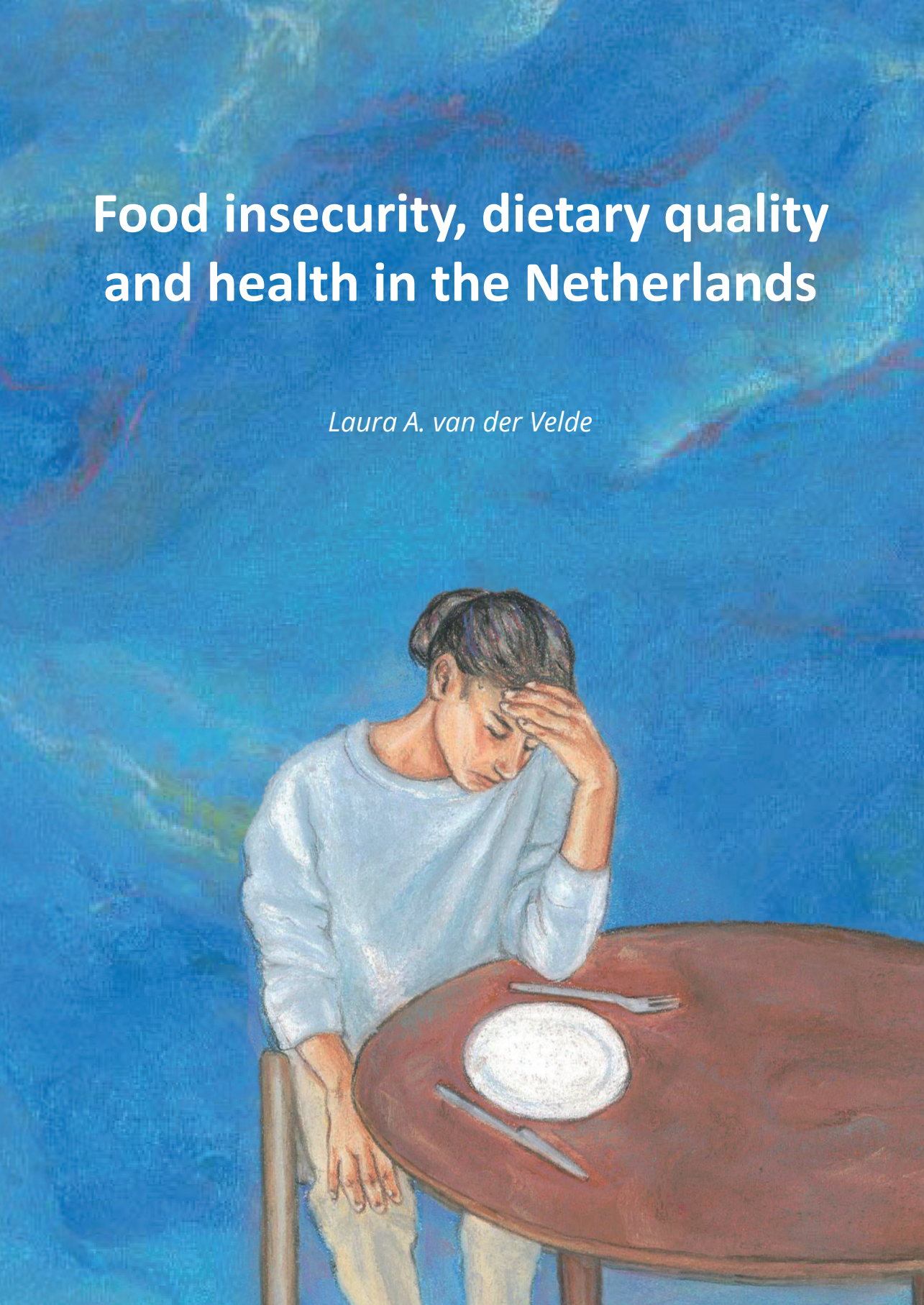
Food insecurity, dietary quality and health in the Netherlands

Laura A. van der Velde



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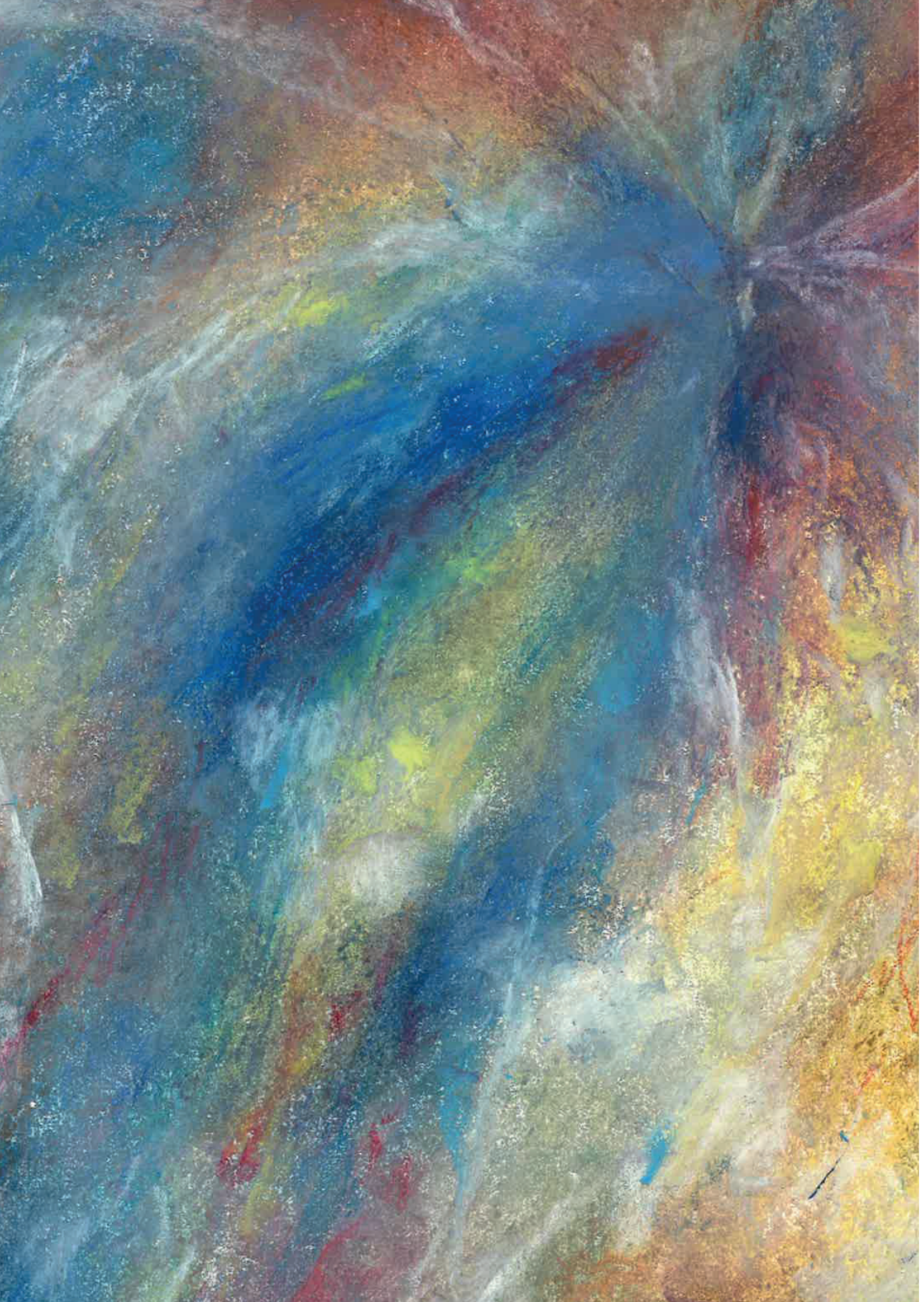

CHAPTER 1

General introduction

Worldwide, major inequalities in health exist between the most and least advantaged groups, which are often expressed in terms of income, education, and employment status. These inequalities are seen between countries, but also within countries and between subgroups (1). Social inequalities are also observed in dietary quality, with less advantaged groups generally consuming less healthy diets (2). To identify cues that will help reduce inequalities in health and diet, it is of the utmost importance to address social determinants of health (1). These are non-medical factors determined by socioeconomic systems that have important health consequences, and are estimated to account for up to 55 percent of health outcomes (3). The WHO describes social determinants of health as "the conditions in which people are born, grow, work, live, and age, and the wider set of forces and systems shaping the conditions of daily life" (3). An important social determinant of health is inadequate access to and availability of food to meet basic food needs: food insecurity. Because of the crucial role of adequate foods for health and survival, food security is recognized as a human right (4), and is included as one of the seventeen Social Development Goals which, amongst others, aim to end hunger and achieve food security and improved nutrition (5). This highlights the importance of identifying food insecurity for health, which nevertheless currently remains a relatively neglected issue in European countries such as the Netherlands.

In this introduction, a summary of current literature describes how food insecurity can be defined, the prevalence of food insecurity in affluent countries, and the groups at risk of food insecurity. Furthermore, associations are outlined between food insecurity, dietary intake and the food environment, and with population health. Finally, the objective and outline of this thesis are presented in this introduction, describing how our studies aim to contribute to developing a better understanding of the prevalence of food insecurity and its consequences for dietary intake and health in the Netherlands.

Defining food insecurity

Food insecurity is an elusive and multidimensional concept and this is reflected in the various definitions currently in use. Food insecurity occurs when people lack consistent physical, social, or economic access to adequate food because of limited resources, and is the opposite of food security. The widely accepted FAO definition states that "food security exists when all people, at all times, have physical and

economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (4). Hence, food insecurity is the opposite of this definition: insufficient physical and economic access to adequate foods.

Food insecurity and hunger are closely related but distinct concepts: hunger is a physiological phenomenon caused by a lack of food, while food insecurity describes a broader and more complex condition defined by unreliable (physical or economic) access to sufficient food. This also includes, for example, anxiety and worries about not having enough (healthy) food. Hunger is a potential, but not a necessary, consequence of food insecurity (6).

Food insecurity can be conceptualized to encompass the hierarchical dimensions availability, accessibility, and utilization (7). Food availability refers to the supply of adequate food and whether this is physically available. Food accessibility refers to the ability of the individual or household to obtain the available food. Major drivers herein are economic access (for example, income and purchasing power) and social access (for example, food distribution within the household and (religious) dietary rules). Lastly, food utilization refers to the use of available food. For example, whether affordable but also nutritionally adequate foods are consumed, whether healthy and safe methods are used to prepare the food, and whether individual health status is sufficient for adequate metabolism of the consumed foods (7). Ultimately, for food security to exist, the availability, accessibility, and utilization of food need to be stable over time (8).

The following quote from one of the participants of our study illustrates the priority of firstly having an adequate amount of food (accessibility of food), and secondly having adequate dietary quality (utilization of food):

> "*Healthy eating for me and my family means ensuring that there is always some food. That is first of all healthy: you have to eat. And secondly, yes, that you pay attention to your diet.*"
>
> Father from a dual-parent household, living in a disadvantaged neighborhood in The Hague, the Netherlands

Besides availability and access to adequate food, feelings of worry and anxiety over food supply and the inability to acquire food in socially acceptable ways are also

important components of food insecurity. These components are incorporated into the definition used by the United States Department of Agriculture (USDA), stating that food insecurity is "the limited or uncertain availability of nutritionally adequate, safe foods or the inability to acquire foods in socially acceptable ways" (**Figure 1**) (9).

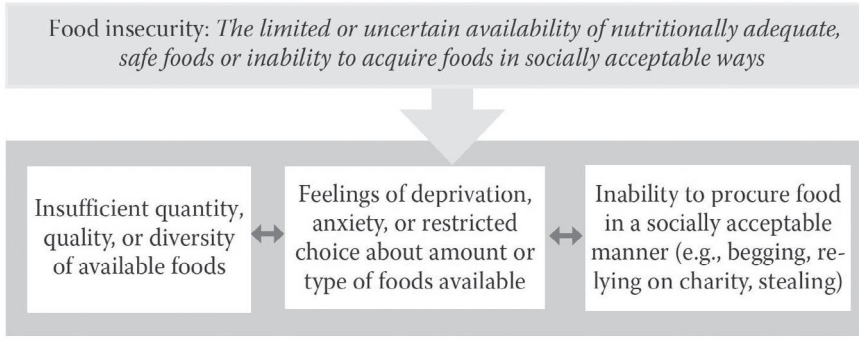

Figure 1. Definition of food insecurity (9)

These definitions attempt to grasp the multidimensionality of the concept of food insecurity, while also addressing psychological and social needs and consequences regarding food access. For example, social exclusion due to an inability to participate in social and cultural norms (i.e., not being able to afford appropriate foods to celebrate religious, social or cultural events) is an important aspect of the experience of food insecurity (10).

Food insecurity prevalence in affluent countries

Food insecurity is increasingly being recognized as a major public health concern facing not only low income countries, but also wealthier countries (11). In high-income countries, food insecurity is often unrelated to lack of access to a sufficient quantity of food (i.e., access to an adequate amount of calories), but rather is an issue of lack of access to a sufficient quality of food (i.e., access to nutrient-dense foods). In the United States, the prevalence of household food insecurity is assessed annually among a representative sample of households, and the most recent report in 2019 found a prevalence of 10.5 percent (12). In contrast, in European countries the prevalence of food insecurity is not routinely monitored. A review outlining the academic discourse on food insecurity in Europe, as expressed in articles published in scientific journals between 1975 to 2013, indicated that scientific knowledge

concerning food insecurity in Europe is limited and highly diverse in terms of reported prevalence, as well as in terms of assessment methods and definitions used (13). This makes it difficult to provide a clear overview of the prevalence of food insecurity in European countries, and as a result, food insecurity remains a relatively little-known issue in these countries (14).

The literature that is available, however, indicates that people living in European countries indeed face issues regarding food security. According to a comprehensive study by Jones at al. (2017), approximately one quarter of people across 39 countries in Europe reported experiencing food insecurity (15). The prevalence of food insecurity varies across populations, regions, and countries. Among European children living in the United Kingdom, France, Germany, Greece, Spain and Greenland, food insecurity ranged from nine percent in the general United Kingdom population, to 100 percent among deprived families receiving charity in the same country (16). Among older European adults (50 years of age and over), over ten percent experienced food insecurity (based on the unaffordability of meat/fish/poultry and fruit/vegetables) (17).

Despite studies suggesting that food insecurity is prevalent in European countries, research focusing on food insecurity in the Netherlands is still scarce, with the exception of some research conducted in the past decade (e.g., (18)).

Food insecurity research is ever more relevant, as prevalence rises due to the global COVID-19 pandemic and public health responses to control viral transmission that impact economies and food systems both locally and worldwide (19, 20). Some studies have already begun to report on these developments, such as a study by Fitzpatrick et al. (2021) that included over ten thousand adults living in the United States, and a study by Niles et al. (2020) which included over 3000 US participants. Both of these studies found increased prevalence of food insecurity since the onset of the pandemic (21, 22).

Those at risk of experiencing food insecurity

As discussed above, the prevalence of food insecurity varies between countries, regions, and populations. Moreover, within countries, regions, and populations, some people are more at risk of experiencing food insecurity than others. Specifically, factors such as belonging to a racial or ethnic minority group, a lower income, a lower

educational level, unemployment, being single, living in an urban area, and lacking a social support network are all associated with an increased risk of food insecurity (16, 23, 24). Independent of these factors, women are generally more at risk than men (24). Gender differences in food insecurity may be explained by economic factors (e.g., women generally have fewer employment opportunities and lower paid jobs) and cultural factors (e.g., women may perceive and react to situations differently given their roles in society, and may feel more responsible for feeding the family which may result in mothers shielding their children from hunger at the expense of their own food security) (25, 26).

Although food insecurity and poverty are closely related, it is important to note that this is not a one-to-one relation: food insecurity and poverty reflect distinct constructs (27). By way of illustration, on the one hand, people living on low incomes may nevertheless be food secure if they possess greater financial and food-management skills that enable them to prepare cheap and nutritious meals (27). Furthermore, good social networks and strong social support - included in social capital - may have a protective effect against food insecurity: a study by Martin et al. (2004) showed that for households with similarly limited financial/food resources, the risk of experiencing hunger was lower for those with higher levels of social capital (28). Social capital reflects the resources that are available due to social behaviors and being part of community networks (28). This may increase access to food, for example by enabling the borrowing of food or the means of transportation from neighbors, or through membership of a religious community which grants access to specific food aid within such communities (e.g. a food pantry run by a church or mosque) (28). Furthermore, previous literature showed that social capital is not only important for adequate food quantity, but also for adequate food quality, as it also influences dietary quality (29, 30).

On the other hand, higher-income groups may experience food insecurity if they have high fixed expenses (limiting the budget available for food), have to prioritize other expenses (such as medical bills), or have poor financial and food-management skills. Furthermore, food insecurity also reflects psychological and social consequences specific to limited access to foods. Taken together, these factors emphasize that indirect indicators such as income are poorly suited as proxies for the experience of food insecurity.

Food insecurity, dietary quality, and the food environment

Earlier literature consistently shows that food insecurity is associated with poor dietary quality among adults: those experiencing food insecurity generally have, amongst others, lower intakes of fruits, vegetables and micronutrients, and higher intakes of calorie-dense foods (31-33). Among children, less evidence exists for the association between food insecurity and poor dietary quality, with the most consistent evidence pointing to an adverse association between food insecurity and fruit intake (31). This may suggest that children are shielded from food shortages by their parents (31), as also suggested by one of the participants in our study:

> "*I don't care because I prefer [caring for] them [children] rather than myself. I can manage with a few slices of bread and peanut butter and then I go to bed. But they can't*."
>
> Father from a dual-parent household, living in a disadvantaged neighborhood in The Hague, the Netherlands

A recent study by Landry et al. (2019), which used the child's own reporting of experienced food insecurity, found evidence for significantly lower dietary quality among food insecure children (34).

Various factors may contribute to suboptimal diets among people experiencing food insecurity. Firstly, limited food availability (i.e., supply of adequate food and whether this is physically available) may pose a barrier for healthy eating among people experiencing food insecurity. Evidence suggests that food deserts - areas with poor access to healthy and affordable food - can be found in disadvantaged areas in the United States, and may contribute to diet-related health disparities (35). In other countries, including the Netherlands, limited evidence for this phenomenon has been found however (36). Nevertheless, an unfavorable food environment with low availability of healthy, nutrient-dense foods and high availability of low-cost, easily accessible fast foods may impede healthy food choices, although evidence for an association is inconsistent (37-39). Similarly, no clear evidence has been found for a differential impact of food environments on diet across socioeconomic position (SEP) groups (40). Research on the food environment and its impact on health is currently emerging, but results have mostly been inconsistent. This may be due to the large variety of methodological choices in these studies, which makes them hard to compare (41, 42). More research in the field of food environments is therefore

warranted, as this may be a promising target for interventions aiming to improve dietary quality.

Secondly, food accessibility, including economic access to foods, is an essential component of food security (7), and the generally higher costs of healthier foods may therefore hamper healthy eating among people experiencing food insecurity (43). One of our participants also indicated financial constraints as a barrier to healthy eating:

> "*I didn't really buy healthy food back then, I just bought what was cheap. I only want to live because you are in a cramp, it's not possible, it's difficult*."
>
> Single mother living in a disadvantaged neighborhood in The Hague, the Netherlands

A comprehensive cross-national study, which estimated the cost of a healthy diet according to national food-based dietary guidelines in 24 European countries, showed that economic access to a healthy diet is an important problem in a range of European countries. In 16 of the 24 countries, at least 10% of (sub)urban residents were at risk of food insecurity due to inadequate economic access to healthy foods (44). Previous literature, including qualitative studies, also suggests that food prices are an important barrier for healthy eating among lower-SEP groups (30, 45-48). Following the conceptual framework proposed by Laraia et al. (2017)(49) (**Figure 2**), poverty indeed influences healthy food purchasing power, but also influences (food) insecurity and biobehavioral mechanisms (including stress, sleep, and cognitive burden). These insecurities in particular trigger hormonal responses (i.e., stress-, appetite-, and hunger-regulating hormones) that shape eating behavior. These factors then create a scarcity mentality, which (together with a poverty-induced reduced purchasing power) adversely influences the ability to focus on longer-term health goals such as healthy eating, thereby adversely influencing eating behavior (49, 50).

