Chapter 9

Integrated Determinant Models (Confirmatory Flagship Set)

Zafer Bekiroğulları[*], & Marilyn A. Huestis[b]

[a]*PhD, International Cognitive and Behavioural Psychotherapies Society (CBPis), Nicosia, Northern Cyprus
[b] *Professor Dr. Dr. (h.c.), Institute for Emerging Health Professions, Thomas Jefferson University, Philadelphia, PA, USA & President, Huestis & Smith Toxicology, LLC, Fredericksburg, VA, USA*

DOI: 10.70020/BI.20260803.9

9.1. Introduction

To address the limitations of domain specific models that precluded direct cross substance comparisons, Chapter 9A applies a unified five block model with identical covariate structures. While four outcomes were originally prespecified for this analysis, cigarette use was not derived due to a missing survey item, whereas both cannabis and polydrug use were excluded due to near zero prevalence. The systematic exclusion of cannabis and polydrug outcomes from the final integrated multivariable frameworks reflects low statistical estimability rather than a substantive absence of these risk behaviors within the adolescent population. Due to near zero prevalence, these specific indicators introduced severe complete separation and variance instability during logistic estimation. Consequently their removal was a necessary mathematical safeguard to prevent structural singularity and ensure model convergence. Consequently, the final integrated framework models 30-day e-cigarette use (*Y_VAPE30*), binge drinking in the last 30 days (*Y_BINGE30*), and any alcohol use in the last 30 days (*Y_ALC30*). This approach provides three key contributions: simultaneous logistic regressions for direct effect

comparison, population attributable fractions to quantify population level burdens, and a prevalence weighted risk ranking index to identify overarching intervention priorities.

9.2. Analytical Strategy

Chapter 9A presents integrated determinant models for three estimable outcomes: 30-day e-cigarette use (*Y_VAPE30*), binge drinking in the last 30 days (*Y_BINGE30*), and any alcohol use in the last 30 days (*Y_ALC30*). Each model incorporates the full five-block covariate structure (Block A: demographic; Block B: family; Block C: school; Block D: peer substance use; Block E: perceived risk and availability) as specified in the protocol. Population attributable fractions (PAF) are computed for three pre-specified modifiable exposures: truancy, peer substance use, and low parental monitoring. A risk-ranking index is constructed by ordering predictors by standardised effect size across outcomes. Cross-outcome comparison of odds ratios is presented to identify consistent determinants. BH-FDR correction is applied across the integrated model family. Penalized likelihood approaches such as Firth logistic regression were considered; however, the low event frequency rendered coefficient stability and substantive interpretability insufficient for confirmatory modelling. External or resampling based validation procedures were not feasible within the current dataset; therefore, model performance estimates should be interpreted as apparent performance metrics.

9.3. Results

9.3.1. Overview and protocol deviations

Four core outcomes were prespecified for Part A: 30-day cigarette use (Y_*TOB30*), binge drinking in the last 30 days (*Y_BINGE30*), 12-month cannabis use (*Y_CAN12*), and polydrug use (*Y_POLY*), defined as use of two or more substance classes. Three of these were not estimable. 30-day cigarette

use (*Y_TOB30*) was not derived as item C07, which elicits 30-day cigarette use frequency, was absent from the North Cyprus survey instrument. It should be noted that the absence of item C07 from the current North Cyprus survey instrument — which prevented the derivation of 30-day cigarette use (Y_TOB30) and its inclusion in the integrated models — represents a meaningful measurement gap; reinstating this item in the next survey wave will restore full comparability with the standard ESPAD protocol and enable tobacco use to be modelled alongside alcohol and e-cigarette outcomes within the same analytical framework. 12-month cannabis use (*Y_CAN12*; n = 10, 0.9%) and polydrug use (*Y_POLY*; n = 12, 1.1%) showed near-zero prevalence, precluding reliable multivariable modelling. Binge drinking in the last 30 days (*Y_BINGE30*) was therefore the sole estimable prespecified outcome; 30-day e-cigarette use (*Y_VAPE30*; n = 91, 8.7%) and any alcohol use in the last 30 days (*Y_ALC30*; n = 282, 26.9%) were additionally modelled as substantively relevant supplementary outcomes, the former serving as the tobacco/nicotine domain representative in place of *Y_TOB30*. Part B is addressed separately in Section 9.4. Analytical samples varied across models due to missing values on perceived risk items arising from “Don't know” recoding: n = 589 for 30-day e-cigarette use (*Y_VAPE30*), n = 706 for any 30-day alcohol use (*Y_ALC30*), and n = 689 for binge drinking (*Y_BINGE30*).

