sources of Bias

Table 2 gives an overview of the potential sources of bias per study, with an "X" indicating a potential problem.

Fourteen studies adjusted for potential mediators such as peer, friend, or sibling smoking. See Supplementary Table 2 for specific covariates included in each study.[2,13,16,18,19,22,25–27,29–31] Six studies may have underadjusted for potential confounders by not including socioeconomic status as a covariate in the analysis.[2,16,22,25–27] Most studies adjusted for sex, race or ethnicity, and population density. Other than socioeconomic status we did not identify other important confounders that were missed.

Four studies had potentially poorly fitting models.[14,15,20,21] The studies by Lipperman-Kreda et al.[20,21] included a large number of variables at the city level compared to the number of city units in which they were measured (seven compared to 45 in 2014 and nine compared to 50 in 2016). Adams et al. included four variables at the school level with 34 schools included in the analysis.[14] In addition, Cantrell et al. [15] may have included too many variables compared to

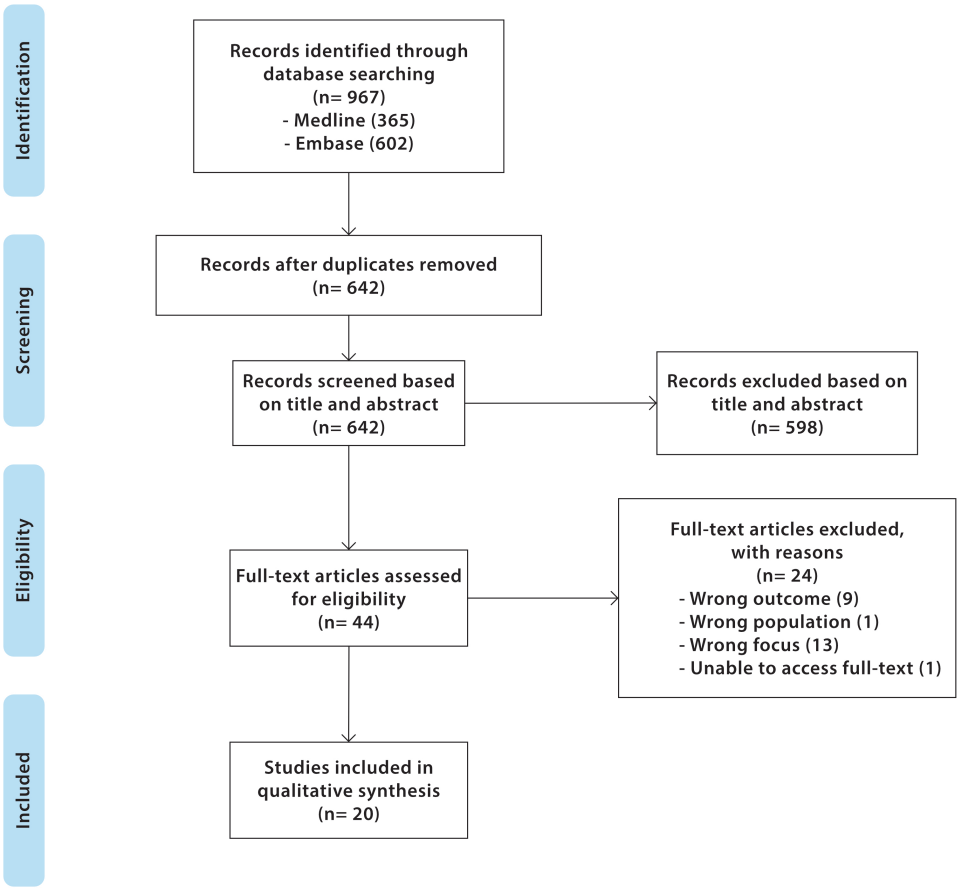

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart of the article selection process.[12]

the number of smokers in the sample (a sample of 96 with approximately 17 degrees of freedom in the model).

