

Place-Based Diminished Returns of Parental Education on Adolescents' Inhalant Use in Rural Areas

Shervin Assari ^{1,2,3,4,*}, Hossein Zare ^{5,6}

¹ Department of Internal Medicine, Charles R. Drew University of Medicine and Science, Los Angeles, CA, United States

² Department of Family Medicine, Charles R. Drew University of Medicine and Science, Los Angeles, CA, United States

³ Department of Urban Public Health, Charles R. Drew University of Medicine and Science, Los Angeles, CA, United States

⁴ Marginalization-Related Diminished Returns (MDRs) Center, Los Angeles, CA, United States

⁵ Department of Health Policy and Management, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, United States

⁶ School of Business, University of Maryland Global Campus (UMGC), Adelphi, MD, United States

*Correspondence: Shervin Assari (shervinassari@cdrewu.edu)

Abstract

Background Adolescent substance use is often influenced by socioeconomic and geographical factors. While higher parental education is typically associated with lower substance use, these protective effects may be weaker for marginalized groups facing structural disadvantages that limit the utility and returns of their economic and social resources. Rural areas, characterized by fewer employment opportunities and limited recreational activities, may contribute to marginalization-related diminished returns (MDRs) of parental education on adolescent substance use, including inhalant use. **Objectives** This study applies the MDRs framework to examine whether the protective effect of higher parental education on current inhalant use (past 30 days) among 12th-grade American adolescents varies by geographic location. Specifically, we assess whether youth from highly educated families in rural areas are at a disproportionate risk of inhalant use compared to their urban and suburban peers. **Methods** Using data from the 2024 Monitoring the Future (MTF) study, a nationally representative survey of 12th-grade adolescents in the U.S., we tested main effects and statistical interactions between parental education and residence (rural vs. urban/suburban) in predicting the odds of inhalant use over the past 30 days. Logistic regression models, both with and without interaction terms, were applied to evaluate whether the protective effects of parental education varied by residence location, controlling for relevant demographic and socioeconomic factors. **Results** Findings indicate a significant interaction between parental education and rural residence. While higher parental education was associated with lower odds of inhalant use in urban and suburban areas, this protective effect was substantially weaker in rural settings. Adolescents from highly educated families in rural areas exhibited a higher-than-expected risk of inhalant use, suggesting that geographic marginalization attenuates the benefits of parental socioeconomic resources. **Conclusions** These results highlight the role of place-based marginalization in shaping adolescent substance use disparities, demonstrating that MDRs extend beyond race and ethnicity to location-based disadvantages. Rural youths from highly educated families may face unique structural and social challenges that counteract the protective effects of parental education. Public health efforts should consider place-based interventions that address the economic, recreational, and social limitations of rural environments to reduce substance use risk among high-SES adolescents residing in rural areas.

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1. Background

Inhalant use remains one of the most common ways adolescents engage in substance use [1]. This includes sniffing glue, inhaling the contents of aerosol spray cans, or breathing in gases and other volatile substances to achieve a high [2]. Due to the widespread availability of household and industrial products such as spray cans, glue, and gasoline, inhalant use has historically been prevalent among adolescents [3]. There are significant risks associated with inhalant use, making it a public health concern [4]. Beyond its immediate dangers and potential for addiction, inhalant use is also linked to the transition to other risk behaviors and may act as a gateway to further substance use [5]. Thus, adolescent inhalant use poses critical long-term implications for health and well-being [6].

Disparities in adolescent inhalant use persist across demographic, socioeconomic, and geographic groups [7]. One of the most consistent protective factors against substance use initiation is parental education [8,9], as higher educational attainment is associated with greater health literacy, lower tolerance for risk behaviors, stronger parental oversight, and enhanced risk communication [10-13]. Well-educated parents also tend to provide better monitoring, emotional support, safer environments, and peer networks that reduce exposure to substance use opportunities [14,15]. However, the effect of parental education in reducing inhalant use risk may not be uniform across all social contexts. Emerging evidence suggests that structural factors related to geographic location shape the extent to which socioeconomic resources, such as parental education, protect against health-risk behaviors [16].

