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Neighborhood physical food environment and cardiovascular risk factors in India: Cross-sectional evidence from APCAPS

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ABSTRACT

There has been increasing interest in associations between neighborhood food environments and cardiovascular risk factors. However, results from high-income countries remain inconsistent, and there has been limited research from low- and middle-income countries. We conducted a cross-sectional analysis of the third wave follow-up of the Andhra Pradesh children and parents study (APCAPS) (n = 5764, median age 28.8 years) in south India. We examined associations between the neighborhood availability (vendor density per km^2 within 400 m and 1600 m buffers of households) and accessibility (distance from the household to the nearest vendor) of fruit/vegetable and highly processed/take-away food vendors with 11 cardiovascular risk factors, including adiposity measures, glucose-insulin, blood pressure, and lipid profile. In fully adjusted models, higher density of fruit/vegetable vendors within 400 m of participant households was associated with lower systolic blood pressure [−0.09 mmHg, 95% confidence interval (CI): −0.17, −0.02] and diastolic blood pressure (−0.10 mmHg, 95% CI: −0.17, −0.04). Higher density of highly processed/take-away food vendors within 400 m of participant households was associated with higher Body Mass Index (0.01 Kg/m^2, 95% CI: 0.00, 0.01), waist circumference (0.22 mm, 95% CI: 0.05, 0.39), systolic blood pressure (0.03 mmHg, 95% CI: 0.01, 0.06), and diastolic blood pressure (0.03 mmHg, 95% CI: 0.01, 0.05). However, within 1600 m buffer, only association with blood pressure remained robust. No associations were found for between neighborhood accessibility and cardiovascular risk factors. Lower density of fruit/vegetable vendors, and higher density of highly processed/take-away food vendors were associated with adverse cardiovascular risk profiles. Public health policies regarding neighborhood food environments should be encouraged in south India and other rural communities in south Asia.

1. Introduction

Cardiovascular disease (CVD) is the leading cause of death and disability-adjusted life years lost worldwide, causing an estimated 17.9 million deaths in 2016 (World Health Organization, 2013). The majority of these deaths occurred in low- and middle-income countries (Murray et al., 2012), with India alone contributing almost one-fifth of the global CVD burden (GBD 2016 DALYs and HALE Collaborators, 2017).

Dietary factors are a key modifiable cause of CVD (GBD 2017 Diet Collaborators, 2019). Adequate fruit and vegetable intake is associated with reduced risk of cardiovascular diseases (hypertension, coronary heart disease, atherosclerosis, and stroke) (Nicklett and Kadell, 2013). Moreover, various cardio-protective diet patterns, such as Mediterranean diet, Nordic diet or the Dietary Approaches to Stop Hypertension diet (DASH), emphasize increasing fruit and vegetable consumption (Gibson et al., 2018; Lankinen et al., 2016; Lichtenstein et al., 2014; Salas-Salvado et al., 2016). On the other hand, highly processed and take-away food, such as sugar-sweetened beverages, packaged breads, cookies, savory snacks, candy, ice cream, breakfast cereal, pre-prepared frozen meals, and hot and cold takeaways (Monteiro et al., 2018; Moubarac et al., 2013; van der Horst et al., 2011) have been linked to

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increased obesity and cardiovascular risk (Duffey et al., 2009; Poti et al., 2017).

Food environment has been defined as “the interface that mediates one's food acquisition and consumption within the wider food system” (Turner et al., 2017). There is growing evidence from diverse settings regarding the influence of neighborhood availability and accessibility of healthy or unhealthy food on individual level risk factors (Fuentes Pacheco et al., 2018). For example, in high-income countries, a number of studies based in regions of the USA found that better access to supermarkets which mainly provide fresh food was associated with increased fruit and vegetable intake (Sharkey et al., 2010b) and reduced levels of overweight and obesity (Gamba et al., 2015). Meanwhile, better access to fast-food restaurants was associated with an increased prevalence of overweight and obesity (Chen et al., 2013). However, evidence from other countries is less consistent. For example, several UK studies have found no links between density of shops selling fruits and vegetables and fruit and vegetable consumption (Hawkesworth et al., 2017) or levels of obesity (Stafford et al., 2007). Moreover, the association between fast-food outlet availability and obesity was weak and inconsistent in one UK study (Hobbs et al., 2019). These findings suggest a need for caution when extrapolating research findings from one country to another. Several studies from low- and middle-income countries have reported no evidence of an association between access to healthy or unhealthy food vendors with overweight/obesity (Turner et al., 2019), although evidence on other cardiovascular risk factors is limited (Jaime et al., 2011; Patel et al., 2017; Velasquez-Melendez et al., 2013).

In order to inform policy for cardiovascular disease prevention in low- and middle-income countries, further evidence on the role of food environments in cardiovascular risk is urgently needed. Thus, in the present study, we investigated whether access to fruit/vegetable or highly processed/take-away food in the local neighborhood is associated with cardiovascular risk factors using cross-sectional data from Andhra Pradesh Children and Parents Study (APCAPS) in South India.

2. Material and methods

2.1. Study population

The Andhra Pradesh children and parents study (APCAPS) is a prospective cohort study conducted in 29 villages near the city of Hyderabad, now located in Telangana State, which has been described in detail previously (Kinra et al., 2014; Kinra et al., 2008). In brief, the index participants were children born during the time of the Hyderabad Nutrition Trial from 1987 to 1990, a controlled trial in which supplemental nutrition was offered to pregnant women and young children. They have been followed-up three times, and during the third wave of follow-up (2010 – 2012) their siblings and parents were also recruited (participation rate 61%). We conducted cross-sectional analysis of data from this third wave of follow-up, which collected a wide variety of data on socio-demographic characteristics, lifestyle, anthropometric measurements, and cardiovascular markers (Kinra et al., 2014).

A total of 6944 participants were included in this follow-up. We excluded 1303 (18.76%) of the participants for the following reasons: 743 with no residential geolocation available; 82 participants with self-reported coronary heart disease and stroke to avoid bias; 355 subjects with missing values on socio-demographic characteristics and lifestyle related variables. The remaining 5764 participants were included in the final analyses. Ethical approval for the study was granted by the National Institute of Nutrition, Hyderabad and the Public Health Foundation of India, New Delhi.

2.2. GPS-based measures of physical food environment

In 2016, GPS (Global Positioning System) coordinates of all shops and services selling food, tobacco or alcohol in the 29 study villages were captured. Data was collected either by observation or interviews as specified in the survey, with photographs taken of vendors' displays for data validation. We defined two vendor typologies based on what products were sold at each shop, broadly categorized as 1) fruit and vegetable vendors (i.e. any shop selling fruit/vegetables at time of survey), and 2) highly processed and take-away food vendors (i.e. any shop selling highly processed/take-away food at time of survey). Two exposure measures for neighborhood food environment were examined, availability and accessibility. In order to be comparable with previous studies and take into consideration the local context of the present study, availability was measured in terms of the density of vendors within two buffer areas of participants' households: 400 m, to capture availability in the immediate locality of participants' households, and 1600 m to capture availability within the whole village (Baldock et al., 2018; Barrientos-Gutierrez et al., 2017; Murphy et al., 2017). Accessibility was measured in terms of distance from the household to the nearest vendor. The R software version 3.5.1 was used for deriving the geographical exposures.