Thirdly, food utilization (i.e., the use of the available food: whether nutritionally adequate foods are consumed, whether healthy and safe methods are used to prepare the food, and whether individual health status is sufficient for adequate metabolism) is an essential component of food security influencing dietary quality (7). Episodic and chronic psychological and emotional stresses associated with food insecurity may adversely impact dietary quality through hormone-induced excessive

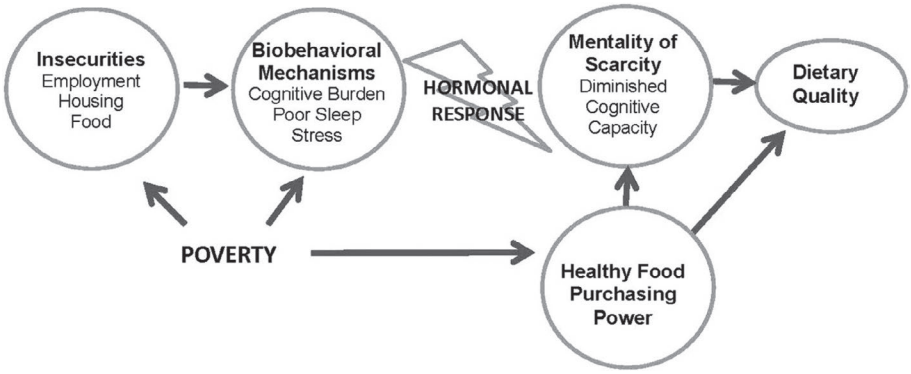

Figure 2. Conceptual framework proposed by Laraia et al. (2017): how poverty creates an environment of scarcity that leads to poor dietary quality (49)

intakes of foods (particularly foods high in fat and sugar), or simply through overeating/binge eating due to hunger when food again becomes available or as a coping mechanism (51, 52).

As described above, various factors may contribute to suboptimal diets among people experiencing food insecurity. It should be noted, however, that although the link between food insecurity and dietary quality is well described in literature, the relationship between food insecurity and dietary behavior is complex. Important research gaps remain in our understanding of underlying mechanisms, the impact on specific subgroups and the cumulative impact over a life course (53).

Food insecurity and population health

As also illustrated in **Figure 2**, food insecurity is an important issue due to its negative consequences for health, and numerous adverse health effects of food insecurity have been reported over the past decades. Experiencing food insecurity is associated with various chronic conditions, including Type 2 diabetes (54, 55), cardiovascular disease (56, 57), chronic kidney disease (58), and asthma (59). Food insecure households in high-income countries are also at increased risk of obesity, and within food insecure households, women are at higher risk of obesity compared to men (60), although the mechanisms and pathways underlying the association between food insecurity and obesity are not yet fully understood (53). Furthermore, adults experiencing food insecurity are more likely to have multiple chronic conditions (61). Moreover, food insecurity increases the risk of anemia, especially among women and children (62).

Besides the impact on physical health, food insecurity also has an adverse effect on mental health, including depression, stress, and anxiety (63, 64). This may be explained by feelings of deprivation and alienation because of inadequate access to food or the inability to acquire food in socially and culturally-accepted ways (64). A review by Bruening et al. (2017) shows that the associations between poor mental health and food insecurity are bidirectional (i.e., experiencing food insecurity increases the risk of poor mental health, but poor mental health also increases the risk of experiencing food insecurity) (65). Women, who are already disproportionally affected by food insecurity, are also at increased risk of poor mental health induced by food insecurity (66). The effect of poor mental health on unfavorable eating behavior is clearly illustrated by the following quote from a single mother, who explained that she lacked energy to prioritize healthy eating or cooking because of poor mental health:

> "*Everyone is in a difficult situation and you are not in the mood; so yes, then it's easy to get a bag of fries and throw them in [the frying pan] and everyone has fries. It requires less effort and if you don't feel well mentally, then washing the dishes is really too much. Going to a supermarket, uh, getting out of bed even, is just too much*."
>
> Single mother living in a disadvantaged neighborhood in The Hague, the Netherlands

People have different social and biological needs throughout their life course, and may therefore be more vulnerable to the consequences of food insecurity at particular stages of life (67). Besides the negative impact of food insecurity on health among adults, experiencing food insecurity in childhood negatively impacts short-term and long-term health, with consequences that include asthma and depressive symptoms, and is associated with increased emergency department visits (68). Living in food insecure households is associated with behavioral, academic, social, and emotional problems among children from infancy to adolescence (69, 70).

As outlined above, food insecurity is associated with disadvantage, interacts with adverse health outcomes, and has different effects during the life course. Therefore, one can argue that in light of socio-ecological inequality and inequity that enhances this adverse interaction, food insecurity reflects a syndemic (i.e., two or more mutually enhancing health conditions that cluster within a specific population) (67).

Himmelgreen et al. (2020) clearly describe this in their proposed dynamic model of the food insecurity and diet-related chronic diseases syndemic (67). In short, this model shows how socio-ecological inequality and inequity induce food insecurity and associated stress, which has an amplifying adverse effect on nutrition and health status (also depending on the life course stage). This can ultimately result in diet-related chronic disease(s), particularly in adulthood. These diseases create a feedback loop that can result in a vicious cycle, thereby amplifying adverse health outcomes (67) (**Figure 3**). The use of a syndemic and life course approach can help provide a more accurate and nuanced understanding of food insecurity and its causes and consequences.

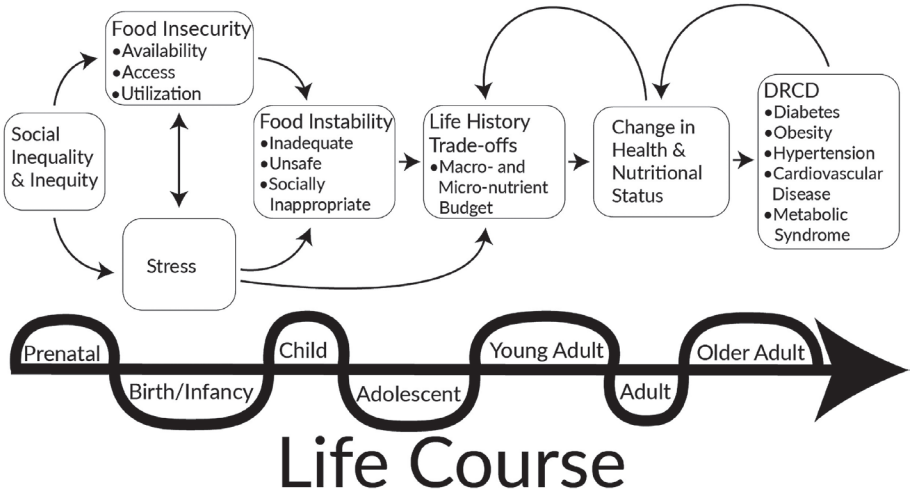

Figure 3. Conceptual model proposed by Himmelgreen et al. (2020) of the food insecurity and diet-related chronic diseases (DRCD) syndemic throughout the life course (67)

All things considered, food insecurity is a multidimensional concept that is interlinked with health through various pathways (9). As described by Weister et al. (2015), determinants within the community, household, and individual level influence health. At the community level, socioeconomic factors and structural factors such as the local availability of food influence food insecurity. At the household level, food insecurity impacts physical health at the individual level, through nutritional, mental health, and behavioral pathways. The influence of nutritional and mental health pathways may be driven by immunologic responses induced by stress or obesity, such as chronic inflammation and negative impacts on the composition of gut microbiota. Importantly, the association between food insecurity and health can be

bidirectional: food insecurity is not only associated with poor health, but poor heath is also associated with food insecurity, thereby creating a vicious cycle (9).

The aforementioned literature clearly indicates a link between experienced food insecurity, dietary intake, and health, thereby underlining the importance of achieving food security for population health. Despite the evident importance for health, food insecurity is still a relatively neglected issue in Europe, illustrated by the limited scientific knowledge and important research gaps concerning food insecurity in European countries (13, 14, 71). Specifically in the Netherlands, research into food insecurity is still rare, but as the prevalence of food insecurity and its consequences are known to differ between and within countries, regions and populations, expanding knowledge of food insecurity in the Netherlands is important.

Objective and outline of this thesis

The overall aim of this thesis was to develop a better understanding of the prevalence of food insecurity in the Netherlands, together with its consequences for dietary quality and health. These studies may identify potential targets for interventions aimed at reducing food insecurity among affected people and families in the Netherlands.

The studies presented in this thesis specifically aimed to:

- Assess the association between food insecurity and obesity among disadvantaged Dutch families, and to explore potential mediation by other risk factors for obesity, such as lifestyle factors and social situations (**Chapter 2**).
- Explore the value of assessing food insecurity and adding this to traditional social determinants of health for explaining poor physical and mental health (**Chapter 3**).
- Gain a better understanding of needs and perceptions regarding healthy eating behavior of people at risk of experiencing food insecurity living in disadvantaged neighborhoods in the Netherlands (**Chapter 4**).
- Explore the interplay between food insecurity, fast-food outlet exposure and dietary quality in disadvantaged neighborhoods in the Netherlands (**Chapter 5**).
- Assess whether extending the Theory of Planned Behavior, with barriers related to financial scarcity and food insecurity, better explains dietary quality (**Chapter 6**).

List of abbreviations

SEP	Socioeconomic position
DRCD	Diet-related chronic diseases

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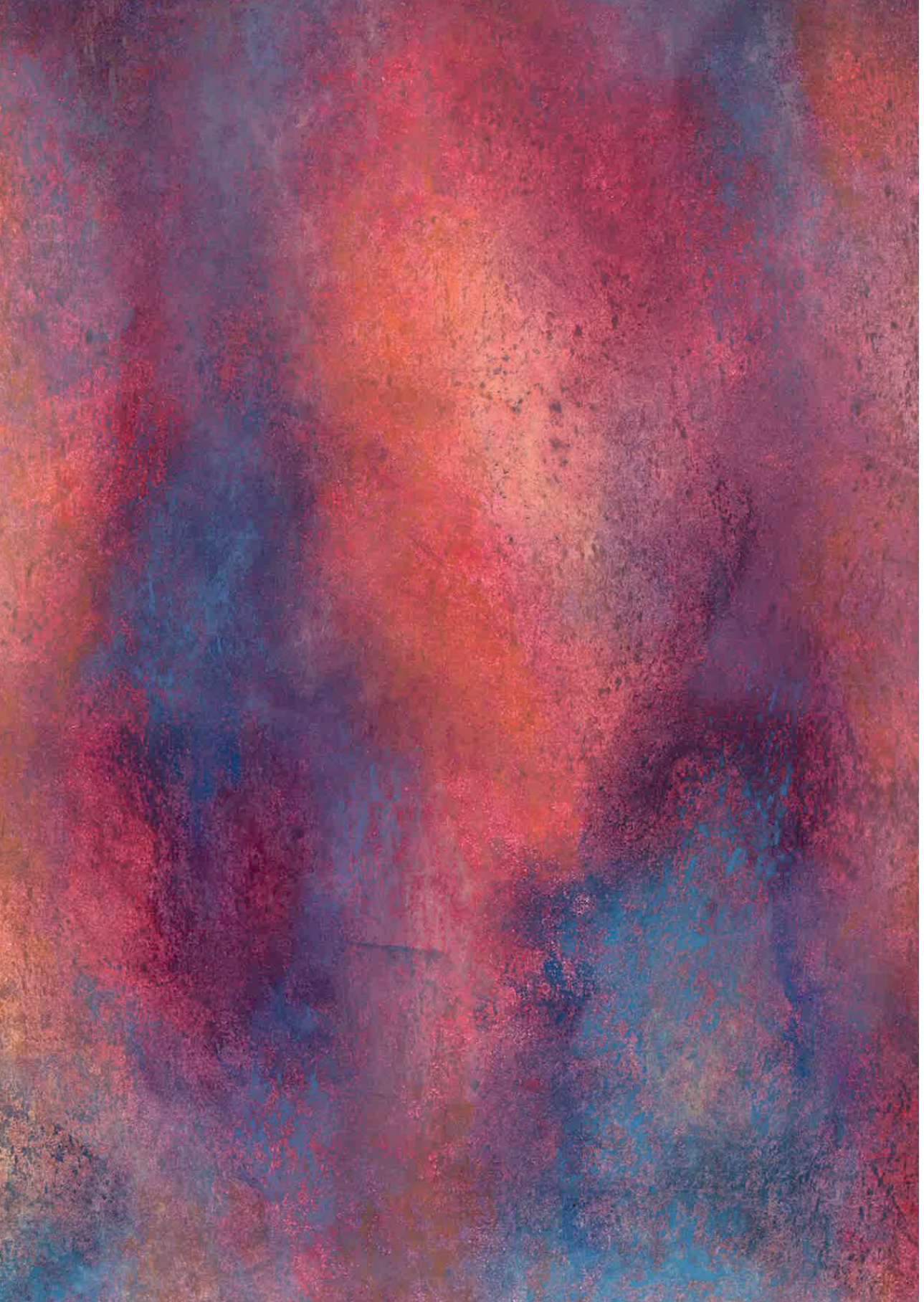

CHAPTER 2

Exploring food insecurity and obesity in Dutch families: a cross-sectional mediation analysis

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Abstract

Background: Food insecurity is related to risk of adverse health outcomes such as obesity, but the explanatory factors underlying this association are still unclear. This study aimed to assess the association between food insecurity and obesity, and to explore potential mediation by sociodemographic and lifestyle factors.

Methods: This cross-sectional study was conducted among 250 participants in a deprived urban area in the Netherlands. Data on sociodemographic and lifestyle factors, food insecurity status and diet quality were collected using questionnaires. Diet quality was determined based on current national dietary guidelines. BMI was calculated from self-reported height and weight. Regression analyses were performed to explore the association between food insecurity and BMI status. Mediation analyses were performed to estimate the total-, direct-, and indirect effect and proportion of total effect mediated of the food insecurity-obesity association.

Results: The overall prevalence of food insecurity was 26 percent. Food insecurity was associated with obesity (OR=2.49, 95%CI=1.16, 5.33), but not with overweight (OR=1.15, 95%CI=0.54, 2.45) in the unadjusted model. The food insecurity-obesity association was partially mediated by living situation (proportion mediated: 15.4%), diet quality (-18.6%), and smoking status (-15.8%) after adjustment for other covariates.

Conclusions: The findings of this study suggest an association between food insecurity and obesity. Living situation, diet quality and smoking status explained part, but not all, of the total association between food insecurity and obesity. Future longitudinal studies are warranted to examine the temporal order of the food insecurity-obesity association and potential mediators in this relationship. In addition, food insecurity and its potential consequences need to be taken into account in obesity prevention programs and policies.

Background

Food security is defined by the Food and Agriculture Organization (FAO) as "physical and economic access to sufficient, safe and nutritious food that meets dietary needs and food preferences for an active and healthy life" (1). Initially, most attention regarding food insecurity was focused on low-income countries. However, emerging evidence suggests that food insecurity is also a public health concern facing middle-, and high-income countries (2). Nevertheless, to date the scientific knowledge on food insecurity in Europe is limited and no clear consensus is reached about the prevalence of food insecurity and its causes and solutions (3). Specifically, in the Netherlands few studies have focused on the prevalence of food insecurity, especially among community-dwelling subjects. A previous study by Neter et al. (2014) found a food insecurity prevalence of 70% among adult Dutch food bank recipients (4). Although the latter target group is a selection of extremely disadvantaged individuals, poverty rates are monitored regularly in the Netherlands and indicate that more than 5% of the Dutch population have an income below the basic needs limit, which includes only minimal expenses to cover fundamental needs like food, clothing and housing (5). Poverty rates are highest in crowded urban districts in the Netherlands (5). In particular, single-parent households with children below 18 years of age, and people with a non-Western migration background are more vulnerable to poverty (5, 6). It is therefore reasonable to expect that other disadvantaged groups in the Netherlands, for example those that are not fully eligible to access food bank services, might also be affected by food insecurity and its consequences.

Extensive evidence suggests that food insecurity is related to risk of chronic diseases (7-10) in adults, and poorer health, growth and development (11, 12) in the young, emphasizing that families with children are particularly vulnerable to the consequences of food insecurity. Although it seems counterintuitive, several studies have found a positive association between food insecurity and obesity in developed countries, particularly among adult women, whereas mixed evidence is found for this association among men and children as well as in developing countries (13-15). A factor that might explain this association is altered food choices that lead to energy-dense but lower quality diets, as a lower diet quality is related to both food insecurity and obesity (16). Healthier foods are generally more expensive than unhealthy foods, which might act as a barrier for low-income families to adopt healthier dietary patterns (17). Studying the factors that might explain the association between food insecurity and obesity is important for public health, since obesity increases the risk

of several diseases and other adverse health effects (15, 18). We therefore assessed the association between food insecurity and obesity among disadvantaged Dutch families, and explored potential mediation by other risk factors for obesity, such as lifestyle factors and social situations.

Methods

Study design and study population

This cross-sectional study was conducted in four disadvantaged neighborhoods in the Dutch city The Hague. These neighborhoods were selected based on predefined criteria used by the Dutch Government to identify disadvantaged neighborhoods in the Netherlands, which combined normative data on the socioeconomic position of the households living in the neighborhood and the quality of the neighborhood (i.e. socioeconomic and physical disadvantages), and residents' opinions on living quality regarding the neighborhood and its residents (19). Participants were eligible for the study if they (1) were living in or near one of the four selected disadvantaged neighborhoods, (2) were 18 years of age or older, and (3) had at least one child below 18 years of age living at home. Only one parent per household could participate. Participants were recruited between April 2017 and June 2018 by actively approaching potential participants at various public places (e.g., community centers, (pre)schools, community events, swimming pools, and general practices). The study was approved by the Medical Ethics Committee of Leiden University Medical Centre (P17.164).

Data collection

Data was collected using paper-based or online questionnaires completed by the participants. Most participants completed the questionnaire and informed consent form at the site of recruitment immediately after being invited to the study. Questionnaires were available in the Dutch, English and Turkish language. If participants had difficulty reading or writing, they were offered help completing the questionnaire. If participants provided contact information, they were contacted by phone or e-mail to complement missing data from their questionnaire if applicable.

Food insecurity status assessment

Household food insecurity status was assessed using the 18-item United States Department of Agriculture Household Food Security Survey Module (USDA HFSSM)

(20). This original survey was translated from the English to the Dutch language based on the translation used in the Dutch study of Neter et al. (2014) which applied the translation and back-translation technique (4). The survey consists of questions about conditions and behaviors that are characteristic for households having difficulty meeting basic food needs, with the past 12 months as reference period. Affirmative responses to these questions were summed and resulted in a continuum of food insecurity status ranging from 0-18, which can be divided into four categories: (1) high food security (0 affirmative responses), (2) marginal food security (1-2 affirmative responses), (3) low food security (3-7 affirmative responses), and (4) very low food security (8-18 affirmative responses) (20). Range (1) and (2) were categorized as 'food secure' (FS), and range (3) and (4) were categorized as 'food insecure' (FI), according to the USDA standards (21).

Dietary assessment and construction of the diet quality scores

Dietary intake was assessed using the Dutch Healthy Diet Food Frequency Questionnaire (DHD-FFQ) (22). The DHD-FFQ is a short questionnaire comprising 25 questions representing 34 food items, with the previous month as reference period, measuring adherence to Dutch dietary guidelines (22). We constructed diet quality scores based on the Dutch dietary guidelines on food intake and food choices as indicated by the Health Council of the Netherlands (23) and the Netherlands Nutrition Centre (24). In this study we present two diet quality score variants: a total diet quality score (TOT-Diet score) and a financially-sensitive diet quality score (FIN-Diet score) (**Table 1**). The TOT-Diet score included 6 components: vegetables, fruit, fish, bread, oils and fats, and sweet and savory snacks; the FIN-Diet score included 3 components: vegetables, fruit, and fish. We developed the FIN-Diet score in addition to the TOT-Diet score because an adequate intake of vegetables, fruit and fish is important for health, because these components are relatively expensive, and intake may be particularly dependent on financial resources (25, 26). For each component, a minimum score of 0 and a maximum score of 10 could be obtained, resulting in a total diet quality score ranging from a theoretical minimum of 0 to a theoretical maximum of 30 for the FIN-Diet score and a theoretical maximum of 60 for the TOT-Diet score, with higher scores indicating better adherence to the dietary guidelines (**Table 1**).