Rural environments differ significantly from urban and suburban areas in terms of resource availability, economic opportunities, and access to public health interventions [17,18]. Rural communities often experience higher unemployment rates, fewer higher education institutions, and more limited access to healthcare and prevention programs [19-21]. These structural disadvantages may create conditions where parental education, even at higher levels, is less effective in discouraging substance use [22,23]. Unlike urban settings, where well-educated parents may have greater access to substance use prevention programs, anti-drug campaigns, and structured recreational activities, rural families may face social norms that are more accepting of substance use and economic dependencies on industries that do not prioritize prevention efforts [24-26]. Additionally, the easy accessibility of inhalants in household and industrial products makes them particularly available to rural youth, increasing use in environments with fewer structured activities and limited regulatory oversight.

Marginalization-related Diminished Returns (MDRs) framework provides a useful lens to examine how the protective effects of socioeconomic resources vary across different social contexts [27,28]. MDRs suggest that individuals from marginalized groups, despite having high socioeconomic status (SES), experience weaker returns on those resources due to structural and contextual barriers [29-33]. While much of the research on MDRs has primarily focused on racial and ethnic disparities, nativity (immigrant status), and sexual orientation, all of which contribute to marginalization, we argue that the MDRs concept can be extended to geographic marginalization in resource-limited settings [16]. Living in a rural area may function as a form of structural disadvantage, limiting the degree to which parental education translates into protective benefits for adolescent

health behaviors [18,34]. In this context, rural residence may reduce the expected protective effect of high parental education against inhalant use among adolescents.

This study applies to the MDRs framework to investigate whether the protective association between parental education and adolescent inhalant use differs by geographic location. Using data from the Monitoring the Future (MTF) study [35-41], a nationally representative survey of U.S. adolescents, we examine whether rural residence moderates the relationship between parental education and the likelihood of ever using inhalants among 12th-grade students. Specifically, we test whether adolescents from highly educated families in rural areas are at a disproportionate risk of inhalant use compared to their peers in urban and suburban settings.

The findings of this study will contribute to a growing body of literature on marginalization-related diminished returns and extend this research to place-based health disparities. Demonstrating that MDRs extend beyond race, ethnicity, nativity, or sexual orientation to geographic location will expand our understanding of the link between place and health. If rural residence attenuates the protective effects of parental education, this suggests that socioeconomic resources are not equally effective in all environments. Rural youth may face unique structural challenges that increase their vulnerability to inhalant use, even when they are from high SES backgrounds. These insights have important public health implications, highlighting the need for targeted interventions that address not only individual and familial factors but also the broader social and economic conditions that shape health behaviors in rural communities. Addressing the structural inequalities and disadvantages associated with rural residence, including limited employment opportunities, reduced access to preventive programs, and fewer recreational alternatives, may be essential in reducing adolescent inhalant use and improving long-term health outcomes for rural populations.

2. Methods

2.1. Data Source and Study Sample

This study utilized data from the 2024 Monitoring the Future (MTF) survey [35-41], a nationally representative survey of U.S. adolescents conducted annually to assess substance use behaviors and related factors. MTF employs a multistage, stratified sampling design to ensure national representativeness. For this analysis, we focused exclusively on 12th-grade students, as they represent the oldest adolescent cohort surveyed and are at a critical stage for substance use behaviors and associated risk factors.

2.2. Participants and sampling

The study included a nationally representative sample of 12th-grade students, regardless of educational performance, school type (public, private, or charter), geographic location (urban, suburban, or rural), or school governance. The total sample size consisted of 7,584 adolescents between age yy-yy.

2.3. Measures

2.3.1. Outcome Variable: Inhalant Use

The primary outcome variable was inhalant use in the past 30 days, measured using the following MTF survey question: "On how many occasions (if any) have you sniffed glue, breathed the contents of aerosol spray cans, or inhaled any other gases or sprays in order to get high during the last 30 days?" Responses were recorded on an ordinal scale, ranging from 0 (never) to higher frequencies of use. For analytic purposes, this variable was dichotomized to indicate any past-month inhalant use (1 = at least once, 0 = never).

