

Country level ecological analysis of per capita sugar and alcohol consumption and their association with dental caries prevalence in South Asian countries

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Short Report

Keywords:

Posted Date: February 27th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-8310665/v1>

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Additional Declarations: No competing interests reported.

Abstract

Background

Dental caries remains a significant public health concern globally. Dental caries is highly prevalent in South Asia, but the contribution of population-level dietary exposures remains unclear. Dietary sugar is a well-established risk factor, while alcohol consumption may influence oral health outcomes in adults. This study examined the ecological associations between per capita refined sugar availability, adult alcohol consumption, and the prevalence of untreated dental caries in South Asian countries.

Methods

Country-level data for seven South Asian countries (Afghanistan, Bangladesh, India, Iran, Maldives, Pakistan, and Sri Lanka) were obtained from the WHO Global Health Observatory. Variables included per capita refined sugar availability, adult per capita alcohol consumption, and prevalence of untreated dental caries in children (1–9 years) and adults (≥ 5 years). Simple linear regressions assessed ecological associations between dietary variables and caries prevalence.

Results

Sugar availability showed negligible associations with caries in both children ($R^2 = 0.052$) and adults ($R^2 = 0.031$). Adult alcohol consumption demonstrated a modest negative association with adult caries prevalence ($R^2 = 0.222$). These ecological associations likely reflect country-level confounding factors such as oral health infrastructure, socioeconomic status, and diet patterns rather than causal relationships.

Conclusion

Ecological analysis of South Asian countries showed limited correlation between sugar and alcohol consumption and dental caries prevalence. These findings highlight the multifactorial nature of caries and the influence of population-level health system and socioeconomic factors in oral health research. Ecological correlations were weak, indicating that national dental caries burdens in South Asia are influenced more by oral health systems and social determinants than by population-level sugar availability or alcohol exposure.

INTRODUCTION

Oral diseases remain a major global public health challenge, affecting an estimated 3.5 billion people worldwide and disproportionately impacting low- and middle-income countries.(1, 2) Among these conditions, dental caries is the most prevalent, contributing to pain, infection, impaired quality of life, and

substantial economic burden.(3, 4) The Global Burden of Disease (GBD) shows untreated dental caries in permanent teeth is the most common health condition globally.(5) South Asia, home to nearly a quarter of the world's population, continues to face a high burden of dental caries in children, with recent global reports identifying the region as having the highest prevalence of caries in primary teeth.(6, 7)

Dietary sugar is one of the most consistently identified modifiable risk factors for dental caries. The biological mechanism is well established: fermentable carbohydrates promote acid production by cariogenic bacteria, leading to demineralization of dental enamel.(8, 9) As such, population-level sugar availability is often used as an indicator of dietary exposure in ecological public health analyses.(10) Several global reports have highlighted rising sugar consumption in developing economies, but the relationship between country-level sugar availability and oral disease burden in South Asia remains poorly understood.(11)

Alcohol consumption, on the other hand, is primarily studied in relation to oral cancer and periodontal disease.(12–14) However, alcohol may indirectly influence dental caries risk through multiple pathways, including reduced salivary flow, high sugar content in certain alcoholic beverages, and associated lifestyle factors such as tobacco use.(15, 16) Despite these theoretical links, ecological evidence on alcohol consumption and dental caries prevalence is limited, particularly in the South Asian context where alcohol use varies dramatically between countries due to cultural, legal, and religious factors.

The World Health Organization's (WHO) Global Health Observatory recently released updated oral health profiles for all member states, providing standardized indicators for dental caries and associated risk factors.(17) These data offer a unique opportunity to explore regional trends and generate hypotheses regarding population-level determinants of oral diseases.

Given this context, the present study aims to examine ecological associations between per capita refined sugar availability, per capita alcohol consumption, and the prevalence of untreated dental caries in both children and adults across seven South Asian countries. By analysing population-level patterns, this ecological approach provides valuable insights into broader trends, helping to inform future public health strategies, research priorities, and oral health policy development in the region.(18)

METHODS

Study Design and Setting

This study employed an ecological cross-sectional design using publicly available country-level data from the World Health Organization (WHO) Global Health Observatory (GHO) oral health database.(17)

The analysis focused on seven South Asian countries for which complete data were available: Afghanistan, Bangladesh, India, Iran, Maldives, Pakistan, and Sri Lanka. These countries were selected as they represent the South Asian region as defined by WHO and possess comparable socio-demographic profiles, with varying dietary patterns and oral health outcomes.

