Food insecurity, dietary quality and health in the Netherlands

Velde, L.A. van der

CHAPTER 5

The interplay between fast-food outlet exposure, household food insecurity and diet quality in disadvantaged districts

Laura A. van der Velde, Femke M. Zitman, Joreintje D. Mackenbach, Mattijs E. Numans, Jessica C. Kiefte-de Jong

Published in *Public Health Nutrition*. 2020 Oct 27;1-9

Abstract

Objective: The current study aimed to explore the interplay between food insecurity, fast-food outlet exposure and dietary quality in disadvantaged neighborhoods.

Design: In this cross-sectional study, main associations between fast-food outlet density and proximity, food insecurity status and dietary quality were assessed using Generalized Estimating Equation analyses. We assessed potential moderation by fast-food outlet exposure in the association between food insecurity status and dietary quality by testing for effect modification between food insecurity status and fast-food outlet density and proximity.

Setting: A deprived urban area in the Netherlands.

Participants: We included 226 adult participants with at least one child below the age of 18 years living at home.

Results: Fast-food outlet exposure was not associated with experiencing food insecurity (fast-food outlet density: b=-0.026, 95%CI=-0.076; 0.024; fast-food outlet proximity: b=-0.003, 95%CI=-0.033; 0.026). Experiencing food insecurity was associated with lower dietary quality (b=-0.48 per unit increase, 95%CI = -0.94; -0.012). This association was moderated by fast-food outlet proximity (p-interaction=0.008), and stratified results revealed that the adverse effect of food insecurity on dietary quality was more pronounced for those with the nearest fast-food outlet located closer to the home.

Conclusions: Food insecurity but not fast-food outlet density is associated with dietary quality. However, the association between food insecurity and dietary quality may be modified by the food environment. These findings could inform policymakers to promote a healthier food environment including less fast-food outlets, with particular emphasis on areas with high percentages of food insecure households.

Introduction

Maintaining a healthy diet is essential for overall health and chronic disease prevention, decreasing the risk of overweight and obesity (1), chronic diseases (2, 3), and poor mental health (4). Despite the evident importance of a healthy diet, many people - especially those of lower socioeconomic status (SES) groups - find it difficult to meet dietary guidelines (5). Suboptimal food choices result from a combination of personal factors, and factors in the physical, social, and economic environment (6), such as an unfavorable food environment with high exposure to low-cost, easily accessible fast-foods. Evidence for such an association is inconsistent (7, 8), although some evidence suggests that an unfavorable food environment indeed impedes healthy food choices (9).

Previous literature describes five dimensions of the food environment: availability, accessibility, affordability, acceptability, and accommodation (10). These first two dimensions (availability and accessibility) reflect geographic distribution (10), and are also important elements of food insecurity, defined as inadequate or insecure access to affordable, healthy foods (11). Narratives of people at risk of food insecurity highlight food outlet availability and accessibility as important factors influencing eating behavior (12). When budget is limited, accessibility is especially important, as (public) transport can entail additional costs. Another emphasized consideration was food pricing (12), which can be influenced by food outlet density, e.g., due to competitive pricing (13). Also, availability may impact variation in food supply and may therefore influence opportunities for consuming a varied diet.

People experiencing food insecurity may adopt an unfavorable diet with high fast-food intake due to financial constraints, as this kind of diet is generally less expensive than healthier diets (14). Experiencing food insecurity may also indirectly influence food choices through impaired mental health, leading to unfavorable food choices (12, 15). These factors help explain why food insecure families tend to have less healthy diets (16). Furthermore, although depending on contextual and individual factors, both food insecurity and fast-food outlets are generally more prevalent in disadvantaged neighborhoods (7, 17). Although mere exposure to fast-food outlets does not necessarily make people eat less healthy (18), it can be speculated that experiencing food insecurity lowers resilience and enhances vulnerability to tempting food cues of low-cost and convenient (fast-)foods (19), and therefore the impact of food outlet exposure on dietary quality could be amplified for those experiencing food insecurity. Ford and Dzewaltowski (2008) describe a similar hypothesis after literature review on food environments in the United States, stating that “while the quality of the retail food environment affects food choice and eating behaviors among both high and low SES populations, the economic (and perhaps social and cultural) resources available to those of higher SES have a protective effect on eating patterns ((20), page 225). Following this hypothesis, a recent study among a large cohort of adult residents of the United Kingdom showed that those most exposed to fast-food outlets and of lowest SES were most at risk of unhealthy dietary intake and obesity, suggesting a double burden of unfavorable food environments and low SES (21). However, a recent literature review found no clear evidence for a differential impact of food environments on dietary quality across socioeconomic groups (22).

All in all, associations between food environments, socioeconomic status and diet remain complex, and to date only limited research has examined the interplay between fast-food outlet exposure, food insecurity, and dietary quality. Therefore, we aimed to explore the interplay between food insecurity, fast-food outlet exposure, and dietary quality in disadvantaged neighborhoods.

Methods

Study population and data collection

Participants for our cross-sectional, observational study were recruited between April 2017 and June 2018 in six disadvantaged neighborhoods in The Hague (**Figure S1**), selected based on predefined criteria of the Dutch Government to identify disadvantaged neighborhoods (23). Participants that met the inclusion criteria (i.e., living in or near one of the selected neighborhoods; aged ≥18 years; and having at least one child aged <18y living at home) were recruited at various public places, such as community centers and (pre)schools. Questionnaires addressing food insecurity status, dietary intake, and sociodemographic variables were available in Dutch, English, and Turkish. Participants that provided contact information were contacted to complement missing data from their questionnaire if applicable. A total of n=250 participants filled out the questionnaire, of whom 24 were excluded (n=8 for having no child <18 years living at home, n=16 for having missing postal code data), resulting in a population of analysis of n=226 **(Figure S2)**. Because the participants’ home postal codes were unevenly distributed over the districts, some districts were merged into larger clusters according to matching neighborhood characteristics (**Document S1**). Participants were placed in one of seven clusters based on their postal code.

Food insecurity assessment

Household food insecurity status was assessed using the 18-item United States Department of Agriculture Household Food Security Survey Module (USDA-HFSSM) (24), which has a previously confirmed construct validity and reliability (25). Questions addressed household food conditions within the past 12 months. Affirmative responses were summed into an ordinal food insecurity score ranging from 0-18. This score was dichotomized into the categories 'food secure'(0-2 affirmative responses) and 'food insecure'(3-18 affirmative responses) (26). Food insecurity status was analyzed continuously ('food insecurity score': 0-18) and dichotomously ('food insecurity status': food secure/food insecure).

Dietary quality assessment

Dietary intake was assessed using an adapted version of the Dutch Healthy Diet Food Frequency Questionnaire (DHD-FFQ), a short questionnaire comprising 25 questions representing 34 food items, with the previous month as reference period, previously found to be an acceptable screening method to rank participants according to their dietary quality (27). From the dietary intake data, a dietary quality score was constructed assessing adherence to the Dutch dietary guidelines for the following six components: vegetables; fruit; fish; bread; oils and fat; and sweet and savory snacks. For each component, a minimum score of 0 and a maximum score of 10 could be obtained, with higher scores indicating a better adherence to the dietary guidelines. These component scores were summed, resulting in an overall dietary quality score ranging from 0-60. Construction of the dietary quality score is described in more detail elsewhere (28).

Food outlet exposure assessment

All food outlets in The Hague were extracted from the commercial database Locatus (29), which was recently validated showing good to excellent agreement compared to field audit data (30). Fast-food outlets were classified as shops that sell food which has been prepared in bulk order in advance and which is ordered and paid for at the counter (31). Branch classification codes for fast-food, grillroom/kebab and takeaway were used (18). The stores were then geo-located based on their geographical coordinates (**Figure S1**). Food outlet exposure measures were calculated using Geographical Information Systems (GIS) in Qgis (version 3.8.0-Zanzibar, Free Software Foundation, 1991, Boston USA) using the center of the 6-digit postal code area (for n=35, 6-digit was not available and therefore 4-digit was used). Geographical data for The Hague and the postal code areas were obtained from OpenStreetMap (32) and the open source Data Platform The Hague (33). We assessed both fast-food outlet proximity (FFP) and fast-food outlet density (FFD) in our study, as these are both important and distinct dimensions of food outlet exposure that may influence eating behavior of people experiencing food insecurity.

Fast-food outlet proximity (FFP)

Euclidean FFP was calculated as a measure of fast-food accessibility (34). This measure reflects the location of the fast-food outlet and the ease of getting there, expressed in the distance to that location (8). FFP was calculated as the shortest distance from the home postal code to the nearest fast-food outlet, expressed in distance per 10m to facilitate interpretation of the results.

