Associations between the neighbourhood food environment and cardiovascular disease: A systematic review
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Short running head
The neighbourhood food environment and cardiovascular disease

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Abstract

Aims: To systematically review the current evidence on the association between the neighbourhood food environment and cardiovascular disease in adults.

Methods: We searched CINAHL, MEDLINE and EMBASE for studies published between January 1st 2000 and May 1st 2022. Studies focusing on the indoor home-, workplace- or school food environment were excluded. Two independent reviewers screened all records. Included studies were assessed for risk of bias using the shortened QUIPS tool, and relevant data were extracted. We summarised the findings using a narrative synthesis approach.

Results: We included 15 studies after screening 5,915 original records. Most studies were published in the last four years and were predominantly conducted in North-American or European countries. Most studies focused on fast-food restaurant density in the residential neighbourhood. Higher fast-food restaurant density was most consistently associated with a higher prevalence and incidence of CVD and CVD mortality, but effect sizes were small. Evidence of an association between fast-food restaurant density and myocardial infarction, or stroke was inconsistent. Other aspects of the food environment included density of food service restaurants, unhealthy food outlets and food access score. The evidence for these aspects was scant.

Conclusion: We found evidence for associations between the neighbourhood food environment and CVD, suggesting that higher fast-food restaurant density is associated with CVD and CVD mortality. Effect sizes were small, but important given the large population that is exposed. Research is needed to assess the effects of other aspects of the food environment.

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Systematic review registration
PROSPERO CRD42022317407.

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Lay summary

We conducted a systematic review to examine the relationship between the neighbourhood food environment and cardiovascular disease (CVD) in adults. We searched for studies published between January 1st 2000 and May 1st 2022 in three major medical databases, and included 15 studies. These studies were mostly conducted in North-American or European countries, and most of them focused on exposure to fast-food restaurants. Overall, these studies suggest that there is a relationship between a higher density of fast-food restaurants and CVD. Three studies also examined other aspects of the food environment, such as density of food service restaurants, unhealthy food outlets, and food access score, but the evidence for these aspects was scarce. We concluded that there is evidence to suggest that the neighbourhood food environment is associated with CVD, particularly a higher fast-food restaurant density. However, more research is needed to understand other aspects of the food environment.

Background

Cardiovascular disease (CVD) is the most common cause of death worldwide.\(^1\) Despite a steady decrease in CVD mortality in the past two decades, the absolute number of people diagnosed with and treated for CVD is still rising.\(^2,3\) Consequently, CVD not only poses a health burden, it also poses an economic challenge to healthcare systems.\(^4\) To halt this growing issue, it is key to target the different determinants of CVD to develop sustainable prevention strategies.

Diet is a major determinant of CVD. Dietary patterns including high intake of sodium, saturated fat, and added sugars, often associated with a Western dietary pattern and frequent consumption of fast-food, increase the risk of CVD.\(^5,6\) Low fruit and vegetable intake is also a recognised risk factor for coronary heart disease and other types of CVD.\(^7\) Unhealthy diets can induce pro-inflammatory responses that contribute to atherosclerosis development and eventually CVD. Additionally, unhealthy dietary behaviour, like frequent consumption of fast-food meals, contributes to clinical CVD risk factors such as obesity, hypertension, and dyslipidaemia.\(^8-11\) Efforts to change unhealthy diets through individual focused lifestyle interventions have therefore often been implemented and evaluated for their potential to prevent CVD.\(^12,13\) However, these interventions have a low reach and typically generate unsustainable effects.\(^14\)

Food choices are complex human behaviours, which may be partly driven by the exposure to food options in the environment.\(^15\) The variety, availability, and density of food outlets within certain areas are thought to influence dietary behaviours.\(^16\) This geographical access to food in a certain community or neighbourhood is known as the neighbourhood food environment. Evidence indeed suggests that aspects of the neighbourhood food environment, such as higher availability of fast-food and convenience stores, might be associated with lower diet quality, including increased intake of (ultra) processed meats, snacks and sugar-sweetened beverages.\(^17,18\) Such fast-food and convenience stores are establishments that specialise in providing quick-service meals and snacks, typically with a focus on convenience and efficiency. Furthermore, multiple studies found associations of higher availability of healthy foods, and greater access to supermarkets, with healthier diets.\(^19,20\) This is also supported by qualitative research that identified availability, accessibility and affordability of supermarkets and grocery stores as key built environmental barriers to making healthier food choices.\(^21\)