2.3. Cardiovascular risk factors

11 cardiovascular risk factors, including adiposity measures, glucose-insulin, blood pressure, and lipid profile, were from the third wave of follow-up of APCAPS which was conducted between 2010 and 2012. A detailed description of this dataset, including anthropometry, physiological measurements, and biochemical assays, has been published previously (Kinra et al., 2014; Kinra et al., 2008). Briefly, fasting glucose, total cholesterol, triglycerides and serum high-density lipoprotein cholesterol (HDL-C) were measured using the glucose oxidase/peroxidase – 4-aminophenazone-phenol enzymatic method and enzymatic calorimetric method. Insulin concentrations were estimated by radioimmunoassay in batches. Low density lipoprotein cholesterol (LDL-C) level was estimated using standard Friedewald-Fredrickson formula (Gupta et al., 2015). Blood pressure was measured in the supine position using a validated oscillometric device (Omron M5-I, Matsusaka Co., Japan). Three readings were taken and the average value was used for analysis. Height, weight and circumferences (waist and hip) were measured using standard instruments (Kinra et al., 2014). Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters. Waist-hip-ratio was calculated as waist circumference divided by hip circumference.

2.4. Covariates

Information on sociodemographic and lifestyle factors including age (year), sex (male, female), education level (illiterate, primary school, middle school and above), occupation (unskilled, skilled, others), Standard of Living Index (low, middle, high), tobacco use (never, former, current), alcohol consumption (gram/day), and physical activity (extremely inactive, sedentary, moderately active, vigorously active) were gathered as part of a questionnaire by trained interviewers. Standard of Living Index were used to estimate the household socioeconomic status in India surveys (Ebrahim et al., 2010). Data on dietary intake (over the past year) and physical activity (over the past week) were collected by semi-quantitative questionnaires (Kinra et al., 2014).

2.5. Statistical analysis

To account for possible clustering of neighborhood physical food environment, three-level mixed-effects linear regression was used to examine the association between the densities and distances of fruit and vegetable vendors and highly processed and take-away food vendors (exposures) with cardiovascular risk factors (outcomes). Three levels used in the present study were individual level (n = 5764), household level (n = 1719), and village level (n = 29). Individuals were the primary unit of analysis, clustered within households and villages using

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

Characteristics (N = 5764)	All	
	Median	P5-P95
Socio-demographic factors		
Age	28.8	16.0–59.9
Sex (%)		
Male	3329 (57.8)	
Female	2435 (42.2)	
Education (%)		
Illiterate	2023 (35.1)	
Primary school	1354 (23.5)	
Middle school and above	2387 (41.4)	
Occupation (%)		
Unskilled	2362 (41.0)	
Skilled	1614 (28.0)	
Others	1788 (31.0)	
Standard of living index (%)		
Low	1571 (27.3)	
Middle	2160 (37.5)	
High	2033 (35.3)	
Alcohol drinking (g/day)	29.1	0–372.0
Smoking status (%)		
Never	4325 (75.0)	
Former	60 (1.0)	
Current	1379 (23.9)	
Physical activity (%)		
Extremely inactive	888 (15.4)	
Sedentary	3156 (54.8)	
Moderately active	1436 (24.9)	
Vigorously active	284 (4.9)	
Food environment		
Fruit and vegetable vendor density (units/km^2)		
≤400 m	19.9	2.0–47.7
≤1600 m	1.9	0.7–3.6
Distance to the nearest vendor (m)	66.7	15.2–294.0
Highly processed/take-away food vendor density (units/km^2)		
≤400 m	35.8	6.0–135.3
≤1600 m	3.2	1.6–17.2
Distance to the nearest vendor (m)	49.6	9.7–153.9
Biological characteristics		
BMI (Kg/m^2)	20.0	15.2–27.4
Waist circumference (mm)	705.0	561.5–905.5
Waist-hip-ratio	0.8	0.7–1.0
Systolic blood pressure (mmHg)	117.0	99.3–149.7
Diastolic blood pressure (mmHg)	76.7	59.3–101.3
Fasting glucose (mg/dl)	91.0	75.6–117.8
Insulin (Uu/ml)	5.2	1.1–16.4
Triglycerides (mmol/L)	1.2	0.6–3.1
Total cholesterol (mmol/L)	4.1	2.8–6.0
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.

random intercepts. In model 1 we adjusted for age (year) and sex (categorical, male/female). In model 2 we further included education level (categorical, illiterate/primary school/middle school and above), occupation (categorical, unskilled/skilled/others), Standard of Living Index (categorical, low/middle/high), tobacco use (categorical, never/former/current), alcohol consumption (gram/day), and physical activity (categorical, extremely inactive/sedentary/moderately active/vigorously active). In model 3 we further included density and nearest distance of other food vendors.

We used the Stata software version 15.1 for statistical analyses.

3. Results

Our final analysis consisted of 5764 participants (3329 men and 2435 women) residing in 29 villages with median age 28.8 years. Table 1 shows the densities and distances of fruit and vegetable vendors and highly processed and take-away food vendors, socio-demographic characteristics of participants, and measures of cardiovascular risk factors. The densities of food vendors within 400 m were higher than that within 1600 m.

3.1. Fruit and vegetable vendors and cardiovascular risk factors

Table 2 shows associations between availability and accessibility of fruit and vegetable vendors and cardiovascular risk factors after adjustment for covariates. In fully adjusted models, a unit per km^2 increase in fruit and vegetable vendor density within 400 m buffer was associated with a decrease in fasting glucose [−0.14 mg/dl, 95% confidence interval (CI): −0.25, −0.03], systolic blood pressure (SBP) (−0.09 mmHg, 95% CI: −0.17, −0.02), and diastolic blood pressure (DBP) (−0.10 mmHg, 95% CI: −0.17, −0.04). However, the association of fruit and vegetable vendor density with other cardiovascular risk factors (insulin, BMI, waist circumference, waist-hip-ratio, triglycerides, total cholesterol, HDL cholesterol, and LDL cholesterol) was weak and inconsistent, and did not persist after further adjustment for highly processed and take-away food vendor density.

3.2. Highly processed and take-away food vendors and cardiovascular risk factors

Table 3 shows associations between availability and accessibility of highly processed and take-away food vendors and cardiovascular risk factors after adjustment for covariates. In fully adjusted models, a unit per km^2 increase in highly processed and take-away food vendor density within 400 m buffer was associated with an increase in BMI (0.01 Kg/m^2, 95% CI: 0.00, 0.01), waist circumference (0.22 mm, 95% CI: 0.05, 0.39), SBP (0.03 mmHg, 95% CI: 0.01, 0.06), and DBP (0.03 mmHg, 95% CI: 0.01, 0.05). Association between highly processed and take-away food vendor density with other cardiovascular risk factors (fasting glucose, insulin, waist-hip-ratio, triglycerides, total cholesterol, HDL cholesterol, and LDL cholesterol) was weak and inconsistent across different models.

