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► To cite this version:

Sarah Bitar, Florian Manneville, Jennifer O'loughlin, Marie-Pierre Sylvestre, Laetitia Minary, et al.. Interaction and effect modification in the association between socioeconomic status and adolescent smoking: a systematic review. *Epidemiologic Reviews*, 2025, 47 (1), pp.mxaf013. <10.1093/epirev/mxaf013>. <hal-05492842>

HAL Id: hal-05492842

<https://hal.univ-lorraine.fr/hal-05492842v1>

Submitted on 6 Feb 2026

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HAL Authorization

*Epidemiologic Reviews Submitted Manuscript*¹

Special Collection: N/A

Title: Interaction and effect modification in the association between socioeconomic status and adolescent smoking: A systematic review

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Key words: Adolescent, Smoking, Social class

Acknowledgments²: N/A

Funding: This research was funded by IResP and INCa as part of the call for research and intervention projects to reduce and combat smoking (Grant IRESP-19-TABAC-V1-02").

Conflict of Interest: There are no competing interests.

Disclaimer: N/A

Data Availability Statement: Data will be made available on request.

ABSTRACT:

² Study investigators, conference presentations, preprint publication information, thanks.

This systematic review aimed to identify effect modification and interaction factors that moderate the association between socioeconomic status (SES) and smoking behavior among adolescents. We searched PubMed, Embase, PsycINFO, and Web of Science using keywords including “adolescents,” “smoking,” “inequality,” “effect modification,” and “interaction.” Peer-reviewed articles published in English or French between January 1, 2011, and December 31, 2021, were included, alongside relevant studies identified from reference lists. Of 3,485 articles, 23 met the eligibility criteria. All reported quantitative observational study designs to identify factors that modify the SES-smoking behavior association. Two independent reviewers extracted data from each article using a standardized form. We assessed reporting quality using the STROBE guidelines. Of 23 studies included, 13 reported statistically significant moderation associations. The most frequently studied moderators were race/ethnicity (n=5; significant in 4) and gender/sex (n=5; no significant associations). Contextual factors including school-level SES (n=2; significant in 1), neighborhood SES (n=2; significant in both), and peer influence (n=2; significant in both), were also examined. Time trends (n=2), country-level factors (n=2), and social capital (n=1) were significant moderators in the few studies that investigated them. Methodologically, adherence to best practices was limited. This review highlights the need for use of a wider range of SES measures, exploration of understudied potential moderators, and consistent adherence to standardized methodologies to better inform public health interventions addressing adolescent smoking inequalities.

INTRODUCTION

Despite substantial progress in tobacco control, smoking remains a critical public health challenge globally. Approximately 1.1 billion people worldwide currently smoke (1). While the proportion of smokers declined by 15% between 2007 and 2017, efforts to combat this issue have not adequately addressed persisting social inequalities in smoking initiation (2). Notably, adolescents from lower socioeconomic backgrounds exhibit higher levels of smoking (3–5).

To effectively address these inequalities, it is essential to better understand contributing factors and the mechanisms underpinning the association between socioeconomic status (SES) and adolescent smoking behavior (6,7). This understanding is key to developing targeted and effective tobacco control strategies. The World Health Organization's conceptual framework on the social determinants of health (8) offers a useful perspective for understanding the origins and persistence of health inequalities, including those related to adolescent smoking. It distinguishes between structural determinants (e.g., socioeconomic and political context, public policies, and social stratification) and intermediary determinants (e.g., material conditions, psychosocial factors, and health-related behaviors). This multilevel approach emphasizes not only the direct effects of SES but also how these effects can vary depending on the broader context in which adolescents live. Applying such a framework helps clarify how and under what conditions inequalities in smoking behavior emerge and persist. It also highlights the relevance of investigating subgroups and contexts in which the SES-smoking relationship is strongest, so that interventions can be tailored to address the complex interplay between these factors.

For example, Mathur and colleagues found evidence for differential effects of individual SES on adolescent smoking for higher and lower neighborhood SES (9). Similarly, racial, ethnic,

and cultural factors may moderate the association between SES and adolescent smoking (10) (11). However, despite these valuable insights, no systematic review has yet comprehensively synthesized what is known about modifying factors in this association, highlighting a critical gap in the literature.

This gap may stem from several factors, including the limited number of studies explicitly addressing modifying factors and the complexity of the methodological approaches required to analyze them. For example, distinguishing between the concepts of effect modification and interaction is essential for clarifying how different factors influence the strength or direction of the SES-smoking relationship (12). Effect modification occurs when the impact of one exposure (e.g., SES) on an outcome (e.g., smoking behavior) varies within the strata of another variable (e.g., gender). This helps identify subgroups where interventions may be particularly needed.

Interaction refers to situations where the combined effect of two exposures (e.g., SES and peer influence) on an outcome (e.g., smoking behavior) differs from the sum of their individual effects. This distinction highlights potential synergy or antagonism between factors. For example, identifying antagonistic interactions can inform strategies to counteract smoking inequalities by promoting modifiable factors that mitigate the effects of SES. Similarly, identifying synergistic interactions is crucial to avoid exacerbating the SES-smoking relationship. Interventions targeting such modifiable factors could help reduce health inequalities by limiting their adverse impacts.

Our aim in this study was to identify effect modification and interaction factors that moderate the SES-smoking association in adolescents.

METHODS

Data sources

This systematic review adheres to a protocol registered in the PROSPERO registry (13) (Number CRD42022324918). It conforms with the PRISMA 2020 statement (14). We searched four databases (Pubmed, Embase, Psychinfo, and Web of Science) using keywords including “adolescents” “smoking” “inequality” and “moderation”. A detailed description of the search strategy is available in Appendix S1. We also reviewed the reference lists in included articles to identify additional relevant papers.

Eligibility criteria

Eligible articles were published in French or English. To cover current methodological practices, we retained articles published between January 1, 2011, and December 31, 2021. We used the WHO definition of adolescents (i.e., individuals ages 10–19 years)(15). Articles describing quantitative observational studies using cross-sectional or longitudinal study designs were included. Conference abstracts, PhD and MSc theses, and research protocols were excluded.

Article selection

After removing duplicates, we reviewed the titles and abstracts and then full texts to select articles eligible for inclusion. This process was undertaken by two independent reviewers (SB, FM), who met periodically to discuss their selections. Disagreements were resolved by consulting two other authors (NA, LM), and final decisions were made by consensus.

Data extraction and analysis

Information extracted pertained to the article (i.e., first author, year of publication, journal), the study (i.e., objectives, study design, recruited sample country, sampling strategy, sample

size), and the sample characteristics (i.e., age, sex, ethnicity). We also extracted information on measures of socioeconomic factors, smoking behavior, and potential interaction or effect modification factors examined (e.g., data collection mode, evidence for validity or reliability of the measure). We recorded whether interaction or effect modification was stated as an objective, whether the article reported empirical or theoretical support for such analysis, the statistical model used, whether multiplicative and/or additive scales were assessed, and the terminology used to describe the analysis (e.g., interaction, subgroups, moderation, stratified analysis, effect modification). Further, we categorized the article as an interaction or effect modification article depending on whether one or more exposures were of primary interest.

Quality assessment

Two reviewers (SB, FM) independently assessed the quality of reporting of the articles using the 22 items listed in the Strengthening the Reporting of Observational Articles in Epidemiology (STROBE) checklist (16). Disagreements were resolved by discussion.

To assess the quality of the methods used to assess the effect modification or interaction, we extracted analyses and corresponding results and described their reporting according to recommendations provided by Knol and VanderWeele (17). Specifically, for effect modification, we assessed adherence to the following:

- a. Present relative risks (RRs), odds ratios (ORs) or risk differences (RDs) with confidence intervals (CIs) and *P*-values for each stratum of SES and the effect modifier with a single reference category (possibly taken as the stratum with the lowest risk of smoking behavior).

- b. Present RRs, ORs or RDs with CIs and *P*-values for SES within strata of the effect modifier.
- c. Present measures of effect modification on both the additive (e.g. Relative Excess Risk from Interaction (RERI) derived from logistic regression) and multiplicative scales with CIs and *P*-values.
- d. List the confounders for which the association between SES and smoking behavior was adjusted.

For interaction analysis, we considered the following:

- a. Present RRs, ORs or RDs with CIs and *P*-values for each stratum of SES and the interaction factor with a single reference category (possibly taken as the stratum with the lowest risk of smoking behavior).
- b. Present RRs, ORs or RDs with CIs and *P*-values of the association between SES and smoking behavior in strata of the interaction factor and of the association between the interaction factor and smoking behavior in strata of SES.
- c. Present measures of interaction on both the additive (e.g. RERI) and multiplicative scales with CIs and *P*-values.

List the confounders adjusted for in the association between (i) SES and smoking behavior, and (ii) the interaction factor and smoking behavior.

RESULTS

Article Selection

Search results and exclusions are shown in Figure 1. We identified 3,485 articles in Pubmed (n = 1,627), Psychinfo (n = 551), Embase (n = 545), and the Web of Science (n = 762). After removing duplicates, we retained 1,881 records for title and abstract screening, and 122 for full text screening. Two additional articles were identified in citation searching. At the end of the selection process, we retained 23 articles that met the inclusion criteria for data extraction.