Three studies had low participation rates[20,27,29] and three other studies did not report a participation rate,[15,22,28] which prevents us from determining whether a sufficient participation rate was reached. Four studies recruited participants through a purchased list, which may lead to selective exclusion of part of the source population (eg, those without a landline telephone).[14,20–22] Unfortunately, these studies did not provide information on how and to what extent samples may have been selective, and whether likelihood of selection varied by smoking prevalence or outlet density or proximity measures.

Eight studies had, what we considered, potential misclassification of the exposure measures.[13,16,18,19,23,25,26,28] Three studies used data from North America Industry Classification System codes to identify tobacco retailers.[13,25,26] This database does not allow differentiation between subclasses of stores that do or do not sell tobacco. Some stores may have, therefore, been misclassified as selling tobacco whereas others may have been left out. Three other studies used the Digital Mapping Technologies Inc. Enhanced Points of Interest data.[16,18,19] There is no clear description of what type of stores this source includes and we did not find information on the extent to which all tobacco retailers were included in this study. One study measured outlet density by driving past all streets while logging any retail location that was licensed to sell tobacco. This raises the possibility of missing stores that are not accessible by car or non-registered retailers.[28] Scully et al.[23] included only retail outlets most likely to be visited by young people to purchase cigarettes (46% milk bars, 14% supermarkets, 13% petrol stations), which means that the remaining 27% of retail outlets were excluded.

Direction of Association

Table 3 gives an overview of the direction of the associations per smoking outcome and setting. Overall, we found more often positive associations (nine) than negative (two). Associations between smoking and outlet density in the school environment were mostly nonsignificant (14 associations), whereas three were positive and two negative. In the home environment, associations tended to be more often positive, with five positive associations and four nonsignificant associations. In settings other than the home and school environment, six associations were nonsignificant and one positive. Looking at the nonsignificant associations across all settings, there were six nonsignificant associations in the positive direction, and only one in the negative direction. Most evidence is available for the outcome past-month smoking, for which mostly nonsignificant associations were found with outlet density in the school environment, but positive associations in the home environment. Findings among the other three smoking outcomes remain varying and overall nonsignificant. All associations between outlet proximity and smoking were nonsignificant.

Four studies accentuated in bold are those of higher methodological quality. These studies reported in total 10 associations.[17,24,30,31] Across all smoking outcomes (except smoking susceptibility), seven nonsignificant, two positive, and one negative association were