3.3. Association between different measures of food environment and cardiovascular risk factors

Unlike the 400 m buffer, the positive effect of fruit and vegetable vendor density and negative effect of highly processed and take-away food vendor density within 1600 m buffer remained similar only in blood pressure, but not fasting glucose or BMI/waist circumference. That is, a unit per km^2 increase in fruit and vegetable vendor density within 1600 m buffer was associated with a 1.37 mmHg (95% CI: −2.54, −0.21) decrease in SBP and a 1.14 mmHg (95% CI: −2.11, −0.18) decrease in DBP, while a unit per km^2 increase in highly processed and take-away food vendor density within 1600 m buffer was associated with a 0.47 mmHg (95% CI: 0.15, 0.79) increase in SBP and a 0.39 mmHg (95% CI: 0.12, 0.66) increase in DBP. Unlike the density measures, we found no robust associations between distance to the nearest fruit and vegetable vendor or highly processed and take-away food vendor with cardiovascular risk factors.

4. Discussion

This study examined how the neighborhood physical food environment was associated with cardiovascular risk factors in data from the third wave of follow-up of APCAPS. A higher density of fruit and vegetable vendors was associated with a decrease in fasting glucose and blood pressure. A higher density of highly processed and take-away food vendors was associated with an increase in BMI/waist circumference and blood pressure. There was stronger evidence for an association between cardiovascular risk factors and food vendor density within 400 m buffer than density within 1600 m buffer or the distance

Table 2
Association between availability and accessibility of fruit and vegetable vendors with cardiovascular risk factors in APCAPS participants.

	Model 1			Model 2			Model 3		
	β	95% CI	*P*-value	β	95% CI	*P*-value	β	95% CI	*P*-value
Glucose (mg/dl)									
Fruit and vegetable vendors density (units/km^2)									
≤400 m	**−0.08**	**−0.15, −0.01**	**0.026**	**−0.09**	**−0.16, −0.02**	**0.010**	**−0.14**	**−0.25, −0.03**	**0.010**
≤1600 m	−0.65	−1.79, 0.50	0.267	−0.72	−1.82, 0.38	0.198	−1.53	−3.15, 0.08	0.063
Distance to the nearest vendor (100 m)	−0.22	−0.81, 0.37	0.460	−0.11	−0.70, 0.48	0.709	−0.39	−1.28, 0.51	0.396
Insulin (Uu/ml)									
Fruit and vegetable vendors density (units/km^2)									
≤400 m	0.01	−0.02, 0.03	0.512	0.00	−0.02, 0.02	0.907	−0.01	−0.05, 0.02	0.489
≤1600 m	0.03	−0.36, 0.42	0.885	0.01	−0.38, 0.40	0.958	−0.33	−0.92, 0.26	0.267
Distance to the nearest vendor (100 m)	−0.09	−0.28, 0.10	0.355	−0.04	−0.23, 0.14	0.639	−0.03	−0.31, 0.26	0.852
BMI (Kg/m^2)									
Fruit and vegetable vendors density (units/km^2)									
≤400 m	0.01	−0.00, 0.02	0.168	0.01	−0.01, 0.02	0.336	−0.01	−0.03, 0.01	0.206
≤1600 m	0.07	−0.12, 0.26	0.454	0.09	−0.10, 0.27	0.370	−0.04	−0.32, 0.23	0.758
Distance to the nearest vendor (100 m)	−0.03	−0.14, 0.08	0.611	−0.00	−0.11, 0.11	0.986	−0.01	−0.18, 0.16	0.915
Waist circumference (mm)									
Fruit and vegetable vendors density (units/km^2)									
≤400 m	**0.40**	**0.06, 0.73**	**0.021**	0.31	−0.02, 0.63	0.062	−0.22	−0.73, 0.29	0.402
≤1600 m	3.37	−1.69, 8.43	0.192	3.71	−1.16, 8.57	0.135	0.01	−7.13, 7.16	0.997
Distance to the nearest vendor (100 m)	−1.73	−4.65, 1.20	0.247	−0.90	−3.71, 1.90	0.528	−1.78	−6.08, 2.52	0.418
Waist-hip-ratio*									
Fruit and vegetable vendors density (units/km^2)									
≤400 m	0.07	−0.13, 0.28	0.470	0.06	−0.14, 0.26	0.549	−0.17	−0.48, 0.15	0.308
≤1600 m	0.18	−3.22, 3.58	0.919	−0.06	−3.38, 3.26	0.970	−1.67	−6.60, 3.27	0.508
Distance to the nearest vendor (100 m)	−1.20	−2.88, 0.48	0.162	−1.08	−2.74, 0.58	0.203	−1.35	−3.89, 1.19	0.298
Systolic blood pressure (mmHg)									
Fruit and vegetable vendors density (units/km^2)									
≤400 m	−0.00	−0.05, 0.05	0.887	−0.01	−0.06, 0.04	0.665	**−0.09**	**−0.17, −0.02**	**0.014**
≤1600 m	−0.01	−0.83, 0.81	0.972	−0.04	−0.85, 0.77	0.918	**−1.37**	**−2.54, −0.21**	**0.021**
Distance to the nearest vendor (100 m)	−0.15	−0.56, 0.25	0.461	−0.08	−0.48, 0.32	0.710	0.01	−0.60, 0.63	0.965
Diastolic blood pressure (mmHg)									
Fruit and vegetable vendors density (units/km^2)									
≤400 m	−0.02	−0.06, 0.02	0.412	−0.02	−0.06, 0.02	0.280	**−0.10**	**−0.17, −0.04**	**0.001**
≤1600 m	−0.04	−0.71, 0.62	0.900	−0.03	−0.69, 0.64	0.940	**−1.14**	**−2.11, −0.18**	**0.020**
Distance to the nearest vendor (100 m)	−0.18	−0.52, 0.16	0.295	−0.12	−0.46, 0.21	0.466	−0.20	−0.71, 0.31	0.432
Triglycerides *(mmol/L)									
Fruit and vegetable vendors density (units/km^2)									
≤400 m	0.34	−2.62, 3.30	0.823	0.06	−2.92, 3.05	0.967	1.95	−2.76, 6.66	0.417
≤1600 m	13.44	−29.32, 56.21	0.538	12.62	−30.99, 56.23	0.571	15.38	−49.95, 80.71	0.644
Distance to the nearest vendor (100 m)	4.50	−22.49, 31.48	0.744	8.44	−18.45, 35.33	0.538	13.71	−27.36, 54.78	0.513
Total cholesterol *(mmol/L)									
Fruit and vegetable vendors density (units/km^2)									
≤400 m	1.34	−2.24, 4.93	0.463	0.87	−2.70, 4.44	0.634	2.59	−3.24, 8.43	0.383
≤1600 m	22.69	−41.42, 86.80	0.488	19.08	−45.28, 83.45	0.561	32.99	−65.67, 131.64	0.512
Distance to the nearest vendor (100 m)	−19.06	−47.95, 9.84	0.196	−15.16	−43.80, 13.49	0.300	−24.64	−68.56, 19.28	0.272
HDL cholesterol *(mmol/L)									
Fruit and vegetable vendors density (units/km^2)									
≤400 m	0.83	−0.42, 2.08	0.193	0.98	−0.27, 2.22	0.124	−0.12	−2.16, 1.93	0.911
≤1600 m	−3.47	−26.92, 19.97	0.771	−2.60	−25.92, 20.72	0.827	11.17	−24.53, 46.88	0.540
Distance to the nearest vendor (100 m)	−2.20	−12.10, 7.71	0.663	−3.13	−13.00, 6.74	0.534	−1.60	−16.74, 13.54	0.836
LDL cholesterol *(mmol/L)									
Fruit and vegetable vendors density (units/km^2)									
≤400 m	1.04	−1.94, 4.01	0.494	0.49	−2.46, 3.45	0.743	0.40	−4.41, 5.21	0.870
≤1600 m	17.51	−34.99, 70.01	0.513	15.23	−37.02, 67.48	0.568	5.24	−74.34, 84.82	0.897
Distance to the nearest vendor (100 m)	−19.26	−43.28, 4.76	0.116	−15.81	−39.61, 8.00	0.193	−28.60	−65.11, 7.91	0.125