9.3.2. Integrated model results

All three models demonstrated strong discriminative performance. 30-day e-cigarette use (*Y_VAPE30*) achieved an AUC of 0.869, any alcohol use in the last 30 days (*Y_ALC30*) an AUC of 0.849, and binge drinking in the last 30 days (Y_*BINGE30*) an AUC of 0.814. Brier scores were acceptable across all models, with a value of 0.064 for 30-day e-cigarette use (*Y_VAPE30*), 0.145 for any alcohol use in the last 30 days (*Y_ALC30*), and 0.136 for binge drinking in the last 30 days (*Y_BINGE30*). Variance inflation factors were below 2.0 for all predictors in all three models, confirming the absence of multicollinearity.

Calibration was excellent across all three integrated models. All models showed logistic calibration curves closely following the ideal diagonal, with a

slope of 1.00 and an intercept near 0.00 for all. Maximum calibration errors were low, yielding an Emax of 0.079 for 30-day e-cigarette use (*Y_VAPE30*), 0.067 for any alcohol use in the last 30 days (*Y_ALC30*), and 0.047 for binge drinking in the last 30 days (*Y_BINGE30*). Spiegelhalter calibration tests were not significant for all outcomes, including 30-day e-cigarette use (*Y_VAPE30*) with S:z = -0.271 and p = .787, any alcohol use in the last 30 days (*Y_ALC30*) with S:z = 0.210 and p = .834, and binge drinking in the last 30 days (*Y_BINGE30*) with S:z = 0.202 and p = .840, confirming adequate calibration across the full range of predicted probabilities.

The Benjamini Hochberg false discovery rate correction was applied across all 47 tests in the flagship family, and eight associations survived this correction.

For 30-day e-cigarette use (*Y_VAPE30*), two predictors survived correction, namely peer tobacco use with an odds ratio of 2.398, 95% confidence interval [1.796, 3.201], and adjusted p < .001, and truancy with an odds ratio of 1.530, 95% confidence interval [1.209, 1.937], and adjusted p = .003. Tobacco accessibility showed a nominal association with an odds ratio of 1.355 and p = .022 that did not survive correction where adjusted p = .101. Perceived risk of occasional tobacco use was marginal and not significant after correction, with an odds ratio of 0.641, p = .056, and adjusted p = .219.

For any alcohol use in the last 30 days (*Y_ALC30*), four predictors survived correction, including peer alcohol use with an odds ratio of 2.007, 95% confidence interval [1.668, 2.414], and adjusted p < .001, alcohol accessibility with an odds ratio of 1.653, 95% confidence interval [1.393, 1.962], and adjusted p < .001, perceived risk of occasional alcohol use with an odds ratio of 0.696, 95% confidence interval [0.571, 0.849], and adjusted p = .003, and truancy with an odds ratio of 1.265, 95% confidence interval [1.062, 1.506], and adjusted p = .049.

For binge drinking in the last 30 days (*Y_BINGE30*), two predictors survived correction, which were peer alcohol use with an odds ratio of 1.672, 95% confidence interval [1.385, 2.019], and adjusted p < .001, and alcohol

accessibility with an odds ratio of 1.712, 95% confidence interval [1.415, 2.071], and adjusted $p < .001$. Perceived risk of occasional alcohol use showed a nominal association with an odds ratio of 0.732 and $p = .017$ that did not survive correction where adjusted $p = .091$.

Influence diagnostics were assessed using Cook's distance across all three integrated models. Maximum Cook's distance values were 0.110 for 30-day e-cigarette use (*Y_VAPE30*) with 52 exceeding cases, 0.036 for any alcohol use in the last 30 days (*Y_ALC30*) with 36 exceeding cases, and 0.041 for binge drinking in the last 30 days (*Y_BINGE30*) with 39 exceeding cases, all well below the substantive concern threshold of 0.5. No observations were considered unduly influential.

9.3.3. Average marginal effects

Average marginal effects (AME) were computed for all three integrated models. For 30-day e-cigarette use (Y_*VAPE30*), peer tobacco use showed the largest marginal effect (AME = 0.057, SE = 0.009, $p < .001$), followed by truancy (AME = 0.028, SE = 0.008, $p < .001$) and tobacco accessibility (AME = 0.020, SE = 0.009, $p = .022$). Perceived risk of occasional tobacco use was not significant (AME = −0.029, $p = .055$).