Table 1 Diet quality score components, dietary guidelines and scoring per component

Component	Recommendations by the Health Council of the Netherlands and/ or the Netherlands Nutrition Centre	% contribution to component score	Units	Score		
				0	5	10
Vegetables[a,b]	Eat at least 200 grams of vegetables daily	100	Grams/ d	0	*Continuous*	≥200
Fruit[a,b]	Eat at least 200 grams of fruit daily	100	Pieces/ d	0	*Continuous*	≥ 2
Fish[a,b]	Eat one serving of fish weekly, preferably oily fish	50	Servings/ w	0	<1	≥ 1
		50		No fish consumed	Lean or both lean and fatty fish	Mostly fatty fish
Bread[b]	Replace refined cereal products by whole-grain products	50		Mostly white bread	Both white and brown/ whole-grain bread	Mostly brown/ whole-grain bread
	Women: 4-5 brown/ whole-grain sandwiches daily	50	Sandwiches/ d	0	*Continuous*	≥ 4
	Men: 6-8 brown/ whole-grain sandwiches daily		Sandwiches/ d	0	*Continuous*	≥ 6
Oils and fats[b]	Replace butter, hard margarines and cooking fats by soft margarines, liquid cooking fats, and vegetable oils	50		Butter, hard margarines	Both butter, hard margarines and oils and soft margarines	Oils and soft margarines
		50		Butter on bread or bread is not buttered at all	Semi-skimmed butter or hard margarine on bread	Diet margarine on bread

Sweet and savory snacks[b]	For products outside the Wheel of Five: choose an item from the daily selection no more than three to five times per day, and something from the weekly selection no more than three times a week	25	Sweet snacks (larger serving)/ w	≥ 3	<1 to 2	Not consumed
		25	Sweet snacks (small serving)/ d	> 3	*Continuous*	Not consumed
		25	Savory snacks (larger serving)/ w	≥ 3	1 to 2	Not consumed
		25	Savory snacks (small serving)/ d	> 3	*Continuous*	Not consumed

[a] Components included in the FIN-Diet score: vegetables; fruit; and fish
[b] Components included in the TOT-Diet score: vegetables; fruit; fish; bread; oils and fats; and sweet and savory snacks

Sociodemographic and lifestyle factors

Sociodemographic and lifestyle information was collected, including age or date of birth, sex, height, weight, gross monthly household income, household composition, marital status, educational level, country of birth of the participant and their parents, employment status, smoking status, food bank use, religion, pregnancy status, and physical activity. Self-reported general health status was assessed using a 5-point Likert scale ranging from excellent to poor, and dichotomized into 'good-to-excellent' and 'fair-to-poor'. Age was calculated by extracting the date of birth of the participant from the date on which the questionnaire was completed and was presented in years. If the date of birth of the participant was not available, we used their self-reported age in years. Body Mass Index (BMI, kg/m^2) of the participants was calculated from their self-reported weight and height, and classified into underweight (BMI$<$18.5 kg/m^2), normal weight (BMI 18.5-25 kg/m^2), overweight (BMI 25-30 kg/m^2) and obese (BMI$\geq$30 kg/m^2), using the WHO cut-off points (25). Only 1.5% of the participants were classified as underweight and the lowest BMI was 17, therefore they were included in the normal weight category.

Gross monthly household income was dichotomized into above or below the Dutch basic needs budget (5), which was calculated taking into account the household size and composition according to the method drawn up by Statistics Netherlands (27). Household composition was presented as the adult/child ratio (number of adults divided by the number of children). Marital status was used to derive the living situation: single or married/partner. The educational level categories were based on the International Standard Classification of Education (ISCED) 2011 (28), and dichotomized into a low educational level ($\leq$ISCED 2) and higher educational level ($\geq$ISCED 3). Migration background of the participants was based on the country of birth of the parents: if one parent was born outside of the Netherlands, the country of birth of that parent determined the participants' migration background. If both parents were born abroad, the country of birth of the mother determined the participants' migration background (29). Physical activity (i.e. days per week and minutes per day being moderately active) was assessed as part of the DHD-FFQ (22).

Potential mediating variables and covariates

To evaluate the magnitude of disparity in obesity due to food insecurity that would remain if an intermediate or downstream determinant is changed, we selected

various potential mediating variables based on literature (13, 30, 31). The association between food insecurity and weight was previously found to be mediated by lifestyle health behaviors like diet quality and physical activity (30). To illustrate, food insecurity might influence weight through changing physical activity and therefore physical activity is considered a potential mediator. For example, experiencing food insecurity may decrease physical activity (i.e., through symptoms of fatigue due to reduced dietary quality and potential deficiencies or limited financial possibilities to engage in sports). In turn, a decrease in physical activity could increase obesity prevalence through an altered energy expenditure (30). Further, living situation and stressors (which might trigger unhealthy coping mechanisms like smoking) were previously indicated as potential mediators in this relationship (13, 31). As a result, the following variables were considered as potential mediating variables that may explain the food insecurity-obesity association: living situation, physical activity, household composition, smoking status, self-reported general health status, FIN-Diet score, and TOT-Diet score. A preliminary theoretical model and explanation of these associations is shown in **Additional Figure 1**. The individual characteristics age, sex, household income, educational level, and migration background were considered as additional covariates.

Statistical analysis

Subject characteristics, food insecurity status, general health status, diet quality, and BMI status were described as median (interquartile range, IQR) for continuous variables and frequencies and percentages for categorical variables. The association between food insecurity and BMI status was evaluated using multinomial logistic regression. Four models were presented: a crude model; and models adjusted for basic characteristics, socioeconomic status (SES) and lifestyle factors.

Mediation analyses were performed for the continuous food insecurity status score-obesity association, with living situation, physical activity, household composition, smoking status, self-reported general health status, FIN-Diet score and TOT-Diet score as potential mediating variables. All potential mediating variables were tested step by step. We used Stata's binary mediation program to estimate the standardized total-, direct-, and indirect effect and the proportion of total effect mediated of each of the above-mentioned potential mediators separately, both crude and controlling for covariates. Standard errors and confidence intervals were obtained using the

bootstrapping method (1000 repetitions) (32). We presented bias-corrected 95% confidence intervals to account for non-normal distributed data, as these are considered most accurate (33, 34). The indirect effect (i.e. the mediated association) was estimated using the product of coefficients approach (32) (**Additional document 1**). The indirect effect reflects the extent to which the independent variable (food insecurity status) is associated with the potential mediating variable, and the extent to which the potential mediating variable is associated with the dependent variable (obesity). Mediation was assumed to have occurred when the indirect effect was statistically significantly different from zero. Complete mediation occurred when the direct effect (i.e., the association between the independent variable and the dependent variable when controlling for the mediating variable) became non-significant, indicating that the total effect (i.e., the sum of the indirect and direct effect) was completely explained by the mediating variable. Partial mediation occurred when both the indirect and direct effect were statistically significantly different from zero, indicating that the mediating variable explained part, but not all, of the total association. If the direct effect is opposite in sign to the indirect effect, this is referred to as inconsistent mediation (35).

Multiple imputation was used to reduce potential attrition bias associated with missing data including all analysis variables, assuming that missing values were missing at random. Ten imputed datasets were generated using fully conditional specification (Markov chain Monte Carlo method) with a maximum of 10 iterations. Predictive mean matching was used for not-normally distributed variables, logistic regression models for categorical variables. Further details of the multiple imputation are presented in **Additional Table 1.** Because participant characteristics were similar in the imputed and unimputed data, pooled results after the multiple imputation were presented (**Additional Table 2**).

Mediation analyses were conducted using Stata version 14.0 (StataCorp,2015. Stata Statistical Software. College Station, TX:StataCorp LP). All other statistical analyses were performed using SPSS version 25.0 (IBM Corp., 2012, Armonk, NY). A two-sided P-value of 0.05 was considered statistically significant.

Results

Participant characteristics

In total, 250 participants completed the questionnaire, of whom 8 were excluded (due to not having children below 18 years of age (n=7), and (n=1) for living outside the study area), resulting in a population of analysis of 242 participants. The overall prevalence of food insecurity was 26.0%; 18.2% of the participants experienced low food security and 7.8% experienced very low food security (**Table 2**).

Table 2 Food insecurity status in four categories and total food secure and food insecure participants

Food insecurity status	n (%)
High food security	127 (52.5)
Marginal food security	52 (21.5)
Total food secure	179 (74.0)
Low food security	44 (18.2)
Very low food security	19 (7.8)
Total food insecure	63 (26.0)

Compared to food secure (FS) participants, food insecure (FI) participants more often had an income below the basic needs budget, had a lower educational level, and were less often currently employed. FI participants more often had a non-Western migration background and were more often Christian and less often Islamic compared to FS participants (**Additional Table 3**). Compared to FS participants, FI participants were more often single parents and current smokers. Self-reported general health status was poorer among FI participants, as they reported fair-to-poor health more than twice as often as FS participants (**Additional Table 4**). The average TOT-Diet score and FIN-Diet score varied across food insecurity status categories, with the lowest scores obtained by participants with a very low food security status. Overall, FI participants had a slightly lower median TOT-Diet score and a 4.6 points lower FIN-Diet score compared to FS participants (**Additional Table 4** and **5**). Only the components fruit, vegetables, and fish differed statistically significantly between FS and FI participants, with FI participants showing lower scores (**Additional Table 5**). **Additional Table 6** shows differences in component and total diet scores for obese and non-obese participants.

Food insecurity and BMI status

Obesity prevalence markedly increased with an increasing food insecurity status; obesity prevalence increased from 23.6% among participants experiencing high food security to 57.9% among participants experiencing very low food security (**Figure 1**). Overall, 25.1% of the FS participants were obese, while 42.9% of the FI participants were obese.

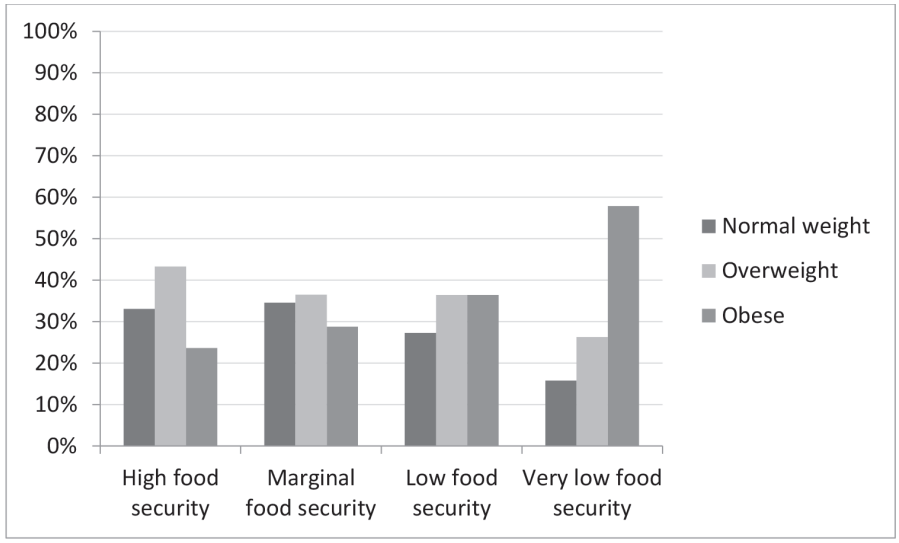

Figure 1 BMI status across food insecurity status categories

Food insecurity was associated with obesity, but not with overweight. FI participants were 2.49 (95%CI = 1.16, 5.33) times more likely to be obese than FS participants. Controlling for basic characteristics, SES and lifestyle factors, the odds ratio was similar but not statistically significant (**Table 3**).

Table 3 Associations between food insecurity status and BMI status

	Overweight		Obesity	
	OR (95%CI)	p-value	OR (95%CI)	p-value
Crude model	1.15 (0.54, 2.45)	0.721	2.49 (1.16, 5.33)	0.019*
Model 1: basic characteristics adjusted	0.78 (0.34, 1.79)	0.559	1.94 (0.84, 4.51)	0.123
Model 2: SES adjusted	0.80 (0.34, 1.89)	0.610	1.57 (0.65, 3.79)	0.312
Model 3: lifestyle factors adjusted	1.15 (0.46, 2.85)	0.769	2.51 (0.98, 6.48)	0.056

CI: Confidence Interval
*Statistically significant (p <0.05)
Normal weight= reference for BMI status
Crude model: food insecurity status (FS and FI). FS= reference for food insecurity status
Model 1: Crude model + age, sex, household composition, living situation (partner/single), religion (Christianity, Islam, not religious/other), and migration background (Western, Turkish, Moroccan, Surinamese, other)
Model 2: Model 1 + educational level (≤ISCED 2, ≥ISCED 3), income (below/above basic needs budget), employment status (currently employed/currently not employed)
Model 3: Model 2+ physical activity (min/day), smoking status (smoker/non-smoker), FIN-Diet score

Explaining the association between food insecurity and obesity

The unadjusted mediation analyses showed that the food insecurity-obesity association was partially mediated by living situation and general health status (consistent mediation). Diet quality (FIN-Diet score) was an inconsistent partial mediator. The proportion of total effect mediated ranged between 15.3% and 19.1% for all described mediators (**Table 4**, **Figure 2**, **Additional Table 7**). After adjustment for covariates, living situation remained a consistent partial mediator and the FIN-Diet score remained an inconsistent partial mediator. Further, smoking status was an inconsistent partial mediator after adjustment (**Table 4**, **Figure 2**, **Additional Table 8**). **Additional Table 7** and **8** show mediation statistics for all tested potential mediators.

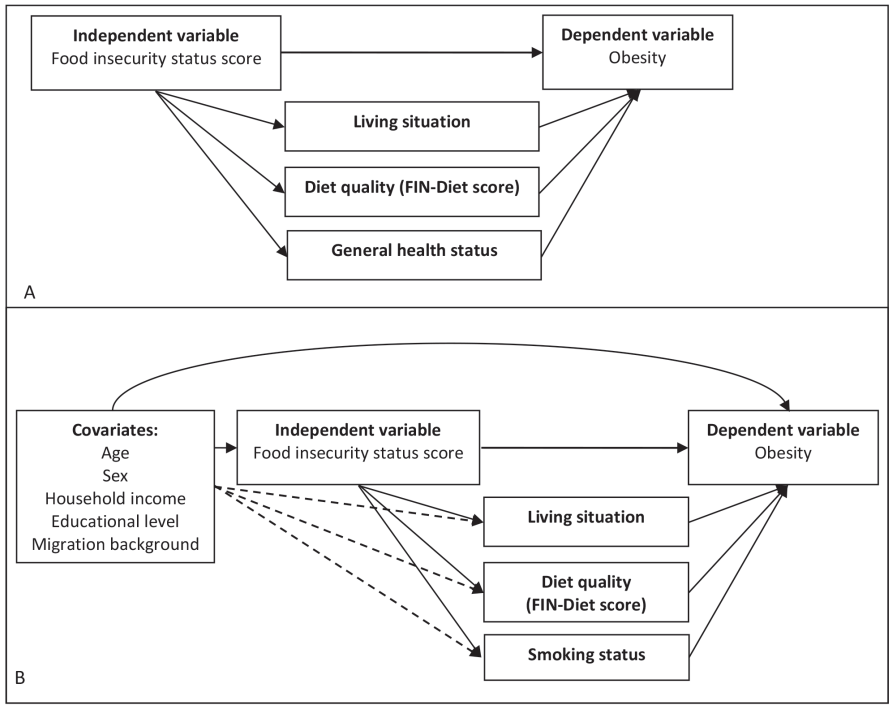

Figure 2 The association between food insecurity status score and obesity and its partial mediators
A= unadjusted, B= adjusted for age, sex, household income, educational level, and migration background

Table 4 Mediation statistics of statistically significant mediators of the food insecurity status score-obesity association

	Unadjusted			Adjusted[a]		
	Indirect effect		Proportion of total effect mediated	Indirect effect		Proportion of total effect mediated
	Estimate	95% CI[b]	%	Estimate	95% CI[b]	%
Mediators						
Living situation	0.037*	0.0073, 0.096	15.3	0.036*	0.0013, 0.11	15.4
Diet quality (FIN-Diet score)	-0.041*	-0.11, -0.0012	-17.7	-0.042*	-0.10, -0.0019	-18.6
General health status	0.044*	0.00089, 0.11	19.1			
Smoking status				-0.034*	-0.11, -0.00034	-15.8

CI: Confidence Interval
*Statistically significant ($p < 0.05$)
[a]Adjusted for age, sex, household income, educational level, and migration background
[b]Bias-corrected

Discussion

The present study showed that a quarter of the participating disadvantaged families experienced food insecurity. Food insecurity status was associated with obesity in the unadjusted model, while after adjustment similar but non-significant effect estimates were observed. Living situation, diet quality (FIN-Diet score) and smoking status explained part, but not all, of the total association between food insecurity and obesity after adjustment for other covariates.

Our result on food insecurity prevalence is agreement with a large global study on food insecurity and mental health, which found approximately the same food insecurity prevalence across 39 countries in Europe, although that study used a different questionnaire to assess food insecurity (36).

Our results suggest a positive association between food insecurity and obesity. Previous studies imply that gender differences and the economic development level of a country are important factors in this association, since a positive association between food insecurity and obesity is particularly evident among women in developed countries, whereas mixed evidence for an association has been found among men and children and among populations living in developing countries (15, 16). For example, a recent systematic review and meta-analysis by Moradi et al. (15) indicates that food insecurity increases the risk of obesity, but not underweight nor overweight among adults in high-income countries. In our study, obesity prevalence increased considerably with increasing food insecurity status. Previous studies also found a linear association between food insecurity status and obesity prevalence, whereas other studies found a U-shaped association (13).

Regarding gender differences, earlier literature suggests that the positive association between food insecurity and obesity is especially evident in women (13-15), which is comparable to our results since the study population consisted predominantly of women. Because of this uneven gender distribution, we were unable to further explore gender differences in our study. However, Martin & Lippert (2012) have elaborated on this and suggest that gender differences in the association between food insecurity and obesity might be attributed to motherhood (and the social role of the mother to feed the family (37)); mothers might adopt unhealthy strategies in order to protect their children when experiencing household food insecurity, which may increase their risk of an unhealthy weight (38).

Notably, the results of our study suggest a positive association between food insecurity status and obesity, but not between food insecurity and overweight. Previous literature also suggests stronger associations between food insecurity and obesity than with overweight (39), which might be due to a larger heterogeneity in factors and situations leading to overweight (such as age related factors), whereas underlying causes of obesity might be more severe and specific (such as mental health issues, stress, and experiencing food insecurity). For example, food insecurity may cause temporal involuntary food intake restrictions due to insufficient resources to access food, followed by a period of excessive food intake when food becomes available again, a phenomenon known as the feast-famine cycle (14). Such a disruptive eating patterns can lead to metabolic alterations and eventually result in obesity (14).

The explanatory factors underlying the association between food insecurity and obesity are not yet completely established (15). By exploring the mediating role of several risk factors for obesity, our study provides additional insight into this complex association. We identified diet quality (the FIN-Diet score) and smoking status as inconsistent partial mediators, and living situation and general health status as partial mediators of the association between food insecurity and obesity.

While food insecurity is clearly associated with obesity and a lower diet quality (16), how food insecurity, diet quality and obesity interrelate is less clear however. One study found no evidence for a mediating role of diet quality in the association between food insecurity and weight (40). Another study suggested fruit and vegetable consumption as a potential mediator in the association between food insecurity and obesity (37). In our study the food insecurity-obesity association was inconsistently partially mediated by the FIN-Diet score and not statistically significantly mediated by the TOT-Diet score, implying that diet quality did not fully explain the association between food insecurity and obesity. The relatively higher cost of a diet high in fruit, vegetables and fish might play a role in the stronger impact that was found for the FIN-Diet score compared to the TOT-Diet score (17). Strikingly, similar results were observed when controlling for income, which suggests that income itself cannot fully explain these findings and that other constructs such as financial capacity or financial stress may be more important. Previous literature also indicates an association between perceived stress and unhealthy eating behaviors, such as emotional eating and haphazard meal planning, which eventually may lead to obesity (41-43).