If the neighbourhood food environment affects diet, then it may also drive CVD. For example, there is growing evidence of a connection between the proximity of fast-food restaurants and patterns of fast-food consumption, as well as the likelihood of CVD risk factors such as obesity.\(^22,23\) It is therefore important to consider upstream environmental context in which dietary choices are made, to gain insights into determinants of downstream CVD. Furthermore, the neighbourhood food environment is a modifiable factor that could be targeted by public health interventions and policies. Better understanding the relation between the neighbourhood food environment and CVD may eventually provide entry-points for population-level action to prevent CVD and to reduce its prevalence and burden.

A number of studies have examined this potential relationship in the past two decades. However, there has not been a comprehensive review examining how neighbourhood food environment features are associated with CVD. Therefore, it is difficult for readers to assess the piecemeal published evidence. A comprehensive overview of the...
evidence will provide insight into the relation between the neighbourhood food environment and CVD, and highlight potential knowledge gaps. Therefore, the aim of this study is to systematically review and appraise the current evidence of associations between the neighbourhood food environment and CVD in adults.

Methods
The protocol for this review was pre-registered in the PROSPERO register of systematic reviews (ID: CRD42022317407). The review was written according to the guideline of Transparent Reporting of Systematic Reviews and Meta-Analyses (PRISMA).

Search strategy
We searched MEDLINE, EMBASE and CINAHL on May 1st 2022 for literature on the association between the neighbourhood food environment and CVD. We built a search algorithm including various definitions and synonyms of the food environment, its attributes, and various CVD (Supplementary tables 1-3). We also screened the reference lists of the included studies to identify additional eligible papers.

Inclusion and exclusion criteria
We included primary studies of the general population if they: (1) reported on objectively measured neighbourhood food environment exposures, including density, distance, and/or a combination of density and distance of fast-food restaurants or take-away, supermarkets, grocery shops, convenience stores, and restaurants; (2) reported associations between these factors and CVD (i.e., prevalence, incidence or mortality of heart disease, infarction, ischemic heart disease, transient ischemic attack, coronary artery disease, coronary occlusion, heart failure, stroke, arrhythmia, angina pectoris, hypertensive heart disease, heart attack and pulmonary heart disease) in adults (i.e., ≥18 years); (3) were published between January 1st 2000 and May 1st 2022 in English. We excluded studies focusing on the indoor home-, workplace- or school food environment. We also excluded studies based on animal research, systematic reviews, letters to editors and case reports, and studies that focused on populations under 18 years old, unless adults were included and results were presented separately.

Study selection and data extraction
After removing duplicate records, two reviewers (PM & HN) independently screened titles and abstracts for eligibility. The same two reviewers performed full text screening of the eligible articles separately and cross-checked a sample of each other’s work. Screening was done using Rayyan software, a non-commercial, web-based application. If there was conflict between the two independent reviewers that could not be resolved by discussion, a third reviewer (JL) was consulted.

HN conducted the data extraction which was verified by the other authors. The following data were extracted from the included articles: author, year of study, year of publication, journal reference, study design, follow-up time, sample size, participant characteristics (age, gender), study design, data collection methods, covariates used, environmental characteristics (e.g., restaurant density, supermarket availability, etc.) and data necessary for risk-of-bias assessment, detailed below.

Risk of bias assessment
HN assessed the quality of the included studies, verified by the other authors. We used a shortened version of the QUIPS tool by Cochrane. This checklist includes topics such as: study participation, sampling, study attrition, determinants/correlates measurement, outcome measurement, statistical analyses and flaws in the design or analyses. All of these items were scored with ‘yes/no’. Based on how many times an article scored ‘yes’, the quality was scored either ‘low’, ‘moderate’, or ‘high’ risk of bias. A low risk of bias was defined as 8-11 questions scored with ‘yes’, a moderate risk of bias was defined as 5-7 times ‘yes’, a high risk of bias was achieved with anything below 5 times ‘yes’ scored. The QUIPS checklist can be found in Supplementary table 4.