For any alcohol use in the last 30 days (*Y_ALC30*), peer alcohol use showed the largest effect (AME = 0.100, SE = 0.011, $p < .001$), followed by alcohol accessibility (AME = 0.072, SE = 0.012, $p < .001$), perceived risk (AME = −0.052, SE = 0.014, $p < .001$), and truancy (AME = 0.034, SE = 0.013, $p = .008$).

For binge drinking in the last 30 days (*Y_BINGE30*), alcohol accessibility showed the largest marginal effect (AME = 0.073, SE = 0.012, $p < .001$), followed by peer alcohol use (AME = 0.069, SE = 0.012, $p < .001$) and perceived risk (AME = −0.042, SE = 0.017, $p = .016$). These marginal effect estimates are consistent with the log-odds coefficients reported above and confirm the substantive and practical significance of the primary predictors across all three outcomes.

9.3.4. Cross-outcome comparison

Peer substance use and perceived availability emerged as the most consistent determinants across all three outcomes. Peer tobacco use was the dominant predictor for 30-day e-cigarette use (*Y_VAPE30*) (OR = 2.398), while peer alcohol use showed strong associations with both any alcohol use in the last 30 days (*Y_ALC30*) (OR = 2.007) and binge drinking in the last 30 days (*Y_BINGE30*) (OR = 1.672). Accessibility showed similarly robust associations across alcohol outcomes (*Y_ALC30*: OR = 1.653; *Y_BINGE30*: OR = 1.712) and 30-day e-cigarette use (*Y_VAPE30*: OR = 1.355). Perceived risk of use operated as a significant protective factor for any alcohol use in the last 30 days after FDR correction, with a marginal not significant association for 30-day e-cigarette use and binge drinking in the last 30 days. Truancy was a significant predictor for 30-day e-cigarette use and any alcohol use in the last 30 days but not binge drinking in the last 30 days after FDR correction, suggesting that general school disengagement is more strongly linked to substance initiation than to heavy episodic drinking patterns. Gender, parental monitoring, family support, family wealth, and school type were not significant across all three outcomes after correction.

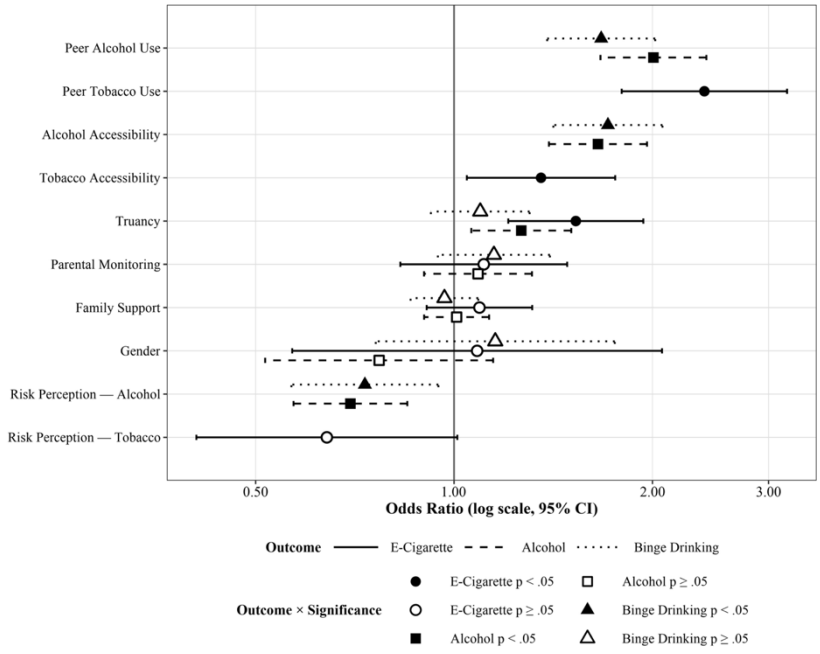

Figure 9.1. Forest Plot. Odds ratios (OR) and 95% confidence intervals for key predictors across three integrated substance use outcome models (Y_VAPE30, Y_ALC30, Y_BINGE30). Filled symbols indicate statistically significant associations ($p < .05$ after BH-FDR correction); open symbols indicate not significant associations. The vertical dashed line represents OR = 1.0. Peer substance use and perceived availability consistently showed the strongest positive associations across outcomes, while risk perception operated as a protective factor primarily for Y_ALC30. Region dummy variables are excluded from the figure for clarity.