Fast-food outlet density (FFD)

FFD in a Euclidean buffer of 500 and 1000m around the home postal code was calculated as a measure of fast-food availability (34), which reflects the adequacy of the variation and amount of food outlets in a certain area (8). The 500m buffer was chosen as an acceptable walking distance, but analyses with 1000m buffers were included in sensitivity analyses for comparison, because maximum acceptable walking distance differs per person and per situation.

The number of fast-food outlets correlated strongly with the total number of food outlets in The Hague (Pearson's rho=0.919, **Document S2**). Therefore, in addition to the *absolute* FFD, we included the *relative* FFD within 500m as a sensitivity measure to evaluate the effect of the FFD taking into account the total number of food outlets (calculated as: FFD/total number of food outlets).

Covariates

Sociodemographic characteristics and socioeconomic status (SES)-proxies were assessed using questionnaires, including age in years; sex (male versus female);

household size (number of adults and children living in the household); marital status (single versus married or cohabiting); and migration background (Western versus non-Western); educational level (low (≤ISCED 2) versus higher (≥ISCED 3)); and gross monthly household income (above versus below the Dutch basic needs budget (35)). The basic needs budget is calculated taking into account the household size and household composition. To illustrate, the basic needs budget limit is 2235 euro gross monthly income for a two-parent household with two children, and 1626 euro for a single-parent household with two children.

Statistical analysis

Subject characteristics were described as mean and standard deviation (SD) or median and interquartile range [IQR] for continuous variables, and percentages for dichotomous variables.

Food insecurity was analyzed both continuously ('food insecurity score') and dichotomously ('food insecurity status'). Main associations between FFD and FFP, food insecurity, and dietary quality were assessed using Generalized Estimating Equation (GEE) analyses using an exchangeable correlation structure. To assess the association between FFD, FFP, and food insecurity, we used GEE analyses with identity link function with food insecurity score as dependent variable and FFD and FFP one by one as independent variables. These analyses were repeated using GEE analyses with logistic link function with food insecurity status as dependent variable. To assess the association between FFD, FFP, and dietary quality, we conducted GEE analyses with identity link function, with dietary quality as dependent variable and FFD and FFP one by one as independent variables. To assess the association between food insecurity and dietary quality, we conducted GEE analyses with identity link function, with dietary quality as dependent variable and food insecurity score and food insecurity status one by one as independent variables. All analyses were clustered by district (crude models), and additionally adjusted for age, sex, migration background, household size, marital status, household income, and educational level (adjusted model). Potential non-linearity was tested by evaluating a quadratic term.

Further, we tested for a moderating effect of fast-food outlet exposure on the association between food insecurity status and dietary quality by one-by-one adding the interaction terms 1) FFD*food insecurity score; 2) FFP*food insecurity score; 3) FFD*food insecurity status; and 4) FFP*food insecurity status to the crude model. If significant interaction was observed, analyses were stratified by the median value for the continuous FFD or FFP. Stratification by the median value was done to obtain two equal-sized subgroups to compare.

Sensitivity analyses were performed conducting the same analyses as described above, but including: 1) *relative* FFD (to explore the effect of taking into account the total number of food outlets); 2) FFD within 1000m (to explore the effect of a larger exposure radius); 3) only non-foodbank users, as food aid may bias the results; 4) only participants with complete 6-digit postal code, as assessments based on 4-digit postal code are less accurate.

Missing data were imputed using the multiple imputation procedure in SPSS, using Predictive Mean Matching (n=10 imputations). The percentage of missing values ranged between 1.2-11.6% (**Document S3**). Results obtained after the multiple imputation procedure are presented.

A two-sided *p*-value of 0.05 was considered statistically significant. Analyses were performed using IBM SPSS statistics version 25.0 (IBM Corp., 2012, Armonk, NY).

Results

Sample characteristics

Overall, 26.5% of the participants experienced food insecurity (**Table 1**). The mean (±SD) age was 38.3 (±7.4) years, and most participants were women (86.6%), had a non-Western migration background (84.2%), and were married or cohabiting (68.2%). Most participants reported a household income below the basic needs budget (66.6%) and 58.3% were higher educated. Only 3.1% of the participants reported foodbank use. The mean (±SD) dietary quality score was 35.4 (±7.3) out of 60. Regarding fast-food outlet exposure, the median [IQR] FFD within 500m was 12.0 [6.0; 18.0], meaning that a median number of 12 fast-food outlets were present within a radius of 500m around the home postal code of the participants. The median [IQR] FFP was 139.4 [109.0; 214.3]m, meaning that the median distance from the home postal code of the participants to the closest fast-food outlet was 139.4m (**Table 1**).

Table 1. Characteristics of included participants (n=226)

Characteristics	Mean/ median/ percentage	SD/ IQR
Age (in years)	38.3	7.4
Sex (% women)	86.6%	
Migration background (% non-Western)	84.2%	
Household size	4.2	1.3
Marital status (% married or cohabiting)	68.2%	
Educational level (% higher level, ≥ISCED 3)	58.3%	
Household income (% below basic needs budget)	66.6%	
Foodbank users (% yes)	3.1%	
Total dietary quality score (range 0-60)	35.4	7.3
Food security (% food insecure)	26.5%	
6-digit postal code known (%)	84.5%	
Total number of places where food is sold within 500m radius	57.0	26.8; 107.3
Shortest distance from home to fast-food outlet (FFP in meters)	139.4	109.0; 214.3
Number of fast-food outlets within 500m radius (FFD in 500m)	12.0	6.0; 18.0
Number of fast-food outlets relative to the total number of food outlets within 500m radius (relative FFD)	18.2	16.2; 25.0
Number of fast-food outlets within 1000m radius (FFD in 1000m)	48.5	25.0; 62.0

SD, Standard Deviation; IQR, Interquartile Range; ISCED, International Standard Classification of Education; FFP, Fast-food outlet proximity; FFD, Fast-food outlet density

For food insecure participants, the median [IQR] FFP was approximately 13m shorter (131.2 [101.1; 225.7] versus 144.6 [108.7; 211.4]), i.e., fast-food outlets were generally 13m closer to the home postal code of food insecure participants (**Table 2**).

Table 2. Median fast-food outlet proximity (FFP) and fast-food density (FFD), for food secure and food insecure participants (n=226)

	Food secure		**Food insecure**	
	Median	IQR	Median	IQR
FFP (shortest distance in m)	144.6	108.7; 211.4	131.2	101.1; 225.7
FFD (in 500 m)	13.0	7.0; 18.0	10.0	6.0; 16.0
Relative FFD (in 500 m)	18.2	16.1; 23.5	19.7	16.4; 26.2
FFD (in 1000 m)	50.0	25.0; 61.3	45.5	22.0; 64.0

IQR, Interquartile Range; FFP, Fast-food outlet proximity; FFD, Fast-food outlet density

Main associations between fast-food outlet exposure, food insecurity and dietary quality

FFP and FFD were not associated with experiencing food insecurity (**Table 3**). FFD was not associated with dietary quality, however, increasing FFP (i.e., the fast-food outlet being further away from the home postal code) was associated with a slightly higher dietary quality (Adjusted model: b=0.12, 95%CI=0.025; 0.21). Experiencing food insecurity was significantly associated with lower dietary quality (food insecurity score, adjusted model: b=-0.48, 95%CI=-0.94; -0.012; Food insecurity status, adjusted model: b=-2.73, 95%CI=-5.18; -0.29) (**Table 3**). The multiple imputation procedure had little impact on the observed estimates (**Document S3: Table 4**).

Table 3. Main associations between fast-food outlet density and proximity, food insecurity and dietary quality (n=226)

	Outcome			
	Food insecurity score (continuous)			
	Crude model		Adjusted model	
	β	95% CI	β	95% CI
FFD (within 500 m)	-0.023	-0.082; 0.037	-0.026	-0.076; 0.024
FFP (per 10 m)	-0.009	-0.043; 0.025	-0.003	-0.033; 0.026
	Food insecurity status (dichotomous)			
	Crude model		Adjusted model	
	OR	95% CI	OR	95% CI
FFD (within 500 m)	0.98	0.92; 1.04	0.96	0.91; 1.01
FFP (per 10 m)	0.98	0.94; 1.02	0.98	0.95; 1.02
	Dietary quality			
	Crude model		Adjusted model	
	β	95% CI	β	95% CI
FFD (within 500 m)	-0.013	-0.17; 0.14	-0.009	-0.16; 0.14
FFP (per 10 m)	0.11	0.014; 0.20*	0.12	0.025; 0.21*
Food insecurity score (continuous)	-0.47	-0.85; -0.093*	-0.48	-0.94; -0.012*
Food insecurity status (dichotomous)	-2.70	-4.47; -0.93*	-2.73	-5.18; -0.29*

* $p < 0.05$
95%CI, 95% confidence interval; FFP, Fast-food outlet proximity; FFD, Fast-food outlet density
OR= odds ratio for being food insecure (being food secure=reference).
β represents the difference in food insecurity score (higher= more food insecure) or dietary quality (higher=better adherence to dietary guidelines).
Crude model: Merely including FFD, FFP or food insecurity as determinant, clustered by district (n=7).
Adjusted model: Crude model additionally adjusted for age, sex, migration background, household size, marital status, household income, and educational level.