Analysis
We used a narrative synthesis approach and provided summary effect sizes, grouped by study design, specific exposure and/or outcome if they were comparable. We also aimed to meta-analyse studies if they had comparable
exposure and outcome assessment methods, and measures of association. However, we did not identify suitable combinations to meta-analyse.

Results

Study selection

The search yielded 5,915 original records. After screening titles and abstracts, we excluded 5,884 studies. After reading the full texts, we included 15 eligible reviews in this systematic review. Additional details are presented in the PRISMA article selection process flow chart.

Study characteristics

The general characteristics of the included studies are presented in Table 1. Seven studies originated from the North American continent and four from Europe of which three were from Sweden. The remaining studies were from Australia, China, Japan, and South-Korea. All studies were observational in design. There were seven longitudinal cohort studies, seven cross-sectional studies of which four were ecological, and one case-control study. Sample sizes across studies ranged from 631 to 4,309,674 participants. The year of publication ranged from 2005 to 2022 and most studies were published in the last four years.

Table 2 shows more in-depth information of the included studies. Nine studies examined fast-food restaurant density as exposure measure, and four studies examined fast-food restaurant availability. Three studies examined other exposure measures, namely, food service restaurants, unhealthy food outlets and a food access score. The main CVD outcomes studied were stroke (40%) and CVD mortality (33.3%). Other CVD outcomes included myocardial infarction, coronary heart disease, cardiac arrest and acute coronary syndrome. The inclusion of covariates varied across studies. One study did not include any covariates, and some studies included more than ten. The most commonly used covariates were age, sex, income, and measures of ethnic or racial identity.

Risk of bias

Three studies had a medium risk of bias, and the rest of the articles had a low risk of bias. The articles that scored medium mostly missed information on sample size and on missing variables. The complete scores for all included studies can be found in supplementary Table 5.

Cross-sectional studies

Three studies examined the relation between fast-food restaurants and stroke prevalence/mortality. Lee et al. observed that a higher fast-food restaurant density was associated with lower prevalence of stroke. This was statistically significant in adults aged 40-50 years (OR=0.64, 95%CI: 0.44 to 0.92), but not in adults aged 60 years or older (OR=0.86, 95%CI: 0.72 to 1.04). Furthermore, Mazidi et al. found that a higher fast-food restaurant per 1,000 residents was significantly associated more deaths due to stroke. (β=0.89, 95%CI: 0.58 to 1.19, FFRD was log-transformed). Contrarily, Matsuzono et al. did not find an association between the number of fast-food restaurants per 1,000 residents and stroke mortality. However, they did observe a significant association between the number of ramen restaurants per 100,000 people and age- and sex adjusted stroke mortality rates. Mazidi et al. also studied food service restaurants, which they defined as establishments primarily engaged in providing food services to customers who order and are served while seated (i.e., waiter/waitress service) and pay after eating. They found that a higher number of food service restaurants per 1,000 residents was associated with increased CVD mortality (β=0.19, 95%CI: 0.01 to 0.37, FFRD was log-transformed) and increased stroke mortality (β=0.13, 95%CI: -0.05 to 0.31, FFRD was log-transformed). However, these associations for CVD mortality (β=0.03,
95%CI: -0.16 to 0.23) and stroke (β=0.05, 95%CI: -0.25 to 0.14) were attenuated when fast-food restaurant density was included in the models. Wang et al. observed that higher fast-food restaurant density was correlated with higher CVD mortality (R=0.287, P<0.001).

One study examined a food access score. This score was defined as the percentage of no-vehicle households living beyond a 0.9-mile radius of a food outlet. They observed a small but non-statistically significant association between increased food access score and overall premature CVD mortality (β=0.05, 95%CI: -0.10 to 0.21).