Included articles and study characteristics

Article characteristics are reported in Table 1. Each article reported the results of a unique study. Eleven of the 23 studies retained were conducted in Europe and nine in North America (7 in the United States; 2 in Canada). Sixteen articles were published between 2015 and 2021. Study designs were cross-sectional (n = 17), longitudinal (n = 3) or repeat cross sectional (n = 3). Sample sizes ranged from 397 in Nazir et al. (18) to 416,419 in Bachman et al. (19). Eighteen studies included females and males; in these articles, 49% of participants were male and 51% were female. Ten studies provided data on participant ethnicity.

Factors modifying the SES-smoking association in adolescents

Smoking behavior measures. Most studies investigated a single smoking behavior; five used multiple measures of smoking behaviors. Overall, ten different measures of self-reported smoking behavior were used including: experimentation, past month cigarette smoking status, intention to smoke, smoking progression, smoking status, early smoking initiation, weekly smoking, tobacco dependence, smoking habits, and daily smoking status.

“Experimentation” was assessed in seven studies and described as “ever smoked part or all a cigarette” in one study (20), and as “ever having smoked” in six studies (20–26). “Past month cigarette smoking” was used in six studies and defined as “smoked one or more days in the past 30 days” in three studies (23,27,28) , and “use of cigarettes during the past 30 days” or “smoked over the past 30 days” in three studies (19,24,29). “Daily smoking status” was measured in four studies (23,30–32). “Smoking status” was reported in three studies using different categories: Moor et al.(33) used never smoking/ less than weekly smoking/ at least weekly smoking, Yáñez et al.(34) used never smokers/ triers/ regular smokers, and Moore et al.(35) used smokers/non-smokers. Other behaviors such as weekly smoking(36,37), intention to smoke(38) and smoking progression(9) were also reported.

Characterizing socioeconomic status measures in adolescents. SES as an exposure variable was measured using a wide range of variables (Table 2). Most studies used a single variable; four studies collected data on multiple indicators of SES (18,21,27,33). SES factors were self-reported by adolescents in 20 studies, and by parents in one study (39). Measurement methods were not specified in two articles (20,34). Different categories of SES measures were identified including family-related measures (n=22), adolescent-related measures (n=3), and neighborhood-related measures (n=2).

Family-related *SES measures* included parental educational attainment (n=11) , family affluence (n=5), family income (n=5) and parents’ occupational social class (n=2). Household deprivation profiles were considered as a measure of SES in one study (40). The validated family affluence scale was used in five studies (25,31,33,35,36). Adolescent-related SES measures included weekly spending money (22), adolescent academic performance (33), and adolescent pocket money (33). Neighborhood-related *SES measures* was used in two

studies (21,41) in which a deprivation index was calculated based on the residential postal code reported by adolescents.

Factors modifying the SES-smoking association in adolescents. A total of 34 factors that potentially influence the association between SES and smoking behavior were assessed in the 23 studies included, 13 of which were reported to be statistically significant. There was considerable variation in the moderators identified across articles.

Individual factors such as ethnicity/race and gender/sex were the most frequently studied. Five studies examined ethnicity, race or both. Among these, three used a combined category of race/ethnicity (19,20,23); one assessed race and ethnicity separately (39), and another considered ethnicity only (24). Moderation of the SES tobacco association by ethnicity and race was statistically significant in four of the five studies, suggestive that higher parental education exerts a weaker protective association with tobacco use outcomes (i.e., experimentation, past month smoking, daily smoking and tobacco dependence) among Black and Hispanic families compared to non-Hispanic White families. Similarly, a weaker protective effect was observed among Latino youth compared to non-Latino youth.

Five studies assessed gender/sex, and none reported a statistically significant moderation association. However, Desai et al. investigated a three-way interaction including gender/sex, not having enough money to pay for school fees, and area of residence, and found that leaving school due to 'not being able to pay for school fees' was significantly associated with past month cigarette smoking, but only among girls living in urban areas (27).

School level SES was considered in two articles using free school meal entitlement as an effect modifier or interaction factor. Moore et al. reported that among children from poorer families, the percent of children classified as smokers was similar regardless of school

affluence, whereas for children from more affluent families, smoking was less likely if they attended a more affluent school (35).

Neighborhoods SES was considered in two articles and was associated with both smoking progression (9) and weekly smoking(37). Residing in higher SES neighborhoods was associated with greater increases in smoking progression over time, particularly among individuals with lower individual SES. Moreover, the relationship between household poverty and weekly smoking differed based on neighborhood socioeconomic deprivation: among students experiencing household poverty, living in more affluent neighborhoods was associated with a higher likelihood of weekly smoking. There was no clear association between neighborhood socioeconomic deprivation and weekly smoking behavior among students not experiencing household poverty.

In two articles, the analysis considered time trends. The first article (26), conducted in 1998, found that boys in the low parental educational attainment group had higher odds of smoking experimentation compared to those in the high parental educational attainment group. However, by 2006, this difference had disappeared. Further, in 1998, there was no difference in the odds of smoking experimentation among girls. However, by 2006, the odds of smoking experimentation were significantly higher among girls from the low compared to the high parental educational attainment group. In the second article (32), disparities in daily smoking prevalence across occupational social classes increased from 1991 to 2014.

The influence of friends smoking on smoking behavior was investigated in two articles. Wellman et al. (21,41) found that among children whose mothers had low education, the risk of smoking experimentation was higher when children had friends who smoked or when participants lived in a home without a smoking ban. In the second article (22), the

association between spending money and smoking experimentation and intention to smoke was weaker when more friends smoked.

Three social capital variables were investigated by Thorlindsson et al. who reported that household poverty was associated with daily smoking - the coefficient for this association declined across communities with increases in the level of three social capital factors (i.e., parental social closeness to neighbors and to their adolescent's friends, parental participation in the adolescent community, and adolescent sport participation (30).

Two articles examined country-level factors as moderators. Rathmann et al. (31) investigated the effect of educational differentiation (i.e. early and long tracking to different school types) in the association between family affluence, and both daily smoking and early smoking initiation. The results indicated that low SES girls had a lower likelihood of daily smoking and early smoking initiation in countries with higher levels of educational differentiation. However, no association was detected between educational differentiation and smoking behaviors in boys. Pförtner et al. (36) suggested that lower adolescent SES was associated with an increased risk of weekly smoking, and weekly smoking among former experimenters, in contexts of higher economic prosperity (as indicated by higher GDP per capita).

Itanyi et al.(28) found notable differences in smoking behaviors between students of different SES in urban and rural schools. Compared to students of low SES in urban schools, students of high SES in rural schools had higher odds of past-month cigarette smoking. Further, the odds of past-month smoking were higher in rural schools compared to urban schools among students of high compared to low SES.

Quality appraisal

Quality of reporting. The results of the quality analysis are reported in Appendix S1 (Table S1). The median number of STROBE items reported was 16. No article reported all 22 STROBE items (mean (SD) number of items reported=15.2 (3.1), range 6–19) (Figure 2). Common issues were failure to report information about: (i) the study design in the title and/or abstract (n=17); (ii) sources of data and method of assessment (n=12); (iii) statistical analyses (n=12); and (iv) providing unadjusted estimates (n=12).

Assessment of interaction and effect modification methodologies. Table 3 describes methodological approaches to interaction and effect modification analysis. Two of 23 (7%) articles did not state that investigating these was an objective, and did not provide empirical or theoretical support for the analysis (18,33). Two did not provide empirical or theoretical support for the analysis despite including these analyses as an objective (40,41). Logistic regression models were the most frequently used statistical models to assess interaction or effect modification (83%).

Distinguishing between effect modification and interaction. In 15 of the 23 articles, we identified that the effect of one exposure within the strata of another exposure was of interest (referred to as “effect modification” in Table 4). In the remaining eight papers the joint effects of two exposures was of interest, and we referred to this as “interaction” in Table 4.

In all 23 articles, the term “interaction” was used to refer to the analyses conducted. In nine, the terms “moderating effect”, “moderator” or “moderation” were also used (9,18,23,24,27,30,34,39,41). “Effect modifier “ was mentioned in two articles (9,28),

“subgroups” was used in two articles (19,29), and “stratified analysis” was referred to in two articles (23,32).

Reporting on additive and multiplicative scales. Table 4 describes reporting approaches in the included articles. The scale (i.e., additive or multiplicative) on which these effects were expressed statistically was specified in two articles (21,28). Of 17 articles reporting significant findings on interaction or effect modification, the effect on an additive scale using the relative excess risk (RERI) was estimated in one article (21).

Transparent reporting practices. The most frequent approach to reporting significant interaction or effect modification (8 of 17 articles, 54%) involved presentation of the estimates of each component of the interaction or effect modification factor, and estimation of the effect on a multiplicative scale (i.e., using a product term), its 95% confidence interval (CI) and its p value (9,22–24,31,35,36,39). Four articles (28%) also reported stratum-specific effect estimates with 95% CI (20,26,27,30) (Table 4). Only two articles (10%) reported estimates for each stratum of SES and the interaction or effect modification factor and joint effect estimates using one reference category (21,28), as recommended by VanderWeele and Knol (7). Two articles reported only a statement of statistical significance (19,29) and one article reported only p-values (40).