Smoking status partially and inconsistently mediated the food insecurity-obesity association, indicating that smoking had an overall suppressing effect on the association between food insecurity and obesity. Food insecure persons may smoke more than their food secure counterparts as a way to cope with stressors such as financial stress and as a way to suppress their appetite, while smoking in turn might lead to a lower body weight due to an increased energy expenditure and reduced food intake (44, 45).

Living situation (specifically being single as opposed to having a partner) was also found to partially mediate the food insecurity-obesity association. Food insecurity and the higher stress levels associated with it may lead to lower marital satisfaction and thereby decreased relationship maintenance (46, 47). In turn, single parents (specifically single mothers) are not only more at risk of food insecurity, but the consequences of food insecurity on their weight are also greater compared to partnered women (38). This could be a reflection of the difficult task of being the sole provider in the household while also being responsible for child care (38).

Finally, general health status partially mediated the food insecurity-obesity association through poorer health. In line with previous studies, we found that food insecurity was associated with poorer health (48) and poorer health was associated with obesity (49). The mediating role of general health status in this association was mainly explained by other sociodemographic factors.

A strength of our study was the assessment of many sociodemographic and lifestyle factors, which enabled an extensive description of the study population, adjustment of the analyses and exploration of several potential mediators. Food insecurity is an elusive concept involving many factors, and many different indicators have been described in literature (50). We used the widely accepted 18-item USDA Household Food Security Survey Module (USDA HFSSM) to assess food insecurity status, which is regarded as the gold standard for Western countries (20, 51). It should, however, be noted that the USDA HFSSM and our translation have not yet been validated specifically for the Dutch population, which may have led to misclassification in our study. However, these effects are assumed to be limited, as the USDA HFSSM has previously been adapted for use in various cultures and languages and generally shows to be a valid tool for the assessment of food insecurity status (52-54). In addition, a recent literature review showed that strategies to cope with food

insecurity are similar across different ethnic/racial groups, but more research on the ethnic differences in perception of food insecurity and coping strategies is needed (55).

Further limitations of this study should also be considered when interpreting our results. Some measures were supposed to reflect the household situation (e.g., income and food insecurity status). Because data were reported by one person, they may not reflect the views of other family members. The data were self-reported which may have led to misclassification. For BMI this may have led to an underestimation of the actual prevalence of overweight and obesity (56), indicating that the obesity prevalence might be even higher than found in our study. Also we used validated measures for dietary intake (22) and general health status (57), thus we assume that misclassification bias had a limited effect on our main findings.

The reference period for the food insecurity assessment was 12 months, whereas the reference period for the dietary intake assessment was only 1 month. These differing reference periods may explain the partial mediation by dietary quality in the association between food insecurity and obesity that was observed in the current study: a stronger effect might have been observed when the reference periods were matched because this would have reflected a more direct association between food insecurity status and dietary quality. However, a previous study by Huddleston-Casas et al. (2009) showed a strong correlation between food insecurity scores over a period of 2 years (58) indicating that food insecurity status is relatively stable over time. Therefore, the effect of this longer reference period is expected to have a limited effect on the association between food insecurity and diet quality and the validity of our conclusions.

The short FFQ used in our study to assess dietary intake and compute diet quality scores contained only a limited range of foods. Although the DHD-FFQ could adequately provide an approximate ranking of subjects according to their diet quality, this FFQ is most applicable to Dutch eating patterns and to a lesser extent to non-Dutch eating patterns (22). Also, this short FFQ did not enable a detailed assessment of nutrient intakes, and therefore our diet quality scores could not be validated by relating them to nutrient adequacy (59), which would have been a valuable contribution.

Our study was cross-sectional and therefore no causal relations could be established. This is especially important for the mediation analyses, as this precludes any

conclusions regarding the nature of the observed associations. It should further be noted that conducting mediation analyses using cross-sectional data and a binary outcome has been criticized by others (60). However, to overcome limitations associated with cross-sectional data and binary outcomes variables, we used the product of coefficients approach as recommended for this situation (61). Also, we did not aim for establishing causal pathways between food insecurity and obesity but rather aimed to evaluate the magnitude of disparity in obesity due to food insecurity that would remain if an intermediate or downstream risk factor is changed. Future longitudinal studies will be needed to examine the temporal order of the food insecurity-obesity association and potential mediators in this relationship.

Conclusion

The findings of this study suggest an association between food insecurity and obesity. This association is partially mediated by living situation, and inconsistently (i.e., the direct effect was opposite in sign to the indirect effect) partially mediated by diet quality (FIN-Diet score) and smoking status in disadvantaged Dutch families, indicating that living situation, diet quality and smoking status explained part, but not all, of the total association between food insecurity and obesity. Overall, our findings emphasize the importance of preventing food insecurity to achieve public health goals. Even though the association between food insecurity status and obesity remains complex, our study contributes to a better understanding of how these two public health concerns might be related. However, because major aspects of the association between food insecurity and obesity are still unexplained, future studies are warranted to test other potential mediators such as financial stress, sleep, and other indices of dietary quality, which might guide future prevention programs.

List of abbreviations

BMI	Body Mass Index
CI	Confidence Interval
DHD	Dutch Healthy Diet
FAO	Food and Agriculture Organization
FFQ	Food Frequency Questionnaire
FS	Food secure
FI	Food insecure
HFSSM	Household Food Security Survey Module
ISCED	International Standard Classification of Education
IQR	Interquartile range
FIN-Diet score	Financially-sensitive diet quality score
TOT-Diet score	Total diet quality score
USDA	United States Department of Agriculture
SES	Socioeconomic status

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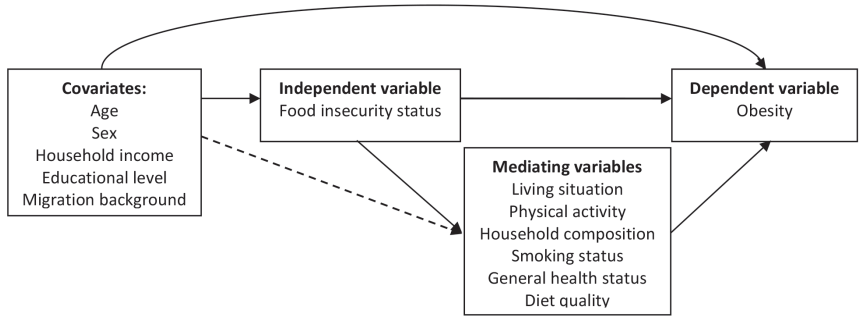
Additional material Chapter 2

Additional Figure 1 Preliminary theoretical model of the food insecurity status-obesity association and its potential mediators[1]



[1]This preliminary theoretical model of the association between food insecurity status and obesity shows that food insecurity might directly influence obesity status, but might also indirectly influence obesity status through the potential mediating variables Living situation; Physical activity; Household composition; Smoking status; General health status; and/or Diet quality. These potential mediating variables were selected based on literature (Franklin et al. (2012); Martinez et al. (2019); Hanson et al. (2007)). The covariates Age; Sex; Household income; Educational level; and Migration background were included in the model to ensure that these variables did not confound any of the assessed direct and indirect associations between food insecurity status and obesity.

Additional Document 1 Example of the Stata do-file used for the mediation analyses

```
/* MEDIATION OF FOOD SECURITY - OBESITY RELATIONSHIP */
/* With Food security score as continuous IV */


/*XXX   M= Living situation (MaritalStat_STATA)  XXX*/


/*Not adjusted for covariates: */

binary_mediation, dv(Obesity_2cat_STATA) iv(Score_
FoodSecurity) mv(MaritalStat_STATA)


/*Create CI intervals using boostrapping*/

quietly bootstrap r(indir_1)r(tot_ind) r(dir_eff) r(tot_
eff), ///
  reps(1000): binary_mediation, dv(Obesity_2cat_STATA)
iv(Score_FoodSecurity) mv(MaritalStat_STATA)
estat bootstrap, percentile bc


/*Adjusted for covariates:*/

binary_mediation, dv(Obesity_2cat_STATA) iv(Score_
FoodSecurity) mv(MaritalStat_STATA) cv(Leeftijd_totaal
Sex_STATA Inkomen_2cat_STATA Opleiding_2cat_STATA
Migratie_2cat_STATA)


/*Create CI intervals using boostrapping*/

quietly bootstrap r(indir_1)r(tot_ind) r(dir_eff) r(tot_
eff), ///
  reps(1000): binary_mediation, dv(Obesity_2cat_
STATA) iv(Score_FoodSecurity) mv(MaritalStat_STATA)
cv(Leeftijd_totaal Sex_STATA Inkomen_2cat_STATA
Opleiding_2cat_STATA Migratie_2cat_STATA)
estat bootstrap, percentile bc
```

Additional Table 1 Details of the multiple imputation process

	Multiple imputation
Software used	IBM SPSS statistics version 25
Imputation method and key settings	Fully conditional specification (Markov chain Monte Carlo method); maximum iterations: 10
No· of imputed data sets created	10
Variables included in the imputation procedure as both predictor variable as a variable to be imputed	Wijken Leeftijd_totaal Geslacht Lengte Gewicht Inkomen_BasicNeeds migratieachtergrond Burgerlijke_staat Opleidingsniveau_3cat Religie Voedselbank roken_totaal Aantal_volwassenen_huishouden Aantal_kinderen_ huishouden Betaalde_baan_totaal Zwanger
Variables added as predictors (not used in the main analyses) of missing data to increase plausibility of missing at random assumption	land_geboren_5cat Land_vader_5cat Land_moeder_5cat Huidig_betaalde_baan Verleden_betaalde_baan Huidig_ Roken Verleden_Roken Score_FoodSecurity_1 Score_FoodSecurity_2 Score_FoodSecurity_3 Score_FoodSecurity_4 Score_ FoodSecurity_5 Score_FoodSecurity_6 Score_FoodSecurity_7 Score_FoodSecurity_8 Score_FoodSecurity_10 Score_FoodSecurity_11 Score_ FoodSecurity_12 Score_FoodSecurity_13 Score_FoodSecurity_14 Score_FoodSecurity_15 Score_ FoodSecurity_16 Eetgewoonten_1a Eetgewoonten_1b Eetgewoonten_1d Eetgewoonten_1e Eetgewoonten_2a Eetgewoonten_2b Eetgewoonten_3a Eetgewoonten_4a Eetgewoonten_4b Eetgewoonten_5 Eetgewoonten_6 Eetgewoonten_7 Eetgewoonten_8a Eetgewoonten_9a Eetgewoonten_10a Eetgewoonten_11a Eetgewoonten_12a Eetgewoonten_13a Eetgewoonten_15_roomboterEetgewoonten_15_vet_uit_ pakje Eetgewoonten_15_vet_uit_fles Eetgewoonten_15_ olie Eetgewoonten_16 Eetgewoonten_17a Eetgewoonten_18a Eetgewoonten_19a Eetgewoonten_20 Eetgewoonten_21a Eetgewoonten_22a Eetgewoonten_23 Eetgewoonten_24 Lichaamsbeweging_minuten SF_1 SF_2a SF_2b SF_3a SF_3b SF_4a SF_4b SF_5 SF_6a SF_6b SF_6c SF_7 Gezondheid_hoge_bloeddruk Gezondheid_hoog_cholesterol Gezondheid_Ingreep_hart Gezondheid_hartaanval Gezondheid_asthma Gezondheid_ COPD Gezondheid_diabetes Gezondheid_anemie Gezondheid_zonder_problemen_boodschappen
Treatment of not normally distributed variables	Predictive mean matching
Treatment of binary/categorical variables	Logistic regression models
Population	For the multiple imputation we included all adult participants living in (or near) one of the selected neighbourhoods in The Hague with children below 18 years of age living at home (n= 242).

Additional Table 2 Participant characteristics in original and imputed data

	Missing in original data	Original data	Data after Multiple Imputation
	n (%)	n=242	n=242
Characteristics			
Age (y) (median (IQR))	13 (5·4)	37·3 (33·6; 42·4)	37·5 (33·5; 42·5)
Sex (n (%) female)	3 (1·2)	209 (87·4)	211 (87·2)
Household income (n (%))	28 (11·6)		
Below basic needs budget		145 (67·8)	159 (65·7)
Above basic needs budget		69 (32·2)	83 (34·3)
Educational level[a] (n (%))	8 (3·3)		
Low (≤ISCED 2)		97 (41·5)	99 (40·9)
Higher (≥ISCED 3)		137 (58·5)	143 (59·1)
Migration background (n (%))	4 (1·7)		
Western (including Dutch)		35 (14·7)	36 (14·9)
Turkish		47 (19·7)	48 (19·8)
Moroccan		66 (27·7)	67 (27·7)
Surinamese		26 (10·9)	27 (11·2)
Other		64 (26·9)	65 (26·4)
Religion (n (%))	25 (10·3)		
Christianity		39 (18·0)	44 (18·2)
Islam		138 (63·6)	142 (58·7)
Not religious/ other		40 (18·4)	56 (23·1)
Living situation (n (%))	8 (3·3)		
Married/ partner		161 (68·8)	165 (68·2)
Single		73 (31·2)	77 (31·8)
Household composition (adult/ child ratio) (median (IQR))	13 (5·4)	1 (0·5;1·0)	1·0 (0·5; 1·0)
Employment status (n (%))	4 (1·7)		
Currently employed		99 (41·6)	100 (41·3)
Employed in the past		90 (37·8)	91 (37·6)
Never employed		49 (20·6)	51 (21·1)
Food Bank use[b] (n (%) yes)	6 (2·5)	7 (3·2)	17 (7·0)
Pregnancy[b] (n (%) yes among women)	4 (1·7)	3 (1·8)	17 (8·1)
Weight status (n (%))	12 (5·0)		
Not obese (BMI < 30)		162 (70·4)	170 (70·2)
Obese (BMI ≥30)		68 (29·6)	72 (29·8)
Weight status (n (%))	12 (5·0)		
Normal weight (BMI <25)[c]		70 (30·4)	75 (31·0)
Overweight (BMI 25-30)		92 (40·0)	95 (39·3)
Obesity (BMI ≥30)		68 (29·6)	72 (29·8)
Smoking status (n (%))	13 (5·4)		
Current smoker		37 (16·2)	41 (16·9)
Past smoker		34 (14·8)	39 (16·1)
Non-smoker		158 (69·0)	162 (66·9)

General health status[b] (n (%))	0 (0·0)		
Good to excellent		149 (74·9)	149 (74·9)
Fair to poor		50 (25·1)	50 (25·1)
Physical activity (min/ d) (median (IQR)	0 (0·0)	8·6 (2·0; 17·1)	8·6 (2·0; 17·1)

[a]ISCED 2= Lower secondary education; ISCED 3= Upper secondary education
[b]These questions were added at a later stage during the study and therefore questions that were missing because they were not yet included in the questionnaires are not included in the percentage missing column Correctly missing (n (%)): 'Food Bank use' (15 (6·2)), 'Pregnancy' (43 (17·8)), 'General health status' (43 (17·8))
[c]Only 2 participants were underweight (BMI < 18·5) and they were therefore included in the normal weight category

Additional Table 3 Covariates used in the mediation analyses in the total population and across food insecurity categories

	Total population (n=242)	High food security (n=127)	Marginal food security (n=52)	Low food security (n=44)	Very low food security (n=19)	Total food secure (n=179)	Total food insecure (n=63)	
Covariates n (%) or median (IQR)								Significance[c] (* = p <0.05)
Age (y) (median (IQR))[a]	37·5 (33·5, 42·5)	37·1 (34·0, 41·5)	35·3 (31·2, 42·4)	39·0 (34·0, 44·7)	39·7 (36·3, 45·5)	37·0 (32·5, 42·0)	39·5 (34·9, 45·0)	*
Sex								
Male	31 (12·8)	18 (14·2)	3 (5·7)	5 (11·4)	5 (26·3)	21 (11·7)	10 (15·9)	
Female	211 (87·2)	109 (85·8)	49 (94·2)	39 (88·6)	14 (73·7)	158 (88·3)	53 (84·1)	
Household income								*
Below basic needs budget	159 (65·7)	63 (49·6)	42 (80·8)	38 (86·4)	16 (84·2)	105 (58·7)	54 (85·7)	
Above basic needs budget	83 (34·3)	64 (50·4)	10 (19·2)	6 (13·6)	3 (15·8)	74 (41·3)	9 (14·3)	
Educational level[b]								*
Low (≤ISCED 2)	99 (40·9)	42 (33·1)	24 (46·2)	23 (52·3)	11 (57·9)	65 (36·3)	34 (54·0)	
Higher (≥ ISCED 3)	143 (59·1)	85 (66·9)	29 (55·8)	21 (47·7)	8 (42·1)	114 (63·7)	29 (46·0)	
Employment status								*
Currently employed	100 (41·3)	69 (54·3)	14 (26·9)	11 (25·0)	6 (31·6)	83 (46·4)	17 (27·0)	
Currently not employed	142 (58·7)	58 (45·7)	38 (73·1)	33 (75·0)	13 (68·4)	96 (53·6)	46 (73·0)	
Migration background								-
Western (including Dutch)	36 (14·9)	21 (16·5)	9 (17·3)	4 (9·1)	2 (10·5)	30 (16·8)	6 (9·5)	
Turkish	48 (19·8)	31 (24·4)	7 (13·5)	6 (13·6)	3 (15·8)	39 (21·8)	9 (14·3)	
Moroccan	67 (27·7)	31 (24·4)	17 (32·7)	11 (25·0)	8 (42·1)	48 (26·8)	19 (30·2)	
Surinamese	27 (11·2)	15 (11·8)	5 (9·6)	6 (13·6)	1 (5·3)	20 (11·2)	7 (11·1)	
Other	64(26·4)	29 (22·8)	14 (26·9)	17 (38·6)	5 (26·3)	42 (23·5)	22 (34·9)	

Religion								*
Christianity	44 (18·2)	16 (12·6)	8 (15·4)	14 (31·8)	6 (31·6)	24 (13·4)	20 (31·7)	
Islam	142 (58·7)	79 (62·2)	30 (57·7)	23 (52·3)	10 (52·6)	109 (60·9)	33 (52·4)	
Not religious/ other	56 (23·1)	32 (25·2)	14 (26·9)	7 (15·9)	3 (15·8)	46 (25·7)	10 (15·9)	

[a]For continuous variables the median (IQR) values of the 10th imputed dataset are presented
[b]ISCED 2= Lower secondary education, ISCED 3= Upper secondary education
[c]For differences between food secure and food insecure participants. * indicates a P-value <0.05, P-values were based on Mann-Whitney U test (continuous variables) or Chi-squared test (categorical variables)

Additional Table 4 Potential mediators used in the mediation analyses in the total population and across food insecurity categories

	Total population (n=242)	High food security (n=127)	Marginal food security (n=52)	Low food security (n=44)	Very low food security (n=19)	Total food secure (n=179)	Total food insecure (n=63)	
Potential mediators n (%) or median (IQR)								Significance[c] (* = p <0.05)
Living situation								*
Married/ partner	165 (68·2)	100 (78·7)	30 (57·7)	25 (56·8)	10 (52·6)	130 (72·6)	35 (55·6)	
Single	77 (31·8)	27 (21·3)	22 (42·3)	19 (43·2)	9 (47·4)	49 (27·4)	28 (44·4)	
Physical activity (min/ d)[a]	8·6 (2·0, 17·1)	10·7 (0·7, 17·1)	9·6 (5·0, 23·0)	5·7 (1·1, 22·5)	4·3 (0·0, 12·9)	10·7 (2·1, 17·1)	5·0 (0·7, 14·3)	-
Household composition (adult/child ratio)[1]	1·0 (0·5, 1·0)	1·0 (0·7, 1·0)	0·7 (0·5, 1·0)	0·7 (0·5, 1·0)	1·0 (0·7, 2·0)	1·0 (0·5, 1·0)	0·7 (0·5, 1·0)	-
Smoking status								*
Smoker	41 (16·9)	15 (11·8)	10 (19·2)	11 (25·0)	6 (31·6)	24 (13·4)	17 (27·0)	
Non-smoker	201 (83·1)	112 (88·2)	42 (80·8)	33 (75·0)	13 (68·4)	155 (86·6)	46 (73·0)	
General health status[b]								*
Good to excellent	149 (74·9)	86 (81·1)	35 (79·5)	23 (65·7)	5 (35·7)	121 (80·7)	28 (57·1)	
Fair to poor	50 (25·1)	20 (18·9)	9 (20·5)	12 (34·3)	9 (64·3)	29 (19·3)	21 (42·9)	
TOT-Diet score[a]	34·2 (30·8, 41·3)	34·4 (31·6, 41·3)	35·9 (31·1, 41·8)	34·2 (28·5, 39·8)	31·4 (26·4, 35·3)	34·7 (31·4, 41·3)	32·8 (27·2, 38·8)	*
FIN-Diet score[a]	17·5 (13·3, 20·9)	18·2 (14·8, 21·3)	18·2 (13·5, 20·9)	14·5 (9·3, 21·1)	12·3 (6·3, 18·0)	18·2 (14·6, 21·3)	13·6 (9·1, 20·0)	*

