



Association of Neighborhood Alcohol Environment With Alcohol Intake and Cardiovascular Risk Factors in India: Cross-Sectional Evidence From APCAPS

Yingjun Li^{1*}, Poppy Alice Carson Mallinson^{2†}, Aastha Aggarwal³, Bharati Kulkarni⁴ and Sanjay Kinra²

¹ Department of Epidemiology and Health Statistics, Hangzhou Medical College School of Public Health, Hangzhou, China, ² Department of Non-communicable Disease Epidemiology, London School of Hygiene and Tropical Medicine, London, United Kingdom, ³ Centre for Chronic Conditions and Injuries, Public Health Foundation of India, New Delhi, India, ⁴ National Institute of Nutrition, Hyderabad, India

OPEN ACCESS

Edited by:

Stefania Triunfo,
University of Milan, Italy

Reviewed by:

Tim Welborn,
Sir Charles Gairdner Hospital,
Australia
Mustafa Agah Tekindal,
İzmir Kâtip Çelebi University, Turkey

*Correspondence:

Yingjun Li
2016034036@hmc.edu.cn

[†] These authors have contributed
equally to this work and share first
authorship

Specialty section:

This article was submitted to
Cardiovascular Epidemiology
and Prevention,
a section of the journal
Frontiers in Cardiovascular Medicine

Received: 27 December 2021

Accepted: 05 April 2022

Published: 29 April 2022

Citation:

Li Y, Mallinson PAC, Aggarwal A,
Kulkarni B and Kinra S (2022)
Association of Neighborhood Alcohol
Environment With Alcohol Intake
and Cardiovascular Risk Factors
in India: Cross-Sectional Evidence
From APCAPS.
Front. Cardiovasc. Med. 9:844086.
doi: 10.3389/fcvm.2022.844086

There are more and more proofs about the impact of neighborhood alcohol environment on alcohol-associated events. The relationship between the neighborhood availability and accessibility of alcohol outlet with individual level of alcohol consumption along with 11 cardiovascular risk factors was explored for the first time in India using data from the 3rd follow-up of the Andhra Pradesh children and parents study (APCAPS) ($n = 6156$, for liquor intake and 5,641 for heart and blood vessel risk elements). In fully adjusted models, volunteers in the lowest tertile performed worse than volunteers in the highest tertile of distance to the closest alcohol outlet were more probably to exhibit less alcohol consumption (-14.40 g/day, 95% CI: $-26.21, -2.59$). A unit per km^2 rise in alcohol outlet density in 400 m buffering area was related to a rise in waist circumference (1.45 mm, 95% CI: 0.13, 2.77), SBP (0.29 mmHg, 95% CI: 0.09, 0.49), and DBP (0.19 mmHg, 95% CI: 0.03, 0.35). A unit per 100 m rise in distance to the closest alcohol outlet was related to a rise in waist circumference (-2.39 mm, 95% CI: $-4.18, -0.59$), SBP (-0.41 mmHg, 95% CI: $-0.68, -0.15$), and DBP (-0.29 mmHg, 95% CI: $-0.51, -0.07$). Neighborhood availability of alcohol outlets within immediate locality of participants' households had a closer relationship with cardiovascular risk factors than that within the whole village. Public health policies designed to limit neighborhood availability and accessibility of alcohol outlets ought to be advocated in southern India.

Keywords: alcohol environment, availability, accessibility, alcohol intake, cardiovascular risk, APCAPS

INTRODUCTION

Cardiovascular disease (CVD) causes huge disease burden and deaths worldwide (1). In India, it contributed 28.1% of the total deaths and 14.1% of the total disability-adjusted life-years in 2016 (2). Alcohol use is a key modifiable risk factor for acute and chronic diseases globally, causing 2.8 million deaths in 2016 (3). Heavy drinking is associated with an increased risk of initial presentation

of several symptomatic manifestations of CVD, such as coronary death, heart failure, cardiac arrest, transient ischemic attack, ischemic stroke, intracerebral hemorrhage, and peripheral arterial disease (4). In India, alcohol attributable deaths would lead to a loss of 258 million life years between 2011 and 2,050, causing significant negative health impact and economic burden (5).

Data from multiple countries indicate a close connection between the neighborhood alcohol environment, especially the availability and accessibility of alcohol (on and/or off-premises), and the individual alcohol consumption (6). However, most of the existing studies have been conducted in high-income countries and have focused on the association between alcohol environment and drinking behaviors and beliefs among adolescents or young adults (7–9). Very few studies have been carried out in low- and middle-income countries. Ibitoye et al. found that high density of alcohol-selling outlets and outdoor advertisements increased alcohol use among adolescents in Tanzania (10). Study from rural South Africa found that density of alcohol outlets was associated with problematic drinking among young men (11).