Model 1 is adjusted for age, sex.
Model 2 is adjusted for model 1+ education, occupation, standard of living index, tobacco, alcohol, and physical activity.
Model 3 is adjusted for model 2+ densities or distances of highly processed/take-away food vendors.
$P < 0.05$
* Independent variable multiply 1000 to show more information.

to the nearest food vendor. To our knowledge, this is the first study to examine both availability and accessibility of fruit and vegetable vendors and highly processed and take-away food vendors in the local neighborhood in relation to multiple cardiovascular risk factors in India.

Previous studies have demonstrated that access to fruit and vegetable vendors is inversely associated with overweight/obesity in North America (Barrientos-Gutierrez et al., 2017; Cerin et al., 2011; Lopez, 2007; Morland and Evenson, 2009). However, similar inverse association was not found in studies from low- and middle-income countries (Dake et al., 2016; Jaime et al., 2011; Velasquez-Melendez et al., 2013), in accordance with our results. Few studies have explored the association of neighborhood food environments with diabetes. Katherine et al. reported no association between walking distance to fruit and vegetable retailers with the risk of prediabetes/diabetes in Australia (Baldock et al., 2018). In the present study, density of fruit and

Table 3
Association between availability and accessibility of highly processed and take-away food vendors with cardiovascular risk factors in APCAPS participants.

	Model 1			Model 2			Model 3		
	β	95% CI	*P*-value	β	95% CI	*P*-value	β	95% CI	*P*-value
Glucose (mg/dl)									
Highly processed/take-away food vendors density (units/km^2)									
≤400 m	−0.01	−0.03, 0.01	0.419	−0.01	−0.04, 0.01	0.209	0.02	−0.01, 0.06	0.224
≤1600 m	0.03	−0.29, 0.34	0.877	−0.02	−0.32, 0.29	0.918	0.30	−0.14, 0.74	0.183
Distance to the nearest vendor (100 m)	−0.04	−0.85, 0.76	0.913	0.10	−0.70, 0.90	0.808	0.50	−0.72, 1.71	0.424
Insulin (Uu/ml)									
Highly processed/take-away food vendors density (units/km^2)									
≤400 m	0.01	−0.00, 0.01	0.158	0.00	−0.00, 0.01	0.488	0.01	−0.01, 0.02	0.331
≤1600 m	0.07	−0.04, 0.18	0.213	0.06	−0.05, 0.17	0.297	0.13	−0.04, 0.29	0.128
Distance to the nearest vendor (100 m)	−0.12	−0.38, 0.13	0.336	−0.06	−0.31, 0.19	0.647	−0.03	−0.41, 0.35	0.875
BMI (Kg/m^2)									
Highly processed/take-away food vendors density (units/km^2)									
≤400 m	**0.01**	**0.00, 0.01**	**0.007**	**0.00**	**0.00, 0.01**	**0.023**	**0.01**	**0.00, 0.01**	**0.015**
≤1600 m	0.03	−0.02, 0.08	0.178	0.04	−0.01, 0.09	0.128	0.05	−0.03, 0.12	0.216
Distance to the nearest vendor (100 m)	−0.04	−0.20, 0.11	0.594	0.01	−0.14, 0.16	0.945	0.01	−0.21, 0.24	0.899
Waist circumference (mm)									
Highly processed/take-away food vendors density (units/km^2)									
≤400 m	**0.20**	**0.09, 0.31**	**< 0.001**	**0.17**	**0.06, 0.27**	**0.002**	**0.22**	**0.05, 0.39**	**0.009**
≤1600 m	1.29	−0.06, 2.64	0.061	**1.37**	**0.07, 2.66**	**0.038**	1.37	−0.58, 3.31	0.168
Distance to the nearest vendor (100 m)	−1.61	−5.57, 2.35	0.426	−0.26	−4.06, 3.54	0.892	1.56	−4.26, 7.38	0.599
Waist-hip-ratio [*]									
Highly processed/take-away food vendors density (units/km^2)									
≤400 m	0.06	−0.01, 0.12	0.095	0.05	−0.01, 0.12	0.120	0.09	−0.01, 0.20	0.078
≤1600 m	0.36	−0.59, 1.30	0.458	0.24	−0.68, 1.16	0.608	0.60	−0.78, 1.98	0.396
Distance to the nearest vendor (100 m)	−1.19	−3.47, 1.08	0.303	−0.90	−3.14, 1.34	0.431	0.48	−2.95, 3.91	0.783
Systolic blood pressure (mmHg)									
Highly processed/take-away food vendors density (units/km^2)									
≤400 m	0.01	−0.00, 0.03	0.105	0.01	−0.01, 0.03	0.213	**0.03**	**0.01, 0.06**	**0.008**
≤1600 m	0.21	−0.02, 0.44	0.070	0.20	−0.03, 0.43	0.085	**0.47**	**0.15, 0.79**	**0.004**
Distance to the nearest vendor (100 m)	−0.23	−0.78, 0.32	0.412	−0.15	−0.69, 0.40	0.597	−0.16	−0.99, 0.67	0.705
Diastolic blood pressure (mmHg)									
Highly processed/take-away food vendors density (units/km^2)									
≤400 m	0.01	−0.00, 0.02	0.153	0.01	−0.01, 0.02	0.258	**0.03**	**0.01, 0.05**	**0.001**
≤1600 m	0.17	−0.02, 0.36	0.079	0.17	−0.02, 0.36	0.075	**0.39**	**0.12, 0.66**	**0.004**
Distance to the nearest vendor (100 m)	−0.13	−0.59, 0.32	0.572	−0.07	−0.51, 0.38	0.777	0.14	−0.55, 0.83	0.684
Triglycerides[*] (mmol/L)									
Highly processed/take-away food vendors density (units/km^2)									
≤400 m	0.20	−1.17, 0.78	0.689	−0.32	−1.31, 0.67	0.525	−0.81	−2.36, 0.74	0.304
≤1600 m	2.26	−9.19, 13.72	0.699	2.07	−9.69, 13.83	0.730	−0.99	−18.52, 16.53	0.912
Distance to the nearest vendor (100 m)	−1.17	−37.85, 35.51	0.950	4.63	−31.87, 41.13	0.804	−9.45	−65.20, 46.30	0.740
Total cholesterol[*] (mmol/L)									
Highly processed/take-away food vendors density (units/km^2)									
≤400 m	1.14	−1.06, 1.33	0.823	−0.05	−1.23, 1.14	0.940	−0.73	−2.67, 1.21	0.462
≤1600 m	2.74	−15.15, 20.63	0.764	1.68	−16.32, 19.68	0.855	−5.20	−32.69, 22.30	0.711
Distance to the nearest vendor (100 m)	−13.99	−52.85, 24.88	0.481	−8.28	−46.79, 30.22	0.673	16.81	−42.24, 75.85	0.577
HDL cholesterol [*](mmol/L)									
Highly processed/take-away food vendors density (units/km^2)									
≤400 m	0.37	−0.05, 0.78	0.082	**0.42**	**0.01, 0.84**	**0.045**	0.45	−0.23, 1.14	0.190
≤1600 m	−2.83	−9.37, 3.71	0.396	−2.65	−9.16, 3.86	0.425	−5.01	−14.98, 4.96	0.325
Distance to the nearest vendor (100 m)	−2.47	−15.77, 10.84	0.716	−4.34	−17.60, 8.91	0.521	−2.71	−23.04, 17.62	0.794
LDL cholesterol[*] (mmol/L)									
Highly processed/take-away food vendors density (units/km^2)									
≤400 m	0.35	−0.64, 1.34	0.490	0.15	−0.84, 1.13	0.771	0.04	−1.56, 1.64	0.962
≤1600 m	5.61	−9.04, 20.25	0.453	4.93	−9.68, 19.54	0.508	3.82	−18.51, 26.15	0.737
Distance to the nearest vendor (100 m)	−11.96	−44.27, 20.34	0.468	−6.47	−38.48, 25.53	0.692	22.65	−26.42, 71.72	0.366