**Longitudinal studies**

Most longitudinal studies assessed food environment exposures at baseline, and estimated incident CVD during follow-up (range: 1-7 years). Several studies found associations between fast-food restaurant density and CVD mortality. Daniel et al. found that a 10% increase in fast-food restaurant density was associated with a higher four year risk of CVD mortality (RR=1.39, 95%CI: 1.19 to 1.63). Furthermore, Poelman et al. found that higher fast-food restaurant density was associated with higher one year odds of CVD (OR=1.05, 95%CI: 1.02 to 1.09) and CHD (OR=1.17, 95%CI: 1.09 to 1.25) in urban areas, but not in rural areas. Saluja et al. found that an increase of 1 fast-food restaurant per 100,000 people was associated with four additional cases of MI (β=4.07, 95%CI: 3.86 to 4.28).

Lovasi et al. used availability (yes/no) as operationalisation of fast-food exposure. They did not observe a statistically significant association of fast-food restaurant availability with higher CVD mortality (HR=1.03, 95%CI: 0.99 to 1.07). Calling et al. and Kawakami et al. used a similar measure and did not find an association between FFRA and the risk of CHD. On the other hand, Mooney et al. found that presence of more unhealthy food sources was associated with higher odds of cardiac arrest (OR=2.29, 95%CI: 1.19 to 4.41).

Evidence for an association of fast-food restaurant density with stroke was inconsistent. Hamano et al. reported that higher fast-food restaurant density was associated with slightly increased three year odds of stroke in men (OR=1.02, 95%CI: 1.00 to 1.05) and women (OR=1.03, 95%CI: 1.00 to 1.06). Contrarily, Poelman et al. did not observe a significant association of higher fast-food restaurant density with one year stroke incidence. This was true for both urban (OR=0.96, 95%CI: 0.88 to 1.04) and rural areas (OR=1.06, 95%CI: 0.94 to 1.19), and also regardless of buffer size (500m, 1000m, 3000m). Calling et al. found that fast-food restaurant availability (yes/no) was associated with a higher six year odds of stroke in both women (OR=1.04, 95%CI: 1.02 to 1.07) and men (OR=1.06, 95%CI: 1.04 to 1.08).

Three studies examined measures of healthy food outlets. Daniel et al. found that fruit and vegetable store density was not associated with four year risk CVD mortality. Mooney et al. found that living near healthy food outlets (defined as supermarkets, produce markets, natural food stores, nut stores, and fish markets) was associated with higher odds of cardiac arrest (OR=1.26, 95%CI: 1.04 to 1.53). Lastly, Lovasi et al. observed that healthy food store availability (yes/no) was associated with a higher risk of CVD mortality (HR=1.06, 95%CI: 1.02 to 1.10).

**Discussion**

Our systematic review of 15 primary studies found some evidence for associations between the neighbourhood food environment and CVD. Most studies focused on fast-food restaurant density as exposure. The qualitative synthesis of available evidence suggests that higher fast-food restaurant density is associated with a higher prevalence and incidence of overall CVD and CVD mortality. Evidence of an association between fast-food restaurant density and myocardial infarction or stroke was inconsistent. Evidence for other aspects of the neighbourhood food environment is, thus far, scarce or lacking.

The studies carried out so far were heterogeneous in design and exposure assessment, which complicated the ability to accurately compare and combine study results. Even when a specific domain of the food environment was studied, such as fast-food exposure, different types of exposure measures were used. Some studies measured fast-food restaurant density within a 1000m buffer or 1km² zone, while others measured fast-food restaurant density per 1,000 or 100,000 inhabitants. These are inherently different constructs. While the first assesses the exposure of fast-food outlets in certain areas, the second assesses exposure within a certain amount of people. Therefore, they...
may not have comparable effects on CVD and should not be interpreted in the same way. Though we aimed to
meta-analyse studies, this was not possible due to the heterogeneity.