Further, there is increasing evidence about the impact of neighborhood alcohol environment on alcohol-related events including experienced violence, injuries, and drunk-driving fatalities (12–14). Higher alcohol outlet density was also shown to be associated with non-injury health outcomes such as liver problems, mental health, sexually transmitted infections, and total deaths (15–17). By now, to the best of our knowledge, no study has addressed the association between the availability and accessibility of alcohol with individual level of alcohol consumption and cardiovascular risk factors in general population in low- and middle-income countries.

In order to inform policies for the control of local alcohol use and disease burden of CVD in low- and middle-income countries, further evidence on the effect of alcohol environment on individual alcohol use as well as cardiovascular risk is urgently needed. Therefore, we carried out data analysis from a per-household cohort study in southern India here to investigate whether access to and availability of alcohol outlets in the local neighborhood is related with alcohol consumption and cardiovascular risk factors.

MATERIALS AND METHODS

Study Participants

The Andhra Pradesh children and parents study (APCAPS) study has been explained previously (18, 19). In short, it's an inter-generation cohort in south India, which started with the follow-up of the participants of the Hyderabad Nutrition Trial (HNT) conducted from 1987 to 1990. It was conducted in 29 villages close to Hyderabad in Ranga Reddy district, Andhra Pradesh. The data used in this cross-sectional analysis are from the 3rd follow-up where the index participants of HNT and their family members were enrolled. Between 2010 and 2012, data on sociodemographic features, lifestyle-related factors, anthropometric measurements, and heart and blood

vessel biomarkers of study participants was collected (20–22). Of the 6,659 participants from 3rd follow-up, current analysis is based on data from 6,156 participants after removing 503 participants with missing information on household address, sociodemographic features, or drinking quantity. For analysis of association between alcohol environment and cardiovascular risk factors, data from $n = 5,641$ participants was considered after removing participants with diagnosed heart disease and/or missing data on lifestyle risk factors.

Global Positioning System-Dependent Surveys of Alcohol Environment

In 2016, geographic coordinates (latitude and longitude) of all the alcohol outlets in study villages were captured by Global Positioning System (GPS). Both availability and accessibility were examined to measure neighborhood alcohol environment. Availability of alcohol outlets was measured near the participants' households and in the entire village by determining density of outlets in two buffering regions of participants' households, 400 and 1,600 m, respectively. The degree of accessibility of an alcohol outlet was measured as the distance from a household to the closest outlet. The R software 3.5.1 was adopted to obtain the geography exposures.

Alcohol Intake and Cardiovascular Risk Factors

Data on alcohol intake were collected through questionnaire by well-experienced researchers in the 3rd follow-up. Fasting glucose, insulin, body mass index (BMI), waist circumference, waist-hip-ratio (WHR), blood pressure, serum triglycerides, total cholesterol, high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) were analyzed as cardiovascular risk factors herein. Fasting blood specimens were collected and prepared for physiological measurements and biochemical assays in the 3rd follow-up (19). Glucose level was estimated *via* the glucose oxidase/peroxidase-4-aminophenazone-phenol procedure. Insulin level was estimated using an electrochemiluminescence immunoassay. Concentrations of triglycerides and cholesterols (HDL, total) were measured using enzymatic calorimetric method (23, 24). LDL-C level was calculated by standard Friedewald–Fredrickson equation (25). The anthropometry evaluations included weight (identified to the nearest 0.1 kg by digitalized SECA scale), height (nearest 1 mm by portable plastic stadiometer), as well as waist circumference and hip circumference (nearest 1 mm by portable plastic stadiometer). The BMI was calculated by dividing weight in kilograms by the square of height in meters. The WHR was calculated by dividing waist circumference by hip circumference. The blood pressure was measured at the right arm in the seated posture *via* an oscillometry equipment (Omron M5-I). Three results were recorded and the average value was considered for these measurements.

Covariates

The data on sociodemographic and lifestyle variables such as age, gender, educational level (illiterate, primary school,

middle school, and above), occupation (unskilled, skilled, and others), Standard of Living Index (SLI) (low, middle, and high), smoking (never, former, and current), drinking (gram/day), and physical activity (extremely inactive, sedentary, moderately active, and vigorously active) were collected using standardized questionnaires by practiced researchers. The SLI was adopted to measure the family socioeconomic conditions (20). The data on diet intake (in the last year) and physical activities (in the last week) were gathered by semi-quantitation questionnaires (19).

Statistical Analysis

Considering the possible clustering of neighborhood alcohol environment, three-level mixed-effects linear regression was employed to evaluate the relationship between the densities and distances of alcohol outlets (exposures) with individual level of alcohol consumption (outcome 1) and cardiovascular risk factors (outcome 2). In the analysis of alcohol consumption, age (continuous, year), and gender [categorical, (male and female)] were adjusted in model 1; education level [categorical, (illiterate, primary school, and middle school and above)], occupation [categorical, (unskilled, skilled, and others)], and SLI [categorical, (low, middle, and high)] were further adjusted in model 2. In the analysis of cardiovascular risk factors, we adjusted for same variables in model 1 and 2; we further included tobacco use [categorical, (never, former, and current)], physical activity [categorical, (extremely inactive, sedentary, moderately active, and vigorously active)], and daily energy intake (continuous, kcal/day) in model 3. To account for the effect of disease diagnosis on behaviors, we performed a sensitivity analysis by excluding participants with diagnosed high blood pressure and/or diabetic disease to account for the effect of disease diagnosis on behaviors.