The role of fast-food outlet exposure in the association between food insecurity status and dietary quality

A significant interaction (*p* = 0.008) was observed for food insecurity score with FFP, whereas no interaction was observed for food insecurity status with FFP (p-interaction = 0.949) nor for FFD with food insecurity score (p-interaction = 0.681) or status (p-interaction = 0.680). Stratification by the population-specific median FFP per 10m (i.e., 13.9m) showed that for individuals with the nearest fast-food outlet per 10m being less than 13.9m from the home, a larger effect size was found for the adverse effect of food insecurity on dietary quality (b= -0.55, 95%CI=-1.34; 0.23), whereas for individuals with the nearest fast-food outlet per 10m being more than 13.9m from the home, a smaller effect size was observed (b= -0.40, 95%CI=-0.77; -0.031) (**Figure 1**).

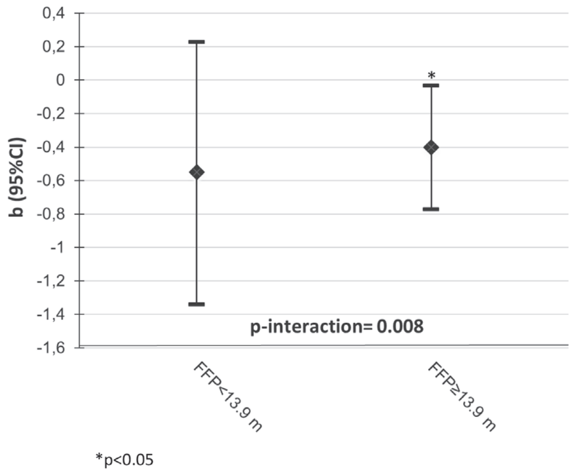


Figure 1. Stratified results for the association between food insecurity score and dietary quality (clustered by district, adjusted for age, sex, migration background, household size, marital status, household income, and educational level), split at the median fast-food outlet proximity (FFP) per 10m: 13.9m

Sensitivity analyses

Relative fast-food density and fast-food density within 1000 m

Results of the analyses including the *relative* FFD within 500m or FFD within 1000m where comparable to the results of the main analyses (**Document S4**). Differing from the main analyses, the association between FFD within 1000m and food insecurity score was significant in the adjusted model, although effect sizes were similar (**Document S4**).

Non-foodbank users

Sensitivity analyses including only non-foodbank users (n=199) showed similar results compared to the main analyses for the associations between FFD and FFP with dietary quality and experiencing food insecurity (**Document S5**). For the associations between experiencing food insecurity and dietary quality, effect sizes were smaller but in the same directions. Further, in the analyses including only non-foodbank users the association between food insecurity and dietary quality was only significant for the crude association between food insecurity status and dietary quality. Stratified results at the median FFP per 10m were similar to the results of the main analyses for FFP per 10 m≥13.9m, however, for FFP per 10m<13.9m effect sizes were in the same direction but smaller (**Document S5**).

Participants that provided complete postal codes

Sensitivity analyses including only the participants that provided their complete 6-digit postal code (n=191) showed mostly similar results compared to the main analyses (**Document S6**). Differing from the main analyses, the association between FFP and dietary quality was non-significant, slightly smaller effect estimates were observed for the association between food insecurity and dietary quality, and the association between experiencing food insecurity and lower dietary quality was only significant for crude model with the dichotomous food insecurity status (**Document S6**).

Discussion

Our study among families living in an urban multi-ethnic setting in the Netherlands showed that fast-food outlet exposure was not associated with experiencing food insecurity. Increasing FFP was associated with a slightly higher dietary quality. Further, experiencing food insecurity was associated with a lower dietary quality. This association was moderated by FFP, and stratification by the median FFP distance in our sample revealed that the adverse effect of food insecurity on dietary quality was more pronounced for those with the nearest fast-food outlet located closer to the home.

In our study, we did not find an indication that fast-food outlet exposure was related to experiencing food insecurity, suggesting that geographic access to fast-food in this context does not contribute to food insecurity. This could be partly explained by the urban setting in which the study was conducted, where so called “food deserts”- areas with poor access to healthy and affordable food - are rare (36). While evidence suggests that food deserts exist in disadvantaged areas in the United States and may there contribute to diet-related health disparities, limited evidence for this phenomenon has been found for other countries including the Netherlands (36, 37). Further, our study focused on access to fast-food, whereas overall food access is more likely to compromise food security. In addition, food pricing seems to be a more important determinant of food purchase behavior than food access for low-income and food insecure families (12, 13). Therefore, the generally higher prices of healthier diets (14) may explain the association between experiencing food insecurity and a lower dietary quality that was observed in our study. Consistent with our findings, previous literature shows substantial evidence for an association between experiencing food insecurity and lower dietary quality (16), but limited and inconsistent evidence for an association between the food environment and dietary quality (38). Our results indicated that FFD was not related to dietary quality, whereas increasing FFP was associated with a slightly higher dietary quality, indicating that maintaining a healthy diet may be easier when living further away from a fast-food outlet.

In line with our hypothesis, our results showed that the adverse effect of food insecurity on dietary quality was more pronounced among those with the nearest fast-food outlet located closer to the home. Previous literature shows no clear evidence for a differential impact of food environments on dietary quality across socioeconomic groups (22). Although food insecurity is more prevalent among lower socioeconomic groups, this is not a one-to-one relationship (i.e., not all people with lower incomes experience food insecurity and vice versa). Therefore, it is possible that the impact of food environments on dietary quality indeed is different for those experiencing food insecurity and not for those just belonging to lower socioeconomic groups. Narratives of people at risk of experiencing food insecurity, living in the same disadvantaged neighborhoods as those included in the current study, strengthen our findings as these participants also indicated high fast-food outlet exposure as a barrier for healthy eating (12). It should be noted that we did not observe the same effect modification when we analyzed food insecurity status dichotomously instead of assessing food insecurity score. This may be explained by the sample size, but may also suggest a potential plateau effect in which fast-food outlet accessibility interacts with food insecurity and dietary quality. For example, with more severe food insecurity, other (severe) problems such as mental health issues may be more important determinants of dietary quality (15). Future research is warranted to further explore the exact tipping point in food insecurity status where fast-food outlet proximity becomes an important negative influence on dietary quality. The possible implications of our findings are illustrated by the results of a recent longitudinal study, which showed an increase in the availability of food retailers offering convenience and ready-to-eat foods in the Dutch food environment in the past 14 years, and higher availability of fast-food outlets in low-SES neighborhoods (39).

Previous literature suggests that the local retail food environment impacts food choices (6), making the food environment a target for interventions. GIS enable assessment of spatial accessibility to food outlets (10). Dimensions of this geographic accessibility include accessibility of food outlets around the home address (10). The construct of food accessibility is a key element in the official definition of food security defined by the Food and Agriculture Organization, stating that food security is the "physical and economic access to sufficient, safe and nutritious food that meets dietary needs and food preferences for an active and healthy life" (11). However, we used the USDA-HFSS (24), which mostly reflects financial accessibility and is less focused on physical accessibility such as often studied in low-income countries.

Previous studies examining the food environment varied greatly in their methodological choices regarding density/proximity measures, Euclidean/street-network measures, absolute/relative measures, buffer levels, and the incorporation of either store prices or people's store preferences (34). This makes studies on the food environment difficult to compare. The current study contributes to the growing body of literature focused on neighborhood fast-food environment influences on food insecurity and dietary quality. To our knowledge, this is the first study showing the differential impact of fast-food outlet exposure on dietary quality for those experiencing food insecurity.

Strengths of this study include the use of both proximity and density measures for quantifying fast-food outlet exposure, and the performance of sensitivity analyses using the relative density and density within a larger radius. This allowed comprehensive analyses and better understanding of the actual associations with fast-food outlet exposure. Further, our study was strengthened by methodological correction using multiple imputation to account for potential bias associated with missing data (40). Limitations of the current study include the relatively small sample size. Our power calculation was initially based on a sample of 250 participants, whereas in the current study some participants were excluded resulting in a slightly smaller sample size of 226 participants. Therefore, null findings need to be interpreted with caution. Because of the cross-sectional design of this study, it was not possible to infer causal or directional relationships. In addition, a potential effect of residential self-selection cannot be ruled out. Residential self-selection indicates that the selection of a neighborhood to live in may be related to the neighborhood exposure (such as the food environment), and the health outcome of interest (such as diet quality) (41), which may lead to biased results (42). For example, if participants have a preference for fast-food restaurants, they may have selected the neighborhoods they lived in for its fast-food outlet presence, while this preference may also negatively impact diet quality. On the other hand, participants may have selected the disadvantaged neighborhoods they lived in because of financial constraints, while fast-food restaurants are also generally more prevalent in these neighborhoods (7). The most common method to account for residential self-selection is model adjustment, as was performed in our study (42). Although we have adjusted our analyses for various factors including household income, it should be noted that other factors influencing neighborhood choice may not have been accounted for, such as personal preference for a certain food environment.