Table 1. Characteristics and Findings of Included Studies

Study	Country	Year	Participant age (years)	Sample size (*N*)	Home/school/other[a] (H/S/O)	Density/proximity	Measured association presented as odds ratio with 95% confidence interval, unless indicated otherwise[b]
Adachi-Mejia et al.[13]	USA	2007	13–18	Ever = 3646 Past-month = 1263	H	Density	Ever = 1.27 (0.92 to 1.76) Past-month = 1.11 (0.70 to 1.79)
						Proximity	Ever = 0.96 (0.67–1.36) Past-month = 0.74 (0.45 to 1.20)
Adams et al.[14]	USA, IL	2000–2005	7–10 grade (~13–16)	9704	S	Density	Past-month = 1.04 (0.95 to 1.14) Ever = 1.10 (1.00 to 1.20)
Cantrell et al.[15]	USA	2013	18–24	1609	O	Density	Ever = 0.98 (0.14 to 6.99)
Chan et al.[16]	Canada, Ontario	2005–2006	9–12 grade (~14–18)	Past-month = 22 899 Susceptibility = 15 361	S	Density	Past-month = 1.00 (0.98 to 1.02) Susceptibility = 1.03 (1.01 to 1.05)
Henriksen et al.[17]	USA, CA	2005–2006	14–18	~24 875	S	Density	Past-month = 3.2 (0.8 to 5.6)[c] Intensity = nonsignificant, not reported
						Proximity	Past-month = 1.11 (–0.9 to 3.0)[c] Intensity = nonsignificant, not reported
Kaai et al.[18]	Canada	2008–2009	9–12 grade (~14–18)	15 982	S	Density	Susceptibility = 1.00 (0.99 to 1.01)
Kaai et al.[19]	Canada	2008–2009	9–12 grade (~14–18)	18 072	S	Density	Past-month = 0.99 (0.97 to 1.02)
Leatherdale and Strath [2]	Canada, Ontario	2000–2001	14–18	19 464	S	Density	Past-month = 1.01 (0.99 to 1.03)
Lipperman-Kreda et al.[20]	USA, CA	2010	13–18	832	H, S	Density	Intensity (H) = 0.34 (0.18 to 0.50)[d] Intensity (S) = 0.124 (–0.02 to 0.27)[d]
						Proximity	Intensity (H) = -1.03 (-2.45 to 0.40)[d] Intensity (S) = 1.28 (–0.83 to 3.39)[d]
Lipperman-Kreda et al.[21]	USA, CA	2009–2011	13–16	1478	O	Density	Ever = 1.12 (1.04 to 1.22)
Loomis et al.[22]	USA, NY State	2000–2008	9–17	In NY City: Susceptibility = 12 759 Past-month = 16 552 Intensity = 1470 In the rest of NY State: Susceptibility = 11 711 Past-month = 43 399 Intensity = 4945	O	Density	In NY City: Past-month = 0.99 (0.88 to 1.11) Intensity[e,f] = 1.27 (0.80 to 2.01) Susceptibility = 1.05 (0.95 to 1.15) In the rest of NY State: Past-month = 1.07 (0.77 to 1.46) Intensity[e,f]= 1.89 (0.57 to 6.19) Susceptibility = 1.14 (0.84 to 1.53)
Marsh et al.[27]	New Zealand	2012	14–15	27 238	S		Past-month = 0.80 (0.67 to 0.96) Susceptibility = 1.07 (1.01 to 1.16)
McCarthy et al.[24]	USA, CA	2003–2004	Mean = 14.9	19 306	S	Density	Past-month = 1.06 (0.94 to 1.20) Intensity = not significant, not reported
Mennis et al.[25]	USA, VA, Richmond	2013–2014	14–18	197	H	Density	Susceptibility = 0.130 (0.034 to 0.225)[g]
						Proximity	Susceptibility = –0.38 (–1.628 to 0.874)[g]
Mennis et al.[26]	USA, VA, Richmond	2013–2014	14–18	187	H	Density	Intensity= –0.08 (–0.28 to 0.13) Susceptibility = 0.14 (0.01 to 0.28)
Mistry et al.[31]	India, Mumbai	2010	8–10 grade (~14–16)	1320	S	Density	Past-month = 1.99 (0.92 to 4.33) Ever = 1.74 (0.86 to 3.51)
Novak et al.[28]	USA, Chicago	1995–1999	11–23	2116	H	Density	Past-month = 1.20 (1.001–1.44)
Schleicher et al.[29]	USA	2011–2012	13–16	2771	H, S	Density	Past-month(H) = 1.01 (1.01 to 1.02) Past-month(S) = 1.00 (1.00 to 1.01)

Table 1. Continued

Study	Country	Year	Participant age (years)	Sample size (N)	Home/school/other[a] (H/S/O)	Density/proximity	Measured association presented as odds ratio with 95% confidence interval, unless indicated otherwise[b]
Scully et al.[23]	Australia, Victoria	2008	12–17	2044	S	Density	Past-month = 1.06 (0.90 to 1.24) Intensity = 1.13 (1.02 to 1.26)[h]
Shortt et al.[30]	Scotland	2010	13–15	20 466	H, S	Density	Past-month(H) = 1.53 (1.27 to 1.85) Past-month(S) = 0.66 (0.50 to 0.86)

[a]Tobacco outlet density measured in the school or home environment, or other: refers to studies that do not specifically assess outlet density within home or school environments. Examples of other environments are city- or country-level densities.
[b]Past-month smoking: cigarette smoking in past 30 days. Ever-smoking: ever having smoked one cigarette in their lifetime, not specified in past-month. Smoking intensity: number of cigarettes within a given time. Susceptibility: intention to smoke in the future.
[c]Percentage points increase with 95% confidence interval.
[d]Beta from negative binomial models (for a one unit change in outlet density/proximity, the difference in the logs of expected counts of the smoking variable is expected to change by the respective regression coefficient, given the other predictor variables in the model are held constant) with robust standard error.
[e]Intensity measured as cigarettes per day among current smokers.
[f]Coefficient from linear regression models (increase in number of cigarettes for a one unit increase in outlet density).
[g]Coefficient from ordinal regression models (for a one unit increase in outlet density/proximity, the smoking variable level is expected to change by the respective regression coefficient on the ordered log-odds scale, given the other predictor variables in the model are held constant).
[h]Adjusted incidence rate ratio with 95% confidence interval.