Data Sources

All variables included in this analysis were extracted from the WHO Global Oral Health Database (GHO, 2025 update), which compiles standardized national statistics derived from surveys, health system reporting, and population-level monitoring initiatives. The following indicators were collected:

1. Per capita availability of refined sugar (g/day)

– Derived from national food balance sheets and represents average availability of refined sugar within the population.

2. Alcohol consumption, per capita (litres of pure alcohol/year, 15+ years)

– A three-year average indicator aligned with SDG 3.5.2; includes recorded and unrecorded consumption.

3. Prevalence of untreated dental caries:

- Deciduous teeth in children aged 1–9 years (%)
- Permanent teeth in people aged ≥ 5 years (%)

These indicators were available for all seven countries in the most recent reporting period.

Data Preparation and Management

Data from each variable were compiled into a unified spreadsheet (Microsoft Excel 365). Because alcohol consumption data for some countries (e.g., Afghanistan, Bangladesh) were reported as ranges (e.g., 0.0 [0.0–0.1]), the lower bound value (0.0) was used for analysis to avoid upward bias. No imputation or transformations were applied due to the small dataset and the interpretability of raw values in ecological research.

Statistical Analysis

All analyses were conducted in Microsoft Excel using built-in statistical tools. The primary objective was to examine country-level associations between:

1. Per capita sugar availability and caries in children (deciduous dentition)
2. Per capita sugar availability and caries in adults (permanent dentition)
3. Per capita alcohol consumption and caries in adults

Given the sample size of countries ($n=7$), simple linear regression was selected as the most appropriate method for exploratory ecological analysis. Scatter plots were generated for each pair of variables, and Excel's "Add Trendline" function was used to obtain:

- Regression equation (slope and intercept)
- Coefficient of determination (R^2)

- Visualization of fitted regression line

No multivariable modelling was performed due to sample size constraints and risk of model overfitting.

Ethical Considerations

The study used publicly accessible, de-identified, aggregated data from WHO databases. As no human participants were involved and no identifiable information was used, ethical approval was not required.

RESULTS

Descriptive Data

Data from seven South Asian countries were analysed. Per capita refined sugar availability ranged from 16.9 g/day in Bangladesh to 75.6 g/day in Sri Lanka. Alcohol consumption among adults (15 + years) showed wide variation, from 0.0 L per capita in Afghanistan and Bangladesh to 4.5 L per capita in India.

The prevalence of untreated dental caries in children (deciduous teeth) ranged from 43.0% to 46.7%, whereas prevalence in adults (permanent teeth) ranged from 27.0% to 36.8% across the region.

A summary of country-level data is presented in Table 1.

Table 1

Per capita sugar and alcohol consumption and prevalence of untreated dental caries in children and adults across South Asian countries

Country	Per capita availability of refined sugar (g/day)	Prevalence of untreated caries of deciduous teeth in children 1–9 years (%)	Prevalence of untreated caries of permanent teeth in people 5 + years (%)	Alcohol, total per capita (15+) consumption (in litres of pure alcohol) (SDG Indicator 3.5.2), three-year average
Afghanistan	46.8	45.8	36.8	0.0
Bangladesh	16.9	43.5	30.4	0.0
India	53.8	43.3	28.8	4.5
Iran	74.6	46.7	33.6	0.1
Maldives	62.8	44.0	28.0	1.6
Pakistan	57.7	45.7	27.0	0.1
Sri Lanka	75.6	43.0	27.4	2.7

Association Between Sugar Availability and Dental Caries in Children

A simple linear regression was performed between per capita sugar availability and the prevalence of untreated caries in children aged 1–9 years as given in Fig. 1.

The fitted regression equation was: $y = 0.0168x + 43.641$

with a coefficient of determination: $R^2 = 0.0524$

The scatter plot of per-capita refined sugar availability and the prevalence of untreated caries in children (1–9 years) shows a very weak positive association ($R^2 = 0.052$). The regression equation ($y = 0.0168x + 43.641$) indicates, that for every 1 g/day increase in sugar availability, caries prevalence increases by only 0.0168%. However, sugar availability explains only 5.2% of the variation in caries across the seven countries, suggesting that sugar alone is not a major determinant of caries in this south asian countries. Other factors such as fluoride exposure, oral hygiene behavior, socioeconomic status, and access to dental care likely play a much larger role.