Another potential drawback is that we focused exclusively on the food outlet exposure surrounding the participants' home and did not take into account other relevant food outlet exposure such as those surrounding the worksite, while clearly these places could add to the food outlet exposure (43). In addition, we assessed fast-food outlet exposure, but we had no information on if and where fast-food was actually purchased or consumed. Therefore, future studies that include a more comprehensive assessment of all relevant fast-food outlet exposure, and taking into account actual food purchase and consumption behavior are warranted to confirm our results. It should further be noted that we based our dietary quality score on Dutch dietary guidelines, which may be less suitable for non-Dutch ethnic groups. In addition, the dietary quality score did not reflect fast-food consumption specifically, but rather reflected overall dietary quality. Also, we used the USDA-HFSSM to assess food insecurity status, which is regarded as the golden standard for Western countries (44) but is not yet validated for the Dutch population.

Conclusions

In conclusion, our study indicated that fast-food outlet exposure was not associated with experiencing food insecurity. Experiencing food insecurity was associated with a lower dietary quality and the adverse effect of food insecurity on dietary quality was more pronounced for those with the nearest fast-food outlet located closer to the home. Future research is warranted to further explore the role of fast-food outlet exposure in the association between food insecurity and dietary quality and the exact tipping point in food insecurity status where fast-food outlet proximity becomes an important negative influence on dietary quality, especially in light of the increasing availability of fast-food outlets in low-SES neighborhoods. If our findings are confirmed by future studies, these results could inform policymakers to promote a healthier food environment including less fast-food outlets, with particular emphasis on areas with high percentages of food insecure households, as this might be a promising strategy for improving dietary quality among those households and thereby reduce health disparities.

References

1. Fung TT, Pan A, Hou T, et al. (2015) Long-Term Change in Diet Quality Is Associated with Body Weight Change in Men and Women. *J Nutr* 145(8):1850-56.
2. Sami W, Ansari T, Butt NS, et al. (2017) Effect of diet on type 2 diabetes mellitus: A review. *Int J Health Sci* 11(2):65-71.
3. Sofi F, Abbate R, Gensini GF, et al. (2010) Accruing evidence on benefits of adherence to the Mediterranean diet on health: an updated systematic review and meta-analysis. *The Am J Clin Nutr* 92(5):1189-96.
4. Lassale C, Batty GD, Baghdadli A, et al. (2019) Healthy dietary indices and risk of depressive outcomes: a systematic review and meta-analysis of observational studies. *Mol Psychiatry* 24(7):965-86.
5. Darmon N, Drewnowski A. (2008) Does social class predict diet quality? *The Am J Clin Nutr* 87(5):1107-17.
6. Larson N, Story M. (2009) A Review of Environmental Influences on Food Choices. *Ann Behav Med* 38(suppl_1):s56-s73.
7. Fleischhacker SE, Evenson KR, Rodriguez DA, et al. (2011) A systematic review of fast food access studies. *Obes Rev* 12(5):e460-e71.
8. Caspi CE, Sorensen G, Subramanian SV, et al. (2012) The local food environment and diet: a systematic review. *Health Place* 18(5):1172-87.
9. Kruger DJ, Greenberg E, Murphy JB, et al. (2014) Local concentration of fast-food outlets is associated with poor nutrition and obesity. *Am J Health Promot* 28(5):340-43.
10. Charreire H, Casey R, Salze P, et al. (2010) Measuring the food environment using geographical information systems: a methodological review. *Public Health Nutr* 13(11):1773-85.
11. FAO (1996) World Food Summit: Rome Declaration on World Food Security and World Food Summit Plan of Action, Rome:FAO
12. van der Velde LA, Schuilenburg LA, Thrivikraman JK, et al. (2019) Needs and perceptions regarding healthy eating among people at risk of food insecurity: a qualitative analysis. *Int J Equity Health* 18(1):184.
13. Lin B-H, Ver Ploeg M, Kasteridis P, et al. (2014) The roles of food prices and food access in determining food purchases of low-income households. *J Policy Model* 36(5):938-52.
14. Darmon N, Drewnowski A. (2015) Contribution of food prices and diet cost to socioeconomic disparities in diet quality and health: a systematic review and analysis. *Nutr Rev* 73(10):643-60.
15. Jones AD. (2017) Food Insecurity and Mental Health Status: A Global Analysis of 149 Countries. *Am J Prev Med* 53(2):264-73.
16. Morales ME, Berkowitz SA. (2016) The Relationship Between Food Insecurity, Dietary Patterns, and Obesity. *Curr Nutr Rep* 5(1):54-60.
17. Ramsey R, Giskes K, Turrell G, et al. (2012) Food insecurity among adults residing in disadvantaged urban areas: potential health and dietary consequences. *Public Health Nutr* 15(2):227-37.

18. Mackenbach JD, Lakerveld J, Generaal E, et al. (2019) Local fast-food environment, diet and blood pressure: the moderating role of mastery. *Eur J Nutr* 58(8):3129-3134.
19. Vogel C, Ntani G, Inskip H, et al. (2016) Education and the Relationship Between Supermarket Environment and Diet. *Am J Prev Med* 51(2):e27-e34.
20. Ford PB, Dzewaltowski DA.(2008) Disparities in obesity prevalence due to variation in the retail food environment: three testable hypotheses. *Nutr rev* 66(4):216-28.
21. Burgoine T, Sarkar C, Webster CJ, et al. (2018) Examining the interaction of fast-food outlet exposure and income on diet and obesity: evidence from 51,361 UK Biobank participants. Int *J Behav Nutr Phys Act* 15(1):71.
22. Mackenbach JD, Nelissen KG, Dijkstra SC, et al. (2019) A systematic review on socioeconomic differences in the association between the food environment and dietary behaviors. *Nutrients* 11(9):2215.
23. Vogelaar C. (2001) Letter from the minister of housing, neighborhoods and integration [Brief van de minister voor wonen, wijken en integratie]. The Hague, 2007. Date cited 8-3-2019.
24. United States Department of Agriculture (USDA). (2017) Definitions of Food Security: United States Department of Agriculture (USDA).
25. Carlson SJ, Andrews MS, Bickel GW. (1999) Measuring food insecurity and hunger in the United States: Development of a national benchmark measure and prevalence estimates. *J Nutr* 129(2):510S-16S.
26. Bickel G, Nord M, Price C, et al. (2000) Guide to measuring household food security, Revised 2000. Measuring Food Security in the United States: U.S. Department of Agriculture, Food and Nutrition Service. https://www.fns.usda.gov/guide-measuring-household-food-security-revised-2000
27. van Lee L, Feskens EJM, Meijboom S, et al. (2016) Evaluation of a screener to assess diet quality in the Netherlands. *Br J Nutr* 115(3):517-26.
28. Van der Velde LA, Nyns C, Engel M, et al. (2020) Exploring food insecurity and obesity in Dutch disadvantaged neighborhoods: a cross-sectional mediation analysis. *BMC Public Health* 20:1-11.
29. Locatus. (2019) Retail Facts. Woerden: Locatus. https://locatus.com
30. Canalia C, Pinho MGM, Lakerveld J, et al. (2020) Field validation of commercially available food retailer data in the netherlands. *Int J Environ Res Public Health* 17(6):1946.
31. Schlosser E. (2002) Fast food nation. London: Penguin books Ltd 2002.
32. © OpenStreetMap contributors. (2019) OpenStreetMap Foundation. https://www.openstreetmap.org/
33. Municipality of The Hague. (2019) Data platform The Hague [Data platform Den Haag]. The Hague: Municipality of The Hague. https://denhaag.dataplatform.nl/
34. Burgoine T, Alvanides S, Lake AA. (2013) Creating ‘obesogenic realities’; do our methodological choices make a difference when measuring the food environment? *Int J Health Geogr* 12(1):33.
35. Hoff S, Wildeboer-Schut JM, Goderis B, et al. (2016) Poverty mapped 2016 [Armoede in kaart 2016]. The Hague: Sociaal Cultureel Planbureau (SCP).