[a]For continuous variables the median (IQR) values of the 10th imputed dataset are presented
[b]The question on general health status was added at a later stage during the study and data are therefore missing for 43 (17·8%) participants
[c]For differences between food secure and food insecure participants. * indicates a P-value <0.05, P-values were based on Mann-Whitney U test (continuous variables) or Chi-squared test (categorical variables)

Additional Table 5 Diet quality (component) scores, for the total study population and split by food insecurity status

		Score median (IQR)			
	Range score	**Total**	**Food secure**	**Food insecure**	**p-value[a]**
Component					
Vegetables	0-10	4·8 (2·5; 7·5)	4·8 (2·9; 7·5)	3·2 (1·6; 7·5)	0·048*
Fruit	0-10	5·9 (2·5; 7·5)	5·9 (3·8; 7·5)	3·8 (1·3; 7·5)	0·001*
Fish	0-10	7·5 (5·0; 7·5)	7·5 (5·0; 7·5)	7·5 (5·0; 7·5)	0·007*
Bread	0-10	7·5 (6·3; 9·2)	7·5 (6·3; 8·8)	7·5 (6·9; 10·0)	0·342
Oils and fats	0-10	5·0 (5·0; 10·0)	5·0 (5·0; 10·0)	7·5 (5·0; 10·0)	0·857
Sweet and savory snacks	0-10	5·0 (3·8; 6·3)	4·6 (3·8; 6·3)	5·4 (3·8; 7·3)	0·232
TOT-Diet score	0-60	34·2 (30·8; 41·3)	34·7 (31·4; 41·3)	32·8 (27·2; 38·8)	0·012*
FIN-Diet score	0-30	17·5 (13·3; 20·9)	18·2 (14·6; 21·3)	13·6 (9·1; 20·0)	<0·001*

*Statistically significant
[a]P-values based on Mann-Whitney U tests

Additional Table 6 Diet quality (component) scores, in total and split by food insecurity status and obesity status

		Score median (IQR)		
	Range score	Non-obese	Obese	p-value[a]
Total population				
Vegetables	0-10	4·8 (2·3; 7·2)	5·0 (3·0; 8·3)	0·173
Fruit	0-10	5·9 (2·5; 7·5)	5·9 (2·5; 7·7)	0·392
Fish	0-10	7·5 (5·0; 7·5)	7·5 (5·0; 7·5)	0·705
Bread	0-10	7·5 (6·3; 8·8)	6·9 (6·3; 10·0)	0·878
Oils and fats	0-10	5·0 (5·0; 10·0)	5·0 (5·0; 10·0)	0·593
Sweet and savory snacks	0-10	5·0 (3·8; 6·8)	5·0 (3·8; 6·3)	0·942
TOT-Diet score	0-60	33·8 (31·1; 40·3)	35·3 (29·9; 42·5)	0·407
FIN-Diet score	0-30	17·3 (13·1; 20·3)	18·2 (13·4; 22·2)	0·234
Food secure				
Vegetables	0-10	4·8 (2·5; 7·1)	5·5 (3·8; 9·6)	0·027*
Fruit	0-10	5·9 (3·8; 7·5)	5·9 (4·4; 7·9)	0·423
Fish	0-10	7·5 (5·0; 7·5)	7·5 (5·0; 7·5)	0·666
Bread	0-10	7·5 (6·3; 8·8)	6·9 (4·7; 10·0)	0·945
Oils and fats	0-10	5·0 (5·0; 10·0)	5·0 (5·0; 10·0)	0·512
Sweet and savory snacks	0-10	4·5 (3·8; 6·4)	4·8 (3·8; 6·3)	0·615
TOT-Diet score	0-60	33·9 (31·4; 40·5)	37·3 (31·3; 44·0)	0·171
FIN-Diet score	0-30	17·5 (14·4; 20·2)	19·5 (16·1; 22·8)	0·035*
Food insecure				
Vegetables	0-10	3·2 (1·6; 7·5)	3·7 (1·6; 7·5)	0·917
Fruit	0-10	2·5 (1·1;7·5)	5·4 (1·5; 7·5)	0·196
Fish	0-10	7·5 (5·0; 7·5)	7·5 (5·0; 7·5)	0·709
Bread	0-10	7·5 (6·9; 10·0)	7·2 (6·4; 10·0)	0·616
Oils and fats	0-10	7·5 (5·0; 10·0)	5·0 (5·0; 9·4)	0·926
Sweet and savory snacks	0-10	5·4 (3·8; 7·3)	5·5 (3·8; 7·3)	0·792
TOT-Diet score	0-60	31·7 (26·5; 37·5)	34·2 (27·3; 39·8)	0·761
FIN-Diet score	0-30	12·5 (9·0; 20·7)	15·5 (9·4; 20·0)	0·580

*Statistically significant
[a]P-values based on Mann-Whitney U tests

Additional Table 7 Mediation statistics of the food insecurity status score-obesity association and all potential mediators (unadjusted)

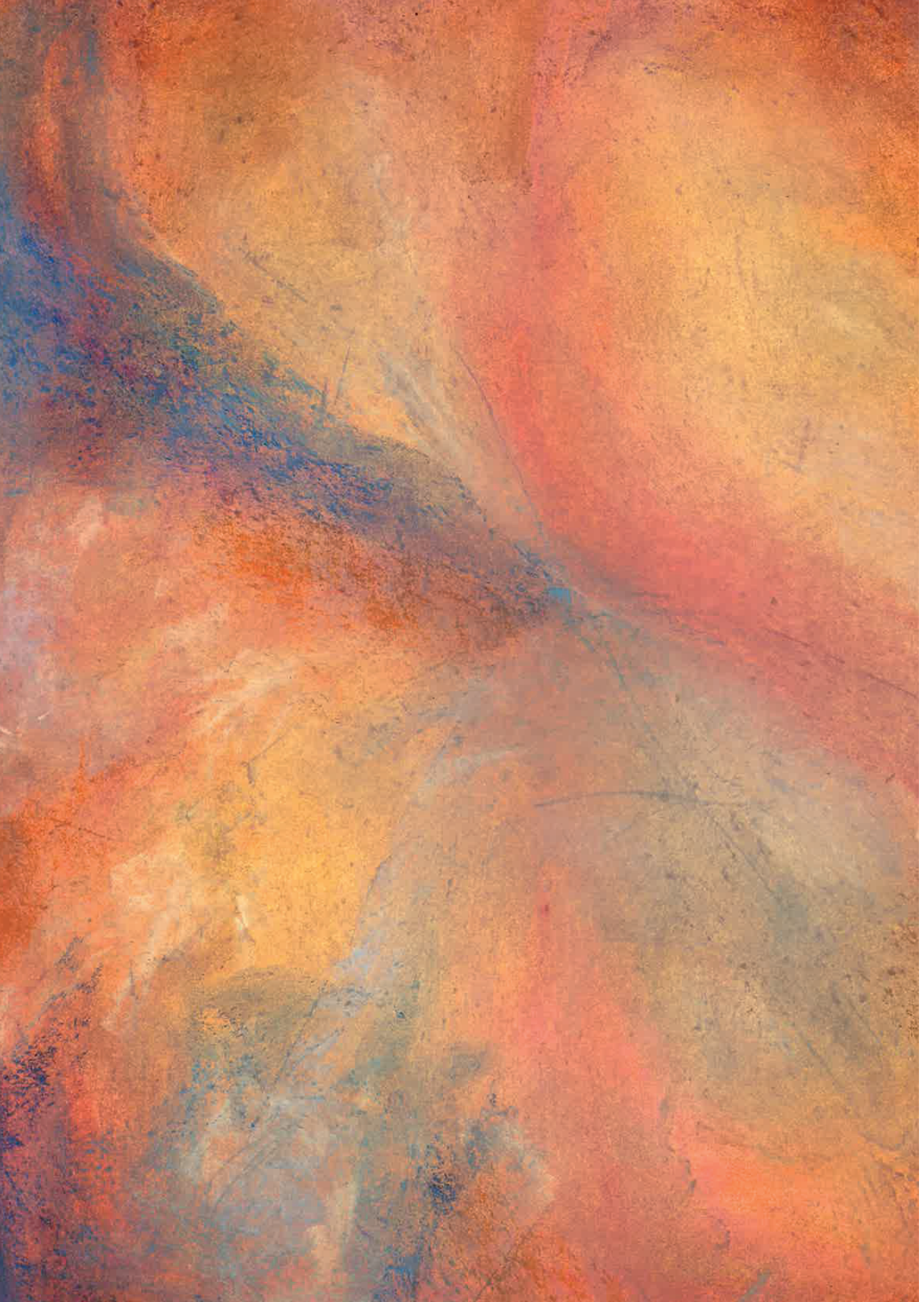
	Indirect effect		Direct effect		Total effect		Proportion of total effect mediated
	Estimate	95% CI[a]	Estimate	95% CI[a]	Estimate	95% CI[a]	%
Mediators							
Living situation	0·0367	0·00734; 0·0961*	0·204	0·0531; 0·344*	0·240	0·0843; 0·374*	15·3
Physical activity	0·00226	-0·00798; 0·0281	0·231	0·0909; 0·368*	0·233	0·0907; 0·369*	0·97
Adult/ child ratio	0·0102	-0·00511; 0·0477	0·225	0·0746; 0·361*	0·235	0·0824; 0·371*	4·4
Smoking status	-0·0283	-0·0870; 0·00310	0·257	0·123; 0·403*	0·229	0·0971; 0·366*	-12·4
General health status	0·0440	0·000891; 0·110*	0·186	0·00406; 0·347*	0·230	0·0633; 0·391*	19·1
FIN-Diet score	-0·0413	-0·105;-0·00120*	0·275	0·133; 0·418*	0·234	0·0887; 0·370*	-17·7
TOT-Diet score	-0·0212	-0·0700; 0·00666	0·255	0·107; 0·389*	0·234	0·0903; 0·361*	-9·1

CI: Confidence Interval
*Statistically significant
[a]Bias-corrected confidence interval

Additional Table 8 Mediation statistics of the food insecurity status score-obesity association and all potential mediators (adjusted[a])

	Indirect effect		Direct effect		Total effect		Proportion of total effect mediated
	Estimate	95% CI[b]	Estimate	95% CI[b]	Estimate	95% CI[b]	%
Mediators							
Living situation	0·0356	0·00130; 0·105*	0·196	0·0249; 0·342*	0·232	0·0551; 0·377*	15·4
Physical activity	0·00265	-0·00792; 0·0306	0·220	0·0441; 0·376*	0·223	0·0496; 0·376*	1·2
Adult/ child ratio	0·00548	-0·00640; 0·0423	0·218	0·0245; 0·377*	0·224	0·0288; 0·375*	2·5
Smoking status	-0·0339	-0·108; -0·000338*	0·248	0·0662; 0·405*	0·214	0·0372; 0·377*	-15·8
General health status	0·0353	-0·00502; 0·104	0·188	-0·0271; 0·362	0·223	0·0104; 0·395*	15·8
FIN-Diet score	-0·0418	-0·102; -0·00185*	0·267	0·0756; 0·409*	0·225	0·0398; 0·370*	-18·6
TOT-Diet score	-0·0206	-0·0714; 0·00289	0·245	0·0519; 0·397*	0·225	0·0257; 0·370*	-9·2

CI: Confidence Interval
*Statistically significant
[a]Adjusted for age, sex, household income, educational level, and migration background
[b]Bias-corrected confidence interval



CHAPTER 3

Food insecurity status is of added value in explaining poor health: a cross-sectional study among parents living in disadvantaged neighborhoods in the Netherlands

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Abstract

Objectives: The aim of this study was to examine the added value of food insecurity in explaining poor physical and mental health beyond other socioeconomic risk factors.

Design, setting, participants and outcome measures: Data for this cross-sectional study were collected using questionnaires with validated measures for food insecurity status and health status, including 199 adult participants with at least one child living at home, living in or near disadvantaged neighborhoods in The Hague, the Netherlands. To assess the added value of food insecurity, optimism-corrected goodness-of-fit statistics of multivariate regression models with and without food insecurity status as a covariate were compared.

Results: In the multivariable models explaining poor physical (PCS) and mental (MCS) health, from all included socioeconomic risk factors, food insecurity score was the most important covariate. Including food insecurity score in those models led to an improvement of explained variance from 6.3% to 9.2% for PCS, and from 5.8% to 11.0% for MCS, and a slightly lower root-mean-squared-error. Further analyses showed that including food insecurity score improved the discriminative ability between those individuals most at risk of poor health, reflected by an improvement in C-statistic from 0.64 (95% CI: 0.59; 0.71) to 0.69 (95% CI: 0.62; 0.73) for PCS and from 0.65 (95% CI: 0.55; 0.68) to 0.70 (95% CI: 0.61; 0.73) for MCS. Further, explained variance in these models improved with approximately one-half for PCS and doubled for MCS.

Conclusions: From these results it follows that food insecurity score is of added value in explaining poor physical and mental health beyond traditionally used socioeconomic risk factors (i.e., age, educational level, income, living situation, employment, migration background) in disadvantaged communities. Therefore, routine food insecurity screening may be important for effective risk stratification to identify populations at increased risk of poor health and provide targeted interventions.

Introduction

It has been extensively shown that individuals of lower socioeconomic position (SEP) groups generally have poorer health outcomes (1). Therefore, improving health in these groups and being able to identify those that are most at risk of poor health has great potential for improving population health. An emerging concept in aiming to improve population health is population health management, which strives to simultaneously improve population health, improve experienced quality of care (by both the patient and health care provider), and reduce healthcare costs (referred to as the Quadruple Aim) (2). A crucial element of effective population health management is risk stratification: identification of populations that are most at risk. In risk stratification, several biomedical and social characteristics of individuals can be combined to establish a risk profile towards poor health outcomes or healthcare utilization. This can be used to proactively identify populations at increased risk of poor health and target prevention (or care) resources specifically to these populations in order to improve successfulness and cost-effectiveness of interventions (3). Predictive modelling is a method that can be used to identify populations at increased risk of poor health and can therefore be used for risk stratification (3).

Many factors have been identified as risk factors in the association between lower SEP and poor health (4-8). Even though numerous studies have examined these associations with poor health, the ability to explain or predict poor health with traditional risk factors and social determinants of health (such as employment status, educational level and income (9)) often proves to be limited. Therefore, we hypothesize that less traditional social determinants of health such as food insecurity might be worthwhile to include in models aiming to explain poor health as a proxy to better identify risk groups and to be used for improving integration of social needs–informed care into medical care (10, 11).

Food insecurity can be defined as an insufficient physical and economic access to adequate food that meets dietary needs and food preferences (12). Food insecurity is a public health concern facing low-, middle-, and high-income regions, including Europe: a large global study found a food insecurity prevalence of 25 percent across 39 European countries (13). Food insecurity can be considered as an adverse health outcome in itself, but also a determinant of poor health (11, 14), and food insecurity is associated with increased healthcare utilization and costs, even when socioeconomic factors are taken into account (15). To date, few studies have focused on food

insecurity prevalence in the Netherlands. These studies indicate a food insecurity prevalence of approximately 25% among people living in an urban disadvantaged setting, and 70% among foodbank recipients (16, 17). Also in the Netherlands, living on a low income is associated with poorer health. However, living on a low income is not one-on-one related to experiencing food insecurity, as the latter reflects not only a scarcity of financial means to acquire adequate food, but amongst others also induces psychosocial stress (14).

Therefore, we hypothesize that it is worthwhile to include food insecurity for better explaining health outcomes in addition to traditional social determinants such as income, to better identify people most at risk of poor health. In the current study, we aim to explore the value of assessing food insecurity and adding this to traditional social determinants of health for better explaining poor physical and mental health.

Methods

Study design and population

Data for this cross-sectional study were collected between April 2017 and June 2018. This study was conducted among families living in highly urbanized disadvantaged neighborhoods in the Dutch city The Hague. Participants were actively recruited at various public places, such as community centers, in four preselected disadvantaged neighborhoods, based on criteria already in use by the Dutch Government to identify disadvantaged neighborhoods (18). Participants were eligible for the study if they were living in or near one of the selected disadvantaged neighborhoods; were aged $\geq$ 18 years; and had at least one child aged $<$ 18 years living at home. Only one parent per household could participate. A total of 199 participants were included in the current study. The study was reviewed by the Medical Ethics Committee of Leiden University Medical Centre and confirmed not to be subject to the Medical Research Involving Human Subjects Act (WMO) (P17.164).

Patient and Public Involvement

Participants were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

Data collection

Data collection was done using paper-based or online questionnaires, available in the Dutch, English and Turkish language. Most participants completed the questionnaire and informed consent form at the site of recruitment immediately after being invited to the study. Participants were offered help completing the questionnaire if they had difficulty reading or writing. If participants provided contact information, they were contacted by phone or e-mail to complement missing data from their questionnaire if applicable.

Primary outcome assessment: general health status

The primary outcome of our models is general health status, assessed using the 12-Item Short Form Health Survey (SF-12) (19). The SF-12 consists of two summary scores: the physical component summary (PCS) score; and the mental component summary (MCS) score. The SF-12 is a widely used, reliable and validated instrument with a relative validity ranging from 0.63 to 0.93 for the 12-item PCS, and 0.60 to 1.07 for the 12-item MCS compared to the best 36-item short-form scale in an adult population (19). The SF-12 assesses self-rated general health and therefore reflects the subjective perception of how physically (PCS) and mentally (MCS) healthy a person feels. In our analyses we used the two continuous summary scores of general health status: the PCS and MCS. PCS and MCS scores were created according to the SF-12 scoring guide by Ware, Kosinski, & Keller (1995) (20). The PCS and MCS scores range from 0 to 100, and these scores were reversed so that higher scores represent poorer health. The PCS and MCS are scored using norm-based methods. In both summary scores all SF-12 items are included, but different weights are assigned to each SF-12 item for the PCS and MCS score calculations. These item weights are chosen so that both scores have a mean of 50 and a standard deviation of 10 in the general US population, as described in the SF-12 scoring guide by Ware, Kosinski, & Keller (1995). An advantage of using this norm-based scoring is that it enables comparison of our results and to interpret them in relation to scores in the general United States (US) population and across other studies using the same scoring weights (20). For instance, scores above 50 indicate a better health than the general US population and scores below 50 indicate a poorer health than the general US population.

Previous literature clearly shows that poorer PCS and MCS scores are associated with higher health care costs (21). To enable evaluation of the discriminative performance

of our models, we also dichotomized the PCS and MCS into scores below 50 and scores above 50, where scores above 50 reflect poorest physical and mental health and therefore highest expected health care use and costs (21, 22).

Food insecurity status assessment

Household food insecurity status was assessed using the 18-item United States Department of Agriculture Household Food Security Survey Module (USDA-HFSSM) (23). The original USDA-HFSSM was translated from the English to the Dutch language based on the translation by Neter et al. (2014), who applied the translation and back-translation technique (16). In the survey, conditions and behaviors that are characteristic for households having difficulty meeting basic food needs are addressed, with the past 12 months as reference period. Affirmative responses to these questions were summed, resulting in a continuum of food insecurity score ranging from 0 to 18, with higher scores reflecting a higher food insecurity. The food insecurity score was dichotomized into 'food secure' (FS: 0-2 affirmative responses), and 'food insecure' (FI: 3-18 affirmative responses), according to the USDA standards (23).

Sociodemographic and lifestyle variables assessment

Sociodemographic and lifestyle information was collected, including age or date of birth, sex, height, weight, gross monthly household income, marital status, educational level, country of birth of the participant and their parents, employment status, smoking status, and presence of common lifestyle-related diseases and medication use. Detailed information on how these data were used to calculate and categorize age, Body Mass Index (BMI), household income, educational level, employment status, living situation, and migration background, is described elsewhere (17).