found. All four studies examined past-month smoking, among which two positive, one negative, and three nonsignificant associations were found. The associations for all other smoking outcomes were nonsignificant. Thus, also among these studies of higher methodological quality, associations were generally nonsignificant.

Discussion

Key Findings

Sixteen of 20 included studies had two or more potential sources of bias. The most frequently detected form of potential bias was the adjustment for variables that may be mediators in the association (in 14 studies), followed by potential misclassification of exposure measurements (in eight studies). Six studies may have underadjusted for confounding. Most studies had limited risk of selection bias. The four studies of higher methodological quality reported in total 10 estimates for the association between outlet density and smoking. Of these, seven were nonsignificant, two positive, and one negative. In the complete body of evidence, we also found more positive associations (nine associations) than negative (two associations). Notably, more nonsignificant associations lean toward a possible positive association (six) than toward negative (one). Associations in the home environment were more often positive than those in the school environment. Four studies examined outlet proximity and found nonsignificant associations. There is, therefore, some support for a positive association between outlet density and youth smoking, but not for outlet proximity.

Limitations to This Review

Even though we applied a systematic approach to the evaluation of the methodological quality, determining the quality of studies was often difficult due to incomplete reporting in studies. If there was uncertainty with regard to the presence of bias, we assumed there was bias. This may have led to an overestimation of the total occurrence of bias.

It was not possible to accurately assess statistical power of the included studies based on the reported information. Insufficient statistical power may, therefore, be one of the reasons that so few studies found statistically significant associations.

Comparability between studies was limited due to considerable variation in study settings, smoking outcomes, and exposure measurements. This variation between studies reduced possibilities for a meta-analysis. Only one study has conducted a meta-analysis,[4] but that meta-analysis was limited to one smoking outcome and did not exclude studies based on methodological quality. Moreover, in that study, the authors recognized the large variations between study methodologies as a limitation of their analysis.

Evaluation of Methodology of Published Studies

In the complete body of evidence as well as in those studies of higher quality, most estimates do not provide support for a positive association between outlet density or proximity and youth smoking. A key question is whether this lack of positive evidence resulted from bias that had led to a systematic underestimation of the association. Lack of statistical power can be one of the reasons that so few studies found statistically significant associations. Potential overadjustment for friend, family, or sibling smoking occurred in most studies (14 of 20), including three of four studies of higher quality. This may have caused an underestimation of the association, but the extent to

Table 2. Potential Bias per Study

	Overadjustment					Selection bias			
	Friend smoking	Family/ parental smoking	Sibling smoking	Under-adjustment for SES	Incorrect fit of statistical model	Low participation rate	Sample recruitment issues	Misclassified exposure	Overall methodological quality score[a]
Adachi-Mejia et al.[13]		X	X					X	Moderate
Adams et al.[14]					X		X		Moderate
Cantrell et al.[15]					X	X			Moderate
Chan et al.[16]	X	X	X	X				X	Lower
Henriksen et al.[17]									Higher
Kaai et al.[18]	X							X	Moderate
Kaai et al.[19]	X	X	X					X	Moderate
Leatherdale and Strath[2b]	X	X	X	X					Lower
Lipperman-Kreda et al.[20]					X	X	X		Moderate
Lipperman-Kreda et al.[21]					X		X		Moderate
Loomis et al.[22]		X		X		X	X		Lower
Marsh et al.[27]	X	X		X		X			Lower
McCarthy et al.[24]	X								Higher
Mennis et al.[25]	X	X		X				X	Lower
Mennis et al.[26]	X	X		X				X	Lower
Mistry et al.[31]	X	X							Higher
Novak et al.[28]						X		X	Moderate
Schleicher et al.[29]	X	X				X			Moderate
Scully et al.[23]		X						X	Moderate
Shortt et al.[30]		X							Higher

SES = socioeconomic status.