Model 1 is adjusted for age, sex.
Model 2 is adjusted for model 1 + education, occupation, standard of living index, tobacco, alcohol, and physical activity.
Model 3 is adjusted for model 2 + densities or distances of fruit and vegetable vendors.
$P < 0.05$

[*] Independent variable multiply 1000 to show more information.

vegetable vendors was inversely related to fasting glucose only, but not insulin or other obesity related outcomes (BMI, waist circumference, and waist-hip-ratio). The negative association between availability to fruit and vegetable vendors and fasting glucose may have been a chance finding due to variability in fasting glucose levels or multiple statistical testing in our study, and needs to be confirmed in further studies. We found a higher density of fruit and vegetable vendors was associated with a decrease in blood pressure. A previous study from the USA found a positive relationship between supermarket density and risk of hypertension (Tamura et al., 2018).

Despite the evidence generated thus far, some ambiguity remains in the association between access to food outlets selling ready-to-eat or take-away foods and cardiovascular risk factors. Increased density of ready-to-eat food outlets and decreased distance to nearest ready-to-eat food outlet were associated with higher risk of type 2 diabetes in 347,551 UK Biobank adult participants (Sarkar et al., 2018). However, we found no association between access to highly processed and take-away food vendors with fasting glucose or insulin, consistent with a recent systematic review that found no convincing evidence for an association between food environments and type 2 diabetes (den Braver et al., 2018). We found a positive relationship between densities of highly processed and take-away food vendors with both SBP and DBP. In a study from the USA, fast food restaurant density was not associated to blood pressure among low-income housing residents in New York City; however, the study may have lacked statistical power due to its small size (N = 102) (Tamura et al., 2018). Unlike fresh food which can be grown/produced, the highly processed and take-away food can generally be purchased through vendors only, which could limit the differences in findings between countries.

Studies have used various methods to quantify the food environment. In our study, food vendor density within 400 m buffer had a closer relationship with cardiovascular risk factors than density within 1600 m buffer and distance to the nearest food vendor. For example, we found that higher density of highly processed and take-away food vendors within 400 m buffer, but not 1600 m buffer or distance to nearest vendor, was associated with increased BMI and waist circumference. Patel et al. found that density of full service and fast food restaurants within 1000 m buffer was not related with overweight/obese in Delhi, India (Patel et al., 2017). Another study from the USA found a 10% increase in distance to the closest fast food restaurant to be associated with a 0.4% decrease in obesity (Mohamed, 2018). Cross-sectional analysis of 401,917 UK Biobank participants revealed a weak inverse association between distance from a fast-food outlet and waist circumference and BMI (AlHasan and Eberth, 2016). Relative to developed countries or even urban centres of developing countries, the commuting distances within the study villages were small, which may account for greater influence of the density of food vendors within smaller buffer zones on cardiovascular risk factors in the present study. Exploring how differences in the association vary by buffer type and distance to food vendors may be important to improving our understanding of the mechanisms by which food environment influences cardiovascular risk factors.

The different association between both availability and accessibility of different food vendors with cardiovascular risk factor in different countries may be due to various social, cultural, economic factors which affect food sale, purchasing and consumption patterns (Turner et al., 2019). A significant research gap remains to identify reasons for this heterogeneity. Comparing the results of studies which use similar methodology from a wide range of settings will be an important first step.

Some limitations of this study must be mentioned. First, the coordinates of food vendors were obtained in 2016, which was four years after the third follow-up data collection in APCAPS. However, cardiovascular risk factors such as hypertension and obesity generally develop and track over a long period of time (Mancia et al., 1993). The temporal relationship between exposure and outcome cannot be ascertained in a cross-sectional analysis; however, undiagnosed cardiovascular risk factors are unlikely to impact on the physical food environment or eating patterns. To confirm this, we conducted a sensitivity analysis excluding those with diagnosed hypertension and diabetes, and the results were largely unchanged (Table SI and Table S2). A further limitation is that our study considered residential food environment only. People are also exposed to food environments as they go about their daily activities (e.g. during travel and at work), although we were unable to measure these exposures. This may have resulted in a dilution of the effects of food environment on cardiovascular risk factors. The data available for our research limited our ability to determine whether attributes other than density and distance, for instance the quality of resources, the average price for healthy and unhealthy food, or mobility (e.g., access to a car) (Sharkey et al., 2010a), could influence cardiovascular risk. Finally, despite controlling for a range of covariates in our analysis, there is a risk in residual and unmeasured confounding and measurement error which may bias our analyses. Future studies should also focus on various food environment measures to shed light on the causal pathways by which food environment impacts on cardiovascular risk factors.