2.3.2. Predictor Variable: Parental Education

The primary independent variable was maximum parental education, defined as the highest level of education attained by either the mother or father. Both parents' education levels were assessed separately in the survey, and we assigned the highest reported level as the max parental education. This variable was treated as a categorical factor, categorized as follows: GRADE SCH (1): Grade school or less; SOME HS (2): Some high school; HS GRAD (3): High school graduate; SOME CLG (4): Some college; CLG GRAD (5): College graduate; and GRAD SCH (6): Graduate school. We also calculated an interaction term for max parental education \times rural residence to assess the potential moderating effect of rurality on the protective role of parental education.

2.4. Covariates

To account for potential confounding factors, we included key demographic and socioeconomic variables known to be associated with substance use:

Age (measured in years): Self-reported by the participant. This variable was dichotomized as under 18 (0) vs. 18 or older (1).

Sex: Self-reported as assigned at birth (male = 1, female = 0 [reference group]).

Race/Ethnicity: Coded as Non-Hispanic White (reference), Non-Hispanic Black, and Hispanic. Two dummy variables were created for Black and Hispanic adolescents, with Non-Hispanic White as the reference group.

Geographic Region: Categorized as Northeast (reference group), Midwest, South, and West.

Rural vs. Non-Rural (Urban or Suburban) Residence: The U.S. Census Bureau defines rural areas as all regions outside of urbanized areas (50,000 or more people) and urban clusters (at least 2,500 but fewer than 50,000 people). Urban areas are characterized by densely developed residential, commercial, and other non-residential land uses, while rural areas typically have lower population density and greater geographic dispersion. Suburban areas, which are often located on the outskirts of urban centers and feature a mix of residential and commercial development, are also considered non-rural. This variable is classified by the MTF.

2.5. Analytic Approach

To account for the complex survey design of MTF, survey weights were applied in all analyses, ensuring national representativeness and accurate variance estimation. Logistic regression models were used to examine the association between max parental education and past 30-day inhalant use [42-45], with an interaction term included to test for potential moderation by geographic location (rural vs. urban/suburban settings). All analyses were conducted using Stata 18, applying the svy command [46-49] to incorporate sampling weights. Statistical significance was set at $p < 0.05$ for all hypothesis tests.

3. Results

Table 1 presents the results of the survey-weighted logistic regression model examining the associations between demographic, socioeconomic, and geographic factors and past 30-day inhalant use among 12th-grade students. Maximum parental education, measured on a 1–6 scale, was inversely associated with inhalant use, though the association did not reach statistical significance (OR = 0.59, 95% CI: 0.32–1.11, $p = 0.102$). Parental presence in the household was not significantly associated with inhalant use. Having one parent present showed an odds ratio of 0.15 but was not statistically significant (95% CI: 0.02–1.34, $p = 0.089$). Having both parents present was also not a significant predictor (OR = 0.40, 95% CI: 0.10–1.53, $p = 0.181$).

Age was not significantly associated with inhalant use (OR = 0.87, 95% CI: 0.31–2.46, $p = 0.798$). Race and ethnicity differences were observed, with Latino adolescents being significantly less likely than non-Latino White adolescents to report inhalant use (OR =

0.32, 95% CI: 0.12–0.81, $p = 0.017$). Due to the survey design, Black adolescents were omitted from the model. Sex was not a significant predictor, as males did not show significantly different odds of inhalant use compared to females (OR = 3.02, 95% CI: 0.59–15.37, $p = 0.184$).

Rural residence was not significantly associated with inhalant use (OR = 1.10, 95% CI: 0.25–4.93, $p = 0.900$), indicating no notable difference in inhalant use between rural and urban/suburban adolescents. Regional differences were also not statistically significant. Compared to participants in the Northeast (reference group), those in the Midwest had lower odds of inhalant use (OR = 0.37, 95% CI: 0.06–2.41, $p = 0.299$). Residence in the South (OR = 1.28, 95% CI: 0.31–5.23, $p = 0.735$) or West (OR = 1.43, 95% CI: 0.14–14.34, $p = 0.760$) were not associated with odds of inhalant use.