36. Helbich M, Schadenberg B, Hagenauer J, et al. (2017) Food deserts? Healthy food access in Amsterdam. *Applied Geography* 83:1-12.
37. Beaulac J, Kristjansson E, Cummins S. (2009) A systematic review of food deserts, 1966-2007. *Prev Chronic Dis* 6(3):A105-A05.
38. Stevenson AC, Brazeau A-S, Dasgupta K, et al. (2019) Neighbourhood retail food outlet access, diet and body mass index in Canada: a systematic review. *Health Promot Chronic Dis Prev Can* 39(10):261-80.
39. Pinho MGM, Mackenbach JD, den Braver NR, et al. (2020) Recent changes in the Dutch foodscape: socioeconomic and urban-rural differences. *Int J Behav Nutr Phys Act* 17(1):43.
40. Sterne JAC, White IR, Carlin JB, et al. (2009) Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. *BMJ* 338:b2393.
41. Boone-Heinonen J, Gordon-Larsen P, Guilkey DK, et al. (2011) Environment and physical activity dynamics: The role of residential self-selection. *Psychol Sport Exerc* 12(1):54-60.
42. Lamb KE, Thornton LE, King TL, et al.(2020) Methods for accounting for neighbourhood self-selection in physical activity and dietary behaviour research: a systematic review. *Int J Behav Nutr Phys Act* 17(1):45.
43. Burgoine T, Forouhi NG, Griffin SJ, et al. (2014) Associations between exposure to takeaway food outlets, takeaway food consumption, and body weight in Cambridgeshire, UK: population based, cross sectional study. *BMJ* 348:g1464.
44. Cook JT, Black M, Chilton M, et al. (2013) Are food insecurity's health impacts underestimated in the U.S. population? Marginal food security also predicts adverse health outcomes in young U.S. children and mothers. *Adv Nutr* 4(1):51-61.

Additional material Chapter 5

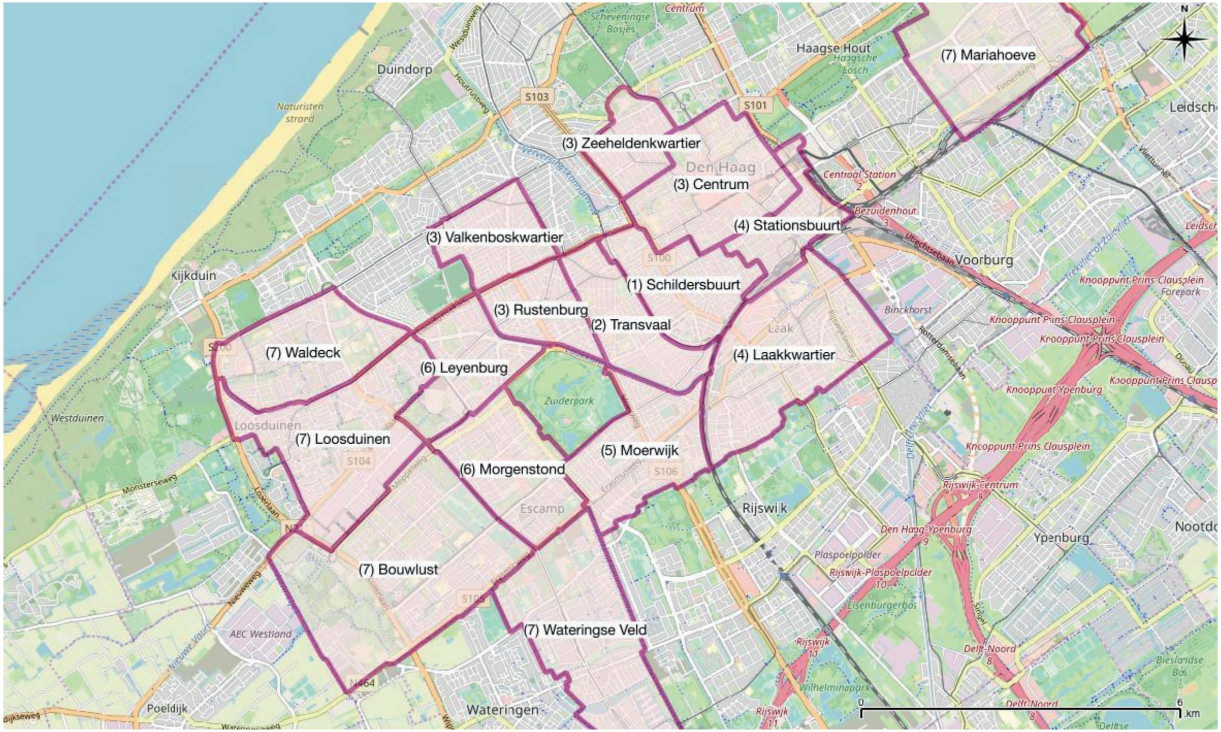


Figure S1. Locations (green-yellow dots) where fast-food is sold in The Hague, according to the Locatus database (selected for the following branches: fast-food, grillroom/kebab and delivery/take out). The six disadvantaged neighborhoods are highlighted in purple.

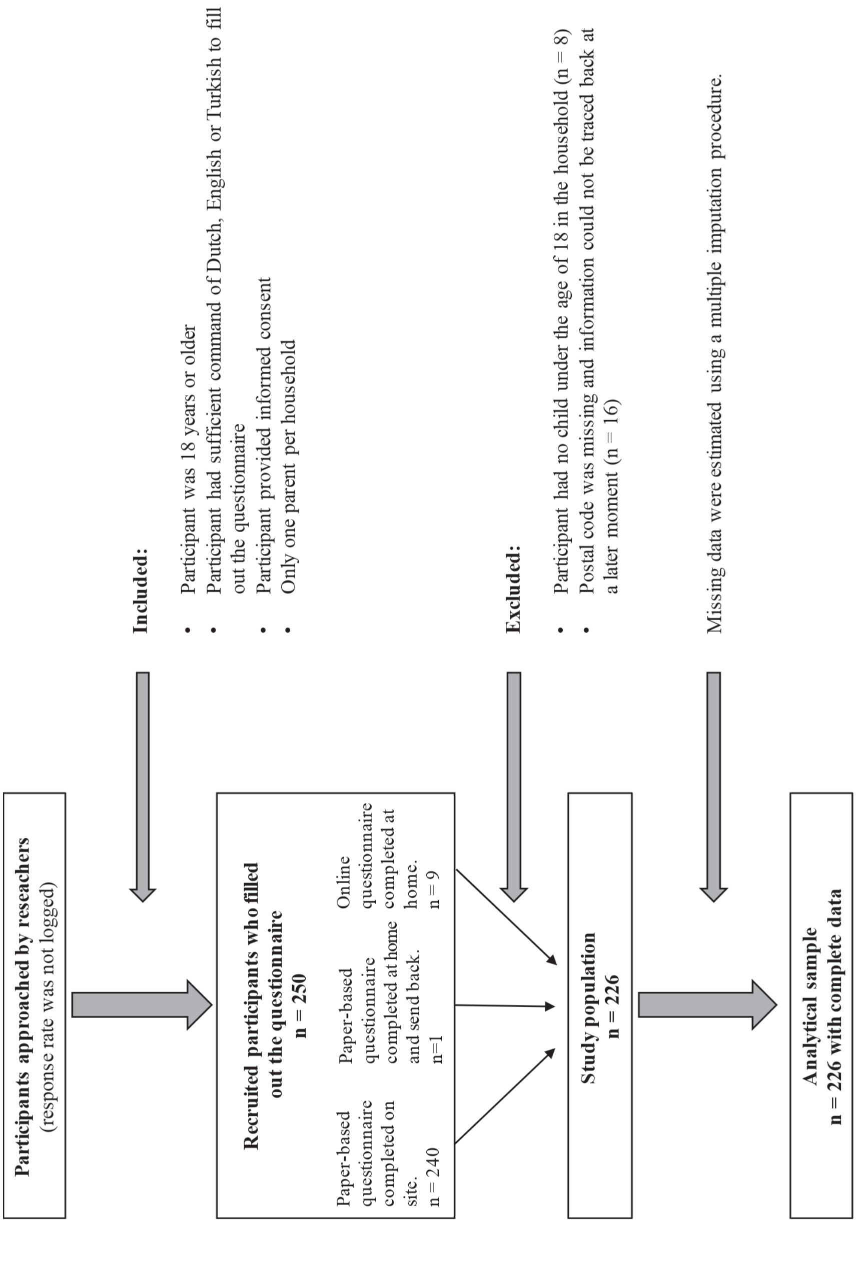
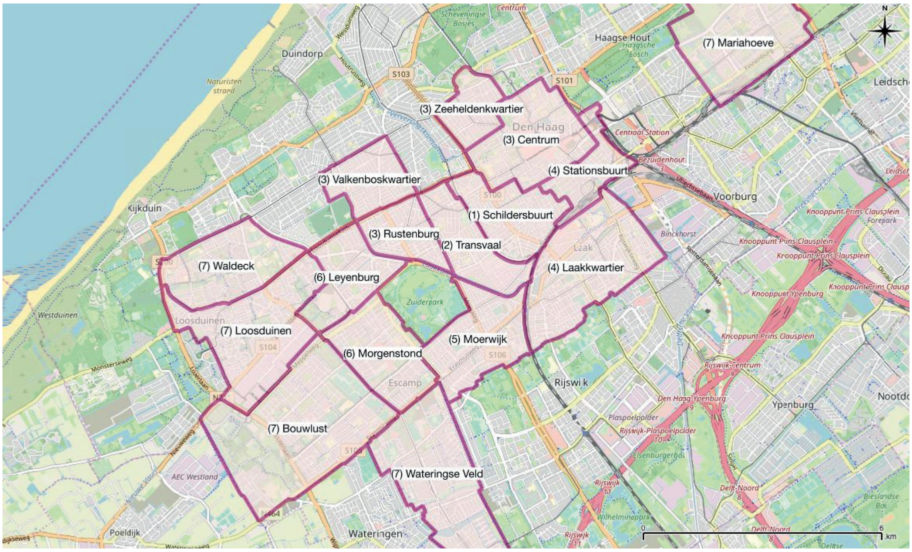