Association Between Sugar Availability and Dental Caries in Adults

Regression analysis between per capita sugar availability and prevalence of untreated caries in adults aged ≥ 5 years as given in Fig. 2.

The fitted regression equation was: $y = -0.0322x + 32.072$

with a coefficient of determination: $R^2 = 0.0311$

This also reflects a very weak association, accounting for only 3.1% of the variability in adult caries prevalence.

The linear regression analysis for untreated dental caries in permanent teeth among individuals aged 5 + years revealed a very weak and negative association with per capita sugar availability ($y = -0.0322x + 32.072$, $R^2 = 0.0311$). The regression equation indicates, for every 1 g/day increase in sugar availability, the prevalence of untreated caries in permanent teeth *decreases* by 0.0322%. Sugar availability explains only about 3.1% of the variation in adult caries prevalence - essentially no meaningful relationship. This suggests that sugar availability alone does not explain the variation in adult caries prevalence in these South Asian countries. The negative slope indicates a slight decrease in caries prevalence with increasing sugar, but this effect is negligible and likely not biologically meaningful.

Association Between Alcohol Consumption and Dental Caries in Adults

Linear regression between alcohol consumption and prevalence of untreated caries in adults aged ≥ 5 years as given in Fig. 3.

The fitted regression equation was $y = -0.2267x + 8.1507$

with a coefficient of determination: $R^2 = 0.2216$

This model explained that higher alcohol consumption is associated with slightly lower adult caries prevalence across South Asian countries, although the effect is small and explains only ~ 22% of the variation.

Regression analysis between adult per capita alcohol consumption and untreated dental caries in adults (5 + years) revealed a weak negative association ($y = -0.2267x + 8.1507$, $R^2 = 0.222$). The regression equation indicates, for every 1 litre increase in per capita alcohol consumption, adult caries prevalence decreases by ~ 0.23%. Alcohol explains only 22% of the variation in adult caries prevalence across these 7 countries - modest at best. This ecological relationship likely reflects country-level confounding factors such as oral health care access, diet, or socioeconomic status rather than a protective effect of alcohol.

Summary of Regression Findings

- Sugar availability showed minimal correlation with dental caries in both children and adults.
- Alcohol consumption was negatively associated with adult caries prevalence, although this association remained modest and ecological in nature.

All regression plots with trendlines, R^2 values, and equations were generated using Microsoft Excel and are available as Figs. 1–3.

Interpretation

Sugar availability showed weak or negligible correlations with dental caries in both children and adults. Adult alcohol consumption was inversely associated with adult caries prevalence at the country level, but this likely reflects confounding by socioeconomic or health system factors rather than a protective effect of alcohol.

DISCUSSION

This ecological analysis examined the association of per capita refined sugar availability and adult alcohol consumption with the prevalence of untreated dental caries across seven South Asian countries. Contrary to the well-established individual-level evidence linking dietary sugar to caries development, the present study found minimal ecological correlation between sugar availability and untreated dental caries in both children and adults.(9, 11) Alcohol consumption demonstrated a modest negative association with adult caries prevalence, though this is likely attributable to contextual and health-system differences rather than a direct protective effect.

The weak associations observed for sugar may be explained by several factors. First, per capita sugar availability does not equate to individual sugar intake, as food availability metrics may mask variation in actual consumption due to household distribution patterns, socioeconomic disparities, food insecurity, and cultural dietary preferences.(19) Second, dental caries is strongly influenced by oral hygiene

behaviors, fluoride exposure, and access to preventive dental care-factors that vary considerably across South Asian countries and may overshadow dietary contributions in ecological analyses.(3) Third, as an aggregate measure, prevalence of untreated caries does not account for restorative care access; countries with more dental services may report lower prevalence, independent of sugar intake.(9)

The inverse association between alcohol consumption and adult dental caries should be interpreted with caution. Alcohol intake is shaped by cultural and religious norms in South Asia, resulting in pronounced differences between countries such as India, and Sri Lanka compared with Afghanistan or Bangladesh. Higher alcohol-consuming countries may also have greater urbanization, higher socioeconomic status, or better oral healthcare infrastructure, which could independently reduce caries prevalence.(20, 21) Therefore, the observed negative association likely reflects confounding by structural and socio-behavioral factors, rather than any causal effect of alcohol on caries risk. Furthermore, alcohol is known to contribute to oral cancer and periodontal disease, and high consumption often correlates with tobacco use-reinforcing that alcohol is not protective for oral health.