5. Conclusion

Our study contributes to the limited body of literature from low- and middle-income countries on the effects of neighborhood availability and accessibility of healthy and unhealthy food vendors on cardiovascular risk factors. Higher density of fruit and vegetable vendors was associated with lower blood pressure, while higher density of highly processed and take-away food vendors was associated with higher blood pressure and BMI/waist circumference. Food vendor density within 400 m of participant households had a closer relationship with cardiovascular risk factors than food vendor density within 1600 m and distance to the nearest food vendor. Public health policies designed to improve the healthiness of neighborhood food environments by increasing the availability of fruit and vegetable vendors and restricting highly processed and take-away food vendors should be encouraged in south India and other rural communities in South Asia. Additional long-term longitudinal studies are needed to establish causality.

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Declaration of competing interest

The author has no conflict of interest to declare.

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References

AlHasan, D.M., Eberth, J.M., 2016. An ecological analysis of food outlet density and prevalence of type II diabetes in South Carolina counties. BMC Public Health 16, 10.

Baldock, K.L., Paquet, C., Howard, N.J., Coffee, N.T., Taylor, A.W., Daniel, M., 2018. Are perceived and objective distances to fresh food and physical activity resources associated with cardiometabolic risk? Int. J. Environ. Res. Public Health 15.

Barrientos-Gutierrez, T., Moore, K.A.B., Auchincloss, A.H., Mujahid, M.S., August, C., Sanchez, B.N., Diez Roux, A.V., 2017. Neighborhood physical environment and changes in body mass index: results from the multi-ethnic study of atherosclerosis. Am. J. Epidemiol. 186, 1237–1245.

Cerin, E., Frank, L.D., Sallis, J.F., Saelens, B.E., Conway, T.L., Chapman, J.E., Glanz, K., 2011. From neighborhood design and food options to residents' weight status. Appetite 56, 693–703.

Chen, S.E., Florax, R.J., Snyder, S.D., 2013. Obesity and fast food in urban markets: a new approach using geo-referenced micro data. Health Econ. 22, 835–856.

Dake, F.A., Thompson, A.L., Ng, S.W., Agyei-Mensah, S., Codjoe, S.N., 2016. The local food environment and body mass index among the urban poor in Accra, Ghana. J. Urban Health 93, 438–455.

den Braver, N.R., Lakerveld, J., Rutters, F., Schoonmade, L.J., Brug, J., Beulens, J.W.J., 2018. Built environmental characteristics and diabetes: a systematic review and meta-analysis. BMC Med. 16, 12.

Duffey, K.J., Gordon-Larsen, P., Steffen, L.M., Jacobs Jr., D.R., Popkin, B.M., 2009. Regular consumption from fast food establishments relative to other restaurants is differentially associated with metabolic outcomes in young adults. J. Nutr. 139, 2113–2118.

Ebrahim, S., Kinra, S., Bowen, L., Andersen, E., Ben-Shlomo, Y., Lyngdoh, T., Ramakrishnan, L., Ahuja, R.C., Joshi, P., Das, S.M., Mohan, M., Davey Smith, G., Prabhakaran, D., Reddy, K.S., Indian Migration Study, g, 2010. The effect of rural-to-urban migration on obesity and diabetes in India: a cross-sectional study. PLoS Med. 7, e1000268.

Fuentes Pacheco, A., Carrillo Balam, G., Archibald, D., Grant, E., Skafida, V., 2018. Exploring the relationship between local food environments and obesity in UK, Ireland, Australia and New Zealand: a systematic review protocol. BMJ Open 8, e018701.

Gamba, R.J., Schuchter, J., Rutt, C., Seto, E.Y., 2015. Measuring the food environment and its effects on obesity in the United States: a systematic review of methods and results. J. Community Health 40, 464–475.

GBD 2016 DALYs, HALE Collaborators, 2017. Global, regional, and national disability-adjusted life-years (DALYs) for 333 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet 390, 1260–1344.

GBD 2017 Diet Collaborators, 2019. Health effects of dietary risks in 195 countries, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet 393, 1958–1972.

Gibson, R., Eriksen, R., Singh, D., Vergnaud, A.C., Heard, A., Chan, Q., Elliott, P., Frost, G., 2018. A cross-sectional investigation into the occupational and socio-demographic characteristics of British police force employees reporting a dietary pattern associated with cardiometabolic risk: findings from the Airwave Health Monitoring Study. Eur. J. Nutr. 57, 2913–2926.

Gupta, V., Millett, C., Walia, G.K., Kinra, S., Aggarwal, A., Prabhakaran, P., Bhogadi, S., Kumar, A., Gupta, R., Prabhakaran, D., Reddy, K.S., Smith, G.D., Ben-Shlomo, Y., Krishna, K.V., Ebrahim, S., 2015. Socio-economic patterning of cardiometabolic risk factors in rural and peri-urban India: Andhra Pradesh children and parents study (APCAPS). Z. Gesundh. Wiss. 23, 129–136.

Hawkesworth, S., Silverwood, R.J., Armstrong, B., Pliakas, T., Nanchahal, K., Sartini, C., Amuzu, A., Wannamethee, G., Atkins, J., Ramsay, S.E., Casas, J.P., Morris, R.W., Whincup, P.H., Lock, K., 2017. Investigating the importance of the local food environment for fruit and vegetable intake in older men and women in 20 UK towns: a cross-sectional analysis of two national cohorts using novel methods. Int. J. Behav. Nutr. Phys. Act. 14, 128.

Hobbs, M., Griffiths, C., Green, M.A., Jordan, H., Saunders, J., Christensen, A., McKenna, J., 2019. Fast-food outlet availability and obesity: considering variation by age and methodological diversity in 22,889 Yorkshire Health Study participants. Spat. Spatiotemporal. Epidemiol. 28, 43–53.

Jaime, P.C., Duran, A.C., Sarti, F.M., Lock, K., 2011. Investigating environmental determinants of diet, physical activity, and overweight among adults in Sao Paulo, Brazil. J. Urban Health 88, 567–581.

Kinra, S., Rameshwar Sarma, K.V., Ghafoorunissa, Mendu, V.V., Ravikumar, R., Mohan, V., Wilkinson, I.B., Cockcroft, J.R., Davey Smith, G., Ben-Shlomo, Y., 2008. 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 337, a605.