Figure S2. Flow chart presenting recruitment, inclusion and exclusion of participants

5

Document S1. Clustering of districts

The 226 participants included in the current study that provided their postal code could be assigned to one of 16 districts in the Dutch city The Hague. Districts are presented outlined in purple in **Document S1: Figure 1**. However, the participants' households were unevenly distributed over the districts (**Document S1: Table 1**), which could bias the results. Districts were therefore merged into 7 larger clusters, with at least 20 participants in each of the clusters. The cluster number for each district is also presented in **Document S1: Figure 1**. When districts were merged, this was done based on neighborhood characteristics (Foundation living in The Hague 2019 (in Dutch: "Stichting wonen in Den Haag 2019"), date cited: 7-8-2019, available from: https://wonenindenhaag.nl), as summarized in **Document S1: Table 1**.



Document S1: Figure 1. *The districts with the number of the cluster they belong to (1 to 7) between brackets.*

Document S1: Table 1. Characteristics of the seven clusters (n=226).

Cluster number	Total nr of participants	Included districts	Nr of participants per district	Merging criteria
1	56	Schildersbuurt	56	NA *
2	41	Transvaal	41	NA *
3	30	Centrum	18	High number of shops
		Zeeheldenkwartier	1	High number of shops
		Rustenburg	5	High number of shops
		Valkenboskwartier	6	High number of shops
4	23	Laakkwartier	8	Near train stations
		Stationsbuurt	15	Near train stations
5	29	Moerwijk	29	NA *
6	21	Morgenstond	17	Adjacent to Zuiderpark
		Leyenburg	4	Adjacent to Zuiderpark
7	26	Wateringseveld	2	Green and spacious neighborhoods
		Bouwlust	21	Green and spacious neighborhoods
		Loosduinen	1	Green and spacious neighborhoods
		Waldeck	1	Green and spacious neighborhoods
		Mariahoeve	1	Green and spacious neighborhoods

** Not applicable with only 1 district in this cluster.*

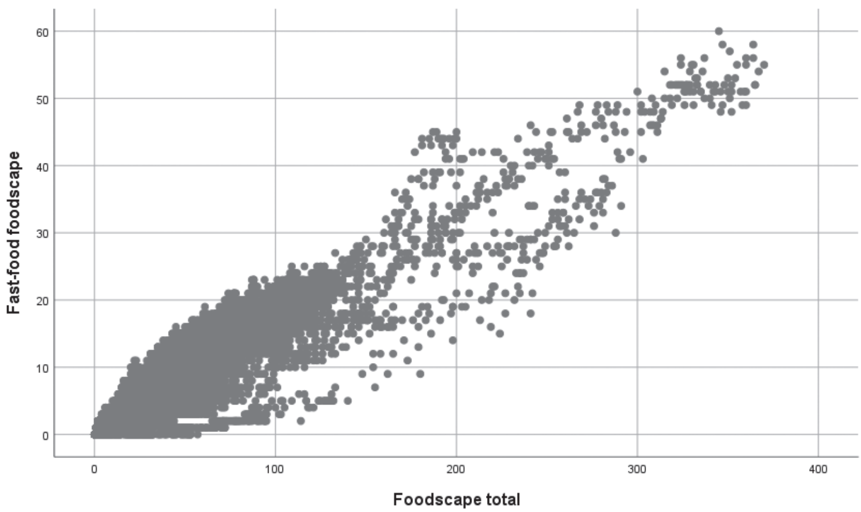
5

Document S2. Fast-food outlets and the total number of food outlet locations in The Hague

The number of fast-food outlets was highly correlated with the total number of food outlets in The Hague (Pearson's rho = 0.919), as shown in **Document S2: Figure 1**. All food outlets in The Hague were extracted from the Locatus database (Locatus (2019). *Retail Facts*. Available from: https://locatus.com). Analyses were performed using Qgis (version 3.8.0-Zanzibar, Free Software Foundation, 1991, Boston USA).

The total number of food outlets within 500m from the center of each 6-digit postal code area (n=14726) included the following branches for food outlets:

• Hotel-restaurant	• Pies / flans	• Restaurant	• Fruit and vegetables
• Lunchroom	• Coffee / tea	• Fast-food	• Toko
• Café-restaurant	• Cheese	• Grillroom/kebab	• Deli
• Fish	• Nuts	• Cafe	• Night shop
• Butchery	• Reform	• Baker	• Poulterer
• Take away / delivery	• Sweets	• Wine shop	• Supermarket
• Coffee shop	• Food public transport	• Ice cream shop	• Hospital shop
• Mini supermarket	• Catering public transport	• Chocolate	• Shisha lounge
• Liquor store			



Document S2: Figure 1. *Graphic representation of the relation between the number of fast-food outlets and the total number of food outlets within a 500m radius of the center of all 6-digit postal code areas in and around the Dutch city The Hague*

Document S3. Details of the multiple imputation procedure for missing values

Missing data were analyzed and addressed using the multiple imputation technique in SPSS. Selected variables for imputation are summarized in **Document S3: Table 1**. A separate variance *t*-test was used for variables with more than 5% missing data: the mean dietary quality score for the present and missing selection was significantly different for the variables household size and household income, but not for age. This suggests that data is missing at random, which is a rationale for imputation and offers opportunities for prediction of missing data. Household income was the variable with the highest number of missing values (28 out of 242, see **Document S3: Table 1**).

5

Document S3: Table 1. Missing data (t-test for variables with more than 5% missing values)

	Numbers		Separate variance *t*-test for Dietary quality score		
Variables	**Missing**	**Present**	**Missing**	**Present**	***p-value***
Age (years)	13	229	34.4	35.4	0.642
Sex (male/ female)	3	239			
Migration background (Western/ non-Western)	4	238			
Household size	13	229	29.8	35.7	0.001
Marital status (single/ married or cohabiting)	8	234			
Educational level (≤ ISCED-2/ ≥ ISCED-3)	8	234			
Household income (below/ above basic needs level)	28	214	31.4	35.9	0.001

Imputation was performed including the 16 participants who did not provide their postal code, i.e. 242 participants were taken into account. To increase prediction power, 70 variables from the original dataset (derived from the complete questionnaire) were used as predictors. These variables are summarized in **Document S3: Table 1** (n= 7) and **Document S3: Table 2** (n= 63).

The missing data were estimated using the Predictive Mean Matching method in SPSS with ten sets of imputations with a maximum of 50 iterations (seed was set at 950 on beforehand). The pooled results of these imputations were used in the analyses described in the main manuscript. This document shows the results for the

Document S3: Table 2. Variables used as predictors in the imputations (excluding the predictors that were also imputed, those are presented in **Document S3: Table 1**).