Among articles reporting no significant effect (n=5), three provided an estimate of the product term, 95% CI, and p-values (18,25,34), one article reported only a statement of non-statistical significance (33), and one article reported only p-values (41).

Controlling for confounding variables. In seven of the eight articles reporting significant interactions or effect modification, a single list of potential confounders was considered for both main exposures; no confounders were mentioned in one article (29).

DISCUSSION

This systematic review identified 23 articles investigating interaction and effect modification in the association between SES and smoking behavior among adolescents. Thirteen studies reported factors that modified the association including race/ethnicity, school-level SES, neighborhood SES, peer influence, and country-level factors. However, most studies focused on individual factors, such as race/ethnicity and gender, limiting broader understanding of the mechanisms driving social inequalities in smoking behavior. The limited range of factors studied, including understudied areas such as school environment and family dynamics, underscores the need for a more comprehensive approach to address the complex interplay between individual, familial, and environmental determinants.

Adherence to best practices, such as those outlined by VanderWeele and Knol, was limited. Only one article reported additive interactions using RERI, and just two studies provided estimates for SES and interaction factors using a single reference category. Additionally, inconsistent terminology between "interaction" and "effect modification" may increase confusion and undermine clarity. These gaps highlight the need for clearer methodological guidelines and consistent reporting practices to improve the validity and applicability of future research findings.

Socioeconomic status measures in the reviewed studies

The heterogeneity of variables used to describe SES underscores that SES is a complex multidimensional construct (42). SES encompasses both objective characteristics (e.g., income, occupation, education) and subjective self-ratings of placement within a socioeconomic spectrum (42). In the context of health, SES attempts to capture an individual's or group's access to the basic resources required to achieve and maintain good health (43). Consequently, a variety of single item and composite measures collected at

different levels (individual, household, neighborhood) have been developed to capture this complexity (44), raising the issue of which SES measure is best to use across which contexts. It seems unlikely that a single measure of SES is optimal across diverse contexts (45). The measure to be used will depend on the research question, the relevant theoretical underpinnings, and the assumptions. The existence of multiple SES measures may limit the feasibility of meta-analyses as in this review, and thus the ability to identify causal relationships between SES and adolescent smoking. It is noteworthy that the SES factors in this review were mostly family-related factors such as parental education and family income, omitting other important levels (e.g., neighborhood-related measures). In addition, SES was generally assessed using a single dimension, limiting consideration of its complexity. This could be due to the common practice in the broader literature of collecting SES data primarily as a potential confounder, rather than as a central focus of the study. Consequently, when SES is not the primary focus of a study, less consideration may be given to selecting comprehensive and appropriate SES measures (46). Based on explanatory pathways and mechanisms, researchers may need to consider measuring as many relevant SES characteristics as possible, and should systematically consider how important unmeasured SES characteristics may affect the findings.

Factors modifying the SES-smoking association

This review identified several factors that modify the SES-smoking association, with some supported by multiple studies. Race/ethnicity was significant in four of five articles (19,20,23), indicating that higher parental education provides less protection against smoking behaviors among Black, Hispanic, and Latino youth. Contextual factors, including school-level SES and neighborhood SES, were significant in one of the two articles that

investigated school-level SES and both articles that investigated them respectively, demonstrating the importance of environmental conditions in shaping smoking behaviors. For example, school-level SES influenced smoking differently among children from higher and lower SES families (35), while neighborhood SES affected smoking progression and weekly smoking (9), particularly among students experiencing household poverty. Similarly, peer smoking influences and time trends were significant in the two studies that examined them (21,41), highlighting the dynamic and evolving nature of smoking behaviors. Country-level factors, such as educational differentiation and economic prosperity (31), also emerged as significant moderators, underscoring the role of broader structural determinants in shaping the SES-smoking relationship. Although social capital and urban-rural differences were investigated in fewer studies (28), they also showed significant associations, suggesting their potential relevance for future research.

The small number of studies investigating factors such as school-level SES, neighborhood SES, peer influence, social capital, urban-rural differences, and country-level determinants highlights a gap in the literature. Despite the limited frequency, the consistent statistical significance across these studies underscores their critical role in modifying the SES-smoking relationship. These findings suggest that while these factors are underexplored, they may play a key role in shaping social inequalities in smoking behavior. Expanding future research to include these underexamined factors is crucial for developing a more comprehensive understanding of the mechanisms driving social inequalities in adolescent smoking behavior and designing tailored public health interventions.

Additionally, the review highlighted that race/ethnicity and gender/sex were the most frequently studied individual factors. However, focusing predominantly on these individual-level factors might obscure the role of broader factors in modifying the SES-smoking

relationship. Based on the World Health Organization's conceptual framework for action on the social determinants of health, the factors that might explain social inequalities in adolescent smoking behavior are currently poorly explored (8). For example, this framework categorized factors into structural (e.g., governance, culture and societal values, gender) and intermediary (e.g., psychosocial factors, living conditions, behavior) determinants of health inequalities. The lack of investigation into a diverse range of interaction or effect modification factors has important implications for understanding how both structural (e.g., societal values, gender) and intermediary (e.g., living conditions, behavior) determinants of health inequities influence the association between SES and smoking behavior in adolescents. Identifying a wider array of factors is essential because it helps pinpoint specific conditions under which social inequalities in smoking behavior are exacerbated or mitigated. These factors could then be leveraged in public health prevention programs to reduce social inequalities in smoking behavior among adolescents. Therefore, researchers should consider a broader set of factors in future studies to enrich the understanding of these associations.

Methodological practices in interaction or effect modification analysis

Distinguishing between effect modification and interaction. There is an important potential for improving methodological aspects of these analyses, ranging from use of correct terminology to methodological considerations. For example, use of "interaction" and "effect modification" interchangeably is a concern. The distinction is not merely conceptual, it has direct implications for identifying high-risk populations and guiding effective intervention strategies (7). Identifying effect modifiers helps target specific groups or contexts in which the relationship between SES and smoking behavior is stronger or weaker. For example, studies showed that race/ethnicity modified the protective effect of parental education

(19,20,23). In Bachman et al. (19), a clear inverse relationship between parental education and smoking prevalence was observed only among White adolescents, while the pattern was weaker and inconsistent among Black and Hispanic youth. In another study (23), higher parental education had a significantly smaller protective effect on lifetime and daily smoking for Hispanic (OR for interaction = 1.90, 95% CI: 1.10–3.30) and Black adolescents (OR for interaction= 1.24, 95% CI: 1.07–1.44), compared to Whites. These findings suggest that higher SES may not confer the same protective effects across racial and ethnic groups. In addition, neighborhood SES was also shown to moderate the association between household poverty and weekly smoking (37). This helps target interventions toward the most vulnerable groups or those likely to benefit the most. On the other hand, understanding interaction enables researchers to assess whether the joint impact of SES and another variable on smoking behavior is more or less than what would be expected based on individual effects (12). This is particularly useful for identifying intervention points when one factor is modifiable and the other is not. For example, one study found that modifiable contextual factors like peer smoking and household rules could intensify the effect of low maternal education on adolescent smoking, illustrating the value of identifying such joint influences (21).

Reporting on additive and multiplicative scales. Only one of the 18 articles reporting significant effects estimated RERI on the additive scale, although additive models are often more relevant for public health because they quantify absolute risk differences (7,47), which is crucial for targeting specific subgroups and allocating resources efficiently. While multiplicative models are easier to implement in standard software, they may understate the combined effect of exposures that are especially harmful when they co-occur. Broader adoption of additive interaction estimates, supported by readily available tools (e.g., RERI

calculators or Excel sheets) (48–50), would help better identify priority populations for SES-smoking interventions. In Wellman et al. (21) the joint effect of low maternal education and absence of a home smoking ban on youth smoking initiation exceeded the sum of their individual effects (RERI = 0.38; 95% CI: 0.19–0.74). From a public health perspective, such a positive interaction on the additive scale suggests that implementing home smoking restrictions may be particularly effective in this subgroup. This is especially useful in resource-limited settings, where interventions must be prioritized for maximum impact.

Controlling for confounding variables. When analyzing interaction effects and considering interventions on two exposures, it is necessary to control for confounding of both exposures, since each exposure may have different confounders (7). Our results revealed a lack of clear consideration of separate sets of confounders for interaction effects. This weakens interpretation and complicates the translation of findings into policy. For example, in an analysis of the interaction between SES and peer smoking, SES may be confounded by parental education, while peer smoking may be influenced by school climate. If separate sets of confounders are not specified and adjusted for, the validity of the observed interaction becomes uncertain. This can lead to biased estimates, particularly on the additive scale, resulting in over- or underestimation of the joint effect. In turn, public health decisions may be misinformed, and interventions based on such evidence may prove ineffective or misdirected.