The findings align with broader evidence emphasizing the multifactorial nature of dental caries, particularly in low- and middle-income regions where preventive systems are unevenly distributed. The results indicate that diet alone cannot explain national patterns of untreated caries without considering oral health service delivery, fluoride programs, health literacy, and broader social determinants. (22)

Strengths and Limitations

A key strength of this study is the use of standardized WHO GHO data, allowing for cross-country comparability. Additionally, this is one of the few analyses exploring sugar–caries ecological relationships specifically within the South Asian region.

However, limitations must be acknowledged. The small number of countries ($n = 7$) restricts statistical power, and ecological designs cannot account for within-country variability or individual-level risk factors, giving rise to potential ecological fallacy. The alcohol consumption values represent population averages and may not reflect actual exposure patterns relevant to oral health. Finally, other important influences on dental caries-such as fluoride use, oral hygiene practices, socioeconomic gradients, and dietary diversity-were not considered in this study.

Implications and Future Directions

These findings highlight the need for country-level oral health surveillance that captures behavioral, environmental, and systemic determinants. Future research should incorporate individual-level datasets, include multivariable models, and explore additional risk factors such as tobacco use, sugar-sweetened beverages, fluoride programs, and access to dental services. Policymakers should prioritize comprehensive oral health strategies that extend beyond dietary interventions to address preventive care access, public awareness, and early detection. Recent evidence supports integrating oral health

education in school curricula and highlights a broad range of social, behavioral, and system-level factors influencing oral disease beyond diet and sugar exposure.(23, 24)

CONCLUSION

This ecological study of seven South Asian countries found limited associations between per capita refined sugar availability and the prevalence of untreated dental caries in both children and adults. Although alcohol consumption showed a modest inverse association with adult caries prevalence, this pattern is likely driven by broader socioeconomic and health-system differences rather than any biological protective effect. Taken together, the findings highlights the complexity of dental caries as a public health issue and demonstrate that national-level oral disease patterns cannot be explained by dietary factors alone. The findings indicate the multifactorial etiology of caries and the importance of country-level oral health policies, preventive programs, and health system factors in mitigating oral disease burden. Policy responses should prioritize oral health system strengthening and prevention programs rather than focusing narrowly on dietary factors alone.

Declarations

Ethical approval

Not applicable. The study utilized publicly accessible, aggregated country-level data and did not involve human subjects or personal health information.

Consent to participate

Not applicable.

Consent to publish

Not applicable.

Clinical trial number

Not applicable

Funding

None

Author Contribution

H.D. conceived the study, collected and analyzed the data, prepared all figures and tables, and wrote the manuscript. H.D. reviewed and approved the final version of the manuscript.

Data Availability

All data used in this study are publicly available through the World Health Organization Global Health Observatory (GHO) oral health database. The dataset can be accessed by searching the oral health indicators within the GHO portal. No proprietary or restricted data were used.

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Figures

Association between per capita sugar availability and prevalence of untreated caries in children (1–9 years) across South Asian countries