Further, the presence of the following common health issues was assessed: high blood pressure, high cholesterol, surgery on the heart, heart attack, asthma, Chronic Obstructive Pulmonary Disease (COPD), diabetes mellitus (participants could additionally specify whether it was type 1 or 2), and anemia (in the previous 12 months). Additionally, obesity status was included (i.e., BMI $>$ 30). The total number of present health issues was calculated as a reflection of comorbid health issues.

Covariates explaining poor health

We selected age (in years, continuous), educational level (low/ higher), household income level (below/ above basic needs budget), living situation (partner/ single), employment status (currently employed/ not currently employed), and migration background (Western/ non-Western) as covariates explaining poor health. These covariates were selected on the basis of variables routinely assessed in health monitors of the Netherlands (24). Food insecurity score and food insecurity status (food secure/ food insecure) were included as covariates to assess their added value in explaining poor health.

Statistical analysis

Power calculation

The current study describes secondary analyses of our study on food insecurity and obesity (17), for which a conservative power calculation was performed based on obesity prevalence. For the current study, we compared 150 food secure to 49 food insecure participants. With an alpha of 0.05, the power was more than 90% to detect a difference in health outcomes of 5.8-7.6 points with standard deviations of 8.3-11.3. For reliable explanatory and prediction modelling, we generally need at least 2 subjects per variable with a continuous outcome; with 199 participants, our number of subjects per variable was well over the minimum required number (25).

Population description

Participant characteristics were described for the total population and separately for participants that reported their health being fair to poor and good to excellent. Continuous variables were reported as median and interquartile range (IQR). Categorical variables were described as frequencies and percentages.

Models explaining poor physical health (PCS) and mental health (MCS)

First, the crude associations between all separate covariates (age, educational level, household income level, living situation, employment status, migration background, food insecurity score and food insecurity status) and the individual outcome measures PCS and MCS were assessed using bivariate linear regression models.

Second, two separate multinomial linear regression models were built with both PCS and MCS as individual outcome variables, including all selected covariates except food insecurity score. Third, the same methods as described above were repeated but now additionally including food insecurity score as a covariate.

For the multivariate models, besides the β-Coefficients also the standardized β-Coefficients were presented to enable a comparison of the relative importance of each covariate. The relative importance of the food insecurity score in explaining poor health would be reflected by a relatively high standardized β-Coefficient.

The potential added value of including food insecurity score in explaining poor health is reflected in an improvement in the goodness-of-fit statistics, namely R-squared (R^2) and the root-mean-square error (RMSE). R^2 presents the proportion of variance in the dependent variable that can be explained by the independent variables. R^2 indicates the percentage of the total variation observed for PCS and MCS that can be explained by the model (a value of 0 indicates that the model explains none of the variation in PCS and MCS, while a value of 1 indicates that the model explains all of the variation). An increase in R^2 and a decrease in RMSE after adding food insecurity score to the model, would imply that adding food insecurity score to the model improves its performance.

Discriminative performance

The power of the model to discriminate between those individuals most at risk of poor health and associated health care use and costs was evaluated by building additional models using logistic regression, including the same covariates as described above but with dichotomous outcome measures of PCS and MCS (i.e., PCS and MCS scores below or above 50). The discriminative performance of the logistic regression models was presented by the C-statistic and Nagelkerke's R^2 (26).

The C-statistic is an indicator of how well the model can discriminate between the two groups and it ranges from 0.5 (no discrimination) to 1.0 (perfect discrimination). The C-statistic represents the area under the Receiver Operating Characteristic (ROC) curve. Herein, the sensitivity (percentage of persons that correctly is predicted to have poor health) is on the y-axis and one minus the specificity (percentage of persons that correctly is predicted not to have poor health) on the x-axis. Nagelkerke's R^2 is an adjusted version of the Cox & Snell R^2 so that it ranges from 0 to 1. It can

be interpreted similarly to the R^2 as described above, i.e., higher values indicate a larger proportion of variance in the dependent variable that can be explained by the independent variables. The added value of including food insecurity score to discriminate between those individuals most at risk of poor health is reflected by an improvement in the C-statistic and Nagelkerke's R^2.

Internal validation to estimate optimism-corrected model performance

We used the same dataset to fit the models and to assess the validity of the model, which can lead to optimistic estimates of the model performance (i.e., statistical optimism) (27). All performance measures (i.e., R^2, RMSE, the C-statistic and Nagelkerke's R^2) were therefore adjusted for statistical optimism by a bootstrap resampling and cross-validation procedure (n=1000). With this procedure, we estimate the loss in predictive accuracy of our model in a new sample and correct for this. Bootstrapping included resampling with replacement from the original sample (28). To correct for the statistical optimism, the performance measures of a model in a bootstrapped sample and the original sample was compared and the average difference between the performance measures of these samples was used as the optimism bias. This optimism was subtracted from the original performance measures to obtain the optimism-corrected performance measures (28, 29).

Multiple imputation

Multiple imputation was used to reduce potential bias associated with missing data in our study. Missing data were imputed and 10 independent datasets were created using fully conditional specification (Markov chain Monte Carlo method) with a maximum of 10 iterations. Predictive mean matching was used for non-normally distributed variables and logistic regression models for categorical variables. A more detailed description of the multiple imputation process including supplementary material providing details of the multiple imputation process and participant characteristics in original and imputed data are provided elsewhere (17). Because results were similar in the imputed and unimputed data, pooled results after the multiple imputation were presented.

The bootstrap procedure to obtain optimism-corrected goodness-of-fit statistics was performed in one randomly selected imputed dataset using R-Studio. All other

statistical analyses were performed using SPSS version 25.0 (IBM Corp., 2012, Armonk, NY). A two-sided P-value of 0.05 was considered statistically significant.

Results

Population description

A total of 199 participants were included, of whom approximately one quarter rated their health fair to poor (**Table 1**). The median (IQR) PCS and MCS scores were 49.0 (45.2; 57.6) and 48.3 (42.1; 54.6) respectively, with higher scores indicating a poorer experienced health. Approximately one quarter of the participants experienced food insecurity. Participants had a median (IQR) age of 38.0 (33.8; 43.5) years. The majority of participants were women (84.9%), had an income below the basic needs budget (64.8%), had an upper secondary educational level or more (61.3%), were married or cohabiting (69.8%), and were currently unemployed (55.8%). Compared to participants who rated their health good to excellent, participants with fair to poor health more often experienced food insecurity (42.0% vs 18.8%), more often had an income below the basic needs budget (78.0% vs 60.4%), more often were lower educated (54.0% vs 32.9%), more often were single (50.0% vs 23.5%), and less often were currently employed (32.0% vs 48.3%). They further had a slightly higher BMI (**Table 1**).

Compared to food secure participants, food insecure participants more often reported fair to poor health, and also had a higher median (IQR) PCS score (56.2 (46.4; 66.1) vs 47.4 (45.2; 54.8)) and MCS score (54.0 (46.3; 63.6) vs 46.3 (41.3; 52.9)), indicating poorer physical and mental health (**Supplemental Table 1**).

Table 1. General health status, food insecurity status, and participant characteristics for the total population and split by general health status categories

	Total population (n=199)	Good-excellent health (n=149)	Fair-poor health (n=50)
General health status			
General health status categories (n (%))			
Good to excellent	149 (74.9)		
Fair to poor	50 (25.1)		
General health status summary scores (range 0-100)[a] (median (IQR))			
PCS	49.0 (45.2; 57.6)	46.4 (44.5; 52.7)	63.3 (54.5; 68.4)
MCS	48.3 (42.1; 54.6)	45.8 (40.9; 50.5)	59.8 (51.4; 66.3)
Food insecurity status			
Food insecurity status score (range 0-18) (median (IQR))	0.0 (0.0; 2.0)	0.0 (0.0; 2.0)	2.0 (0.0; 5.0)
Food insecurity status categories (n (%))			
Food secure	150 (75.4)	121 (81.2)	29 (58.0)
Food insecure	49 (24.6)	28 (18.8)	21 (42.0)
Characteristics			
Age (years) (median (IQR))	38.0 (33.8; 43.5)	37.3 (33.6; 43.1)	39.4 (34.3; 44.7)
Sex (n (%) female)	169 (84.9)	125 (83.9)	44 (88.0)
Household income (n (%))			
Below basic needs budget	129 (64.8)	90 (60.4)	39 (78.0)
Above basic needs budget	70 (35.2)	59 (39.6)	11 (22.0)
Educational level[b] (n (%))			
Low (≤ISCED 2)	77 (38.7)	49 (32.9)	27 (54.0)
Higher (≥ISCED 3)	122 (61.3)	100 (67.1)	23 (46.0)
Migration background (n (%))			
Western (including Dutch)	32 (16.1)	24 (16.1)	9 (18.0)
Turkish	38 (19.1)	31 (20.8)	7 (14.0)
Moroccan	56 (28.1)	41 (27.5)	15 (30.0)
Surinamese	21 (10.6)	13 (8.7)	7 (14.0)
Other	52 (26.1)	41 (27.5)	12 (24.0)
Living situation (n (%))			
Married/ partner	139 (69.8)	114 (76.5)	25 (50.0)
Single	60 (30.2)	35 (23.5)	25 (50.0)

Employment status (n (%))			
Currently employed	88 (44.2)	72 (48.3)	16 (32.0)
Employed in the past	74 (37.2)	49 (32.9)	25 (50.0)
Never employed	37 (18.6)	28 (18.8)	9 (18.0)
BMI (kg/m^2)(median (IQR))	27.7 (24.4; 31.1)	27.2 (23.9; 30.1)	29.1 (26.4; 33.3)
Smoking status (n (%))			
Current smoker	33 (16.6)	23 (15.4)	10 (20.0)
Past smoker	36 (18.1)	24 (16.1)	12 (24.0)
Non-smoker	130 (65.3)	102 (68.5)	28 (56.0)
Health issue presence (n (%) yes)			
Obesity	62 (31.2)	39 (26.2)	23 (46.0)
High blood pressure	14 (7.0)	8 (5.4)	6 (12.0)
High cholesterol	14 (7.0)	9 (6.0)	5 (10.0)
Surgery on the heart	6 (3.0)	3 (2.0)	3 (6.0)
Heart attack	1 (0.5)	1 (0.7)	0 (0.0)
Asthma	20 (10.1)	10 (6.7)	10 (20.0)
COPD	3 (1.5)	0 (0)	3 (6.0)
Diabetes Mellitus	8 (4.0), of which 1 Type 1, 6 Type 2, 1 unknown	2 (1.3), of which 1 Type 1, 1 Type 2	6 (12.0), of which 5 Type 2, 1 unknown
Anemia in past 12 months	38 (19.1)	23 (15.4)	15 (30.0)
Total number of comorbid health issues (median (IQR))[c]	1.0 (0.0; 1.0)	0.0 (0.0; 1.0)	1.0 (0.0; 2.0)

10th imputation was used for continuous variables
IQR: interquartile range; PCS: Physical Component Summary; MSC: Mental Component Summary; ISCED: International Standard Classification of Education; BMI: Body mass index; COPD: Chronic Obstructive Pulmonary Disease
[a]PCS and MCS scores range from 0-100, higher scores indicate a poorer health
[b]ISCED 2= Lower secondary education; ISCED 3= Upper secondary education
[c]Mean (±SD) total number of comorbid health issues: total population 0.84 (±1.09); good-excellent health 0.63 (±0.95); fair-poor health 1.44 (±1.26)

Variables explaining poor physical and mental health status

Crude associations with physical and mental health

The dichotomous food insecurity status was a strong individual covariate explaining both poorer physical (PCS) and mental (MCS) health in the unadjusted models: food insecure participants had a 5.79 (95%CI: 2.89;8.68) points higher PCS and a 7.61 (95%CI: 4.67;10.54) points higher MCS compared to food secure participants (**Table 2)**.

Table 2. Crude associations between selected covariates and the PCS and MCS

	PCS[a]		MCS[a]	
	β-Coefficient	95%CI	β-Coefficient	95%CI
Age (years)	0.20	0.025; 0.37*	0.17	-0.013; 0.36
Educational level[b]				
Low (≤ISCED 2)	*Reference*		*Reference*	
Higher (≥ISCED 3)	-1.87	-4.56; 0.84	-3.33	-6.11; -0.56*
Household income				
Above basic needs budget	*Reference*		*Reference*	
Below basic needs budget	4.76	2.10; 7.42***	4.22	1.36; 7.09**
Living situation				
Married/ partner	*Reference*		*Reference*	
Single	3.30	0.47; 6.13*	1.84	-1.13; 4.82
Employment status				
Currently employed	*Reference*		*Reference*	
Currently not employed	2.62	0.023; 5.22*	5.07	2.44; 7.71***
Migration background				
Western	*Reference*		*Reference*	
Non-Western	1.28	-2.26; 4.82	0.57	-3.11; 4.24
Food insecurity score (0-18)	0.91	0.46; 1.35***	1.12	0.66; 1.57***
Food insecurity status				
Food secure	*Reference*		*Reference*	
Food insecure	5.79	2.89; 8.68***	7.61	4.67; 10.54***

*Indicates a p-value <0.05; ** indicates a p-value <0.01; *** indicates a p-value <0.001
PCS: Physical Component Summary; MSC: Mental Component Summary; ISCED: International Standard Classification of Education
[a]PCS and MCS scores range from 0-100, higher scores indicate a poorer health
[b]ISCED 2= Lower secondary education; ISCED 3= Upper secondary education

Multivariable models explaining poor physical and mental health

Adding the food insecurity score as a covariate to the model with PCS as the outcome, this was the most important covariate (standardized β:0.21), followed by age (standardized β:0.16), household income (standardized β:0.14) and living situation (standardized β:0.13). With MCS as outcome, including food insecurity score as a covariate, again this was the most important covariate (standardized β 0.27), followed by employment status (standardized β:0.20), and age (standardized β:0.11) (**Table 3**).

The optimism-corrected R^2 for the multivariable model with PCS as outcome improved from 6.3% to 9.2% when adding food insecurity score as a covariate, an improvement in explained variance of 2.9%. The optimism-corrected R^2 for the multivariable model with MCS as outcome improved from 5.8% to 11.0% when food insecurity score was included as a covariate, an improvement in explained variance of 5.2%. The models including food insecurity score were a better fit compared to the models not including food insecurity score, as indicated by lower optimism-corrected RMSEs (**Table 3**).

Table 3. Associations between selected covariates and the PCS and MCS, with and without including food insecurity status score as a covariate

	Multivariable model without food insecurity status score			**Multivariable model with food insecurity status score**		
	Standardized β	**β-Coefficient**	**95%CI**	**Standardized β**	**β-Coefficient**	**95%CI**
PCS[a]						
Age (years)	0.17	0.20	0.028; 0.38*	0.16	0.19	0.019; 0.37*
Educational level[a]						
Low (≤ISCED 2)	*Reference*			*Reference*		
Higher (≥ISCED 3)	0.026	0.27	-2.61; 3.14	0.029	0.55	-2.27; 3.38
Household income						
Above basic needs budget	*Reference*			*Reference*		
Below basic needs budget	0.18	3.60	0.41; 6.79*	0.14	2.70	-0.49; 5.89
Living situation						
Married/ partner	*Reference*			*Reference*		
Single	0.13	2.91	0.006; 5.82	0.13	2.65	-0.198; 5.502
Employment status						
Currently employed	*Reference*			*Reference*		
Currently not employed	0.059	1.12	-1.87; 4.10	0.052	0.98	-1.94; 3.90
Migration background						
Western	*Reference*			*Reference*		
Non-Western	0.044	1.11	-2.38; 4.59	0.040	1.02	-2.40; 4.44
Food insecurity score (0-18)	*Not included*			0.21	0.68	0.22; 1.14**
	$R^2_{optimism\text{-}corrected}$: 0.063 $RMSE_{optimism\text{-}corrected}$: 9.09			$R^2_{optimism\text{-}corrected}$: 0.092 $RMSE_{optimism\text{-}corrected}$: 9.05		

MCS[a]						
Age (years)	0.12	-0.15	-0.34; 0.051	0.11	0.13	-0.061; 0.32
Educational level[b]						
Low (≤ISCED 2)	*Reference*			*Reference*		
Higher (≥ISCED 3)	-0.048	0.95	-2.076; 3.97	-0.028	-0.56	-3.48; 2.36
Household income						
Above basic needs budget	*Reference*			*Reference*		
Below basic needs budget	0.083	-1.67	-5.13; 1.78	0.023	0.46	-2.91; 3.83
Living situation						
Married/ partner	*Reference*			*Reference*		
Single	0.10	-2.07	-5.17; 1.03	0.082	1.72	-1.27; 4.71
Employment status						
Currently employed	*Reference*			*Reference*		
Currently not employed	0.21	-4.04	-7.16; -0.92*	0.20	3.85	0.85; 6.86*
Migration background						
Western	*Reference*			*Reference*		
Non-Western	0.002	-0.051	-3.70; 3.60	-0.003	-0.066	-3.59; 3.46
Food insecurity score (0-18)	*Not included*			0.27	0.92	0.45; 1.39***
	$R^2_{optimism\text{-}corrected}$: 0.058 $RMSE_{optimism\text{-}corrected}$: 9.42			$R^2_{optimism\text{-}corrected}$: 0.11 $RMSE_{optimism\text{-}corrected}$: 9.13		

*Indicates a p-value <0.05; ** indicates a p-value <0.01; *** indicates a p-value <0.001
PCS: Physical Component Summary; MSC: Mental Component Summary; ISCED: International Standard Classification of Education; RMSE: Root Mean Squared Error
[a]PCS and MCS scores range from 0-100, higher scores indicate a poorer health
[b]ISCED 2= Lower secondary education; ISCED 3= Upper secondary education

Discriminative performance

Including the food insecurity score as a covariate for the dichotomous PCS score improved the optimism-corrected C-statistic from 0.64 (95%CI: 0.59;0.71) to 0.69 (95%CI: 0.62;0.73) and Nagelkerke's R^2 from 9.6% to 14.0%, an improvement of 4.4%. Including the food insecurity score as a covariate for the dichotomous MCS score improved the C-statistic from 0.65 (95%CI: 0.55;0.68) to 0.70 (95%CI: 0.61;0.73) and Nagelkerke's R^2 from 5.4% to 11.0%, an improvement of 5.6% (**Table 4**).

Table 4. Optimism-corrected C-statistic and Nagelkerke's R^2 for the multivariable models explaining dichotomous PCS and MCS scores, with and without including food insecurity status score as a covariate

	Multivariable model without food insecurity status score	Multivariable model with food insecurity status score
PCS (dichotomous score)[a]		
C-statistic $_{optimism\text{-}corrected}$ (95%CI)	0.64 (0.59; 0.71)	0.69 (0.62; 0.73)
Nagelkerke's $R^2_{optimism\text{-}corrected}$	0.096	0.14
MCS (dichotomous score)[a]		
C-statistic $_{optimism\text{-}corrected}$ (95%CI)	0.65 (0.55; 0.68)	0.70 (0.61; 0.73)
Nagelkerke's $R^2_{optimism\text{-}corrected}$	0.054	0.11

PCS: Physical Component Summary; MSC: Mental Component Summary
[a]The PCS and MCS scores were dichotomized into scores below 50 and scores above 50

Discussion

The results of our study indicate that food insecurity status was a strong covariate explaining both poorer physical and mental health in unadjusted models. In the multivariable models explaining PCS and MCS, from all included socioeconomic risk factors, the food insecurity score was the most important covariate. Including food insecurity score in those models led to an increase in explained variance of nearly one-half for PCS, an almost two-fold increase in explained variance for MCS, and a slightly better model fit. Further analyses showed that including food insecurity score improved the discriminative ability between those individuals most at risk of poor health (i.e., the ability to distinguish between shore having a score below 50 and those having a score above 50, which indicates poorest physical and mental health), reflected by an increased C-statistic and an improvement in explained variance for both PCS and MCS. From these results it follows that food insecurity status is of added value in explaining poor health, particularly mental health, beyond traditionally used socioeconomic risk factors (i.e., age, educational level, household income level, living situation, employment status, and migration background). Therefore, including food insecurity status may be important for effective risk stratification to identify populations at increased risk of poor health.