Study design considerations. While effect modification and interaction analyses can be conducted using cross-sectional data, longitudinal designs over extended time periods offer distinct advantages when the goal is to assess how SES-smoking associations evolve over time and vary across contexts (51). Longitudinal data are particularly valuable for identifying periods when inequalities are most pronounced (e.g., the transition from early to late

adolescence) and for understanding how specific contextual factors, such as changes in peer smoking or the implementation of a home smoking ban, may mitigate these associations. Such insights can help identify when and for whom interventions may be most effective. Given that the majority of studies included in this review were cross-sectional, future research employing longitudinal designs could further elucidate which subgroups are most at risk under varying social environments, ultimately enhancing the timing and targeting of public health strategies.

Limitations

Limitations of this review include the inclusion of articles published between 2011 and 2021, excluding earlier articles that might have provided valuable historical perspectives on methodological evolution in the field. Furthermore, the inclusion of one article from 2011 means that it may not have followed methodological guidelines such as VanderWeele's, published in 2012, as these guidelines were not available at that time. Additionally, there was considerable variability in the sample sizes of included articles, ranging from 397 to 416,419 participants. This variability affects the statistical power to detect statistically significant effects, particularly in smaller studies. This highlights the importance of considering sample size and power in the interpretation of findings related to the analysis.

CONCLUSION

This review highlights numerous challenges in articling interaction or effect modification in the relationship between SES and adolescent smoking. The methodological limitations and reporting gaps identified suggest that there is an important need for improvement in this literature. The complexity and multidimensional nature of SES challenges comprehensive

meta-analyses. The focus on family-related SES factors underscores a gap in understanding broader determinants of adolescent smoking. Interaction or effect modification factors investigated (mainly race/ethnicity and gender/sex) reflect a narrow range of hypotheses explored, which has likely limited insights into the mechanisms driving social inequalities in adolescent smoking. Methodologically, there is room for improvement in defining and using terminology consistently, especially in distinguishing "interaction" and "effect modification." The underreporting of effects on the additive scale highlights a gap in understanding SES impacts on smoking behavior. Standardized reporting practices facilitated by publicly available tools can enhance clarity and precision in this literature.

REFERENCES

1. WHO report on the global tobacco epidemic 2021: addressing new and emerging products [Internet]. [cited 2023 May 2]. Available from: <https://www.who.int/publications-detail-redirect/9789240032095>
2. Hill S, Amos A, Clifford D, Platt S. Impact of tobacco control interventions on socioeconomic inequalities in smoking: review of the evidence. *Tob Control*. 2014 Nov;23(e2):e89-97.
3. Rasmussen M, Due P, Damsgaard MT, Holstein BE. Social inequality in adolescent daily smoking: has it changed over time? *Scand J Public Health*. 2009 May;37(3):287-94.
4. Park MJ, Scott JT, Adams SH, Brindis CD, Irwin CE. Adolescent and young adult health in the United States in the past decade: little improvement and young adults remain worse off than adolescents. *J Adolesc Health Off Publ Soc Adolesc Med*. 2014 Jul;55(1):3-16.
5. de Looze M, ter Bogt T, Hublet A, Kuntsche E, Richter M, Zsiros E, et al. Trends in educational differences in adolescent daily smoking across Europe, 2002-10. *Eur J Public Health*. 2013 Oct;23(5):846-52.
6. VanderWeele TJ. Explanation in causal inference: developments in mediation and interaction. *Int J Epidemiol*. 2016 Dec;45(6):1904-8.
7. VanderWeele TJ, Knol MJ. A Tutorial on Interaction. *Epidemiol Methods*. 2014 Dec 1;3(1):33-72.
8. A Conceptual Framework for Action on the Social Determinants of Health [Internet]. [cited 2023 Nov 6]. Available from: <https://www.who.int/publications-detail-redirect/9789241500852>
9. Mathur C, Erickson DJ, Stigler MH, Forster JL, Finnegan JR. Individual and Neighborhood Socioeconomic Status Effects on Adolescent Smoking: A Multilevel Cohort-Sequential Latent Growth Analysis. *Am J Public Health*. 2013 Mar;103(3):543-8.
10. Health NC for CDP and HP (US) O on S and. Social, Environmental, Cognitive, and Genetic Influences on the Use of Tobacco Among Youth [Internet]. Preventing Tobacco Use Among Youth and Young Adults: A Report of the Surgeon General. Centers for Disease Control and Prevention (US); 2012 [cited 2021 May 8]. Available from: <http://www.ncbi.nlm.nih.gov/books/NBK99236/>
11. Nowlin PR, Colder CR. The role of ethnicity and neighborhood poverty on the relationship between parenting and adolescent cigarette use. *Nicotine Tob Res Off J Soc Res Nicotine Tob*. 2007 May;9(5):545-56.
12. VanderWeele TJ. On the distinction between interaction and effect modification. *Epidemiol Camb Mass*. 2009 Nov;20(6):863-71.
13. Schiavo JH. PROSPERO: An International Register of Systematic Review Protocols. *Med Ref Serv Q*. 2019;38(2):171-80.

14. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021 Mar 29;372:n71.
15. Adolescent health [Internet]. [cited 2024 Jul 12]. Available from: <https://www.who.int/health-topics/adolescent-health>
16. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: Guidelines for reporting observational studies. *Prev Med*. 2007 Oct 1;45(4):247–51.
17. Knol MJ, VanderWeele TJ. Recommendations for presenting analyses of effect modification and interaction. *Int J Epidemiol*. 2012 Apr;41(2):514–20.
18. Ashraf Nazir M, Almas K. Awareness about the effects of tobacco consumption on oral health and the possibility of smoking behavior among male Saudi schoolchildren. *Eur J Dent*. 2017 Jan;11(01):029–35.
19. Bachman JG, O'Malley PM, Johnston LD, Schulenberg JE, Wallace JM. Racial/Ethnic Differences in the Relationship Between Parental Education and Substance Use Among U.S. 8th-, 10th-, and 12th-Grade Students: Findings From the Monitoring the Future Project. *J Stud Alcohol Drugs*. 2011 Mar;72(2):279–85.
20. Epperson AE, Gonzalez M, Skorek M, Song AV. Challenging Assumptions About Race/Ethnicity, Socioeconomic Status, and Cigarette Smoking Among Adolescents. *J Racial Ethn Health Disparities*. 2022 Apr;9(2):436–43.
21. Wellman RJ, Sylvestre MP, O'Loughlin EK, Dutczak H, Montreuil A, Datta GD, et al. Socioeconomic status is associated with the prevalence and co-occurrence of risk factors for cigarette smoking initiation during adolescence. *Int J Public Health*. 2018 Jan;63(1):125–36.
22. Bergenwall AL, Kelloway EK, Barling J. Odd Jobs, Bad Habits, and Ethical Implications: Smoking-Related Outcomes of Children's Early Employment Intensity. *J Bus Ethics*. 2014 Jun;122(2):269–82.
23. Assari S, Mistry R, Caldwell CH, Bazargan M. Protective Effects of Parental Education Against Youth Cigarette Smoking: Diminished Returns of Blacks and Hispanics. *Adolesc Health Med Ther*. 2020;11:63–71.
24. Assari S, Boyce S, Caldwell CH, Bazargan M. Parent Education and Future Transition to Cigarette Smoking: Latinos' Diminished Returns. *Front Pediatr*. 2020;8:457.
25. Shackleton N, Allen E, Bevilacqua L, Viner R, Bonell C. Associations between socio-economic status (including school- and pupil-level interactions) and student perceptions of school environment and health in English secondary schools. *Br Educ Res J*. 2018 Oct;44(5):748–62.
26. Pitel L, Madarasova Geckova A, Reijneveld SA, van Dijk JP. Socioeconomic gradient shifts in health-related behaviour among Slovak adolescents between 1998 and 2006. *Int J Public Health*. 2013 Apr;58(2):171–6.

27. Desai R, Mercken LAG, Ruiter RAC, Schepers J, Reddy PS. Cigarette smoking and reasons for leaving school among school dropouts in South Africa. *BMC Public Health*. 2019 Dec;19(1):130.
28. Itanyi I, Onwasigwe C, Ossip D, Uzochukwu B, McIntosh S, Aguwa E, et al. Predictors of current tobacco smoking by adolescents in Nigeria: Interaction between school location and socioeconomic status. *Tob Induc Dis* [Internet]. 2020 Mar 3 [cited 2022 Mar 10];18(March). Available from: <http://www.journalssystem.com/tid/Predictors-of-current-tobacco-smoking-by-adolescents-in-Nigeria-interaction-between,117959,0,2.html>
29. Moon SS, Boyas J, Kim YK. Using a classification tree modeling approach to predict cigarette use among adolescents in the United States. *Subst Use Misuse*. 2020;55(1):12–22.
30. Thorlindsson T, Valdimarsdottir M, Jonsson S. Community social structure, social capital and adolescent smoking: A multi-level analysis. *Health PLACE*. 2012 Jul;18(4):796–804.
31. Rathmann K, Moor I, Kunst A, Dragano N, Pfortner T, Elgar F, et al. Is educational differentiation associated with smoking and smoking inequalities in adolescence? A multilevel analysis across 27 European and North American countries. *Sociol Health Illn*. 2016 Sep;38(7):1005–25.
32. Holstein BE, Andersen A, Damsgaard MT, Due P, Bast LS, Rasmussen M. Trends in socioeconomic differences in daily smoking among 15-year-old Danes 1991-2014. *Scand J Public Health*. 2020 Aug;48(6):667–73.
33. Moor I, Kuipers MAG, Lorant V, Pfortner TK, Kinnunen JM, Rathmann K, et al. Inequalities in adolescent self-rated health and smoking in Europe: comparing different indicators of socioeconomic status. *J Epidemiol Community Health*. 2019 Oct;73(10):963–70.
34. Yáñez AM, Leiva A, Estela A, Čukić I. The associations of personality traits and parental education with smoking behaviour among adolescents. Verdejo-García A, editor. *PLOS ONE*. 2017 Mar 23;12(3):e0174211.
35. Moore GF, Littlecott HJ. School- and Family-Level Socioeconomic Status and Health Behaviors: Multilevel Analysis of a National Survey in Wales, United Kingdom. *J Sch Health*. 2015 Apr;85(4):267–75.
36. Pfortner TK, Moor I, Rathmann K, Hublet A, Molcho M, Kunst AE, et al. The association between family affluence and smoking among 15-year-old adolescents in 33 European countries, Israel and Canada: the role of national wealth. *Addict Abingdon Engl*. 2015 Jan;110(1):162–73.
37. Denny S, Lewycka S, Utter J, Fleming T, Peiris-John R, Sheridan J, et al. The association between socioeconomic deprivation and secondary school students' health: findings from a latent class analysis of a national adolescent health survey. *Int J EQUITY Health*. 2016 Jul 16;15.
38. Cremers H, Oenema A, Mercken L, Candel M, de Vries H. Explaining socio-economic differences in intention to smoke among primary school children. *BMC PUBLIC Health*. 2014 Feb 21;14.