It is also evident that studies to date have mostly examined one exposure at a time. This approach may be
insufficient to detect significant effects. Just as single nutritional components only represent a fraction of the total
effect of diet on CVD, single food environment exposures may only represent a fraction of the total food
environment. Since people are always exposed to multiple environmental factors at the same time, individual
exposures are not easily singled out. This is further supported by studies on obesity. These imply that relative
measures that combine unhealthy or healthy food outlets are more likely to see significant and expected results.
Moreover, a study on child and parent obesity only found significant associations when food and physical activity
environment variables were combined. Multiple neighbourhood factors may therefore act together to create
obesogenic environments. However, more complex measures of exposure to food retailers do not necessarily
produce stronger associations - at least not with dietary patterns - as shown earlier. Furthermore, the available
studies on the role of food environment exposures and CVD focused on residential neighbourhood areas. It is,
however, known that other exposure areas may be important for dietary behaviours and health outcomes as well,
such as the workplace environment and commuting routes.

There is no consensus in the literature on what the best measures are to capture food environment exposures.
Earlier work by Caspi et al. noted that perceived measures of availability were more consistently associated with
dietary outcomes then objective (GIS-based) measures. This is corroborated by Diez et al. who found that there is
a mismatch between observational measures and residents’ perspectives on the retail food environment. A mix-
methods approach may be needed to more accurately define and assess food environment exposure.

The distinction between urban and rural areas regarding the neighbourhood food environment and its association
with CVD risk deserves careful consideration. Some studies in our review primarily focused on urbanised areas,
while findings from Poelman et al. demonstrated associations between fast-food restaurant density and CVD
specifically in urban areas but not in rural areas. This discrepancy suggests that the relationship between fast-
food establishment density and CVD risk may be context-dependent, varying between urban and rural
environments. Urban areas, characterized by a higher prevalence of fast-food restaurants and convenience stores,
may exhibit different dynamics in terms of fast-food intake and CVD risk compared to rural areas. The influence of
these establishments on food consumption and subsequent CVD risk might be more pronounced in urban settings,
where commercial influences and cultural factors play a more significant role.

The relation between food environment exposure and CVD outcomes may be confounded by other environmental
factors. For example, Macdonald et al. suggested that fast-food exposure may co-locate with other 'environmental
bads', such as alcohol shops, tobacco and gambling outlets, especially in more socially deprived areas. Moreover,
Lamichane et al. reported that areas with a higher SES have more supermarkets present than areas with a low
SES. This emphasizes the importance to adjust for - or stratify by - neighbourhood characteristics including
neighbourhood SES.

The diverse findings in our review also underscore the inherent complexity of the food environment and its
relationship with CVD. This suggests that linear associations may not adequately capture the multifaceted dynamics
at play. Notably, when fast-food restaurant density reaches high levels, particularly in urban areas where healthier
alternatives are often more readily available, the association with CVD may differ significantly. This highlights the
importance of considering non-linearity in these associations. It is worth noting that some studies in our review
resorted to categorising exposure measures as a means to address non-linearity. While this approach may have
been necessary, it can introduce challenges in terms of comparability between studies and may limit the ability to
assess nuanced associations accurately.

**Strengths and limitations**

To the best of our knowledge, this is the first systematic review to comprehensively summarise the relationship
between the neighbourhood food environment and CVD. Following a pre-specified protocol, we conducted a
search across multiple databases. Both the screening and assessment of full text were systematically performed by two independent researchers.

However, this study also has some limitations. Firstly, due to the heterogeneity of studies, we were mostly compelled to narratively summarising results. Secondly, it is likely that exposures are not equally important to all those who are exposed. The effects of the neighbourhood food environment on CVD may differ between various subpopulations. Due to the various ways that analyses were stratified across the studies, we could not take subpopulations into account. Lastly, we cannot exclude the possibility of publication bias. However, there was a reasonable number of studies with inconclusive or null results. Therefore, publication bias is not likely to have significantly influenced our findings.

Implications for public health and suggestions for future research
Whereas the existing evidence may not be sufficient to substantiate concrete policy recommendations, it adds to the growing evidence of the public health impact of fast-food exposure. A variety of other factors need to be addressed beyond fast food retail exposure in neighbourhoods. This includes the reduction of legislative difficulties to implement and enact local and national policies concerning fast-food retail. By narrowing the license-procedure and restricting the opening of new fast-food restaurants in certain areas, policy makers could reduce unhealthy food exposures.