Kinra, S., Radha Krishna, K.V., Kuper, H., Rameshwar Sarma, K.V., Prabhakaran, P., Gupta, V., Walia, G.K., Bhogadi, S., Kulkarni, B., Kumar, A., Aggarwal, A., Gupta, R., Prabhakaran, D., Reddy, K.S., Smith, G.D., Ben-Shlomo, Y., Ebrahim, S., 2014. Cohort profile: Andhra Pradesh Children and Parents Study (APCAPS). Int. J. Epidemiol. 43, 1417–1424.

Lankinen, M., Schwab, U., Kolehmainen, M., Paananen, J., Nygren, H., Seppanen-Laakso, T., Poutanen, K., Hyotylainen, T., Riserus, U., Savolainen, M.J., Hukkanen, J., Brader, L., Marklund, M., Rosqvist, F., Hermansen, K., Cloetens, L., Onning, G., Thorsdottir, I., Gunnarsdottir, I., Akesson, B., Dragsted, L.O., Uusitupa, M., Oresic, M., 2016. A healthy Nordic diet alters the plasma lipidomic profile in adults with features of metabolic syndrome in a multicenter randomized dietary intervention. J. Nutr. 146, 662–672.

Lichtenstein, A.H., Carson, J.S., Johnson, R.K., Kris-Etherton, P.M., Pappas, A., Rupp, L., Stitzel, K.F., Vafiadis, D.K., Fulgoni 3rd, V.L., 2014. Food-intake patterns assessed by using front-of-pack labeling program criteria associated with better diet quality and lower cardiometabolic risk. Am. J. Clin. Nutr. 99, 454–462.

Lopez, R.P., 2007. Neighborhood risk factors for obesity. Obesity (Silver Spring) 15, 2111–2119.

Mancia, G., Omboni, S., Parati, G., Santucciu, C., Trazzi, S., Ulian, L., 1993. Clinical value of ambulatory blood pressure monitoring. Am. J. Hypertens. 6, 9S–13S.

Mohamed, R., 2018. Resident perceptions of neighborhood conditions, food access, transportation sage, and obesity in a rapidly changing Central City. Int. J. Environ. Res. Public Health 15.

Monteiro, C.A., Cannon, G., Moubarac, J.C., Levy, R.B., Louzada, M.L.C., Jaime, P.C., 2018. The UN decade of nutrition, the NOVA food classification and the trouble with ultra-processing. Public Health Nutr. 21, 5–17.

Morland, K.B., Evenson, K.R., 2009. Obesity prevalence and the local food environment. Health Place 15, 491–495.

Moubarac, J.C., Claro, R.M., Baraldi, L.G., Levy, R.B., Martins, A.P., Cannon, G., Monteiro, C.A., 2013. International differences in cost and consumption of ready-to-consume food and drink products: United Kingdom and Brazil, 2008-2009. Glob. Public Health 8, 845–856.

Murphy, M., Koohsari, M.J., Badland, H., Giles-Corti, B., 2017. Supermarket access, transport mode and BMI: the potential for urban design and planning policy across socio-economic areas. Public Health Nutr. 20, 3304–3315.

Murray, C.J., Vos, T., Lozano, R., Naghavi, M., Flaxman, A.D., Michaud, C., Ezzati, M., Shibuya, K., Salomon, J.A., Abdalla, S., Aboyans, V., Abraham, J., Ackerman, I., Aggarwal, R., Ahn, S.Y., Ali, M.K., Alvarado, M., Anderson, H.R., Anderson, L.M., Andrews, K.G., Atkinson, C., Baddour, L.M., Bahalim, A.N., Barker-Collo, S., Barrero, L.H., Bartels, D.H., Basanez, M.G., Baxter, A., Bell, M.L., Benjamin, E.J., Bennett, D., Bernabe, E., Bhalla, K., Bhandari, B., Bikbov, B., Bin Abdulhak, A., Birbeck, G., Black, J.A., Blencowe, H., Blore, J.D., Blyth, F., Bolliger, I., Bonaventure, A., Boufous, S., Bourne, R., Boussinesq, M., Braithwaite, T., Brayne, C., Bridgett, L., Brooker, S., Brooks, P., Brugha, T.S., Bryan-Hancock, C., Bucello, C., Buchbinder, R., Buckle, G., Budke, C.M., Burch, M., Burney, P., Burstein, R., Calabria, B., Campbell, B., Canter, C.E., Carabin, H., Carapetis, J., Carmona, L., Cella, C., Charlson, F., Chen, H., Cheng, A.T., Chou, D., Chugh, S.S., Coffeng, L.E., Colan, S.D., Colquhoun, S., Colson, K.E., Condon, J., Connor, M.D., Cooper, L.T., Corriere, M., Cortinovis, M., de Vaccaro, K.C., Couser, W., Cowie, B.C., Criqui, M.H., Cross, M., Dabhadkar, K.C., Dahiya, M., Dahodwala, N., Damsere-Derry, J., Danaei, G., Davis, A., De Leo, D., Degenhardt, L., Dellavalle, R., Delossantos, A., Denenberg, J., Derrett, S., Des Jarlais, D.C., Dharmaratne, S.D., Dherani, M., Diaz-Torne, C., Dolk, H., Dorsey, E.R., Driscoll, T., Duber, H., Ebel, B., Edmond, K., Elbaz, A., Ali, S.E., Erskine, H., Erwin, P.J., Espindola, P., Ewoigbokhan, S.E., Farzadfar, F., Feigin, V., Felson, D.T., Ferrari, A., Ferri, C.P., Fevre, E.M., Finucane, M.M., Flaxman, S., Flood, L., Foreman, K., Forouzanfar, M.H., Fowkes, F.G., Fransen, M., Freeman, M.K., Gabbe, B.J., Gabriel, S.E., Gakidou, E., Ganatra, H.A., Garcia, B., Gaspari, F., Gillum, R.F., Gmel, G., Gonzalez-Medina, D., Gosselin, R., Grainger, R., Grant, B., Groeger, J., Guillemin, F., Gunnell, D., Gupta, R., Haagsma, J., Hagan, H., Halasa, Y.A., Hall, W., Haring, D., Haro, J.M., Harrison, J.E., Havmoeller, R., Hay, R.J., Higashi, H., Hill, C., Hoen, B., Hoffman, H., Hotez, P.J., Hoy, D., Huang, J.J., Ibeanusi, S.E., Jacobsen, K.H., James, S.L., Jarvis, D., Jasrasaria, R., Jayaraman, S., Johns, N., Jonas, J.B., Karthikeyan, G., Kassebaum, N., Kawakami, N., Keren, A., Khoo, J.P., King, C.H., Knowlton, L.M., Kobusingye, O., Koranteng, A., Krishnamurthi, R., Laden, F., Lalloo, R., Laslett, L.L., Lathlean, T., Leasher, J.L., Lee, Y.Y., Leigh, J., Levinson, D., Lim, S.S., Limb, E., Lin, J.K., Lipnick, M., Lipshultz, S.E., Liu, W., Loane, M., Ohno, S.L., Lyons, R., Mabweijano, J., MacIntyre, M.F., Malekzadeh, R., Mallinger, L., Manivannan, S., Marcenes, W., March, L., Margolis, D.J., Marks, G.B., Marks, R., Matsumori, A., Matzopoulos, R., Mayosi, B.M., McAnulty, J.H., McDermott, M.M., McGill, N., McGrath, J., Medina-Mora, M.E., Meltzer, M., Mensah, G.A., Merriman, T.R., Meyer, A.C., Miglioli, V., Miller, M., Miller, T.R., Mitchell, P.B., Mock, C., Mocumbi, A.O., Moffitt, T.E., Mokdad, A.A., Monasta, L., Montico, M., Moradi-Lakeh, M., Moran, A., Morawska, L., Mori, R., Murdoch, M.E., Mwaniki, M.K., Naidoo, K., Nair, M.N., Naldi, L., Narayan, K.M., Nelson, P.K., Nelson, R.G., Nevitt, M.C., Newton, C.R., Nolte, S., Norman, P., Norman, R., O'Donnell, M., O'Hanlon, S., Olives, C., Omer, S.B., Ortblad, K., Osborne, R., Ozgediz, D., Page, A., Pahari, B., Pandian, J.D., Rivero, A.P., Patten, S.B., Pearce, N., Padilla, R.P., Perez-Ruiz, F., Perico, N., Pesudovs, K., Phillips, D., Phillips, M.R., Pierce, K., Pion, S., Polanczyk, G.V., Polinder, S., Pope 3rd, C.A., Popova, S., Porrini, E., Pourmalek, F., Prince, M., Pullan, R.L., Ramaiah, K.D., Ranganathan, D., Razavi, H., Regan, M., Rehm, J.T., Rein, D.B., Remuzzi, G., Richardson, K., Rivara, F.P., Roberts, T., Robinson, C., De Leon, F.R., Ronfani, L., Room, R., Rosenfeld, L.C., Rushton, L., Sacco, R.L., Saha, S., Sampson, U., Sanchez-Riera, L., Sanman, E., Schwebel, D.C., Scott, J.G., Segui-Gomez, M., Shahraz, S., Shepard, D.S., Shin, H., Shivakoti, R., Singh, D., Singh, G.M., Singh, J.A., Singleton, J., Sleet, D.A., Sliwa, K., Smith, E., Smith, J.L., Stapelberg, N.J., Steer, A., Steiner, T., Stolk, W.A., Stovner, L.J., Sudfeld, C., Syed, S., Tamburlini, G., Tavakkoli, M., Taylor, H.R., Taylor, J.A., Taylor, W.J., Thomas, B., Thomson, W.M., Thurston, G.D., Tleyjeh, I.M., Tonelli, M., Towbin, J.A., Truelsen, T., Tsilimbaris, M.K., Ubeda, C., Undurraga, E.A., van der Werf, M.J., van Os, J., Vavilala, M.S., Venketasubramanian, N., Wang, M., Wang, W., Watt, K., Weatherall, D.J., Weinstock, M.A., Weintraub, R., Weisskopf, M.G., Weissman, M.M., White, R.A., Whiteford, H., Wiebe, N., Wiersma, S.T., Wilkinson, J.D., Williams, H.C., Williams, S.R., Witt, E., Wolfe, F., Woolf, A.D., Wulf, S., Yeh, P.H., Zaidi, A.K., Zheng, Z.J., Zonies, D., Lopez, A.D., AlMazroa, M.A., Memish, Z.A., 2012. Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet 380, 2197–2223.