Figure 9.1 presents a visual summary of odds ratios and 95% confidence intervals for key predictors across the three integrated outcome models. The forest plot confirms the patterns reported in the text. Peer substance use emerged as the most consistently strong positive predictor across all three outcomes, with peer tobacco use showing the largest effect for 30-day e-cigarette use (*Y_VAPE30*) (OR = 2.398) and peer alcohol use showing strong effects for both any alcohol use in the last 30 days (*Y_ALC30*) (OR = 2.007) and binge drinking in the last 30 days (Y_BINGE30) (OR = 1.672). Perceived availability showed similarly robust positive associations for alcohol outcomes (*Y_ALC30*: OR = 1.653; *Y_BINGE30*: OR = 1.712) and vaping (OR = 1.355). Risk perception operated as a significant protective factor for *Y_ALC30*, with confidence intervals entirely below 1.0; for

Y_VAPE30 and *Y_BINGE30*, credible intervals crossed 1.0, consistent with the not significant FDR-corrected findings. Truancy showed a significant positive association for *Y_VAPE30* and *Y_ALC30* but not *Y_BINGE30*, with overlapping confidence intervals across the two alcohol outcomes suggesting comparable effect sizes. Demographic variables such as gender, family support, parental monitoring, and school type, showed confidence intervals crossing 1.0 across all three outcomes, consistent with the not significant findings reported in the regression tables

9.3.5. Population attributable fractions

PAF estimates were computed for three pre-specified modifiable exposures using the Levin formula. Exposure prevalences were: Truancy ≥2 days = 32.9%, peer substance use ≥ some friends = 36.5% (alcohol) and 27.1% (tobacco), and low parental monitoring (≤ sample median) = 55.9%.

Peer substance use carried the largest attributable burden across outcomes. For 30-day e-cigarette use (*Y_VAPE30*), peer tobacco use accounted for an estimated 27.5% of cases, with truancy contributing an additional 14.8%. For any alcohol use in the last 30 days (*Y_ALC30*), peer alcohol use accounted for 26.9% of cases, truancy for 8.0%, and low parental monitoring for 4.7%. For binge drinking in the last 30 days (*Y_BINGE30*), peer alcohol use accounted for 19.7% of cases, with low parental monitoring (7.7%) exceeding truancy (3.1%) as the second largest modifiable contributor.

9.3.6. Risk ranking

Across all three outcomes, peer substance use consistently ranked as the highest-priority determinant when effect size was weighted by exposure prevalence. Perceived availability ranked second for alcohol outcomes. Truancy ranked second for 30-day e-cigarette use (*Y_VAPE30*) and third for any alcohol use in the last 30 days (*Y_ALC30*) after FDR correction. Parental monitoring showed a modest ranking for binge drinking, consistent with its larger PAF estimate for that outcome. Demographic variables such as gender,

school type, family wealth, and region did not rank among the top determinants in any model, suggesting that the primary drivers of adolescent substance use in this sample are social and perceptual rather than structural.

9.3.7. Conclusion and policy recommendations

These empirical findings closely align with recent longitudinal and cross sectional literature highlighting the primacy of social peer dynamics and behavioral patterns over purely demographic factors.

In a longitudinal study conducted by Sokolovsky et al. (2026) on tobacco products, alcohol, and cannabis use in the last thirty days, the co-use of electronic cigarettes with cannabis and alcohol was higher among adolescents in the fifteen to seventeen age group compared to other age groups, emphasizing the necessity of designing specific interventions such as treatment and family training programs tailored to this particular developmental stage. Robalino and Macy (2018) highlight the prominent influence of peers on the increase of adolescent smoking. The researchers emphasize that smoking among the most popular peers drives other adolescents to smoke, while the tendency of adolescents to avoid behaviors exhibited by their unpopular peers further increases smoking behavior.

Investigating adolescents perceptions of alcohol related content shared by their peers on social media, Meisel et al. (2022) reported that if an adolescent holds negative expectations regarding alcohol use, their peers alcohol-related social media posts reinforce these negative expectations. Furthermore, participants who perceive that their friends make alcohol-related posts exhibit higher alcohol consumption in the last thirty days, even after controlling for demographic factors, social media use, and descriptive norms regarding peer alcohol use. Additionally it is highlighted that adolescents who share alcohol related content on social media engage more frequently in binge drinking behaviors.