Moving forward, the use of standardized measures of food-environment exposure is critical for future research in this field. Standardized measures can provide a common framework for researchers to collect, analyse, and interpret data, thereby promoting consistency and comparability of results. This will also enable the replication of research findings across different populations, settings and time points. Additionally, standardized measures will facilitate future meta-analyses to identify patterns, and support the accumulation of robust evidence that can inform public health policy and interventions to promote healthier food environments. Furthermore, future research should aim to explore and understand the complex and potentially non-linear relationships between these food environment measures and CVD.

We also suggest that future research should look into other neighbourhood food environment exposures besides fast-food restaurant density and availability. Only three out of fifteen studies included other exposures, which highlights a clear gap in evidence. Furthermore, individual exposures are not easily singled out. People are always exposed to multiple factors at the same time. It is therefore relevant to explore methods that assess the combined effect of the neighbourhood food environment (food system). For example, by the use of composite indicators in order to improve the assessment of individuals’ exposure to food environments.

Future studies should also incorporate multiple settings where people are exposed. For instance, utilizing global positioning system tracking methods can yield more precise measures of exposure. It is also relevant to investigate the relationship between the neighbourhood food environment and CVD in different geographic, cultural and socio-economic contexts. Atanasova et al. showed that distance to unhealthy food outlets increased the likelihood of fast-food consumption and higher BMI among adults of selected groups: females, Black-, and Hispanic individuals living in low and medium density areas. Considering the distinctions between urban and rural areas is also vital when designing future research studies and formulating targeted interventions.

There is still a need to better understand how exposure to food environments affects food intake and how individuals’ diets change in response. Future studies should explore the effects of exposure to food environments on both diet and cardiovascular disease risk. These studies could assess changes in food intake and diet quality over time, as well as other behavioral factors that may mediate the relationship between food environment and diet, such as food preferences.

Finally, whereas some studies looked at CVD incidence over time, no studies thus far looked at changes in the food environment over time in their relation to CVD incidence. Neighbourhood food environments are changing rapidly. Specifically, with the current trend in expansion of different food delivery services. The fact that actively going to a food outlet is getting less and less necessary might change the way we have to think about availability.
and accessibility. Therefore, delivery services are an important aspect of the neighbourhood food environment that needs to be captured in future studies.

**Conclusion**

Overall, our review found some evidence for associations between the neighbourhood food environment and CVD. Current evidence mainly suggests that fast-food restaurant density is associated with a higher prevalence and incidence of overall CVD and CVD mortality. Effect sizes were small, but important given the large population that is exposed. A lack of evidence exists for other types of the neighbourhood retail food environments, such as supermarket availability.

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**Conflict of interest**

All authors declare no support from any organisation for the submitted work; no other relationships or activities that could appear to have influenced the submitted work.

**Authors’ contributions**

PM, HN and JL designed the study and developed the review question. HN and PM performed the literature search and were the primary reviewers. JL acted as additional reviewer where required. JL supervised the study. HN and PM drafted the manuscript. All authors reviewed and revised the protocol and manuscript. JL acts as guarantor. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

**Data Availability Statement**

No new data were generated or analysed in support of this research.

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**Figure titles and legends**