39. Assari S, Caldwell CH, Bazargan M. Association Between Parental Educational Attainment and Youth Outcomes and Role of Race/Ethnicity. *JAMA Netw Open*. 2019 Nov 22;2(11):e1916018.
40. Denny S, Lewycka S, Utter J, Fleming T, Peiris-John R, Sheridan J, et al. The association between socioeconomic deprivation and secondary school students' health: findings from a latent class analysis of a national adolescent health survey. *Int J Equity Health*. 2016 Dec;15(1):109.
41. Cremers HP, Oenema A, Mercken L, Candel M, de Vries H. Explaining socio-economic differences in intention to smoke among primary school children. *BMC Public Health*. 2014 Dec;14(1):191.
42. Navarro-Carrillo G, Alonso-Ferres M, Moya M, Valor-Segura I. Socioeconomic Status and Psychological Well-Being: Revisiting the Role of Subjective Socioeconomic Status. *Front Psychol* [Internet]. 2020 [cited 2023 Oct 27];11. Available from: <https://www.frontiersin.org/articles/10.3389/fpsyg.2020.01303>
43. Shavers VL. Measurement of socioeconomic status in health disparities research. *J Natl Med Assoc*. 2007 Sep;99(9):1013–23.
44. Conway DI, McMahon AD, Brown D, Leyland AH. Measuring socioeconomic status and inequalities. In: Vaccarella S, Lortet-Tieulent J, Saracci R, Conway DI, Straif K, Wild CP, editors. *Reducing social inequalities in cancer: evidence and priorities for research* [Internet]. Lyon (FR): International Agency for Research on Cancer; 2019 [cited 2023 Nov 6]. (IARC Scientific Publications). Available from: <http://www.ncbi.nlm.nih.gov/books/NBK566205/>
45. Fotso JC, Kuate-Defo B. Measuring socioeconomic status in health research in developing countries: Should we be focusing on households, communities or both? *Soc Indic Res*. 2005 Jun 1;72(2):189–237.
46. Braveman PA, Cubbin C, Egerter S, Chideya S, Marchi KS, Metzler M, et al. Socioeconomic Status in Health Research One Size Does Not Fit All. *JAMA*. 2005 Dec 14;294(22):2879–88.
47. Rothman KJ, Greenland S, Walker AM. Concepts of interaction. *Am J Epidemiol*. 1980 Oct;112(4):467–70.
48. Alli BY. InteractionR: An R package for full reporting of effect modification and interaction. *Softw Impacts*. 2021 Nov 1;10:100147.
49. Lundberg M, Fredlund P, Hallqvist J, Diderichsen F. A SAS program calculating three measures of interaction with confidence intervals. *Epidemiol Camb Mass*. 1996 Nov;7(6):655–6.
50. Andersson T, Alfredsson L, Källberg H, Zdravkovic S, Ahlbom A. Calculating measures of biological interaction. *Eur J Epidemiol*. 2005;20(7):575–9.
51. Caemmerer JM, Hennessy B, Niileksela CR. Third variables in longitudinal research: Application of longitudinal mediation and moderation in school psychology. *J Sch Psychol*. 2024 Apr 1;103:101283.

Figure 1: Flow diagram representing the process of identifying papers eligible for the systematic review of analytic approaches used in moderation analyses

Figure 2. Percent of all articles included in the systematic review (n = 23) reporting each item of the STROBE checklist

Note: **Q1:** (a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found. **Q2:** Explain the scientific background and rationale for the investigation being reported. **Q3:** State specific objectives, including any prespecified hypotheses. **Q4:** Present key elements of study design early in the paper. **Q5:** Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection. **Q6:** Give the eligibility criteria, and the sources and methods of selection of participants. **Q7:** Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable. **Q8:** For each variable of interest, give sources of data and details of methods of assessment (measurement). **Q9:** Describe any efforts to address potential sources of bias. **Q10:** Explain how the study size was estimated. **Q11:** Explain how quantitative variables were handled in the analysis. If applicable, describe which groupings were chosen and why. **Q12:** (a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) Cohort study—If applicable, explain how loss to follow-up was addressed **Q13:** (a) Report numbers of individuals at each stage of study—e.g. numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analyzed (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram. **Q14:** (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest. **Q15:** Report numbers of outcome events or summary measures. **Q16:** (a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period. **Q17:** Report other analyses done—e.g. analyses of subgroups and interactions, and sensitivity analyses. **Q18:** Summarize key results with reference to study objectives. **Q19:** Discuss limitations of the study, considering sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias. **Q20:** Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence. **Q21:** Discuss the generalizability (external validity) of the study results. **Q22:** Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based.

Table 1: Study characteristics of 23 studies included in the systematic review of analytic approaches used in moderation analyses

1st author/ Year of publication	Journal	Country	Study design	Sample size	Age (year)	inter	Ethnicity
Desai 2019	BMC Public Health	South Africa	cross-sectional	4,185	Mean:17.4 (SD 1.6)	Male 58% Female 42%	Black African 72.5% colored 21.8% Indian 1.7% White 1.4% other 2.6%
Epperson 2021	Journal of Racial and Ethnic Health Disparities	USA	cross-sectional	12,474	Range: 12-17	Not mentioned	American Indian/Alaska Native 0.7% Asian 5.9% Black 14% Hispanic 25.4% White 54%
Shackleton 2018	British Educational Research Journal	UK	cross-sectional	6,667	Range: 10-13 Mean: 11.76	Male 47% Female 53%	Not mentioned
Assari 2019	JAMA Network Open	USA	cross-sectional	10,619	Range: 12-17	Male 52% Female 48%	Non-Hispanic 77.6% Hispanic 22.4%
Nazir 2017	European journal of dentistry	Saudi Arabia	cross-sectional	397	Range: 15-19	Male 100%	Not mentioned
Thorlindsson 2012	Health & Place	Iceland	cross-sectional	6,590	Range: 15-16	Not mentioned	Not mentioned
Assari 2020	Frontiers in Pediatrics	USA	longitudinal	5,021	Range: 12-17	Male 50.8% Female 49.2%	Non-Latino 69.7% vs Latino 30.3% White 79.8% vs African American 20,2%
Cremers 2014	BMC Public health	The Netherlands	cross-sectional	2,612	Range:10-11 Mean:10.35	Male 46.6% Female 53.4%	Western ethnic background 87.1% Non-Western ethnic background 12.9%

Mathur 2013	Am J Public Health	USA	longitudinal	3,635	Range:12-16	Male 49.2% Female 50.8%	White 85.2% African American 5.0% American Indian 2.5% Hispanic or Latino 2.3% Asian 2.4% other 2.6%
Moor 2019	Journal of epidemiology and community health	Europe (The Netherlands, Portugal, Germany, Italy, Belgium, Finland)	cross-sectional	10,900	Range:12-19	Male 48.0% Female 52.0%	Not mentioned
Rathmann 2016	Sociology of health and illness	27 European and North American countries	cross-sectional	48,025	15	Male 47.9% Female 52.1%	Not mentioned
Bachman 2011	Journal of Studies on Alcohol and Drugs	USA	repeated cross-sectional	416,419	Not mentioned Grades 8, 10, and 12.	Not mentioned	According to grade white: 61.2-67.7% African American: 11.9-13.3% Hispanic: 11.2-12.7% Asian: 3.2-3.9% other: 5.4-9.1%
Yáñez 2017	PLoS One	Spain	cross-sectional	842	Range: 14-15 Mean: 14.6 (SD 0.6)	Males 45.5% Female 54.5%	Not mentioned
Pitel 2013	International journal of public health	Slovakia	Repeated cross-sectional	2,616 in 1998 and 1,081 in 2006	<u>1998</u> Range :13.7-17.5 Mean:14.8 <u>2006</u> Range:13.09-16.83 Mean:14.33	<u>1998</u> Male 52.4% Female 47.6% <u>2006</u> Male 47% Female 53%	Not mentioned
Assari 2020	Adolesc Health Medicine and Therapeutics	USA	cross-sectional	10,878	Range:12-17	Male 51.7% female 48.3%	Non-Hispanic White 60.63% Hispanic White 20.66% Non-Hispanic Black 16.86%