Nicklett, E.J., Kadell, A.R., 2013. Fruit and vegetable intake among older adults: a scoping review. Maturitas 75, 305–312.

Patel, O., Shahulhameed, S., Shivashankar, R., Tayyab, M., Rahman, A., Prabhakaran, D., Tandon, N., Jaacks, L.M., 2017. Association between full service and fast food restaurant density, dietary intake and overweight/obesity among adults in Delhi, India. BMC Public Health 18, 36.

Poti, J.M., Braga, B., Qin, B., 2017. Ultra-processed food intake and obesity: what really matters for health-processing or nutrient content? Curr. Obes. Rep. 6, 420–431.

Salas-Salvado, J., Guasch-Ferre, M., Lee, C.H., Estruch, R., Clish, C.B., Ros, E., 2016. Protective effects of the Mediterranean diet on type 2 diabetes and metabolic syndrome. J. Nutr. 146, 920S–927S.

Sarkar, C., Webster, C., Gallacher, J., 2018. Are exposures to ready-to-eat food environments associated with type 2 diabetes? A cross-sectional study of 347 551 UK biobank adult participants. Lancet Planet Health 2, e438–e450.

Sharkey, J.R., Horel, S., Dean, W.R., 2010a. Neighborhood deprivation, vehicle ownership, and potential spatial access to a variety of fruits and vegetables in a large rural area in Texas. Int. J. Health Geogr. 9, 26.

Sharkey, J.R., Johnson, C.M., Dean, W.R., 2010b. Food access and perceptions of the community and household food environment as correlates of fruit and vegetable intake among rural seniors. BMC Geriatr. 10, 32.

Stafford, M., Cummins, S., Ellaway, A., Sacker, A., Wiggins, R.D., Macintyre, S., 2007. Pathways to obesity: identifying local, modifiable determinants of physical activity and diet. Soc. Sci. Med. 65, 1882–1897.

Tamura, K., Elbel, B., Athens, J.K., Rummo, P.E., Chaix, B., Regan, S.D., Al-Ajlouni, Y.A., Duncan, D.T., 2018. Assessments of residential and global positioning system activity space for food environments, body mass index and blood pressure among low-income housing residents in New York City. Geospat. Health 13.

Turner, C., Kadiyala, S., Aggarwal, A., Coates, J., Drewnowski, A., Hawkes, C., Herforth, A., Kalamatianou, S., Walls, H., 2017. Concepts and methods for food environment research in low and middle income countries. In: Agriculture, Nutrition and Health Academy Food Environments Working Group (ANH-FEWG) Innovative Methods and Metrics for Agriculture and Nutrition Actions (IMMANA) Programme. London, UK.

Turner, C., Kalamatianou, S., Drewnowski, A., Kulkarni, B., Kinra, S., Kadiyala, S., 2019. Food Environment Research in Low- and Middle-Income Countries: A Systematic Scoping Review. Adv Nutr.

van der Horst, K., Brunner, T.A., Siegrist, M., 2011. Fast food and take-away food consumption are associated with different lifestyle characteristics. J. Hum. Nutr. Diet. 24, 596–602.

Velasquez-Melendez, G., Mendes, L.L., Padez, C.M., 2013. Built environment and social environment: associations with overweight and obesity in a sample of Brazilian adults. Cad. Saude Publica 29, 1988–1996.

World Health Organization, 2013. Global Action Plan for the Prevention and Control of NCDs 2013–2020. Noncommunicable Diseases and Mental Health.