Stata software 15.1 was used for statistical analyses. PASS software 15.0 was used for power analysis in linear regression. Take SBP for example, a sample size of 5,641 achieves 99% power to detect a change in slope from 0.00 under the null hypothesis to 0.31 under the alternative hypothesis when the standard deviation of the alcohol outlet density (units/km²) within 400 m buffering area is 2.96, the standard deviation of SBP (mmHg) is 15.89, and the two-sided significance level is 0.05.

RESULTS

Baseline Characteristics

Our data set for the analysis of the association between alcohol environment and cardiovascular risk factors included 5,641 individuals (3,244 men and 2,397 women) residing in 29 villages with median age of 29.1 years. **Table 1** presents the sociodemographic characteristics of participants, densities and distances of alcohol outlets, and measures of alcohol intake and cardiovascular risk factors. The median intake of alcohol was 29.1 gram (interquartile range: 68.6 gram) per day and the densities of alcohol outlets (on and/or off-premise) within 400 m were higher than that within 1,600 m.

TABLE 1 | Socio-demographic, food environment, and biological characteristics of APCAPS participants.

Characteristics (N = 5,641)	All	
	Median	P5-P95
Socio-demographic factors		
Age (years)	29.1	16.2–60.0
Sex (%)		
Male	57.5	
Female	42.5	
Education (%)		
Illiterate	35.7	
Primary school	23.3	
Middle school and above	41.0	
Occupation (%)		
Unskilled	41.32	
Skilled	27.83	
Others	30.85	
Standard of living index (%)		
Low	27.3	
Middle	37.6	
High	35.2	
Alcohol drinking (g/day)	29.1	0–373.6
Energy intake (kcal/day)	2117.3	1106.2–3987.4
Smoking status (%)		
Never	74.8	
Former	1.1	
Current	24.1	
Physical activity (%)		
Extremely inactive	15.2	
Sedentary	54.7	
Moderately active	25.1	
Vigorously active	5.0	
Alcohol environment		
Alcohol outlet density (units/km²)		
≤400 m	4.0	0–9.9
≤1,600 m	0.4	0.1–1.0
Distance to the nearest outlet(m)	159.8	31.0–505.8
Biological characteristics		
BMI (Kg/m ²)	20.0	15.3–27.4
Waist circumference (mm)	705.0	563.0–905.5
WHR	0.8	0.7–1.0
Systolic blood pressure (mmHg)	117.3	99.7–150.0
Diastolic blood pressure (mmHg)	76.7	59.3–101.3
Fasting glucose (mg/dl)	90.9	75.5–118.1
Insulin (Uu/ml)	5.2	1.1–16.4
Triglycerides (mmol/L)	1.2	0.6–3.1
Total cholesterol (mmol/L)	4.2	2.8–6.04
HDL cholesterol (mmol/L)	1.1	0.7–1.7
LDL cholesterol (mmol/L)	2.4	1.3–3.9

P5, 5th percentile; P95, 95th percentile.

Alcohol Outlet and Alcohol Consumption

Table 2 presents associations between availability and accessibility of alcohol outlets and individual level of alcohol

TABLE 2 | Association between alcohol availability and accessibility with individual level of alcohol intake in APCAPS participants ($n = 6,156$).

	Model 1			Model 2		
	β	95% CI	p	β	95% CI	p
Outlet density in 400 m buffer (units/km²)						
Linear, per 1- units/km ² increment	0.06	-1.97, 2.09	0.956	0.14	-1.87, 2.14	0.893
Tertile 1	Reference			Reference		
Tertile 2	6.72	-8.76, 22.21	0.395	8.13	-7.16, 23.43	0.297
Tertile 3	4.26	-13.20, 21.71	0.633	5.50	-11.77, 22.76	0.533
Outlet density in 1,600 m buffer (units/km²)						
Linear, per 1- units/km ² increment	-25.19	-56.15, 5.77	0.111	-23.76	-54.30, 6.77	0.127
Tertile 1	Reference			Reference		
Tertile 2	1.85	-21.11, 24.80	0.875	3.21	-19.41, 25.82	0.781
Tertile 3	-11.73	-32.06, 8.60	0.258	-10.69	-30.73, 9.35	0.296
Distance to the nearest outlet						
Linear, per 100 m increment	-0.75	-3.35, 1.86	0.574	-0.91	-3.48, 1.67	0.490
Tertile 1	Reference			Reference		
Tertile 2	-5.01	-15.88, 5.85	0.366	-4.23	-14.95, 6.50	0.440
Tertile 3	-14.07	-26.02, -2.12	0.021	-14.40	-26.21, -2.59	0.017

Model 1 is adjusted for age and sex. Model 2 is adjusted for model 1 + education, occupation, and Standard of Living Index. Bold number indicates that the estimates reach statistical significance.

consumption. In model 1, compared with participants at the lowest tertile, those at the highest tertile of distance to the nearest alcohol outlet were more likely to have lower level of alcohol consumption [-14.07 g/day, 95% CI: -26.02, -2.12]. The association stayed robust in fully adjusted model 2 (-14.40 g/day, 95% CI: -26.21, -2.59). There was no association between density of alcohol outlet within 400 m buffering area or 1,600 m buffering area with daily alcohol intake.