							Hispanic Black 1.85%
Itanyi 2020	Tobacco included diseases	Nigeria	cross-sectional	4,332	Range :10-19	Males 43.7% Females 56.3%	Not mentioned
Wellman 2017	International journal of public health	Canada	longitudinal	1,451	Mean:10.7	Male 44% Female 56%	Not mentioned
Denny 2016	International journal of equity in health	New Zealand	cross-sectional	8,500	Range:13-17	Male 45.7% Female 54.3%	Asian 12.43% Māori 20.0% Pacific 14.3% European 47.3% Other 6%
Holstein 2019	Scandinavian Journal of Public Health	Denmark	repeated cross-sectional	8,641	15	Male 48.8% Female 51.2%	Not mentioned
Moon 2019	Substance use and misuse	USA	cross-sectional	3,717	Range:12-19	Male 53.3% Female 46.6%	Non-Hispanic White 59.9% African American 8.8% American Indian Alaska Native 2.7% Asian 2.4% Latinx/hispanic 20.0% Other 6%
Bergenwall 2014	Journal of Business Ethics	Canada	cross-sectional	19,018	Range: 10-15	Males 50.1% Female 49.9%	Not mentioned
Pförtner 2014	Addiction	33 European countries, Israel, and Canada	cross-sectional	60,490	15	Not mentioned	Not mentioned
Moore 2015	Journal of school health	UK	cross-sectional	9,194	Range: 11-16	Males 50.2% Females 49.8%	Not mentioned

Table 2: Exposure, outcomes and moderation factors investigated in 23 studies included in the systematic review of analytic approaches used in moderation analyses

1st author/ Year of publication	Exposure		Outcome		Moderation factor		
	SES factor considered	Measurement of SES factor	Smoking behavior considered	Measurement of smoking behavior	Moderation factor considered	Measurement of moderation factor	Association with smoking behavior
Desai 2019	Reasons for leaving school: not enough money to pay school fees/ working to support the family	Self-reported questionnaire by adolescents	<u>Past month cigarette smoking status</u> : non-smokers (smoked 0 days) and smokers (smoked 1–30 days)	Self-reported questionnaire by adolescents	-Gender -Gender* residence area (urban/rural)	Self-reported questionnaire by adolescents	-No association -Leaving school due to not having enough money to pay for school fees was associated with less past month cigarette smoking, but only among girls living in urban areas
Epperson 2021	Family income	Not mentioned	<u>Experimentation</u> : ever smoked part or all a cigarette	Self-reported questionnaire by adolescents	Race/ Ethnicity	Self-reported questionnaire by adolescents	No association
Shackleton 2018	Family affluence	Validated questionnaire reported by adolescents: the Family Affluence Scale	<u>Experimentation</u> : ever having smoked	Self-reported questionnaire by adolescents	School level socioeconomic status: Free School Meal	Government data on the percentage of pupils within each secondary school eligible for free school meals	No association
Assari 2019	Parental educational attainment	Self-reported questionnaire by parents	<u>Tobacco dependence</u>	Standard measure used to model tobacco dependence in youth, self-reported by adolescents	Race Ethnicity	Self-reported questionnaire by adolescents	Race: No association Ethnicity: Interactions were significant between Hispanic ethnicity and education on tobacco dependence → the protective effect of high parental educational attainment on youth development might be systemically smaller for Hispanic than for non-

							Hispanic youth.
Nazir 2017	- Family income - Father's educational attainment	Self-reported questionnaire by adolescents	Not clearly defined "smoking habit"	Self-reported questionnaire by adolescents	Academic grades	Self-reported questionnaire by adolescents	No associations
Thorlindsson 2012	Household poverty	Self-reported questionnaire by adolescents	<u>Daily smoking status:</u> Daily smoker if a respondent smoked at least one cigarette daily	Self-reported questionnaire by adolescents	-Parental social closure -Parental participation in the adolescent community -Adolescent sport participation	Self-reported questionnaire by adolescents	Household poverty increases the likelihood of daily smoking, but the coefficient for poverty declines significantly across communities according to the level of social closure, parental participation, and organized sport participation (low level → high level)
Assari 2020	Parental educational attainment	Self-reported questionnaire by adolescents	<u>Experimentation:</u> ever try cigarette smoking <u>Past month cigarette smoking status:</u> smoked one or more days <u>Daily smoking status:</u> smoked every day in the last month	Self-reported questionnaire by adolescents	Race/Ethnicity	Self-reported questionnaire by adolescents	-Higher parent education has a smaller protective effect on youth tobacco use outcomes for Black and Hispanic than non-Hispanic White families
Cremers 2014	SES of the neighborhood	index score based on the indicated postal code in a self-reported questionnaire by adolescents	<u>Intention to smoke:</u> intended to start smoking anytime in the future/would never start smoking in the future	Self-reported questionnaire by adolescents	Gender	Self-reported questionnaire by adolescents	No association
Mathur 2013	Individual SES: Parental	Phone interview with adolescents	<u>Smoking progression:</u> 6	Self-reported questionnaire by adolescents	Neighborhood socioeconomic	questionnaire/phone interview with	Among higher SES neighborhood participants,

	educational attainment		categories representing increasing levels of smoking (1 = never smoker, 2 = trier, 3 = less than a monthly smoker, 4 = experimental smoker, 5 = regular smoker, 6 = established smoker).	adolescents	status: combined multiple indicators from the US Census 2000 database to create a measure	adolescents	smoking stage increased more over time among the lower individual SES group than among the higher individual SES group. In addition, among the lower neighborhood SES participants, smoking stage increased more over time among the lower individual SES group than among the higher individual SES group.
Moor 2019	- Parental educational attainment - Family affluence - Subjective social status - Adolescent academic performance - Adolescent Pocket money	Self-reported questionnaire by adolescents (validated questionnaire for family affluence scale and subjective social status)	<u>Smoking status:</u> never smoking/ less than weekly smoking/ at least weekly smoking	Self-reported questionnaire by adolescents	Gender Age	Self-reported questionnaire by adolescents	No associations
Rathmann 2016	Family affluence	Validated questionnaire reported by adolescents: the Family Affluence Scale	<u>Daily smoking status:</u> Adolescents who smoke every day were considered as daily smokers <u>Early smoking initiation:</u> early smokers' if age of smoking initiation is lower than the	Self-reported questionnaire by adolescents	Countries educational differentiation index (i.e. early and long tracking to different school types)	Van de Werfhorst index	Low affluent girls reveal lower likelihoods of daily smoking in countries with higher levels of educational differentiation. Low affluent girls reveal lower likelihoods of early smoking initiation in countries with higher levels of educational differentiation No significant association could be observed for

			median within the country				inequalities in daily smoking and early smoking initiation for boys.
Bachman 2011	Parental educational attainment	Self-reported questionnaires by adolescents	<u>Past month cigarette smoking status</u> : Any use of cigarettes during the past 30 days	Self-reported questionnaire by adolescents	Racial/ethnic group	Self-reported questionnaire by adolescents	Only among White students a clear negative relations appear between parental education levels and smoking
Yáñez 2017	Parental educational attainment	Not mentioned	<u>Smoking status</u> : never smokers/ triers/ regular smokers	Self-reported validated questionnaire by adolescents	Adolescents' personality traits: -Openness -Conscientiousness -Extraversion -Agreeableness -Instability	Validated questionnaire reported by adolescents: The big five questionnaire for children	No associations
Pitel 2013	Parental educational attainment	Self-reported questionnaires by adolescents	<u>Experimentation</u> : ever try cigarette smoking	Self-reported questionnaire by adolescents	Time period:1998-2006	NA	In 1998 boys from the low SE group had statistically significant higher odds compared to those from the high SE group and this difference had disappeared in 2006. In 1998, no difference in the odds of girls, while in 2006 the odds of girls from the low SE group were significantly higher when compared with the high SE group.
Assari 2020	Parental educational attainment	Audio computer-assisted self-interviewing system	<u>Experimentation</u> : ever try cigarette smoking <u>Past month cigarette smoking status</u> : smoked over the past 30 days (current	Audio computer-assisted self-interviewing system	Ethnicity	Audio computer-assisted self-interviewing system	A higher parent education has a smaller protective effect on youth tobacco use outcomes (ever smoker and current smokers) for Latino than non-Latino youth