In line with previous literature (11, 14), our results show that experiencing food insecurity is associated with poorer physical and mental health. The differences between food secure and food insecure participants in physical and mental health that were found in our study were well above the minimal 'Clinically Important Difference' of 3-5 points proposed by Samsa, Edelman & Rothman (1999:(30)). Food insecurity may be linked to poor health through multiple potential pathways such as shifting towards less expensive, lower-quality foods (31) and elevated levels of depression and (chronic) stress (14). Also, impaired adherence to medical recommendations due to budgetary constraints may play a role, for example having to choose between food and medicine (32). Food insecurity is forecasted to increase due to the current COVID-19 pandemic, thereby further increasing the risk of poor health in the short-term and long-term through several pathways (33). For example, a recent study including over 2700 low-income Americans showed that food insecurity caused by the COVID-19 pandemic was highly associated with mental health issues (34).

As described by Predmore et al. (2019), addressing social determinants of health within health care organizations contributes to achieving the Triple Aim (35). With regard to predictive risk modelling, one of their proposed applications is "social predictive modelling and case finding" by incorporating social risk factors (35), as was done in our study. However, despite the large body of literature showing that incorporating social determinants of health improves the ability to identify people at risk for poor health (11, 35), food insecurity status is barely used for the identification of populations at increased risk of poor health.

Elaborating on this knowledge, our results underline the importance of using food insecurity status data to identify populations at increased risk of poor health in a Dutch urban setting. Implementing this requires availability of data on food insecurity status, emphasizing the urge to start routinely collecting data on food insecurity status in the Netherlands. Screening for food insecurity status has value beyond better identification of people at risk of poor health, because it also helps making health care providers aware of the existence of social risk factors such as food insecurity. Only when they are aware of these issues among their patients, they can address them and improve access to resources, if available (36). Multiple tools are currently available for screening for food insecurity, ranging from very short, one-item screening tools to more elaborate surveys (36). For example, short, validated screening tools are available that allow minimal additional time and costs associated with the screening,

which helps to maintain acceptability for both the person being screened and the person performing the screening (37). In the Netherlands, screening among high-risk groups could be done in clinical settings such as the general practice (as most Dutch citizens regularly visit their primary care physician) and/ or nonclinical settings such as community centers (as these centers are generally visited by disadvantaged people) (35). Importantly, the identification of people at risk of food insecurity should ideally be followed by referral to effective interventions or resources, and options to integrate these into routine care in the Dutch context should be further explored. This may also call for referral to resources across domains, such as the social domain (i.e., social prescribing), which is challenging in the current Dutch context due to different funding streams.

Our results suggest the need for screening high-risk groups for food insecurity and the development and implementation of interventions addressing food insecurity and its consequences (while incorporating the needs and preferences of this population and the health care provider that performs the screening). Together, these actions are expected to contribute to the Quadruple Aim by improving experienced quality of care (as underlying needs associated with food insecurity and its consequences can be addressed), reducing healthcare costs (which will follow from reduced food insecurity prevalence), improved provider experience (as also their needs and preferences are considered and they can offer better help to their patients in need), and ultimately improved population health (2, 38).

Our study is among the first to investigate the added value of food insecurity status in explaining poor health. Our study is strengthened by the use of validated measures of our main outcome and covariate. As a measure of poor health, we used the SF-12 which is a widely used, reliable and well-validated measure of general health (19), and strongly associated with both short and long-term mortality risk (39) and higher health care use and costs (21). Previous research has indicated that the SF-12 is a suitable alternative for the more elaborate SF-36, also in the Dutch population (40).

We assessed food insecurity status using the widely applied 18-item USDA-HFSSM, which is regarded as the golden standard for Western countries (41). Because being poor is not one-to-one related to experiencing food insecurity, it is important not to use indirect indicators such as income as a proxy for food insecurity status (42), as was done in the current study. Food insecurity is a complex phenomenon that encompasses many dimensions, reflecting a condition where there is unreliable

(physical or economic) access to sufficient food. Food insecurity may for example include (anxiety and worries about) not having enough (healthy) foods, the inability to acquire food in socially acceptable ways, or (perceived) social exclusion because of the inability to participate in the social and cultural norms. One could argue that food insecurity interacts with adverse health outcomes, and therefore reflects a potential syndemic (i.e., two or more mutually enhancing health conditions that cluster within a specific population, in light of socio-ecological inequality and inequity that enhances this adverse interaction (43)). Himmelgreen et al. (2020) clearly describe this in their proposed dynamic model of the food insecurity- diet-related chronic diseases syndemic (44). In short, this model shows how socio-ecological inequality and inequity induce food insecurity and associated stress, which has an amplifying adverse effect on nutrition and health status (also depending on the life course stage), which can ultimately result in diet-related chronic disease(s). These diseases create a feedback loop that can create a vicious cycle, thereby amplifying adverse health outcomes (44). This theory helps explain the added value of food insecurity beyond traditional social determinants of health in explaining poor health, as food insecurity may also comprise this syndemic effect. It should be noted that our measure of food insecurity, based on the USDA-HFSSM, mostly focusses on economic access to food, and may still not fully capture other dimensions of food insecurity that are also important for explaining poor health. However, we found a strong association between the food insecurity status as assessed using the USDA-HFSSM and poor physical and mental health, indicating that this measure adequately captured the food insecurity dimensions important for health.

Another important consideration is that we treated food insecurity as a covariate explaining poor health and aiding risk-stratification, not as a health outcome on itself. Conceptualizing health from a broader, multidimensional and positive perspective (e.g., 'positive health'), health can be seen as more than the mere absence of disease, as it also includes functioning/resilience, resources/supports and quality of life (45). From this perspective, one could argue that food insecurity is a health outcome on itself rather than a covariate explaining poor health. For treating food insecurity as an outcome, different analyses and models than the ones used in the current study would have been more appropriate. However, our approach using a social determinant such as food insecurity as a covariate for better identification of high-risk populations is better aligned with how the current Dutch healthcare system operates.

It should further be noted that, although including food insecurity in the models improved the explained variance in poor health, these models still explained only about ten percent of health differences. As health is a multidimensional concept that is influenced by many factors, it is not uncommon to find a relatively low explained variance (e.g., (46)). This suggests that besides food insecurity, other factors such as lifestyle behaviors or chronic stress, or social factors such as social networks, are important for explaining poor health. For example, a large study among middle-aged and older adults in Norway showed that the association between SEP and health was mediated by loneliness, suggesting that this is an important factor contributing to poor health (46).

Our study is strengthened by accounting for statistical optimism in our multivariate models explaining poor health. We used the same dataset to fit the models and to assess the validity of our model, whereas ideally we would have externally validated our results using a test dataset from the same population to verify your results, which was not possible in our study (27). This can lead to optimistic estimates of model performance (i.e., the models built using the same dataset as the one that was used to fit the models performs better in explaining poor health than it would have if a different dataset was used). One solution to assess the model performance without having a test set is by using bootstrapping, as was done in our study.

An important methodological consideration is the use of cross-sectional data for our analyses, which is not suitable for a traditional clinical prediction models wherein a future outcome is predicted and temporality can be ensured. In addition, we assume that experiencing food insecurity precedes poor health, which is plausible considering previous research, however, it is also possible that poor health leads to food insecurity (for example, through increased stress, or medical costs or job loss leading to reduced budgets for food). The issue of reverse causality cannot be ruled out using cross-sectional data. Our approach was, however, suitable for our main aim as it enabled us to show that including information on food insecurity and adding this to traditional social determinants of health seems to have value for better explaining poor health.

Further, our sample mainly included women living in a disadvantaged urban setting, and therefore the results may not be generalizable to the general Dutch population. Previous studies indicate that women are more at risk of food insecurity and its accompanying health consequences (e.g., (47)), but due to the small number of men

in our study sample we were unable to explore these gender differences further in the current study. Also, the sample size was relatively small, especially when compared to large-scale food insecurity screening surveys such as those annually conducted by the United States Department of Agriculture. However, it should be noted that food insecurity is a relatively understudied area in the Netherlands, and the presented results can stimulate larger-scale, routine screening for food insecurity in the Netherlands as well. Future studies should validate our results in other populations and settings, ideally using longitudinal data to confirm the temporality assumption.

Conclusions

Food insecurity status is important for explaining poor health, particularly mental health, beyond other socioeconomic risk factors in disadvantaged communities. Our results need confirmation in other populations and settings. Food insecurity status hereto needs to be assessed in routine data collections. These data can be used to better identify people with increased risk of poor health and optimize the allocation of available resources to the people most in need.

Strengths and limitations of this study

- Socioeconomic risk factors such as age, educational level, household income level, living situation, employment status, and migration background are associated with poor health, but the ability to explain poor health with these traditional socioeconomic risk factors is limited.
- Our study is among the first to investigate the value of assessing food insecurity and adding this to traditional social determinants of health for explaining poor physical and mental health.
- Food insecurity is a relatively understudied area in the Netherlands, and the presented results can stimulate larger-scale, routine screening for food insecurity in the Netherlands.
- Our study population mainly included women living in a disadvantaged urban setting, and therefore the results may not be generalizable to the general Dutch population.
- Our study is strengthened by the use of validated measures of our main outcome and covariate and by accounting for statistical optimism in our multivariate models, however, future studies are warranted to externally validate our results to verify your findings, also in other populations and settings.

Abbreviations

BMI	Body Mass Index
CI	Confidence Interval
COPD	Chronic Obstructive Pulmonary Disease
US	United States
USDA-HFSSM	United States Department of Agriculture Household Food Security Survey Module
SEP	Socioeconomic position
SF-12	12-Item Short Form Health Survey
PCS	Physical component summary
MCS	Mental component summary
ISCED	International Standard Classification of Education
IQR	Interquartile range
ROC curve	Receiver Operating Characteristic curve

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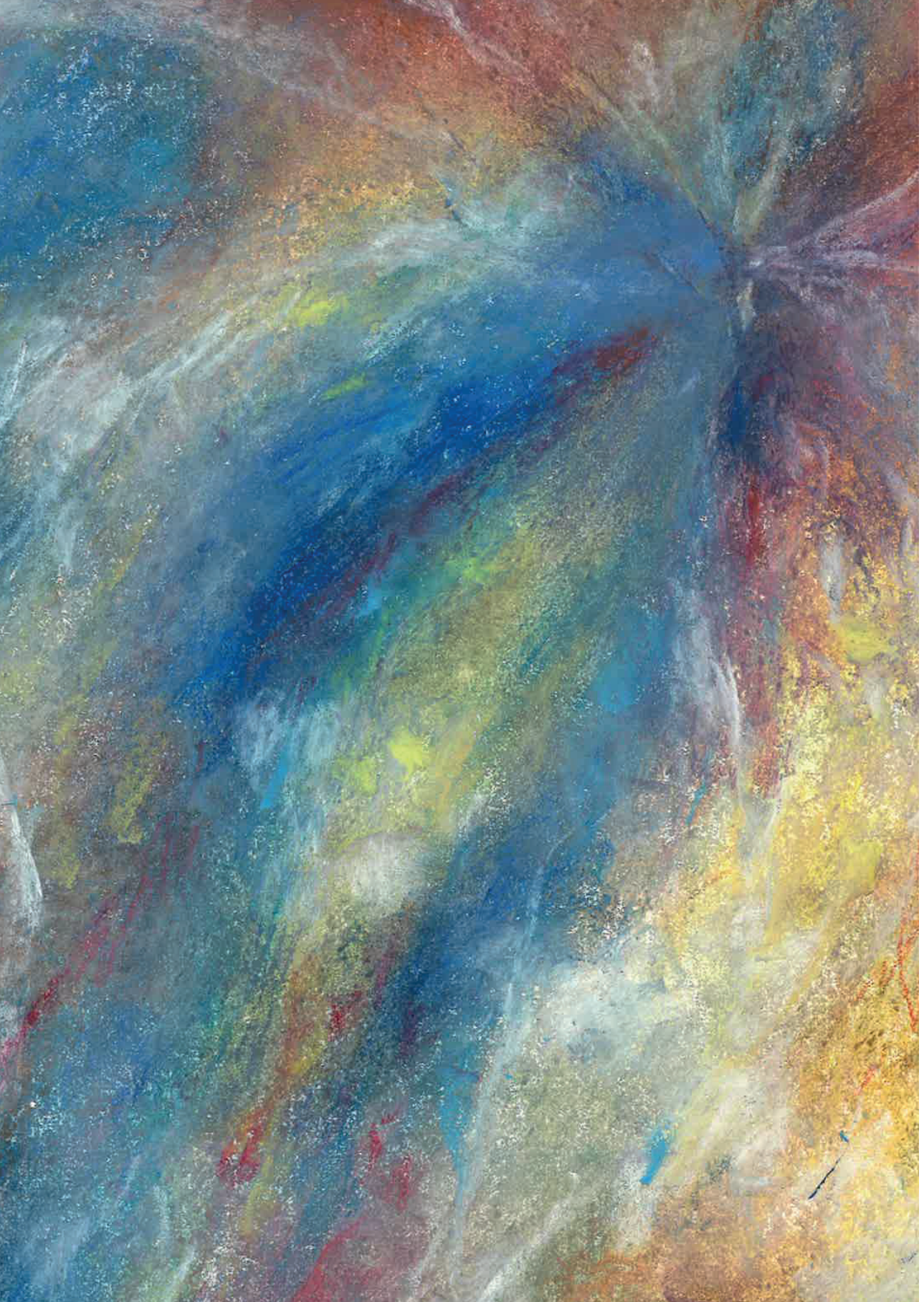
Additional material Chapter 3

Supplemental Table 1. Food insecurity status, general health status and participant characteristics, split by food insecurity status categories

	Total population (n=199)	Food secure (n=150)	Food insecure (n=49)
Food insecurity status			
Food insecurity status score (range 0-18) (median (IQR))	0.0 (0.0; 2.0)		
Food insecurity status categories (n (%))			
Food secure	150 (75.4)		
Food insecure	49 (24.6)		
General health status			
Categories (n (%))			
Good to excellent	149 (74.9)	121 (80.7)	28 (57.1)
Fair to poor	50 (25.1)	29 (19.3)	21 (42.9)
General health status summary scores[a] (median (IQR))			
PCS (range 0-100)	49.0 (45.2; 57.6)	47.4 (45.2; 54.8)	56.2 (46.4; 66.1)
MCS (range 0-100)	48.3 (42.1; 54.6)	46.3 (41.3; 52.9)	54.0 (46.3; 63.6)
Characteristics			
Age (y) (median (IQR))	38.0 (33.8; 43.5)	37.5 (33.3; 42.5)	39.7 (35.0; 45.3)
Sex (n (%) female)	169 (84.9)	130 (86.7)	39 (79.6)
Household income (n (%))			
Below basic needs budget	129 (64.8)	87 (58.0)	41 (83.7)
Above basic needs budget	70 (35.2)	63 (42.0)	8 (16.3)
Educational level[b] (n (%))			
Low (≤ISCED 2)	77 (38.7)	50 (33.3)	26 (53.1)
Higher (≥ISCED 3)	122 (61.3)	100 (66.7)	23 (46.9)
Migration background (n (%))			
Western (including Dutch)	32 (16.1)	26 (17.3)	6 (12.2)
Turkish	38 (19.1)	30 (20.0)	8 (16.3)
Moroccan	56 (28.1)	41 (27.3)	15 (30.6)
Surinamese	21 (10.6)	16 (10.7)	5 (10.2)
Other	52 (26.1)	37 (24.7)	15 (30.6)
Living situation (n (%))			
Married/ partner	139 (69.8)	110 (73.3)	29 (59.2)
Single	60 (30.2)	40 (26.7)	20 (40.8)
Employment status (n (%))			
Currently employed	88 (44.2)	73 (48.7)	15 (30.6)
Employed in the past	74 (37.2)	49 (32.7)	25 (51.0)
Never employed	37 (18.6)	28 (18.7)	9 (18.4)
BMI (kg/m^2)(median (IQR)	27.7 (24.4; 31.1)	27.3 (24.2; 30.1)	29.4 (26.1; 33.1)
Smoking status (n (%))			
Current smoker	33 (16.6)	17 (11.3)	16 (32.7)
Past smoker	36 (18.1)	26 (17.3)	10 (20.4)
Non-smoker	130 (65.3)	107 (71.3)	23 (46.9)

Lifestyle-related disease presence (n (%) yes)			
Obesity	62 (31.2)	39 (26.0)	23 (46.9)
High blood pressure	14 (7.0)	9 (6.0)	5 (10.2)
High cholesterol	14 (7.0)	9 (6.0)	5 (10.2)
Surgery on the heart	6 (3.0)	5 (3.3)	1 (2.0)
Heart attack	1 (0.5)	1 (0.7)	0 (0.0)
Asthma	20 (10.1)	12 (8.0)	8 (16.3)
COPD	3 (1.5)	1 (0.7)	2 (4.1)
Diabetes Mellitus	8 (4.0), of which 1 Type 1;6 Type 2;1 unknown	5 (3.3), of which 1 Type 1;3 Type 2;1 unknown	3 (6.1), of which 3 Type 2
Anemia in past 12 months	38 (19.1)	26 (17.3)	12 (24.5)
Total nr of comorbid health issues present (median (IQR))[c]	0.0 (0.0; 1.0)	0.0 (0.0; 1.0)	1.0 (0.0; 2.0)

10th imputation was used for continuous variables
IQR: interquartile range; PCS: Physical Component Summary; MSC: Mental Component Summary; ISCED: International Standard Classification of Education; BMI: Body mass index; COPD: Chronic Obstructive Pulmonary Disease
[a]PCS and MCS range from 0-100, higher scores indicate a poorer health
[b]ISCED 2= Lower secondary education; ISCED 3= Upper secondary education
[c]Mean (±SD) total number of comorbid health issues present: total population 0.84 (±1.09); food secure 0.71 (±0.98); food insecure 1.22 (±1.33))



CHAPTER 4

Needs and perceptions regarding healthy eating among people at risk of food insecurity: a qualitative analysis

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Abstract

Background: Healthy eating behavior is an essential determinant of overall health. This behavior is generally poor among people at risk of experiencing food insecurity, which may be caused by many factors including perceived higher costs of healthy foods, financial stress, inadequate nutritional knowledge, and inadequate skills required for healthy food preparation. Few studies have examined how these factors influence eating behavior among people at risk of experiencing food insecurity. We therefore aimed to gain a better understanding of the needs and perceptions regarding healthy eating in this target group.

Methods: We conducted a qualitative exploration grounded in data using inductive analyses with 10 participants at risk of experiencing food insecurity. The analysis using an inductive approach identified four core factors influencing eating behavior: Health related topics; Social and cultural influences; Influences by the physical environment; and Financial influences.

Results: Overall, participants showed adequate nutrition knowledge. However, eating behavior was strongly influenced by both social factors (e.g., child food preferences and cultural food habits), and physical environmental factors (e.g., temptations in the local food environment). Perceived barriers for healthy eating behavior included poor mental health, financial stress, and high food prices. Participants had a generally conscious attitude towards their financial situation, reflected in their strategies to cope with a limited budget. Food insecurity was mostly mentioned in reference to the past or to others and not to participants' own current experiences. Participants were familiar with several existing resources to reduce food-related financial strain (e.g., debt assistance) and generally had a positive attitude towards these resources. An exception was the Food Bank, of which the food parcel content was not well appreciated. Proposed interventions to reduce food-related financial strain included distributing free meals, facilitating social contacts, increasing healthy food supply in the neighborhood, and lowering prices of healthy foods.

Conclusion: The insights from this study increase understanding of factors influencing eating behavior of people at risk of food insecurity. Therefore, this study could inform future development of potential interventions aiming at helping people at risk of experiencing food insecurity to improve healthy eating, thereby decreasing the risk of diet-related diseases.

Background

Healthy eating behavior is an essential determinant of overall health. Previous literature extensively shows that people with lower socioeconomic status (SES) generally exhibit less healthy eating behaviors (1) and have increased risk of obesity and related illnesses (2, 3). The same holds for people experiencing food insecurity (4-6), which is an inadequate physical and economic access to adequate food that meets dietary needs and food preferences (7). The concept of food insecurity is closely related to lower SES, although this is a complex relationship and people with lower SES do not always experience food insecurity and vice versa (8). However, it is evident that food insecurity is more common among people with lower SES and therefore people with lower SES or living in disadvantaged neighborhoods have an increased risk of experiencing food insecurity (9).