Alcohol Outlet and Cardiovascular Risk Factors

The association between availability and accessibility of alcohol outlets and cardiovascular risk factors is presented in Table 3. In fully adjusted models, a unit per km² increase in alcohol outlets' density within 400 m buffering area was associated with an increase in waist circumference (1.45 mm, 95% CI: 0.13, 2.77), systolic blood pressure (SBP) (0.29 mmHg, 95% CI: 0.09, 0.49), and diastolic blood pressure (DBP) (0.19 mmHg, 95% CI: 0.03, 0.35). There was no association between densities of alcohol outlets within 1,600 m buffering area with cardiovascular risk factors.

In fully adjusted models, a unit per 100 m increase in distance to the closest alcohol outlet was associated with a decrease in waist circumference (-2.39 mm, 95% CI: -4.18, -0.59), SBP (-0.41 mmHg, 95% CI: -0.68, -0.15), and DBP (-0.29 mmHg, 95% CI: -0.51, -0.07). Association between density and distance of alcohol outlet with other cardiovascular risk factors was weak and inconsistent across different models.

Sensitivity Analysis

Supplementary Table 1 presents associations between availability and accessibility of alcohol outlets and cardiovascular risk

factors after excluding participants with high blood pressure and diabetic disease ($n = 5,294$). The results were largely unchanged except the association between alcohol outlets density within 400 m buffering area and waist circumference. The significant association disappeared in fully adjusted model (1.15 mm, 95% CI: -0.12, 2.43).

DISCUSSION

We examined associations between neighborhood alcohol environment with individual level alcohol intake and cardiovascular risk factors in data from the 3rd wave of follow-up of APCAPS. Greater distance to the nearest alcohol outlet was associated with a lower daily alcohol intake, waist circumference and blood pressure. Higher density of alcohol outlets within 400 m buffering area was associated with higher waist circumference and blood pressure. There was no link found between alcohol outlets within 1,600 m buffering zone and daily alcohol intake and cardiovascular risk factors. To the best of our knowledge, this is the first study to examine both availability and accessibility of alcohol outlets in the local neighborhood in relation to both alcohol intake and multiple cardiovascular risk factors in India.

Previous studies have indicated that density of alcohol outlets is significantly associated with increased alcohol consumption in developed countries (26–28). Few studies have been reported from the low- and middle-income countries. A study carried out in rural South Africa found that alcohol outlet density was not associated with prevalence of heavy drinking (11), which was in accordance with our results. We found no association between density of alcohol outlets within 400 m buffering area or 1,600 m buffering area with daily alcohol intake. Azar et al. found significant association between density

TABLE 3 | Association between alcohol availability and accessibility with cardiovascular risk factors in APCAPS participants ($n = 5,641$).