			smokers)				
Itanyi 2020	Parental educational attainment	Self-reported questionnaires by adolescents	<u>Past month cigarette smoking status</u> : use on one or more days within past 30 days	Self-reported questionnaire by adolescents	School location(urban/rural)	Self-reported questionnaire by adolescents	Compared to students of low SES in urban schools, students of high SES in rural schools had higher odds of being current cigarette smokers; The odds of current smoking in rural compared to urban schools were much higher for students of high SES compared to students of low SES. Conversely, in urban schools, students of high SES had lower odds of being current smokers although not statistically significant while in rural schools, high SES increased the odds of smoking.
Wellman 2017	- SES of the neighborhood - Maternal education level (high, moderate or low)	Material deprivation index calculated based on postal code indicated in a self-reported questionnaire by adolescents	<u>Experimentation</u> : ever tried cigarette smoking	Self-reported questionnaire by adolescents	13 smoking risk factor: father's, mother's, siblings' and friends' smoking; home smoking ban; having smokers in the home; smoking in cars; perceived low academic performance; susceptibility to smoking; depressive symptoms; low self-esteem; feeling disconnected from school; and use of non-cigarette	Self-reported questionnaire by adolescents	-No association -Two significant positive additive interactions suggest an excess risk of initiation associated with low maternal education. Among children whose mothers had low education, excess risk of initiation was conferred by also having friends who smoked or by living in a home without a smoking ban

					tobacco products		
Denny 2016	Household deprivation (deprivation profiles)	Audio computer-assisted self-interviewing on internet tablets with adolescents: profiles were created of the following variables: household deprivation, Parents worry about having enough money for food, More than 2 people per bedroom, No family holiday in last 12 months, Moved homes 2 or more times in the last 12 months, Living room or garage used as bedrooms, No parent at home with full-time employment	<u>weekly smoking:</u> smoking at least weekly at present	no details (survey)	Level of socioeconomic deprivation of neighborhoods: the New Zealand 2013 Deprivation Index	Audio computer-assisted self-interviewing on internet tablets	Students experiencing household poverty were more likely to report weekly cigarette smoking if they lived in more affluent neighbourhoods; For students not experiencing household poverty there was no clear relationship between their weekly cigarette smoking and level of socioeconomic deprivation of their neighbourhood.
Holstein 2019	Parents' occupational social class	Validated questionnaire reported by adolescents: standardized HBSC	<u>Daily smoking status:</u> every day/ not every day	Self-reported question by adolescents from the internationally standardized HBSC questionnaire	Survey year	NA	The statistical interaction between parents' occupational social class and survey year was significant, which suggests the relative socioeconomic differences

		questionnaire					increased from 1991 to 2014
Moon 2019	Household income	In-person question with adolescents via a computer-assisted interview module	<u>Past month cigarette smoking status</u> : smoking at least part of a cigarette in the past month	In-person question via a computer-assisted interview module	Gender Age Race/Ethnicity Alcohol abuse/Dependence Depression	In-person question via a computer-assisted interview module	Family income intersected with age, race/ethnicity, and mental health. The most vulnerable group with the highest odds of using cigarettes was the group aged between 16 and 17 years among non-Hispanic White, American Indian/Alaska Native, with higher depression scores.
Bergenwall 2014	Weekly spending money	Self-reported question by adolescents	<u>Experimentation</u> : ever tried cigarette smoking <u>Intention to smoke</u> : ever seriously thought about trying smoking	Self-reported question by adolescents	- Number of smoking parents - Proportion of smoking friends	Self-reported question by adolescents	-No association - The relationship between spending money and smoking behavior (experimentation and intention) was weaker when more of the friends smoked, suggesting that children are less likely to spend their money on cigarettes when their friends smoke.
Pförtner 2014	Family affluence	Validated questionnaire reported by adolescents: the Family Affluence Scale	<u>Weekly smoking</u> : smoking at least weekly at present <u>Early smoking initiation</u> : having smoked a cigarette before age 13 <u>Weekly smoking among former experimenters</u> : currently smoke at least weekly/	Three Self-reported questions by adolescents from the internationally standardized HBSC questionnaire	GDP per capita	World Bank database	The risk of smoking weekly at present for less affluent adolescents rose on average by 0.5%, with a rise of GDP per capita by 1000 international dollars in PPP. A similar cross-level interaction was found for risks of smoking by family affluence among smoking experimenters and was less strong for early smoking behaviour.

			currently smoke less than weekly or not smoke at all				
Moore 2015	Family affluence	Validated questionnaire reported by adolescents: the Family Affluence Scale	<u>Smoking status:</u> smoker (“every day,” “at least once a week,” “less than once a week,”) or non-smokers (“I don’t smoke.”)	Self-reported question by adolescents from the internationally standardized HBSC questionnaire	School level socioeconomic status: Free School Meal	Government data on the percentage of pupils within each secondary school eligible for free school meals	Among children from poorer families, smoking levels are similar regardless of school affluence, whereas for children from more affluent families, smoking is less likely if attending a more affluent school

Table 3: Reporting on moderation analysis in 23 studies included in the systematic review of analytic approaches used in moderation analyses

1st author/ Year of publication	Terms used to describe moderation	Moderation stated as one of the objectives of the study	Empirical or theoretical support for the moderation	Statistical model used to evaluate the moderation	Measures of Fit for the statistical model	Scale on which moderation effect was statistically expressed
Desai 2019	Moderating effect Interaction	Yes	Explicitly mentioned	Logistic regression models	No	Not mentioned
Epperson 2021	Intersection Interaction	Yes	Explicitly mentioned	Logistic regression models	No	Not mentioned
Shackleton 2018	Interaction	Yes	Explicitly mentioned	Multilevel logistic regression models	No	Not mentioned
Assari 2019	Interaction Moderator	Yes	Explicitly mentioned	Binary logistic regression models	No	Not mentioned
Nazir 2017	Interaction Moderation	No	Not mentioned	Logistic regression models	No	Not mentioned
Thorlindsson 2012	Interaction Moderation	Yes	Explicitly mentioned	Hierarchical regression models	No	Not mentioned
Assari 2020	Interaction Moderator	Yes	Explicitly mentioned	Logistic regression models	No	Not mentioned
Cremers 2014	Interaction Moderator	Yes	Not mentioned	Linear and logistic regression models	No	Not mentioned
Mathur 2013	Interaction, Effect modifier Moderator	Yes	Explicitly mentioned	Multiple group, multiple cohort latent growth models	No	Not mentioned
Moor 2019	Interaction	No	Not mentioned	Logistic regression models	No	Not mentioned
Rathmann 2016	Interaction	Yes	Explicitly mentioned	Multilevel logistic regression models	No	Not mentioned
Bachman 2011	Interaction Subgroups	Yes	Explicitly mentioned	Linear regression models	No	Not mentioned
Yáñez 2017	Interaction Moderation	Yes	Explicitly mentioned	Logistic regression models	No	Not mentioned
Pitel 2013	Interaction	Yes	Explicitly mentioned	Logistic regression models	No	Not mentioned
Assari	Interaction	Yes	Explicitly mentioned	Logistic regression	Yes	Not mentioned

2020	Moderator Stratified analysis			models		
Itanyi 2020	Interaction Effect modifier	Yes	Explicitly mentioned	Multilevel mixed effects logistic regression models	Yes	Multiplicative scale (Notes of tables)
Wellman 2017	Interaction	Yes	Explicitly mentioned	Generalized linear models (Poisson regression)	No	Additive scale (Methods and results)
Denny 2016	Cross-level interaction	Yes	Not mentioned	Cross-classified multilevel logistic models	No	Not mentioned
Holstein 2019	Interaction Stratified analysis	Yes	Explicitly mentioned	Logistic regression models	No	Not mentioned
Moon 2019	Interaction Subgroups	Yes	Explicitly mentioned	Classification and regression tree (CART) analyses	No	Not mentioned
Bergenwall 2014	Interaction	Yes	Explicitly mentioned	Logistic regression models	No	Not mentioned
Pförtner 2014	Interaction	yes	Explicitly mentioned	Logistic regression models	No	Not mentioned
Moore 2015	Interaction	Yes	Explicitly mentioned	Logistic regression models	No	Not mentioned

Table 4: Different levels of reporting on moderation in 23 studies included in the systematic review of analytic approaches used in moderation analyses

1st author/ Year of publication	Moderation effect evaluated	Estimates of the effect of the exposure on the outcome	Estimates of the effect of the moderation factor on the outcome	Confounders for the association between the exposure and the outcome	Confounders for the association between the moderation factor and the outcome	Measures of moderation effect on additive scale	Measures of moderation effect on multiplicative scale	Estimates of exposure on outcome/ moderation factor on outcome, with the stratum of lowest risk as the reference	Joint effect estimates (exposure and moderation factor on outcome) with the stratum of lowest risk as the reference	Stratum effect	Level of reporting
Desai 2019	Effect modifier										
	Not enough money to pay for school fees*gender on past month cigarette smoking	Yes: No significant association	Yes: significant association	Yes	NA	No	Estimate of the product term, 95% CI and p values: no significant interaction	No	No	No	Product term not significant
	Effect modifier										
	Working to help family*gender on past	Yes: No significant association	Yes: significant association	Yes	NA	No	Estimate of the product term, 95% CI and p values:	No	No	No	Product term not significant

	month cigarette smoking						no significant interaction				
	Effect modifier										
	Not enough money to pay for school fees* area*gend er	Yes: significant association	Yes: significant association	Yes	NA	No	Estimate of the product term, 95% CI and p values: significant interaction	No	No	Yes	Measure of moderation effect on multiplicative scale with CIs and P-values + Stratum- specific effect estimates with 95% CI and P- values
Epperson 2021	Effect modifier	Yes: significant association	Yes: significant association	Yes	NA	No	Estimate of the product term and 95% CI: significant interaction	No	No	Yes: no significant association	Measure of moderation effect on multiplicative scale with CIs and P-values + + Stratum- specific effect estimates with 95% CI
Shackleton 2018	Interaction	Yes: No significant association	Yes: No significant association	Yes: one list of confounder s	Yes: one list of confounders	No	Estimate of the product term, 95% CI: no significant	No	No	No	Product term not significant