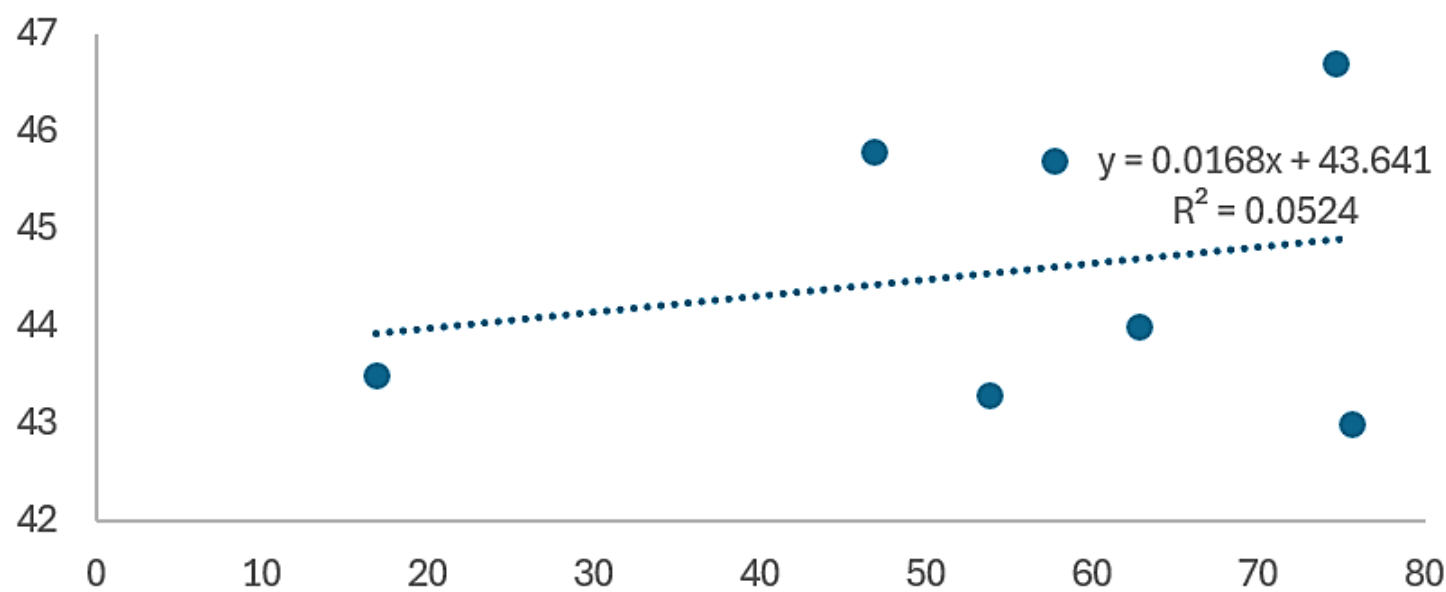


Figure 1

Association between per capita sugar availability and prevalence of untreated caries in children (1–9 years) across South Asian countries

Association between per capita sugar availability and prevalence of untreated caries in adults (≥5 years) across South Asian countries