	Model 1			Model 2			Model 3		
	β	95% CI	p	β	95% CI	p	B	95% CI	p
Glucose									
Alcohol outlet density (units/km²)									
≤400 m	0.09	-0.20, 0.37	0.557	0.05	-0.24, 0.34	0.741	0.06	-0.22, 0.34	0.684
≤1600 m	2.46	-1.74, 6.67	0.251	2.29	-1.90, 6.47	0.284	2.36	-1.67, 6.38	0.251
Distance to the nearest outlet (100 m)	-0.18	-0.57, 0.21	0.372	-0.14	-0.53, 0.25	0.472	-0.15	-0.54, 0.24	0.454
Insulin									
Alcohol outlet density (units/km²)									
≤400 m	0.08	-0.01, 0.18	0.095	0.05	-0.05, 0.14	0.328	0.04	-0.05, 0.14	0.380
≤1600 m	1.05	-0.38, 2.49	0.151	0.91	-0.52, 2.33	0.213	0.90	-0.54, 2.34	0.220
Distance to the nearest outlet (100 m)	-0.73	-1.63, 0.16	0.109	-0.47	-1.36, 0.41	0.296	-0.46	-1.34, 0.43	0.312
BMI									
Alcohol outlet density (units/km²)									
≤400 m	0.06	0.01, 0.11	0.025	0.04	-0.01, 0.09	0.096	0.04	-0.01, 0.09	0.130
≤1600 m	0.48	-0.21, 1.18	0.171	0.47	-0.20, 1.15	0.171	0.46	-0.24, 1.15	0.197
Distance to the nearest outlet (100 m)	-0.08	-0.16, -0.01	0.021	-0.07	-0.14, 0.00	0.067	-0.06	-0.13, 0.01	0.076
Waist circumference									
Alcohol outlet density (units/km²)									
≤400 m	2.03	0.68, 3.38	0.003	1.53	0.23, 2.84	0.021	1.45	0.13, 2.77	0.031
≤1,600 m	13.92	-4.50, 32.35	0.139	14.50	-3.15, 32.14	0.107	13.91	-4.20, 32.02	0.132
Distance to the nearest outlet (100 m)	-2.92	-4.77, -1.08	0.002	-2.44	-4.23, -0.64	0.008	-2.39	-4.18, -0.59	0.009
WHR*									
Alcohol outlet density (units/km²)									
≤400 m	0.61	-0.22, 1.45	0.152	0.51	-0.31, 1.34	0.223	0.48	-0.34, 1.31	0.251
≤1,600 m	10.87	-1.52, 23.27	0.086	11.27	-0.84, 23.38	0.068	11.20	-0.99, 23.40	0.072
Distance to the nearest outlet (100 m)	-0.68	-1.81, 0.44	0.232	-0.68	-1.78, 0.43	0.230	-0.66	-1.76, 0.44	0.241
Systolic blood pressure									
Alcohol outlet density (units/km²)									
≤400 m	0.31	0.11, 0.51	0.002	0.29	0.09, 0.49	0.004	0.29	0.09, 0.49	0.005
≤1600 m	2.74	-0.26, 5.74	0.074	2.75	-0.23, 5.74	0.071	2.76	-0.24, 5.75	0.071
Distance to the nearest outlet (100 m)	-0.44	-0.71, -0.17	0.001	-0.42	-0.68, -0.15	0.002	-0.41	-0.68, -0.15	0.002
Diastolic blood pressure									
Alcohol outlet density (units/km²)									
≤400 m	0.22	0.05, 0.38	0.009	0.20	0.03, 0.36	0.018	0.19	0.03, 0.35	0.020
≤1,600 m	2.20	-0.20, 4.59	0.072	2.27	-0.12, 4.67	0.063	2.28	-0.12, 4.68	0.063
Distance to the nearest outlet (100 m)	-0.31	-0.53, -0.09	0.006	-0.29	-0.51, -0.07	0.009	-0.29	-0.51, -0.07	0.010
Triglycerides									
Alcohol outlet density (units/km²)									
≤400 m	-0.00	-0.01, 0.01	0.757	-0.00	-0.02, 0.01	0.658	-0.00	-0.02, 0.01	0.618
≤1,600 m	0.02	-0.14, 0.19	0.780	0.04	-0.13, 0.21	0.674	0.04	-0.13, 0.21	0.679
Distance to the nearest outlet (100 m)	0.00	-0.01, 0.02	0.719	0.00	-0.01, 0.02	0.725	0.00	-0.01, 0.02	0.711
Total cholesterol									
Alcohol outlet density (units/km²)									
≤400 m	-0.01	-0.02, 0.01	0.292	-0.01	-0.03, 0.00	0.174	-0.01	-0.03, 0.00	0.154
≤1,600 m	-0.03	-0.26, 0.21	0.835	-0.02	-0.26, 0.21	0.842	-0.02	-0.26, 0.21	0.849
Distance to the nearest outlet (100 m)	-0.00	-0.02, 0.01	0.664	-0.00	-0.02, 0.02	0.792	-0.00	-0.02, 0.02	0.809
HDL cholesterol									
Alcohol outlet density (units/km²)									
≤400 m	-0.00	-0.01, 0.00	0.716	-0.00	-0.01, 0.00	0.878	-0.00	-0.01, 0.00	0.886
≤1,600 m	-0.07	-0.15, 0.02	0.118	-0.07	-0.15, 0.02	0.110	-0.07	-0.15, 0.02	0.110
Distance to the nearest outlet (100 m)	0.00	-0.00, 0.01	0.497	0.00	-0.01, 0.01	0.701	0.00	-0.01, 0.01	0.704
LDL cholesterol									
Alcohol outlet density (units/km²)									
≤400 m	-0.00	-0.02, 0.01	0.599	-0.01	-0.02, 0.01	0.354	-0.01	-0.02, 0.01	0.326
≤1600 m	0.03	-0.16, 0.22	0.766	0.03	-0.16, 0.22	0.775	0.03	-0.16, 0.22	0.777
Distance to the nearest outlet (100 m)	-0.01	-0.02, 0.01	0.334	-0.01	-0.02, 0.01	0.523	-0.01	-0.02, 0.01	0.535

*Independent variable multiplies 1,000 to show more information. Model 1 is adjusted for age, sex. Model 2 is adjusted for model 1 + education, occupation, and Standard of Living Index. Model 3 is adjusted for model 2 + tobacco, physical activity, and energy. Bold number indicates that the estimates reach statistical significance.

of alcohol outlets and clubs with risky drinking only existed among residents in urban communities but not in rural areas of Australia (29). On the other hand, a systematic review found that density measures are far more frequently examined than distance measures in studies on alcohol environment and alcohol consumption (30). No significant association was found between the physical distance from an individual's home to their nearest alcohol outlet with frequency and quantity of alcohol consumption in both urban and mixed communities of developed countries (31–33). However, a study carried out in Tanzania found that close distance to alcohol outlets may facilitate and increase adolescent alcohol use (10). In the current study, greater distance to the nearest alcohol outlet was associated with a decrease in daily alcohol consumption. The relationship between neighborhood alcohol outlet density and distance with alcohol consumption is complex and may vary due to differences in neighborhood design, travel patterns, local alcohol control policies, and enforcement, as well as drinking norms (34).