Table 1. Summary of Survey Logistic Regression

	OR	SE	95%	CI	p
Age (18 Yrs or Above)	0.87	0.46	0.31	2.46	0.798
Race/Ethnicity					
Non-Latino White	Ref.				
Black	1.00	(omitted)			
Latino	0.32	0.15	0.12	0.81	0.017
Sex (Male)	3.02	2.50	0.59	15.37	0.184
Rural Area	1.10	0.84	0.25	4.93	0.9
Geographic Region					
North-East	Ref.				
Mid-West	0.37	0.35	0.06	2.41	0.299
South	1.28	0.92	0.31	5.23	0.735
West	1.43	1.68	0.14	14.34	0.76
Number of Parents Present in the household					
None	Ref.				
One	0.15	0.17	0.02	1.34	0.089
Two	0.40	0.27	0.10	1.53	0.181
Parental Education (1-6)	0.59	0.19	0.32	1.11	0.102
Intercept	0.17	0.25	0.01	3.02	0.226

Note: Outcome: Inhalant Use in the Last 30 Days; SES: Socioeconomic Status

Table 2 presents the results of the survey-weighted logistic regression model examining the associations between demographic, socioeconomic, and geographic factors and past 30-day inhalant use among 12th-grade students. Parental presence in the household was not significantly associated with inhalant use. Having one parent present showed an odds ratio of 0.16 but was not statistically significant (95% CI: 0.02–1.54, $p = 0.112$). Having both parents present was also not a significant predictor (OR = 0.40, 95% CI: 0.11–1.49, $p = 0.173$). However, maximum parental education, measured on a 1–6 scale, was inversely associated with inhalant use (OR = 0.46, 95% CI: 0.23–0.91, $p = 0.026$), suggesting that higher parental education levels were protective against adolescent inhalant use.

A significant interaction effect was observed between maximum parental education and rural residence (OR = 6.33, 95% CI: 1.33–30.17, $p = 0.021$). This finding indicates that while higher parental education is protective overall, its effect is significantly weaker in rural settings, consistent with the Marginalization-related Diminished Returns (MDRs) framework. Adolescents from highly educated families in rural areas had higher odds of

inhalant use, suggesting that the protective effect of parental education does not extend equally across geographic contexts. These results underscore the importance of considering geographic and socioeconomic contexts when assessing adolescent substance use risks and designing targeted public health interventions.

Age was not significantly associated with inhalant use (OR = 0.86, 95% CI: 0.29–2.53, $p = 0.778$). Race and ethnicity differences were observed, with Latino adolescents being significantly less likely than non-Latino White adolescents to report inhalant use (OR = 0.21, 95% CI: 0.08–0.57, $p = 0.002$). Due to low frequency of high SES Black participants with inhalant use in rural areas, the variable race (Black vs White) was automatically omitted from the model by Stata. Sex was not a significant predictor, as males did not show significantly different odds of inhalant use compared to females (OR = 2.88, 95% CI: 0.57–14.48, $p = 0.199$).

Rural residence was significantly associated with lower odds of inhalant use (OR = 0.00, 95% CI: 0.00–0.87, $p = 0.046$), suggesting that students in rural areas were less likely to report inhalant use compared to their urban and suburban counterparts. Regional differences were not statistically significant, though some variations were observed. Compared to students in the Northeast (reference group), those in the Midwest had lower odds of inhalant use (OR = 0.39, 95% CI: 0.06–2.47, $p = 0.316$). Residence in South (OR = 1.36, 95% CI: 0.33–5.53, $p = 0.670$) or West (OR = 1.45, 95% CI: 0.15–14.21, $p = 0.747$) were not associated with odds of inhalant use.

Table 2. Summary of Survey Logistic Regression

	OR	SE	95% CI	CI	p
Age (18 Yrs or Above)	0.86	0.47	0.29	2.53	0.778
Race/Ethnicity					
Non-Latino White	Ref.				
Black	1.00	(omitted)			
Latino	0.21	0.11	0.08	0.57	0.002
Sex (Male)	2.88	2.37	0.57	14.48	0.199
Rural Area	0.00	0.00	0.00	0.87	0.046
Geographic Region					
North-East	Ref.				
Mid-West	0.39	0.37	0.06	2.47	0.316
South	1.36	0.97	0.33	5.53	0.67
West	1.45	1.69	0.15	14.21	0.747
Number of Parents Present in the Household					
None					
One	0.16	0.18	0.02	1.54	0.112
Two	0.40	0.27	0.11	1.49	0.173
Parental Education (1-6)	0.46	0.16	0.23	0.91	0.026
Parental Education (1-6) x Rural Residence	6.33	5.04	1.33	30.17	0.021
Intercept	0.44	0.70	0.02	9.75	0.605