Variables used as predictors		
• Length	• Weight	• Pregnancy status
• Number of adults in the house	• Number of children in the house	• Marital status (5 categories)
• Country where you were born	• Country where father is born	• Country where mother is born
• Religion	• Currently employed	• Employed in the past
• Currently smoking	• Smoked in the past	• How much do you smoke a day
• What do you smoke	• Do you buy food at the supermarket	• Do you buy food at the Turkish supermarket
• Do you buy food at the market	• Do you buy food at the deli	• Do you make use of the foodbank
• High blood pressure	• Blood pressure medication	• High cholesterol
• Cholesterol medication	• Cardiac treatment	• Open heart surgery
• Heart attack	• Asthma	• COPD
• Lung medication	• Diabetes	• Type of diabetes
• Do you use insulin for your diabetes	• Do you use tablets for your diabetes	• Anemic
• Do health issues hinder you with the shopping	• Number of days a week physical activity	• Minutes a day physical activity
• Food security questionnaire - question 1	• Food security questionnaire - question 2	• Food security questionnaire - question 3
• Food security questionnaire - question 4	• Food security questionnaire - question 5	• Food security questionnaire - question 6
• Food security questionnaire - question 7	• Food security questionnaire - question 8	• Food security questionnaire - question 9
• Food security questionnaire - question 10	• Food security questionnaire - question 11	• Food security questionnaire - question 12
• Food security questionnaire - question 13	• Food security questionnaire - question 14	• Food security questionnaire - question 15
• Food security questionnaire - question 16	• Dietary quality score (6 components)	• Location of sampling
• Number of fast-food outlets in 500m radius	• Number of fast-food outlets in 1000m radius	• Distance to nearest fast-food outlet
• Postal code	• District	• Cluster

Document S3: Table 3. Characteristics of included participants, in original and imputed data

	Original data		Imputed data	
		Number of missings		Number of missings
Age (in years)	38.3 (±7.4)	5	38.3 (7.4)	0
Sex (% women)	86.3%	2	86.6%	0
Migration background (% non-Western)	84.1%	1	84.2%	0
Household size	4.2 (±1.3)	10	4.2 (1.3)	0
Marital status (% married or cohabiting)	66.4%	6	68.2%	0
Educational level (% lower level)	40.1%	8	41.7%	0
Household income (% below basic needs budget)	61.1%	23	66.6%	0
Total score dietary quality (range 0-60)	35.4 (±7.3)	0	35.4 (7.3)	0
Food security (% food insecure)	26.5%	0	26.5%	0

Numbers are means (±SD) or percentages.

original (non-imputed) data for the 226 participants who could be geo-located in one of the districts in The Hague and were included in the current study. **Document S3: Table 3** shows the descriptive analyses of the variables in the original and the imputed data: changes due to imputation were relatively small, with an uppermost increase of 8% for household income. **Document S3: Table 4** show results from the same analyses as presented in the main manuscript (**Table 3**), in the original and imputed data. Similar effect sizes were observed for these analyses in original and imputed data. (**Document S3: Table 4**).**Document S3:**

Document S3: Table 4. Main associations between fast-food outlet density and proximity, food insecurity and dietary quality in original and imputed data (n=226)

	Original data				Imputed data			
	Outcome				Outcome			
	Food insecurity score (continuous)				Food insecurity score (continuous)			
	Crude model		Adjusted model		Crude model		Adjusted model	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI
FFD (within 500 m)	-0.023	-0.082; 0.037	-0.026	-0.076; 0.024	-0.023	-0.082; 0.037	-0.026	-0.076; 0.024
FFP (per 10 m)	-0.009	-0.043; 0.025	0.00	-0.033; 0.033	-0.009	-0.043; 0.025	-0.003	-0.033; 0.026
	Food insecurity status (dichotomous)				**Food insecurity status (dichotomous)**			
	Crude model		Adjusted model		Crude model		Adjusted model	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
FFD (within 500 m)	0.98	0.92; 1.04	0.95	0.91; 1.00*	0.98	0.92; 1.04	0.96	0.91; 1.01
FFP (per 10 m)	0.98	0.94; 1.02	0.99	0.95; 1.02	0.98	0.94; 1.02	0.98	0.95; 1.02
	Dietary quality				**Dietary quality**			
	Crude model		Adjusted model		Crude model		Adjusted model	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI
FFD (within 500 m)	-0.013	-0.167; 0.141	-0.079	-0.21; 0.054	-0.009	-0.16; 0.14	-0.022	-0.17; 0.13
FFP (per 10 m)	0.11	0.014; 0.201*	0.10	0.021; 0.19*	0.12	0.025; 0.21*	0.11	0.017; 0.20*
Food insecurity score (continuous)	-0.47	-0.85; -0.093*	-0.38	-0.80; -0.052	-0.48	-0.94; -0.012*	-0.49	-0.95; -0.028*
Food insecurity status (dichotomous)	-2.70	-4.47; -0.93*	-2.50	-4.55; -0.46*	-2.73	-5.18; -0.29*	-2.89	-5.33; -0.45*

** $p < 0.05$*
95% CI = 95% confidence interval
OR= odds ratio for being food insecure (being food secure=reference)
β represents the difference in food insecurity score (higher= more food insecure) or dietary quality (higher=better adherence to dietary guidelines)
Crude model: Merely including FFD, FFP or food insecurity as determinant, clustered by district (n=7)
Adjusted model: Crude model additionally adjusted for age, sex, migration background, household size, marital status, household income, and educational level

Document S4. Main associations between the relative fast-food density within 500 meter and the absolute fast-food density within 1000 meter, food insecurity and dietary quality

In addition to the analyses with absolute FFD within a 500m radius, we also performed the analyses with the relative FFD and FFD within a 1000m radius. For the association with food insecurity score (continuous), similar to the results of the main analyses including the absolute FFD within 500m, the *relative* FFD within 500m was not significantly associated with experiencing food insecurity, although effect sizes were larger and in the opposite direction (*relative* FFD within 500m, Adjusted model: b=0.031, 95%CI=-0.004; 0.066; *absolute* FFD within 500m, Adjusted model: b= -0.026, 95%CI=-0.076; 0.024). For the FFD within 1000m effect sizes were similar compared to the main analyses with absolute FFD within 500m, but significant in the adjusted model (Adjusted model: b=-0.017, 95%CI=-0.032; -0.001) (**Document S4: Table 1; Main manuscript: Table 3**).

For the association with food insecurity status (dichotomous), similar to the results of the main analyses including the absolute FFD within 500m, the relative FFD and FFD within 1000m were not significantly associated with experiencing food insecurity, with odds ratio's around 1 (**Document S4: Table 1**).

For the association with dietary quality, similar to the results of the main analyses including the absolute FFD within 500m, the relative FFD and FFD within 1000m were not significantly associated with dietary quality (**Document S4: Table 1**).

Similar to the results of the analyses including the absolute FFD within 500m, no significant interaction between food insecurity status and relative FFD within 500m (continuous score: p=0.841, dichotomous status: p=561) or FFD within 1000m (continuous score: p=0.807; dichotomous status: p=760) was found (data not shown).

Document S4: Table 1. Main associations between the relative fast-food density within 500 meter and the absolute fast-food density within 1000 meter, food insecurity and dietary quality (n=226)

	Outcome			
	Food insecurity score (continuous)			
	Crude model		Adjusted model	
	β	95% CI	β	95% CI
Relative FFD (within 500m)	0.040	-0.005; 0.086	0.031	-0.004; 0.066
Absolute FFD (within 1000m)	-0.012	-0.031; 0.006	-0.017	-0.032; -0.001*
	Food insecurity status (dichotomous)			
	Crude model		Adjusted model	
	OR	95% CI	OR	95% CI
Relative FFD (within 500m)	1.02	0.98; 1.05	1.01	0.98; 1.05
Absolute FFD (within 1000m)	1.00	0.98; 1.01	0.99	0.97; 1.00
	Dietary quality			
	Crude model		Adjusted model	
	β	95% CI	β	95% CI
Relative FFD (within 500m)	-0.072	-0.22; 0.080	-0.076	-0.20; 0.048
Absolute FFD (within 1000m)	0.013	-0.025; 0.051	0.016	-0.014; 0.046

** $p < 0.05$*
95% CI = 95% confidence interval
OR= odds ratio for being food insecure (being food secure=reference)
β represents the difference in food insecurity score (higher= more food insecure) or dietary quality (higher=better adherence to dietary guidelines)
Crude model: Merely including Relative FFD (within 500m) or Absolute FFD (within 1000m) as determinant, clustered by district (n=7)
Adjusted model: Crude model additionally adjusted for age, sex, migration background, household size, marital status, household income, and educational level

Document S5. Sensitivity analyses including only non-foodbank users

Only 7 participants answered the question regarding foodbank services use affirmative. However, for an additional 20 participants their answer was missing. We performed sensitivity analyses excluding all participants that either answered to be foodbank users or did not answer the question about foodbank use. **Document S5: Table 1** presents the main associations between fast-food outlet density and proximity, food insecurity and dietary quality for non-foodbank users. For the associations between FFD and FFP with dietary quality and experiencing food insecurity, effect sizes closely resembled the results of the analyses were all participants were included (**Main manuscript: Table 3**).

For the associations between experiencing food insecurity and dietary quality, effect sizes were smaller but in the same directions compared to the main analyses including all participants (**Document S5: Table 1**; **Main manuscript: Table 3**). Further, the results including all participants showed a significant association between experiencing food insecurity and lower dietary quality in all models, whereas in the analyses including only non-foodbank users this association was only significant for the crude association between food insecurity status (dichotomous) and dietary quality (b=-2.40, 95%CI=-4.79; -0.009) (**Document S5: Table 1**; **Main manuscript: Table 3**).