In a previous study carried out in south India, Li et al. found that higher density of unhealthy food vendors was associated with increased prevalence of obesity-related outcomes and blood pressure (35). Immoderate consumption of alcohol, like unhealthy food, is associated with serious health problems (36). To our knowledge, no study has been reported to assess the association between densities or physical distance of alcohol outlets with individual levels of cardiovascular risk factors, such as adiposity measures, glucose-insulin, blood pressure, and lipid profile. We found that not only density of alcohol outlets but also distance to the nearest alcohol outlet were associated with waist circumference and blood pressure. Annual gain in waist circumference was associated with increased consumption of alcoholic beverages in the PREDIMED trial (37). A systematic review and meta-analysis found that a reduction in alcohol intake was associated with increased blood pressure reduction in people who drank more than two drinks per day (38). Higher density and lower physical distance may increase the frequency of cues related to drinking and make alcohol more accessible, thus increasing the risk of obesity and high blood pressure through immoderate alcohol consumption.

Some limitations of this study must be acknowledged. One thing is that the coordinates of alcohol outlets were derived in 2016, which was 4 years after the third wave of follow-up in APCAPS. The temporal association between alcohol environment with higher levels of waist circumference and blood pressure cannot be ascertained in the present study. Awareness of having CVDs may change the behavior of alcohol access and alcohol drinking in participants and generate bias (39). Thus, we conducted sensitivity analysis in dataset after excluding participants with diagnosed hypertension and diabetes. The results were largely unchanged. Other limitations should also be mentioned. We only assessed the physical availability and accessibility of alcohol outlets. The available data did not allow us to look into other alcohol environment factors such as travel patterns, local alcohol control policies, or drinking norms, which could also influence alcohol consumption as

well as cardiovascular risk factors. Moreover, the resulting data on alcohol use was self-reported through semi-quantitative questionnaires, which may have resulted in under-reporting by respondents (40).

CONCLUSION

Despite limitations, our study is the first to examine the association between neighborhood availability and accessibility of alcohol outlets with alcohol consumption as well as cardiovascular risk factors in south India. Shorter distance to the nearest alcohol outlet was associated with increased alcohol consumption. Higher waist circumference and blood pressure were associated with a shorter distance to the nearest alcohol outlet as well as a higher density of alcohol outlets. Neighborhood availability of alcohol outlets within immediate locality of participants' households had a closer relationship with cardiovascular risk factors than that within the whole village. Public health policies designed to limit neighborhood availability and accessibility of alcohol outlets should be encouraged in south India.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

YL and PM: study conception and study design. AA, BK, and SK: data analysis. YL, PM, and AA: manuscript drafting. All authors have approved the submitted version and agreed to publication.

FUNDING

This study was supported by a Wellcome Trust Strategic Award Grant No Z/084674.

ACKNOWLEDGMENTS

We would like to acknowledge our dedicated field teams led by Santhi Bhogadi and the study participants who made this study possible. We also acknowledge the contribution of Srivalli Addanki and Naveen Chittaluri to data processing and management and the reviewers for their constructive comments.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fcvm.2022.844086/full#supplementary-material>