[a]A study with less than two potential sources of bias was classified under *higher quality*, a study with two potential sources of bias was classified under *moderate quality,* and studies with more than two potential sources of bias were classified under *lower quality*.

[b]Owing to incomplete reporting by Leatherdale and Strath,[2] it is unclear which covariates were included in the analysis for the outcome past-month smoking. We, therefore, assumed the same covariates were included as in the analysis for the outcome access to cigarettes.

which this may have occurred is difficult to establish. The other identified sources of bias would either be more likely to lead to an overestimation of the association (underadjustment for confounders), or have uncertain effects on association estimates (selection bias and measurement bias of exposure).

In addition to the specific sources of bias identified for individual studies, the methodology of most or all included studies falls short on several points. Firstly, most studies (19 of 20) were cross-sectional. The evidence on causality from this type of studies is limited as compared to longitudinal studies that would assess whether a reduction in outlet density would be followed by a decline in smoking. Second, studies fail to assess the actual individual exposure of adolescents to tobacco outlets, that is, how often they pass or visit stores selling tobacco. Third, studies are limited to measurements of outlet density and smoking outcomes, providing little understanding of the mechanisms underlying the association between the two. Finally, density measurements used circular buffer zones to measure areas of exposure, which may not correspond with the areas in which young people move in real life.

A common feature of all studies is that the density of outlets is measured with reference to a restricted space around homes or schools. However, these restricted areas may overlap only partially with the "activity space" of individual students. Young people do not only spend time around home or school, but within wider daily activity spaces that include for example sports areas and shopping malls.[32,33] The failure to capture these wider spaces may be one reason for why extant research did not show strong associations between tobacco outlet density and youth smoking. One study that did look at young people's activity spaces observed that the density of tobacco outlets is larger in the wider activity spaces than round home or school.[33]

Interpretation of Findings

To understand the large proportion of nil-findings in the evidence we may need to explore the mechanisms driving or blocking a potential association between tobacco outlet density or proximity and smoking. An important aspect to consider is adolescents' access to cigarettes. Many adolescents make use of social sources of cigarettes,[34–36] which may limit their dependency on and exposure to tobacco outlets. Moreover, when adolescents do use commercial sources of cigarettes, they buy them in stores that are known to be easily accessible, such as small non-franchised shops.[37–40] Not all types of tobacco outlets are important in this regard and, therefore, the overall density of tobacco outlets may be of limited relevance. Thus far, no studies have measured density or proximity of only those outlets that are easily accessible to youth.

One might expect the impact of high outlet density to be reduced by bans on tobacco advertising and display at points of sales, because such bans would prevent exposure to tobacco marketing when visiting tobacco retail outlets. However, this cannot explain the large proportion of null-findings in our review. Of the 20 studies included in the review, 18 collected data during a time when point-of-sale display of tobacco products was allowed (see Supplementary Table 3). The two possible exceptions are studies on Canadian provinces during a period that point-of-sale display bans were being implemented at varying times.[18,19] These studies found no associations with outlet density, but the authors do not mention point-of-sale display bans as a possible reason.

Table 3. Direction of Associations per Outcome and Setting

	Past-month smoking	Ever-smoking	Smoking susceptibility	Smoking intensity
School setting				
Adams et al.[14]	0	(+)		
Chan et al.[16]	0		+	
Henriksen et al.[17]	**+, (+)**[a]			**0, 0**[a]
Kaai et al.[19]	0			
Kaai et al.[18]			0	
Leatherdale and Strath[2]	0			
Lipperman-Kreda et al.[20]				0, (+)[a]
Marsh et al.[27]	–		+	
McCarthy et al.[24]	**0**			**0**
Mistry et al.[31]	**0**	**0**		
Schleicher et al.[29]	0			
Scully et al.[23]	0			
Shortt et al.[30]	–			
Home setting				
Adachi-Mejia et al.[13]	0, 0[a]	0, 0[a]		
Lipperman-Kreda et al.[21]				+, (–)[a]
Mennis et al.[25]			+, 0[a]	
Mennis et al.[26]			(+)	0
Novak et al.[28]	+			
Schleicher et al.[29]	+			
Shortt et al.[30]	**+**			
Other setting				
Cantrell et al.[15]		0		
Lipperman-Kreda et al.[21]		+		
Loomis et al.[22] (in NY City)	0		0	(+)
Loomis et al.[22] (in the rest NY State)	0		0	(+)