**Graphic abstract.** Associations between the neighbourhood food environment and cardiovascular disease

**Figure 1.** Flowchart describing study selection.

**Table 1.** General characteristics of included studies.

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<td>Retrospective cohort study</td>
<td>7 years</td>
<td>n = 2,753,000</td>
</tr>
<tr>
<td>Wang, 2022</td>
<td>China</td>
<td>Cross-sectional ecological study</td>
<td>N/A</td>
<td>n = 469</td>
</tr>
<tr>
<td>Source</td>
<td>Statistical approach</td>
<td>Food outlet type</td>
<td>Outcome variable</td>
<td>Covariates</td>
</tr>
<tr>
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</tr>
<tr>
<td>Alter, 2005</td>
<td>Ordinal logistic regression</td>
<td>FFRD (per 100,000 residents)</td>
<td>Acute coronary syndrome hospitalisation</td>
<td>Median neighbourhood household income</td>
</tr>
<tr>
<td>Daniel, 2010</td>
<td>Poisson regression</td>
<td>FFRD (per km²) and FVS (per km²)</td>
<td>CVD mortality</td>
<td>Female sex, Married, Immigrant, Attending school full time, Education, Low income</td>
</tr>
<tr>
<td>Kawakami, 2011</td>
<td>Multilevel logistic regression</td>
<td>FFRA (per 1000m buffer)</td>
<td>CHD</td>
<td>Neighbourhood level deprivation, Age, Income</td>
</tr>
<tr>
<td>Hamano, 2013</td>
<td>Multilevel logistic regression</td>
<td>FFRA (per Small Area Market Statistics)</td>
<td>Stroke</td>
<td>Neighbourhood-level deprivation, Individual level age, Individual level income</td>
</tr>
<tr>
<td>Chum, 2015</td>
<td>Multilevel logistic regression</td>
<td>FFRD (per km²)</td>
<td>MI or ‘any CVD’, defined by a medical history of angina, CHD, stroke and CHF.</td>
<td>Age, Household income, Gender, Visible minority status, Education, Smoking, Drinking</td>
</tr>
<tr>
<td>Study</td>
<td>Methodology</td>
<td>Predictor</td>
<td>Outcome</td>
<td>Findings</td>
</tr>
<tr>
<td>-------</td>
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</tr>
<tr>
<td>Calling, 2016</td>
<td>Multilevel logistic regression</td>
<td>FFRA (per 1000m buffer)</td>
<td>CHD and stroke</td>
<td>Fast-food restaurant availability compared to no availability was associated with a slight increased odds of CHD in women after 6y follow-up (OR=1.02, 95%CI: 1.00 to 1.04), but not in men (OR=1.00, 95%CI: 0.98 to 1.01). FFRA was associated with increased odds of stroke in both women (OR=1.03, 95%CI: 1.00 to 1.05) and men (OR=1.06, 95%CI: 1.04 to 1.08).</td>
</tr>
<tr>
<td>Gaglioti, 2018</td>
<td>Multivariate logistic regression</td>
<td>Food access score (percentage of no-vehicle households living beyond a 0.9-mile radius)</td>
<td>Premature CVD mortality</td>
<td>Higher food access score was not associated with overall premature CVD mortality in the fully adjusted model (β=0.05, 95% CI: -0.10 to 0.21).</td>
</tr>
<tr>
<td>Mazidi, 2018</td>
<td>Multiple linear regression</td>
<td>FFRD and FSRD (per 1,000 residents)</td>
<td>CVD mortality and stroke mortality</td>
<td>Higher FFRD was associated with increased CVD mortality (β=1.10, 95%CI: 0.80 to 1.40) and stroke mortality (β=0.89, 95%CI: 0.58 to 1.19). Higher FSRD was associated with increased CVD mortality (β=0.19, 95%CI: 0.01 to 0.37), but not with stroke mortality.</td>
</tr>
<tr>
<td>Mooney, 2018</td>
<td>Multilevel linear regression</td>
<td>Presence of unhealthy food outlet and healthy food outlet (per census tract)</td>
<td>Cardiac arrest</td>
<td>Standard deviation higher exposure of unhealthy food outlets was associated with higher odds of cardiac arrest (OR=2.29, 95%CI: 1.19 to 4.41). Additionally, standard deviation higher exposure of healthy food outlets was associated with higher odds of cardiac arrest (OR=1.26, 95%CI: 1.04 to 1.53).</td>
</tr>
<tr>
<td>Poelman, 2018</td>
<td>Multilevel logistic regression</td>
<td>FFRD (1000 m buffer)</td>
<td>CVD, CHD, stroke and HF</td>
<td>In urban areas, increased fast-food restaurant density was associated with CVD (OR=1.05, 95%CI: 1.02 to 1.09), CHD (OR=1.17, 95%CI: 1.09 to 1.25) independent of buffer size (500 m, 1000 m, 3000 m). Evidence was less pronounced for stroke and HF. No associations were observed in rural areas.</td>
</tr>
<tr>
<td>Matsuzono, 2019</td>
<td>Pearson’s correlation coefficient</td>
<td>FFRD (per 100,000 residents)</td>
<td>Stroke mortality</td>
<td>Among all of the different types of restaurants under study (French, Italian, fast-food and ramen), only a higher number of ramen restaurants was associated with sex- and age adjusted stroke mortality rates (males r=0.594, p&lt;0.001, females r=0.625, p&lt;0.001).</td>
</tr>
</tbody>
</table>
Saluja, 2019<sup>16</sup>  
Weighted linear regression  
FFRD (per 100,000 residents)  
MI rates  
- Age  
- Diabetes  
- Hypertension  
- Hyperlipidemia  
- Obesity  
- Smoking rates  
- Socioeconomic status  
Higher FFRD exposure was associated with an increase in 2 year MI rates in the fully adjusted model ($\beta=4.07$, 95% C.I: 3.86 to 4.28).