REFERENCES

- GBD 2016 Causes of Death Collaborators. Global, regional, and national age-sex specific mortality for 264 causes of death, 1980-2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet*. (2017) 390:1151-210. doi: 10.1016/S0140-6736(17)32152-9
- India State-Level Disease Burden Initiative CVD Collaborators. The changing patterns of cardiovascular diseases and their risk factors in the states of India: the Global Burden of Disease Study 1990-2016. *Lancet Glob Health*. (2018) 6:e1339-51. doi: 10.1016/S2214-109X(18)30407-8
- GBD 2016 Alcohol Collaborators. Alcohol use and burden for 195 countries and territories, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet*. (2018) 392:1015-35.
- Bell S, Daskalopoulou M, Rapsomaniki E, George J, Britton A, Bobak M, et al. Association between clinically recorded alcohol consumption and initial presentation of 12 cardiovascular diseases: population based cohort study using linked health records. *BMJ*. (2017) 356:j909. doi: 10.1136/bmj.j909
- Jyani G, Prinja S, Ambekar A, Bahuguna P, Kumar R. Health impact and economic burden of alcohol consumption in India. *Int J Drug Policy*. (2019) 69:34-42. doi: 10.1016/j.drugpo.2019.04.005
- Popova S, Giesbrecht N, Bekmuradov D, Patra J. Hours and days of sale and density of alcohol outlets: impacts on alcohol consumption and damage: a systematic review. *Alcohol Alcohol*. (2009) 44:500-16.
- Chen MJ, Grube JW, Gruenewald PJ. Community alcohol outlet density and underage drinking. *Addiction*. (2010) 105:270-8. doi: 10.1111/j.1360-0443.2009.02772.x
- Paschall MJ, Lipperman-Kreda S, Grube JW. Effects of the local alcohol environment on adolescents' drinking behaviors and beliefs. *Addiction*. (2014) 109:407-16. doi: 10.1111/add.12397
- Morrison CN, Byrnes HF, Miller BA, Wiehe SE, Ponicki WR, Wiehe DJ. Exposure to alcohol outlets, alcohol access, and alcohol consumption among adolescents. *Drug Alcohol Depend*. (2019) 205:107622. doi: 10.1016/j.drugalcdep.2019.107622
- Ibitoye M, Kaaya S, Parker R, Likindikoki S, Ngongi L, Sommer M. The influence of alcohol outlet density and advertising on youth drinking in urban Tanzania. *Health Place*. (2019) 58:102141. doi: 10.1016/j.healthplace.2019.05.019
- Leslie HH, Ahern J, Pettifor AE, Twine R, Kahn K, Gomez-Olive FX, et al. Collective efficacy, alcohol outlet density, and young men's alcohol use in rural South Africa. *Health Place*. (2015) 34:190-8. doi: 10.1016/j.healthplace.2015.05.014
- Treno AJ, Johnson FW, Remer LG, Gruenewald PJ. The impact of outlet densities on alcohol-related crashes: a spatial panel approach. *Accid Anal Prev*. (2007) 39:894-901. doi: 10.1016/j.aap.2006.12.011
- Anderson P, Chisholm D, Fuhr DC. Effectiveness and cost-effectiveness of policies and programmes to reduce the harm caused by alcohol. *Lancet*. (2009) 373:2234-46. doi: 10.1016/S0140-6736(09)60744-3
- Nesoff ED, Milam AJ, Pollack KM, Curriero FC, Bowie JV, Knowlton AR, et al. Neighbourhood alcohol environment and injury risk: a spatial analysis of pedestrian injury in Baltimore City. *Inj Prev*. (2019) 25:350-6. doi: 10.1136/injuryprev-2018-042736
- Theall KP, Scribner R, Cohen D, Bluthenthal RN, Schonlau M, Lynch S, et al. The neighborhood alcohol environment and alcohol-related morbidity. *Alcohol*. (2009) 44:491-9. doi: 10.1093/alc/alcp042
- Richardson EA, Hill SE, Mitchell R, Pearce J, Shortt NK. Is local alcohol outlet density related to alcohol-related morbidity and mortality in Scottish cities? *Health Place*. (2015) 33:172-80. doi: 10.1016/j.healthplace.2015.02.014
- Theall KP, Wallace M, Felker-Kantor E, Madkour AS, Brashear M, Ferguson T, et al. Neighborhood alcohol environment: differential effects on hazardous drinking and mental health by sex in persons living with HIV (PLWH). *AIDS Behav*. (2019) 23:3237-46. doi: 10.1007/s10461-019-02632-3
- Kinra S, Rameshwar Sarma KV, Ghafoorunissa, Mendu VV, Ravikumar R, Mohan V, et al. Effect of integration of supplemental nutrition with public health programmes in pregnancy and early childhood on cardiovascular risk in rural Indian adolescents: long term follow-up of Hyderabad nutrition trial. *BMJ*. (2008) 337:a605. doi: 10.1136/bmj.a605
- Kinra S, Radha Krishna KV, Kuper H, Rameshwar Sarma KV, Prabhakaran P, Gupta V, et al. Cohort profile: Andhra Pradesh Children and Parents Study (APCAPS). *Int J Epidemiol*. (2014) 43:1417-24. doi: 10.1093/ije/dyt128
- Ebrahim S, Kinra S, Bowen L, Andersen E, Ben-Shlomo Y, Lyngdoh T, et al. The effect of rural-to-urban migration on obesity and diabetes in India: a cross-sectional study. *PLoS Med*. (2010) 7:e1000268. doi: 10.1371/journal.pmed.1000268