Assari 2019	Effect modifier	Yes: significant association	Yes: significant association	Yes	NA	No	interaction Estimate of the product term, 95% CI and p values: significant interaction	No	No	No	Individual estimates+ Measure of moderation effect on multiplicative scale with CIs and P-values
Nazir 2017	Effect modifier	Yes: no significant association	Yes: significant association	No	NA	No	Estimate of the product term and 95% CI: no significant interaction	No	No	No	Product term not significant
Thorlindsson 2012	Effect modifier	Yes: significant association	Yes: significant association	Yes	NA	No	Estimate of the product term and p values: significant interaction	NA SES and moderation factor are continuous	NA SES and moderation factor are continuous	Yes	Measure of moderation effect on multiplicative scale with CIs and P-values + Stratum-specific effect estimates with 95% CI

Assari 2020	Effect modifier	Parental educational attainment *ethnicity on experimentation	Yes: significant associations	Yes: significant associations	Yes	NA	No	Estimate of the product term, 95% CI: and p values: significant interaction	No	No	No	Individual estimates+ Measure of moderation effect on multiplicative scale with CIs and P-values
	Effect modifier	Parental educational attainment *ethnicity on current smoker	Yes: No significant associations	Yes: significant associations	Yes	NA	No	Estimate of the product term, 95% CI: and p values: significant interaction	No	No	No	Individual estimates+ Measure of moderation effect on multiplicative scale with CIs and P-values
Creemers 2014	Effect modifier		Yes: significant association	No	yes	NA	No	P value: No significant interaction	No	No	No	Only descriptive with statistical significance
Mathur 2013	Interaction		Yes: significant association	Yes: significant association	Yes: one list of confounders	Yes: one list of confounders	No	Estimate of the product term and p values: significant	No	No	only figure with estimates of growth factors	Individual estimates+ Measure of moderation effect on

							interaction					multiplicative scale with CIs and P-values
Moor 2019	Effect modifier	Yes: significant association	No	No	NA	No	No	No	No	No	No	Only descriptive (“no significant interactions”)
Rathmann 2016	Interaction	Yes: significant association	Yes: significant association	Yes: one list of confounders	Yes: one list of confounders	No	Estimate of the product term 95% CI and p values: significant interaction	NA moderation factor is continuous	NA moderation factor is continuous	Only figures with predicted probabilities	Individual estimates+ Measure of moderation effect on multiplicative scale with CIs and P-values	
Bachman 2011	Effect modifier	No	No	No	NA	No	No	No	No	No	No	Only descriptive (“There are clear interactions”)
Yáñez 2017	Interaction											
	Parental education* Openness on triers	Yes: No significant association	Yes: No significant association	Yes: one list of confounders	Yes: one list of confounders	No	Estimate of the product term, 95% CI and p values: no significant interaction	NA	NA	No	Product term not significant	
	Interaction											
	Parental education* Conscientiousness on triers	Yes: No significant association	Yes: significant association	Yes: one list of confounders	Yes: one list of confounders	No	Estimate of the product term, 95% CI and p values: no significant	NA	NA	No	Product term not significant	

						interaction				
Interaction										
Parental education* Extraversion on triers	Yes: No significant association	Yes: significant association	Yes: one list of confounders	Yes: one list of confounders	No	Estimate of the product term, 95% CI and p values: no significant interaction	NA	NA	No	Product term not significant
Interaction										
Parental education* Agreeableness on triers	Yes: No significant association	Yes: No significant association	Yes: one list of confounders	Yes: one list of confounders	No	Estimate of the product term, 95% CI and p values: no significant interaction	NA	NA	No	Product term not significant
Interaction										
Parental education* Emotional Instability on triers	Yes: No significant association	Yes: significant association	Yes: one list of confounders	Yes: one list of confounders	No	Estimate of the product term, 95% CI and p values: no significant interaction	NA	NA	No	Product term not significant
Interaction										
Parental education* Openness on regular smokers	Yes: significant association	Yes: No significant association	Yes: one list of confounders	Yes: one list of confounders	No	Estimate of the product term, 95% CI and p values: no significant interaction	NA	NA	No	Product term not significant

Interaction										
Parental education* Conscientiousness on regular smokers	Yes: significant association	Yes: significant association	Yes: one list of confounders	Yes: one list of confounders	No	Estimate of the product term, 95% CI and p values: no significant interaction	NA	NA	No	Product term not significant
Interaction										
Parental education* Extraversion on regular smokers	Yes: significant association	Yes: significant association	Yes: one list of confounders	Yes: one list of confounders	No	Estimate of the product term, 95% CI and p values: no significant interaction	NA	NA	No	Product term not significant
Interaction										
Parental education* Agreeableness on regular smokers	Yes: significant association	Yes: No significant association	Yes: one list of confounders	Yes: one list of confounders	No	Estimate of the product term, 95% CI and p values: no significant interaction	NA	NA	No	Product term not significant
Interaction										
Parental education* Emotional Instability on regular smokers	Yes: significant association	Yes: significant association	Yes: one list of confounders	Yes: one list of confounders	No	Estimate of the product term, 95% CI and p values: no significant interaction	NA	NA	No	Product term not significant

Pitel 2013	Effect modifier	No	No	Yes	NA	No	Estimate of the product term, 95% CI and p values: significant interaction	No	No	Yes	Measure of moderation effect on multiplicative scale with CIs and P-values + Stratum-specific effect estimates with 95% CI
Assari 2020	Effect modifier	Yes: significant association	Yes: significant association	Yes	NA	No	Estimate of the product term, 95% CI and p values: significant interaction	No	No	Yes	Individual estimates+ Measure of moderation effect on multiplicative scale with CIs and P-values
Itanyi 2020	Interaction	Yes: no significant association	Yes: significant association	Yes: one list of confounders	Yes: one list of confounders	No	Estimate of the product term, 95% CI and p values: significant interaction	Yes	Yes	Yes	Effect estimates for each stratum of exposure and moderation factor with a single reference category + stratum effect+ joint effect estimate using

											1 reference category
Wellman 2017	Interaction Potential risk factor* Neighborhood SES on smoking initiation	No	Yes: significant associations	Yes: one list of confounders	Yes: one list of confounders	Yes: only descriptive results “no statistically significant additive interactions »	No	Yes	Yes	No	Effect estimates for each stratum of exposure and moderation factor with a single reference category + joint effect estimate using 1 reference category
	Interaction Potential risk factor* Maternal education on smoking initiation	No	Yes: significant associations	Yes: one list of confounders	Yes: one list of confounders	Yes: significant RERI 95% CI and p-values for two potential risk factors	No	Yes	Yes	No	Individual effect estimates and the joint effect estimate using 1 reference category
Denny 2016	Effect modifier	Yes: significant association	No	Yes	NA	No	only p-value: significant association	No	No	Only descriptive figures with predicted probabilities and CI	Only descriptive with statistical significance
Holstein 2019	Effect modifier	Yes: significant	No association	Yes	NA	No	only p-value: significant	No	No	Yes	Stratum-specific effect

		association	estimates but Cochran-Armitage test for trend to study trends in prevalence of daily smoking over time				association				estimates with 95% CI
Moon 2019	Interaction	Yes: significant associations	Yes: significant associations for age, race, alcohol abuse/dependence, depression, No significant association for gender	NA	NA	NA	NA	NA	NA	NA	Only descriptive
Bergenwall 2014	Effect modifier	Yes: significant associations	Yes: significant associations	Yes	NA	No	Estimate of the product term and p values: significant associations for one moderator (proportion of smoking friends)	No	No	Only descriptive figures with predicted probabilities	Individual estimates+ Measure of moderation effect on multiplicative scale with CIs and P-values
Pförtner 2014	Effect modifier	Yes: significant association for all the	Yes: significant association for only one	Yes	NA	No	Estimate of the product term 95% CI and p values:	NA SES is continuous and moderation	NA SES is continuous and moderation	Only descriptive figures with	Individual estimates+ Measure of moderation

		three outcomes	outcome (Weekly smoking)				significant interactions	factor is ordinal	factor is ordinal	predicted probabilities	effect on multiplicative scale with CIs and P-values
Moore 2015	Interaction	Yes: significant association	Yes: significant association	Yes: one list of confounders age, sex, urban/rural classification	Yes: one list of confounders age, sex, urban/rural classification	No	Estimate of the product term 95% CI and p values: significant interaction	No	No	Only descriptive figures with percentages	Individual estimates+ Measure of moderation effect on multiplicative scale with CIs and P-values