In their study aimed at determining the perception of peer alcohol use among adolescents, Colder et al. (2017) expressed that peer perception directly influences drinking behavior during early adolescence, likely through

modeling and social reinforcement, and that the drive for acceptance and alignment with peers contributes to positive attitudes toward drinking. Finally Tomé et al. (2012) emphasized that peer groups contribute to adolescents negative attitudes toward school, which may consequently lead adolescents to exhibit riskier behaviors such as truancy and violent conduct. Consistently, Henry and Thornberry (2010) noted that truancy is a powerful predictor of substance use among adolescents and that as truancy increases, substance use rises concurrently.

Based on the integrated model findings and the established literature, the following targeted policy recommendations are proposed to mitigate adolescent substance use and related behavioral risks in North Cyprus:

i. School Based Positive Peer Influence Programs

Given the dominant effect of peer substance use across all flagship outcomes, interventions must center on peer social dynamics. Schools should implement positive peer influence programs that leverage popular peer leaders to model healthy behaviors. Additionally, social norm correction campaigns should address adolescents tendency to overestimate substance use among their peers. By presenting empirical data showing that the vast majority of peers do not smoke or drink regularly, these initiatives can effectively dismantle the artificial social pressure to conform.

ii. Social Media Literacy and Digital Peer Norm Interventions

Reflecting empirical evidence that peer alcohol-related content on social media reinforces negative expectations and increases consumption risks, comprehensive media literacy modules should integrate into the school curriculum. National youth awareness campaigns should focus on how digital portrayals of substance use manipulate adolescent perceptions. By mobilizing peer leaders to generate protective and informative content on popular digital platforms, descriptive peer norms can be restructured online to favor healthier lifestyle choices.

iii. Early Warning Systems for School Truancy

Because truancy operates as a powerful and consistent predictor of substance use, education authorities and school administrations should collaborate to establish digitally-driven early warning systems. Mental health and counseling services must be automatically triggered upon a student's first unexcused absence to detect underlying peer pressure or negative attitudes toward school before they become chronic. Truancy should be treated not merely as an administrative disciplinary issue but as a critical behavioral marker for targeted early substance use prevention.

iv. Structural and Legal Restrictions on Perceived Accessibility

The high marginal effects of perceived ease of access for both alcohol and e-cigarettes necessitate stringent supply side policies. Enforcement of age limits and legal restrictions must be dramatically intensified around school perimeters, accompanied by strict administrative sanctions on illicit supply chains. Furthermore, public awareness programs should educate parents on restricting access to alcohol and prescription medications within the home environment, as reducing physical and psychological availability is vital to delaying the initiation and maintenance of use.

References

Colder, C. R., Read, J. P., Wieczorek, W. F., Eiden, R. D., Lengua, L. J., Hawk, L. W., Jr, Trucco, E. M., & Lopez-Vergara, H. I. (2017). Cognitive appraisals of alcohol use in early adolescence: Psychosocial predictors and reciprocal associations with alcohol use. *The Journal of Early Adolescence*, *37*(4), 525–558. https://doi.org/10.1177/0272431615611256

Henry, K. L., & Thornberry, T. P. (2010). Truancy and escalation of substance use during adolescence. *Journal of Studies on Alcohol and Drugs*, *71*(1), 115–124. https://doi.org/10.15288/jsad.2010.71.115

Meisel, S. N., Nesi, J., Janssen, T., & Jackson, K. M. (2022). Adolescent (mis)perceptions of peer alcohol posts on social media: Prospective associations with alcohol attitudes and use. *Alcoholism, Clinical and Experimental Research*, *46*(11), 2054–2067. https://doi.org/10.1111/acer.14935

Robalino, J. D., & Macy, M. (2018). Peer effects on adolescent smoking: Are popular teens more influential? *PloS One*, *13*(7), e0189360. https://doi.org/10.1371/journal.pone.0189360

Sokolovsky, A. W., Micalizzi, L., & Murphy, C. M. (2026). Longitudinal trends in the past 30-day co-use of nicotine/tobacco, alcohol, and cannabis among youth and adults in the PATH study. *Addictive Behaviors*, *176*, 108633. https://doi.org/10.1016/j.addbeh.2026.108633

Tomé, G., Matos, M., Simões, C., Diniz, J. A., & Camacho, I. (2012). How can peer group influence the behavior of adolescents: explanatory model. *Global Journal of Health Science*, *4*(2), 26–35. https://doi.org/10.5539/gjhs.v4n2p26