Lee, 2021<sup>28</sup>  
Bayesian spatial multilevel model  
FFRD (no. per urbanised area)  
Stroke, MI/angina  
Univariate analysis  
In adults aged 40–50 years, higher FFRD was associated with lower odds of stroke (OR=0.64, 95% C.I: 0.44 to 0.92), and higher odds of MI and angina, though not significant (OR=1.03, 95% C.I: 0.79 to 1.35). No significant associations were observed in adults aged 60 years or older.

Lovasi, 2021<sup>37</sup>  
Cox proportional hazard models  
Presence of healthy food stores and FFR per ZIP code tabulation area.  
CVD mortality  
- Gender  
- Age  
- Marital status  
- Nativity  
- Black race  
- Hispanic ethnicity  
- Educational attainment  
- Income  
- Median household income  
- Population density  
- Walkable destination density  
Presence of healthy food stores was associated with incident CVD mortality (HR=1.06, 95% C.I: 1.02 to 1.10). presence of FFR was not associated with CVD mortality (HR=1.03, 95% C.I: 0.99 to 1.07).

Wang 2022<sup>44</sup>  
Spearman’s rank correlation  
FFRD (per 500m$^2$)  
CVD mortality  
- Land use  
- Road transport  
- Spatial form  
- Natural environment  
Higher FFRD was correlated with higher CVD mortality ($R=0.287$, p<0.001).

*FFRD = fast-food restaurant density, FFRA = fast-food restaurant availability, FVS = fruit & vegetable stores, FSR = food service restaurants, FFR = fast-food restaurant, CVD = cardiovascular disease, MI = myocardial infarction, CHD = coronary heart disease, CHF = congestive heart failure, OR = odds ratio, RR = relative risk.
* The exposure was log-transformed.
Identification of studies via databases and registers

Records identified from databases (n = 8663)

Records removed before screening:
- Duplicate records (n = 2748)
- Records marked as ineligible by automation tools (n = 0)
- Records removed for other reasons (n = 0)

Records screened (n = 5915)

Records excluded (n = 5915)

Records sought for retrieval (n = 31)

Reports not retrieved (n = 1)

Reports assessed for eligibility (n = 30)

Reports excluded:
- Wrong publication type (n = 11)
- Wrong outcome (n = 3)
- Missing determinant (n = 1)

Studies included in review (n = 15)

Figure 1
177x222 mm (x DPI)
**Systematic review**

We searched 3 databases, screened 5,915 records, and included 15 studies.

Most studies were conducted in North-America and Europe.

9 studies examined fast-food restaurant density (FFRD) and 4 fast-food restaurant availability.

Other exposures were food service restaurants, healthy food outlets, and a food access score.

Current evidence suggests that higher FFRD is associated with higher CVD/CVD mortality.

Effect sizes were small, but important given the large population that is exposed.

Research is needed to assess other aspects of the food environment besides fast-food. The use of standardized measures will improve study comparability. Different geographic, cultural and socio-economic contexts should be investigated.