Note: Outcome: Inhalant Use in the Last 30 Days

4. Discussion

This study aimed to examine whether the protective effect of parental education on adolescent inhalant use varies by geographic location, particularly between rural and urban settings. Our findings suggest that while parental education generally serves as a

protective factor against inhalant initiation in urban and suburban areas, its effectiveness is weaker in rural areas. Adolescents from highly educated families in rural areas exhibit a higher likelihood of inhalant use than their urban and suburban counterparts, supporting the Place-based Marginalization related Diminished Returns (MDRs).

Inhalant use remains a public health concern in rural areas due to several interrelated factors. Rural regions often have higher rates of substance use among adults, which may normalize inhalant use for youth. Additionally, rural adolescents may have greater access to inhalants through household products and peers, with weaker enforcement of substance use prevention measures compared to urban areas. Limited access to recreational spaces such as sports facilities, cinemas, and shopping malls may reduce engagement in alternative activities, increasing the likelihood of inhalant experimentation. The abundance of unstructured free time in rural areas may further elevate the risk of behaviors such as inhalant use. Furthermore, substance-related industry has historically targeted rural populations through strategic marketing, reinforcing substance use as an accepted behavior.

Rural residence can be considered a form of structural marginalization due to its associated economic, social, and healthcare disadvantages [50-53]. Education quality is often lower in rural areas, with fewer well-trained teachers and limited access to extracurricular activities and educational resources [54-56]. Additionally, the financial benefits of education may be weaker in rural areas, as high levels of education do not necessarily translate into higher income or wealth [16]. While living costs are lower in rural areas, wages tend to be lower as well, limiting economic mobility for highly educated families [57-61]. For well-educated parents, rural residence may mean fewer employment opportunities, reducing their ability to accumulate wealth and invest in their children's future [62-65]. Even well-educated parents in rural areas may struggle to shield their children from inhalant use due to fewer public health campaigns, weaker regulation of inhalant products, and social norms that minimize the risks of inhalant experimentation.

Rural adolescents may turn to inhalants and other substances as a means of coping with boredom, stress, or a lack of recreational alternatives. The scarcity of extracurricular activities, youth programs, and structured social environments can lead to increased inhalant use as a form of entertainment or socialization. In rural areas, few activities compete with substance use, as many alternative recreational activities require resources that are not readily available. In contrast, inhalants are easily accessible household products that do not require specialized access like alcohol or illicit drugs. Additionally, economic hardships and feelings of isolation in rural areas may contribute to higher rates of inhalant use and other risk behaviors among youth.

4.5. Limitations

This study has several limitations. First, while the Monitoring the Future (MTF) study provides nationally representative data, self-reported measures of inhalant use may be subject to report biases. Second, our analysis does not account for all possible confounders, such as peer influence or parental substance use behaviors, which may independently affect inhalant initiation. Finally, while this study highlights geographic disparities, further research is needed to explore other contextual factors, such as variations in state-level substance use policies and enforcement.

4.6. Future Research

Future studies should examine additional factors that may moderate the relationship between parental education and inhalant use in rural areas, such as peer networks, school policies, and state-level substance use regulations. Longitudinal research is also necessary to determine whether the diminished protective effect of parental education persists into adulthood and how it interacts with other social determinants of health. Additionally,

qualitative studies could provide deeper insights into the lived experiences of rural adolescents and their perceptions of inhalant use.

5. Conclusion

This study contributes to the growing literature on place-based health disparities by demonstrating that the protective effect of parental education against adolescent inhalant use is weaker in rural areas than in urban and suburban settings. These findings underscore the importance of addressing structural inequality associated with rural residence, including economic hardship, social norms around substance use, and limited access to prevention resources. Public health efforts should consider geographically tailored interventions that address the unique challenges faced by rural youth, ensuring that the benefits of socioeconomic resources are equitably distributed across different environments. By improving access to education, healthcare, and recreational opportunities, policymakers can help reduce inhalant use among rural adolescents and promote long-term health equity.

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Authors Contribution

SA: Concept, design, analysis, first draft, approval of the final version. HZ: review, revision, approval of the final version.

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