- Kinra S, Johnson M, Kulkarni B, Rameshwar Sarma KV, Ben-Shlomo Y, Smith GD. Socio-economic position and cardiovascular risk in rural Indian adolescents: evidence from the Andhra Pradesh children and parents study (APCAPS). *Public Health*. (2014) 128:852-9. doi: 10.1016/j.puhe.2014.06.005
- Matsuzaki M, Sullivan R, Ekelund U, Krishna KVR, Kulkarni B, Collier T, et al. Development and evaluation of the Andhra Pradesh children and parent study physical activity questionnaire (APCAPS-PAQ): a cross-sectional study. *BMC Public Health*. (2016) 16:48. doi: 10.1186/s12889-016-2706-9
- Roeschlau P, Bernt E, Gruber W. Enzymatic determination of total cholesterol in serum. *Z Klin Chem Klin Biochem*. (1974) 12:226.
- Siedel J, Schiefer S, Rosseneu M, Bergeaud R, De Keersgieter W, Pautz B, et al. Immunoturbidimetric method for routine determinations of apolipoproteins A-I, A-II, and B in normo- and hyperlipemic sera compared with immunonephelometry. *Clin Chem*. (1988) 34:1821-5. doi: 10.1093/clinchem/34.9.1816
- Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clin Chem*. (1972) 18:499-502. doi: 10.1093/clinchem/18.6.499
- Brenner AB, Borrell LN, Barrientos-Gutierrez T, Diez Roux AV. Longitudinal associations of neighborhood socioeconomic characteristics and alcohol availability on drinking: results from the Multi-Ethnic Study of Atherosclerosis (MESA). *Soc Sci Med*. (2015) 145:17-25. doi: 10.1016/j.socscimed.2015.09.030
- Foster S, Hooper P, Knuiaman M, Lester L, Trapp G. Associations between proposed local government liquor store size classifications and alcohol consumption in young adults. *Health Place*. (2018) 52:170-3. doi: 10.1016/j.healthplace.2018.06.001
- Slutske WS, Deutsch AR, Piasecki TM. Neighborhood alcohol outlet density and genetic influences on alcohol use: evidence for gene-environment interaction. *Psychol Med*. (2019) 49:474-82. doi: 10.1017/S0033291718001095
- Azar D, White V, Coomber K, Faulkner A, Livingston M, Chikritzhs T, et al. The association between alcohol outlet density and alcohol use among urban and regional Australian adolescents. *Addiction*. (2016) 111:65-72. doi: 10.1111/add.13143
- Shih RA, Mullins L, Ewing BA, Miyashiro L, Tucker JS, Pedersen ER, et al. Associations between neighborhood alcohol availability and young adolescent alcohol use. *Psychol Addict Behav*. (2015) 29:950-9. doi: 10.1037/adb0000081
- Abbey A, Scott RO, Smith MJ. Physical, subjective, and social availability: their relationship to alcohol consumption in rural and urban areas. *Addiction*. (1993) 88:489-99. doi: 10.1111/j.1360-0443.1993.tb02055.x
- Scribner RA, Cohen DA, Fisher W. Evidence of a structural effect for alcohol outlet density: a multilevel analysis. *Alcohol Clin Exp Res*. (2000) 24:188-95. doi: 10.1111/j.1530-0277.2000.tb04590.x
- Young R, Macdonald L, Ellaway A. Associations between proximity and density of local alcohol outlets and alcohol use among Scottish adolescents. *Health Place*. (2013) 19:124-30. doi: 10.1016/j.healthplace.2012.10.004
- Schonlau M, Scribner R, Farley TA, Theall K, Bluthenthal RN, Scott M, et al. Alcohol outlet density and alcohol consumption in Los Angeles county and southern Louisiana. *Geospat Health*. (2008) 3:91-101. doi: 10.4081/gh.2008.235
- Li Y, Mallinson PAC, Bhan N, Turner C, Bhogadi S, Sharma C, et al. Neighborhood physical food environment and cardiovascular risk factors in India: cross-sectional evidence from APCAPS. *Environ Int*. (2019) 132:105108. doi: 10.1016/j.envint.2019.105108
- Cohen D, Rabinovich L. Addressing the proximal causes of obesity: the relevance of alcohol control policies. *Prev Chronic Dis*. (2012) 9:E94. doi: 10.5888/pcd9.110274
- Konieczna J, Romaguera D, Pereira V, Fiol M, Razquin C, Estruch R, et al. Longitudinal association of changes in diet with changes in body weight and waist circumference in subjects at high cardiovascular risk: the PREDIMED trial. *Int J Behav Nutr Phys Act*. (2019) 16:139. doi: 10.1186/s12966-019-0893-3
- Roerecke M, Kaczorowski J, Tobe SW, Gmel G, Hasan OSM, Rehm J. The effect of a reduction in alcohol consumption on blood pressure: a systematic

- review and meta-analysis. *Lancet Public Health*. (2017) 2:e108–20. doi: 10.1016/S2468-2667(17)30003-8
39. Eames S, Hoffmann TC, Phillips NF. Evaluating stroke patients' awareness of risk factors and readiness to change stroke risk-related behaviors in a randomized controlled trial. *Top Stroke Rehabil*. (2014) 21(Suppl. 1):S52–62. doi: 10.1310/tsr21S1-S52
40. Bowen L, Bharathi AV, Kinra S, Destavola B, Ness A, Ebrahim S. Development and evaluation of a semi-quantitative food frequency questionnaire for use in urban and rural India. *Asia Pac J Clin Nutr*. (2012) 21:355–60.

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Copyright © 2022 Li, Mallinson, Aggarwal, Kulkarni and Kinra. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.