Studies of higher methodological quality are highlighted in **bold.** 0 = no significant association found; + = significant association in the positive direction; – = significant association in the negative association; (+) = nonsignificant association in the positive direction; (–) = nonsignificant association in the negative direction. When the effect estimate was larger than a quarter of the total 95% confidence interval (derived from Table 1) the effect estimate was considered nonsignificant in positive/negative direction, indicated by parentheses.

[a]Studies looking at the association between tobacco outlet proximity and smoking.

We found a number of positive associations of smoking with outlet density in the home environment, compared to mostly nonsignificant and negative associations in the school environment. Similar findings were reported in a previous meta-analysis focused on past-month smoking.[4] Three potential explanations for these differences have been previously suggested.[4,29] First, relevant areas around schools may be difficult to demarcate, and often used circular zones that may not capture the area around a school that students naturally visit during breaks. Second, tobacco retailers around schools may have a higher inspection rate and, therefore, may be more compliant with restrictions on sales to minors.[29,30] Third, the home environment may be more important as adolescents may spend more unsupervised time there with friends, which is associated with increased tobacco use.[41,42] High tobacco outlet density may facilitate such peer influence.

We found some evidence suggesting that associations were more consistently positive for past-month smoking than for other smoking outcomes (past-month smoking, ever-smoking, smoking intensity, and smoking susceptibility). Outlet density or proximity may affect these outcomes differently. For example, smoking initiation (ie, ever-smoking) may be mainly affected by tobacco outlet density and/or proximity due to the influence of tobacco marketing on social norms, and this may occur through increases in smoking susceptibility.[43–45] Increasing smoking intensity, however, may be influenced by the high visibility of tobacco that increases the tendency toward impulse purchasing.[46–48] Impulse purchasing can also lead to less successful quit attempts,[46,49] although the association between outlet density and adolescent smoking cessation, has, to the best of our knowledge, not been studied. Further research is required to assess to what extent and in what timeframe these mechanisms take place. Associations for past-month smoking outcome may be more consistent, because this outcome captures a larger range of smoking behaviors, including smoking initiation as well as smoking cessation, and, therefore, multiple mechanisms may be at play.

Future Research

The generalized shortcomings in the current literature that were identified earlier imply a great need for research with improved methodology. First, quasiexperimental studies with longitudinal or repeat cross-sectional designs could measure youth smoking behavior before and after a reduction of outlet density, for example, following the implementation of policy measures such as licensing systems. Such quasiexperimental studies would provide stronger evidence on the causal association between outlet density or proximity and youth smoking. Second, the measurement of outlet density using buffer zones could be improved by measuring geographical spaces where adolescents actually travel. In addition, their actual exposure to outlets can be measured by combining geographical positioning systems and geographical information systems. Finally, qualitative studies of young people's access to tobacco products and their

perception and use of tobacco outlets may provide more insight into the ways in which outlet density and proximity do or do not affect their smoking behaviors.

Conclusions

Although there is some support for a positive direction, current literature does not provide consistent evidence for a positive association between outlet density and smoking. This is not necessarily due to bias in specific studies, but may be related to fundamental challenges in study design and exposure measurements. There is an urgent need for quasiexperimental studies that assess trends in smoking after substantial changes in outlet density, geographical information systems-based studies that measure the actual exposure of youth to tobacco outlets, and qualitative studies that identify potential mechanisms by taking the perspective of youth themselves.

Supplementary Material

Supplementary data are available at *Nicotine and Tobacco Research* online.

Funding

This study is part of the SILNE-R project, which received funding from the European Commission (EC), Horizon 2020 program, Call PHC6-2014, under Grant Agreement no. 635056.

Declaration of Interests

None declared.

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