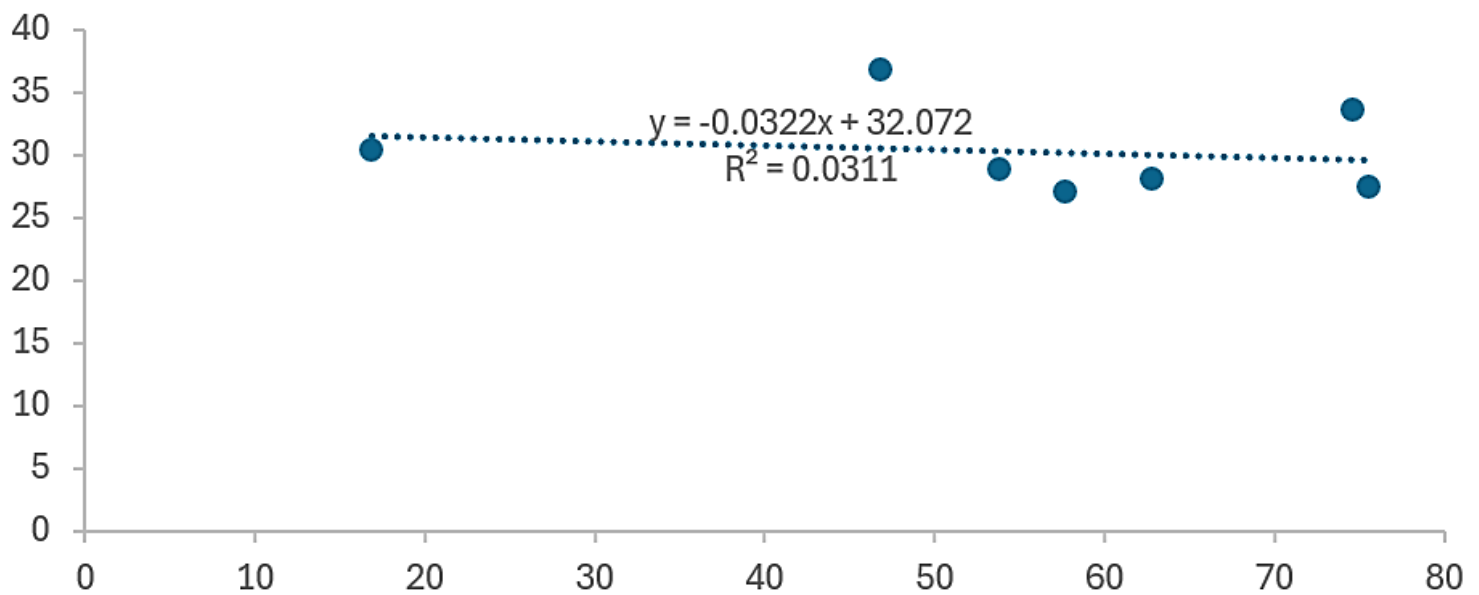


Figure 2

Association between per capita sugar availability and prevalence of untreated caries in adults (≥5 years) across South Asian countries

Association between adult per capita alcohol consumption and prevalence of untreated caries in adults (≥ 5 years) across South Asian countries

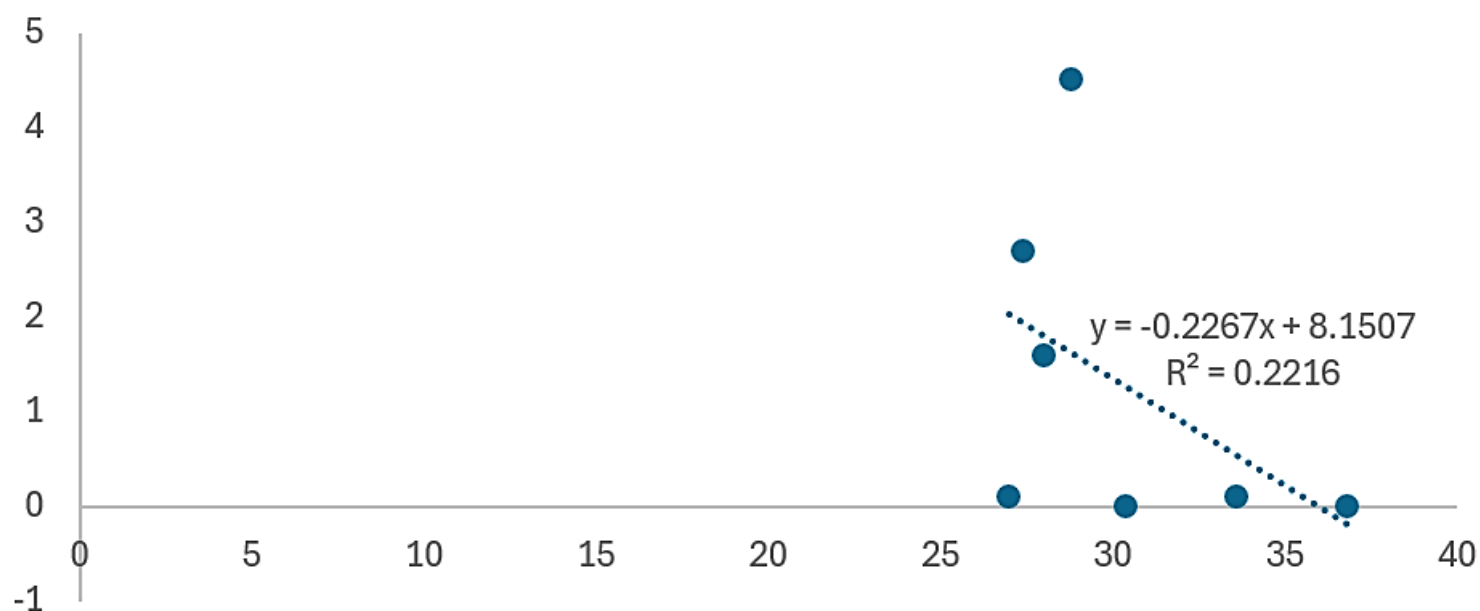


Figure 3

Association between adult per capita alcohol consumption and prevalence of untreated caries in adults (≥ 5 years) across South Asian countries