Similar to the results presented in the main manuscript including all participants, a significant interaction (p=0.001) was observed for food insecurity score (continuous) with FFP, whereas no significant interaction was observed for food insecurity status (dichotomous) with FFP nor for food insecurity (both continuous and dichotomous) with FFD (**Document S5: Table 2**).

Stratified results at the median FFP per 10m were similar to the results of the main analyses including all participants for FFP per 10 m≥13.9m, however, for FFP per 10m<13.9m effect sizes were in the same direction but smaller compared to the results of the main analyses including all participants (**Document S5: Table 2; Main manuscript: Figure 1**).

Document S5: Table 1. Main associations between fast-food outlet density and proximity, food insecurity and dietary quality, analyses including only non-foodbank users (n=199)

	Outcome			
	Food insecurity score (continuous)			
	Crude model		Adjusted model	
	β	95% CI	β	95% CI
FFD (within 500 m)	-0.024	-0.075; 0.027	-0.024	-0.067; 0.020
FFP (per 10 m)	-0.013	-0.018; 0.022	-0.005	-0.035; 0.026
	Food insecurity status (dichotomous)			
	Crude model		Adjusted model	
	OR	95% CI	OR	95% CI
FFD (within 500 m)	0.98	0.93; 1.04	0.98	0.93; 1.02
FFP (per 10 m)	0.97	0.94; 1.01	0.98	0.94; 1.02
	Dietary quality			
	Crude model		Adjusted model	
	β	95% CI	β	95% CI
FFD (within 500 m)	-0.008	-0.20; 0.19	-0.007	-0.19; 0.18
FFP (per 10 m)	0.13	0.040; 0.21*	0.14	0.047; 0.23*
Food insecurity score (continuous)	-0.41	-0.85; 0.018	-0.38	-0.88; 0.11
Food insecurity status (dichotomous)	-2.40	-4.79; -0.009*	-2.32	-5.24; 0.60

** $p < 0.05$;*
95% CI = 95% confidence interval
OR= odds ratio for being food insecure (being food secure=reference)
β represents the difference in food insecurity score (higher= more food insecure) or dietary quality (higher=better adherence to dietary guidelines)
Crude model: Merely including FFD, FFP or food insecurity as determinant, clustered by district (n=7)
Adjusted model: Crude model additionally adjusted for age, sex, migration background, household size, marital status, household income, and educational level

Document S5: Table 2. Stratified results for the association between food insecurity and dietary quality, split at the median fast-food outlet proximity (FFP) per 10m: 13.9m, analyses including only non-foodbank users (n=199)

	FFP per 10 m <13.9m		FFP per 10 m ≥13.9m		
Food insecurity score (continuous)					
	β	95%CI	β	95%CI	
Crude model	-0.50	-1.06; 0.068	-0.36	-0.79; 0.066	p-interaction[1]=0.001
Adjusted model	-0.33	-1.16; 0.49	-0.38	-0.81; -0.056	
Food insecurity status (dichotomous)					
	β	95%CI	β	95%CI	
Crude model	-1.75	-5.66; 2.16	-3.13	-5.11; -1.34*	p-interaction[2]=0.592
Adjusted model	-1.01	-5.55; 3.54	-3.52	-6.04; -1.00*	

**p<0.05*
*[1] Interaction term= FFP per 10 m * **continuous** food insecurity score*
[2] Interaction term= FFP per 10 m **dichotomous** food insecurity status*
β *represents the difference in dietary quality score with increasing food insecurity (i.e., being more food insecure)*
Crude model: Merely including food insecurity status as determinant, clustered by district (n=7)
Adjusted model: Crude model additionally adjusted for fast-food outlet density (FFD) within 500m, age, sex, migration background, household size, marital status, household income, and educational level

Document S6. Sensitivity analyses including only participants that provided their full 6-digit postal code

Not all participants provided their full 6-digit postal code (comprising 4 numbers and 2 letters): for n=35 participants the two letters were missing. A 4-digit postal code can be used to assign the home of a participant to a neighborhood, but this is far less accurate compared to the 6-digit postal code. A sensitivity analysis including only the participants that provided their full 6-digits postal code (85.5% of the study population) was performed to examine whether the results in the main analyses (**Main manuscript: Table 3**) were influenced by a decreased accuracy due to the n=35 incomplete (4-digit) postal codes.

Document S6: Table 1 presents the main associations between fast-food outlet density and proximity, food insecurity and dietary quality for participants that provided their full 6-digit postal code. For the associations between FFD and FFP with dietary quality and experiencing food insecurity, effect sizes closely resembled the results of the main analyses were all participants were included, although the association between FFP and dietary quality was non-significant when only participants that provided their full 6-digit postal code were included (**Document S6: Table 1; Main manuscript: Table 3**).

For the associations between experiencing food insecurity and dietary quality, effect sizes were slightly less strong but in the same directions compared to the main analyses including all participants (**Document S6: Table 1**; **Main manuscript: Table 4**). Further, the results including all participants showed a significant association between experiencing food insecurity and lower dietary quality in all models, whereas in the analyses including only participants that provided their full 6-digit postal code this association was only significant for the crude and adjusted associations between food insecurity status (dichotomous) and dietary quality (Adjusted model: b-2.45, 95%CI=-4.44; -0.47) (**Document S6: Table 1**; **Main manuscript: Table 3**).

Similar to the results presented in the main manuscript including all participants, a significant interaction (p=0.019) was observed for food insecurity score (continuous) with FFP, whereas no significant interaction was observed for food insecurity status (dichotomous) with FFP nor for food insecurity (both continuous and dichotomous) with FFD (**Document S6: Table 2**).

Stratified results at the median FFP per 10m were similar to the results of the main analyses including all participants (**Document S6: Table 2; Main manuscript: Figure 1**).

Document S6: Table 1. Main associations between fast-food outlet density and proximity, food insecurity and dietary quality, analyses including only participants that provided their full 6-digit postal code (n=191)

	Outcome			
	Food insecurity score (continuous)			
	Crude model		Adjusted model	
	β	95% CI	β	95% CI
FFD (within 500 m)	-0.026	-0.099; 0.047	-0.029	-0.086; 0.028
FFP (per 10 m)	-0.01	-0.045; 0.025	-0.001	-0.033; 0.032
	Food insecurity status (dichotomous)			
	Crude model		Adjusted model	
	OR	95% CI	OR	95% CI
FFD (within 500 m)	0.98	0.91; 1.04	0.97	0.91; 1.03
FFP (per 10 m)	0.98	0.94; 1.02	0.99	0.95; 1.02
	Dietary quality			
	Crude model		Adjusted model	
	β	95% CI	β	95% CI
FFD (within 500 m)	0.008	-0.121; 0.137	0.006	-0.12; 0.13
FFP (per 10 m)	0.078	-0.02; 0.176	0.087	-0.006; 0.18
Food insecurity score (continuous)	-0.42	-0.84; 0.012	-0.44	-0.96; 0.086
Food insecurity status (dichotomous)	-2.45	-4.44; -0.47*	-2.56	-5.21; 0.087

** $p < 0.05$;*
95% CI = 95% confidence interval
OR= odds ratio for being food insecure (being food secure=reference)
β represents the difference in food insecurity score (higher= more food insecure) or dietary quality (higher=better adherence to dietary guidelines)
Crude model: Merely including FFD, FFP or food insecurity as determinant, clustered by district (n=7)
Adjusted model: Crude model additionally adjusted for age, sex, migration background, household size, marital status, household income, and educational level

5

Document S6: Table 2. Stratified results for the association between food insecurity and dietary quality, split at the median fast-food outlet proximity (FFP) per 10m: 13.9m, analyses including only participants that provided their full 6-digit postal code (n=191)

	FFP per 10 m <13.9m		FFP per 10 m ≥13.9m		
Food insecurity score (continuous)					
	β	95%CI	β	95%CI	
Crude model	-0.60	-1.18; -0.012*	-0.30	-0.72; 0.12	p-interaction[1]=0.019
Adjusted model	-0.56	-1.49; 0.36	-0.36	-0.78; -0.065	
Food insecurity status (dichotomous)					
	β	95%CI	β	95%CI	
Crude model	-2.08	-5.61; 1.46	-2.95	-4.93; -0.98*	p-interaction[2]=0.911
Adjusted model	-1.43	-6.15; 3.29	-3.53	-5.82; -1.25*	

**p<0.05*
[1] *Interaction term= FFP per 10 m * **continuous** food insecurity score*
[2] *Interaction term= FFP per 10 m* **dichotomous** food insecurity status*
β *represents the difference in dietary quality score with increasing food insecurity (i.e., being more food insecure)*
Crude model: Merely including food insecurity status as determinant, clustered by district (n=7)
Adjusted model: Crude model additionally adjusted for fast-food outlet density (FFD) within 500m, age, sex, migration background, household size, marital status, household income, and educational level