Thus far, knowledge on food insecurity in Europe is limited (10). A previous study among Dutch Food Bank recipients found a food insecurity prevalence of almost 73 percent (11). Our recent study has shown that approximately one quarter of families living in disadvantaged neighborhoods in The Netherlands experienced food insecurity (12). Results of this study further showed that general health, diet quality, and weight were suboptimal, especially among food insecure participants. A possible intervention for reducing food insecurity is the Food Bank, but despite the high prevalence of food insecurity it was hardly used (12). The Dutch Food Bank is a non-governmental organization that distributes donated food to offer temporal food aid to people in need (13). This is done through providing food parcels, meant to supplement the usual diet, to eligible persons. Eligibility is based on household size-adjusted monthly disposable income. The food parcel content largely depends on donated foods and therefore varies per time and location of Food Bank. Recent research indicated that the parcel content was generally not in line with nutritional guidelines, which may contribute to suboptimal dietary intake among people eligible for Food Bank use (14).

Various factors may contribute to the generally suboptimal eating behavior among people at risk of experiencing food insecurity, including stress (15-17), inadequate knowledge and skills regarding healthy eating and food preparation (18), and higher costs of healthy foods (19). These higher costs might be an even more prominent issue than previously, since the Dutch Government recently increased taxes of all basic necessities such as foods (including foods that are considered healthy like fruit

and vegetables) from 6 to 9 percent (20). This price increase may lead to less healthy eating behavior, as previous research shows that pricing affects food choices (21, 22).

Much uncertainty still exists about contributing factors to suboptimal eating behavior among people at risk of experiencing food insecurity. Improving insight is essential for developing targeted interventions to support this population, focused on improving healthy eating behavior and thereby decreasing diet-related disease risk. Therefore, we aimed to gain a better understanding of the needs and perceptions regarding healthy eating behavior of people at risk of experiencing food insecurity living in disadvantaged neighborhoods in the Netherlands.

Methods

Rationale and study sample

Participants were selected from a sample of 242 participants included in a cross-sectional study on food insecurity in disadvantaged neighborhoods in The Hague, The Netherlands (12). These neighborhoods were selected based on predefined criteria used by the Dutch Government to identify disadvantaged neighborhoods in the Netherlands (23). Participants lived in or near the preselected disadvantaged neighborhoods and had at least one child below the age of 18 years living at home. A detailed description of the methods and results of this study are described elsewhere (12). Participants who provided valid contact information were invited to take part in an interview. None of the participants that agreed to participate dropped out of the study. Reasons for refusing to participate included being too busy, thinking an interview of approximately 60 minutes was too long, and being or going on holiday. A convenience sample, taking into account the diversity of the study sample, of a total of 10 participants (either fathers or mothers, one parent per household) were interviewed. After those 10 interviews, thematic saturation was reached. Interviews were conducted between April and July 2018. Sociodemographic characteristics, food insecurity status and diet quality scores of the participants were previously assessed (12). Food insecurity status was assessed using the 18-item United States Department of Agriculture (USDA) Household Food Security Survey Module. Affirmative responses to the questions (described in **Additional Table 1**) were summed and resulted in a continuum of food insecurity status ranging from 0-18, categorized as 'food secure' (0-2 affirmative responses), and 'food insecure' (≥3 affirmative responses), according to the USDA standards (24, 25). Dietary intake was assessed using the Dutch Healthy

Diet Food Frequency Questionnaire (DHD-FFQ) (26). Based on this dietary intake data we constructed a food group-based 6-component diet quality score (**Additional Table 2**). Each component score reflected the adherence to the dietary guidelines of the concerning food group. Component scores were summed to obtain the total diet quality score (range 0-60), with higher scores indicating a better diet quality. Written informed consent was obtained from all participants. Participants received a financial compensation of 10 euros for their effort and any travel expenses were refunded. The study was approved by the Medical Ethics Committee of Leiden University Medical Centre (P17.164).

Study design

Face-to-face open interviews were conducted, guided by a topic list (**Additional Table 3**). The topic list was created at the start of the study based on issues raised in the previous study (12) and consisted of topics to discuss and open ended example questions for each topic to guide the interviewer. These topics and example questions were discussed within the research team. The interviews started with general questions concerning participants' background, family, and living conditions to make the participant feel at ease, followed by questions focusing on perceptions regarding healthy eating, including knowledge; skills; external, social, and cultural influences; health; finances; stress; environmental factors; opinions about eating on a low budget; existing resources; and Food Bank use. Interviewees were also free to introduce other topics that were of interest to them. The topic list was merely used as guidance during the interviews and was re-evaluated after each interview and if appropriate adjusted or complemented with new topics that emerged during the interview. During the interviews, two members of the study team were present; one of them conducted the interview and the other observed. All interviews were audio-recorded with participants' permission using a digital voice recorder and transcribed verbatim. Participants were interviewed at a time and place that was most convenient to them. Interviews were held for 22 to 76 minutes with an average interview time of 47 minutes.

Analysis

We used a general inductive approach to analyze the data (27). Segments of the interview texts in the transcripts were coded using open coding, i.e., codes were built and modified throughout the coding process. Some text segments were assigned to

more than one code category and text segments that were not relevant for the study objectives were not included in any category. During the process, some of the codes were merged with other codes that had a similar meaning, resulting in 79 codes. One researcher coded the interviews. A second researcher coded two randomly selected interviews to check inter-rater reliability (IRR) (28), calculated as:

$$IRR = \frac{number\ of\ agreements}{number\ of\ agreements + disagreements}$$

We found an IRR of 93%.

Codes were grouped into subthemes, which were then grouped into main themes (29). Four main themes were identified that comprised the allocated codes for all transcripts. No new themes emerged towards the end of the study, suggesting thematic saturation was reached.

The software Atlas.ti version 7.5.6 (Scientific Software Development, Berlin) was used to assist the coding process and extraction of quotes and themes. The quotes presented in this paper were chosen based on their illustration of the described theme or clarifying role of the common or uncommon viewpoints.

Results

Two males and eight females were interviewed, aged between 35 and 55 years (**Table 1**). Most participants had an income below the basic needs budget and were lower educated. Six participants were single parents and half of the participants had a paid job. Participants had a Moroccan, Colombian, Surinamese, Curacao, or Polish migration background. Participants were all either overweight or obese, based on their self-reported height and weight. Seven participants were classified as food insecure. The four main themes related to healthy eating behavior and the corresponding subthemes that were identified in the analyses are described below and depicted in **Figure 1**.

Table 1 Sociodemographic characteristics of the participants (n=10)

	Age category in years	Sex	Educational level	Household income	Employment status	Marital status	Migration background	Food Bank use	BMI1 category	Diet quality score	Food security status
Participant number											
1	45-50	Male	ISCED 2	Below basic needs budget	Currently paid job	Two parent household	Moroccan	No	Overweight	36/ 60	Food insecure
2	40-45	Female	ISCED 2	Below basic needs budget	Currently no paid job	Single parent	Colombian	No	Overweight	31/ 60	Food insecure
3	45-50	Female	ISCED 2	Below basic needs budget	Currently no paid job	Single parent	Surinamese	No	Obese Class I (moderately obese)	29/ 60	Food insecure
4	40-45	Female	ISCED 5	Below basic needs budget	Currently paid job	Single parent	Surinamese	No	Overweight	33/ 60	Food secure
5	40-45	Female	ISCED 2	Below basic needs budget	Currently paid job	Single parent	Curacao	No	Obese Class I (moderately obese)	41/ 60	Food insecure
6	40-45	Male	ISCED 1	Below basic needs budget	Currently no paid job	Two parent household	Moroccan	Yes	Obese Class I (moderately obese)	35/ 60	Food insecure
7	35-40	Female	ISCED 4	Below basic needs budget	Currently no paid job	Two parent household	Polish	No	Obese Class I (moderately obese)	31/ 60	Food secure
8	50-55	Female	ISCED 1	Below basic needs budget	Currently no paid job	Single parent	Moroccan	No	Obese Class III (Very severely obese)	46/ 60	Food insecure
9	45-50	Female	ISCED 7	Above basic needs budget	Currently paid job	Two parent household	Surinamese	No	Overweight	32/ 60	Food secure
10	35-40	Female	ISCED 3	Above basic needs budget	Currently paid job	Single parent	Surinamese	No	Overweight	43/ 60	Food insecure

[1]BMI: Body Mass Index

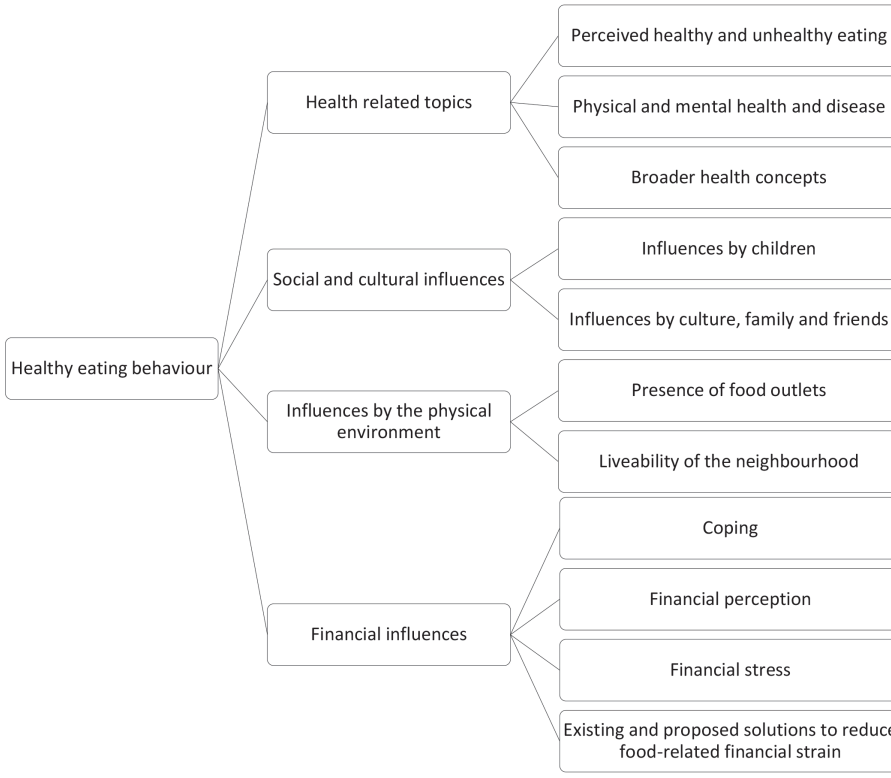

Figure 1. Main themes and their corresponding subthemes

Theme 1. Health related topics

Perceived healthy and unhealthy eating

Overall, participants demonstrated relatively good nutrition knowledge; adequate fresh fruit and vegetable intakes were perceived as essential components of a healthy diet. Snacks, fast-food, fatty foods, sugar, and overeating were considered unhealthy. Brown bread consumption was generally considered healthy, in contrast to white bread. Some participants indicated that bread consumption could lead to becoming overweight. Participants had conflicting opinions about whether meat consumption was healthy. Some participants considered meat as an essential component of a heathy diet, whereas others considered meat to be very unhealthy.

A frequently mentioned strategy to improve dietary intake was to replace sugar-containing beverages with water. Another strategy to improve dietary intake, and control intakes of unfavorable meal constituents like salt, was home cooking (e.g.,

making pizza from scratch). Barriers for healthy eating included feeling rushed and pressed for time or tired (e.g., after a working day).

> "*Hurry hurry, you know. For example, if you have to go somewhere, for example they have extra lessons in the mosque. Then I notice, quickly baking chips with a minced-meat hot dog and stuff. […] Sometimes you have those empty moments. And then you bake a minced-meat hot dog*."
>
> Participant 1

Some participants indicated that healthy cooking and home cooking were difficult and laborious compared to unhealthy cooking and takeaway foods, whereas in the opinion of others healthy cooking was not difficult at all, because healthier cooking techniques (like steaming and oven cooking) were considered easier than less healthy techniques (like frying). Some misconceptions about dietary advice were present, e.g. stating coconut oil as being specifically beneficial for health, while saturated fats like coconut oil are usually not recommended in international and national dietary guidelines (30, 31). Participants mentioned mostly consulting social media or acquaintances for information regarding healthy eating.

Physical and mental health and disease

Most participants clearly linked a healthier diet to chronic disease prevention for themselves and their children.

> "*If children eat healthy, they are not ill. Have fewer problems with everything. With concentration too*."
>
> Participant 7

Participant 6 really regretted his unhealthy eating pattern in the past, which in his opinion had led to diabetes, and he wanted to prevent that from happening to his children:

> "*An example of me. I have always eaten unhealthy and now I have it [disease]. Custard, ice cream, chocolate… […] I should not have done that. But you never knew in advance that you could become a diabetic. If my parents had said that, I would not have done it. But they did not say much. […] They never said: 'that is good and that is bad'. […] It is a pity, but... I did not get it from them*."
>
> Participant 6

Another participant became more aware of her lifestyle after being warned by her physician to lose weight in order to prevent cardiovascular diseases and diabetes. One participant mentioned experiencing poorer mental and physical health because of an unhealthy diet and overeating. Contrariwise, poor mental health was seen as a cause of unfavorable eating behavior. Participants explained they lacked energy to prioritize healthy eating or cooking when feeling unwell, worried, stressed or depressed.

> "*Everyone has a difficult situation and you are not in the mood, yes then it is easy to get a bag of fries and throw them in [the frying pan] and everyone has fries. Because it requires fewer actions and if you do not feel mentally well, then washing the dishes is really too much. Going to a supermarket uh, getting out of bed even, is just too much.*"
>
> Participant 3

Broader health concepts

Besides a healthy diet, a healthy weight was considered an important aspect of overall health. Many participants mentioned healthy eating and physical activity as ways to obtain or maintain a healthy weight. One participant felt these factors were interrelated:

> "*But I think that if you start exercising, that you, that diet is going to change automatically a little bit*."
>
> Participant 2

Some participants mentioned having the intention to exercise more often but not (yet) actually had changed their physical activity level, for example because it was perceived too hard to make time or set one's mind to it. Costs were not discussed as a barrier for physical activity.

Theme 2. Social and cultural influences

Influences by children

Children played a major role in food choices and food purchases. Participants indicated finding it difficult not to give in to their child's unhealthy food wishes. Various reasons were indicated for giving in: participants felt sorry for their children if they would not give in, they found it hard to repeatedly reject their child, or they

wanted to compensate their lack of time for their child (e.g., due to a busy work schedule) by buying food that the child liked:

> "*I work a lot. Night shifts, day shifts and evening shifts. She [child] is alone, I am there with my aunt, but then I felt guilty and then when I left, she started to cry. When I came back, I had cookies for her, 'mommy has brought you cake'. […] You know, or I went to get her at the babysitter and then she said: 'I missed you, you should not go to work anymore'. 'That's okay, mommy will buy a cake for you okay?'*"
>
> Participant 10

Child food preferences also influenced food purchases and dinner choices. Parents mentioned several strategies to broader their children's exposure to and taste for healthy food including repeated exposure to disliked foods so children could get used to the taste and cooking preferred dishes in a healthier way, such as a homemade pizza rather than store bought or hiding vegetables within a (favorite) dish.

> "*It's weird, but they [children] do not want vegetables. But yes, if you for example make chili con carne or for example sauce for spaghetti, then you just throw it through that zucchini. But that is how they eat it. *laughing* So yes, that's how you do it*."
>
> Participant 1

Setting a good example for their child was mentioned as a motivation for healthy eating by some participants. Further, school food regulations positively influenced child-eating behavior at school and sometimes also translated into healthier eating behaviors at home. For example, at some schools, unhealthy snacks or drinks were not allowed in class, which also made the children and parents reconsider consuming these products at home. Most participants had a positive attitude towards these school food regulations as they considered it a helpful contribution to adopting healthier eating behavior.

Influences by culture, family and friends

Besides child influences, extended family and friends also influenced eating and food purchasing behaviors. Eating with friends was generally more associated with having a nice time than with healthy eating. Attempts to adopt healthier cooking styles were sometimes hindered by other family members, e.g., when they disliked the lower-

salt meals. Eating at family gatherings mostly negatively influenced dietary intake, as family gatherings were often accompanied by unhealthy eating, overeating and sometimes setting bad examples:

> "*Well, uh, not really influence but they [family] try to force trough their vision or their will and I find that difficult. For example, if I go to my mother, well that she uh thinks he [child] should eat peppers, well, I don't agree with that. […] After a day at Grandma's, he [child] goes home and then he ate chocolate, he ate crisps, he ate cake, he ate candy, he ate dinner and preferably ate three other things as well and then also coke and ice cream. Yes, I just think that, I'm really annoyed by that. Really that is just such a frustration.*"
>
> Participant 3

One participant even decided to limit family visits to reduce her child's exposure to unhealthy eating habits of the family. Another mentioned strategy was to bring healthy products to these gatherings themselves. Positive influences were also mentioned, as friends and family sometimes served as an exemplary role for healthy behavior or provided guidance about child upbringing:

> "*But the bigger she [child] grew, the more rebellious she became, and I say, 'no, this is not going to happen'. Then I went to talk to my aunt, and she coached me a bit and told me I should be strong. No remains no. That's how I started to learn.*"
>
> Participant 10

Participants' cultural background also influenced their eating behavior, which was reflected in food customs (e.g., providing and consuming large quantities of food at social gatherings) and food choices (e.g., purchasing and cooking traditional foods, mostly indicated to be unhealthy, fatty of sugary foods).

Theme 3. Influences by the physical environment

Presence of food outlets

Participants lived in or near a disadvantaged neighborhood in The Hague. The presence of sufficient food shops and other facilities in these neighborhoods was appreciated:

> "*Advantages are uhm, yes you can get almost everything here, also from your own culture the groceries. Everything is close by.*"
>
> Participant 3

The abundance of supermarkets, small food shops (e.g., Turkish shops) and the market were mentioned in this regard. The market was seen as a place to buy large quantities of cheap fruit and vegetables, although some mentioned that these products did not last long enough as they were not fresh. A downside of the abundance of food outlets in the neighborhood was mentioned to be the food outlets offering unhealthy foods, as participants felt that the presence of these food outlets tempted them into making unhealthy food choices. The food supply at the supermarket checkouts was also considered unhealthy and tempting. Resisting these temptations was especially difficult for children.

> "*I also want to leave this neighborhood. Because […] you cannot blame [name child] because he walks out and it already starts, that Bulgarian there, the fries shop there. I mean, in the morning at around a quarter past eight, he already has fried chicken. Yes, you go with your child to the market to get watermelon, he is twice in the fight at the Kentucky. And then he looks at me like that again […] and then, yes you have to disappoint him. And as a mother you also get tired of that no, no, no […]. So, uh sometimes we have a little fight about this too. […] I just want to live somewhere that if you walk out the first ten minutes you will not come across a single snack something. […] this is really too bad for a child.*"
>
> Participant 3

The school food environment was mostly viewed as healthy by the participants, which is not surprising as most schools adhered to healthy school food regulations. However, as long as the food outlets surrounding the schools offered unhealthy foods, children were tempted to buy those unhealthy foods during the breaks or after school.

Livability of the neighborhood

Participants had a mostly positive attitude towards their neighborhoods, for example because of the closeness of shops and facilities, social support of the neighbors, perceived safety, openness towards each other and towards different cultures, and

multicultural influences in the neighborhood. Some negative aspects about the neighborhoods were mentioned as well, for example noise pollution, dirty streets and perceived lack of safety of the neighborhood resulting in restricting the child's outdoor activities.

Theme 4. Financial influences

Coping

Most participants had an income below the basic needs limit and prices were considered important for food purchasing. Various strategies were used to cope with a limited budget, such as careful budgeting and planning, budget-friendly cooking, buying secondhand items and buying cheap groceries or groceries on sale. Supermarkets where specific products were the cheapest at that moment were consciously selected, and some participants went to the market around closing time when products were sold for dumping prices. Advantages of planning grocery shopping in advance were firstly preventing buying unnecessary things and thereby saving money, and secondly sticking to healthy eating intentions. Some participants indicated specific financially induced adaptations in their food purchasing behavior, such as limiting outdoor eating to save money and switching from premium brands to cheaper alternatives of the same products, although the budget products sometimes were perceived less tasty or induced feelings of shame:

> "*Yes, I used to be ashamed to buy cheap products […]. I really thought those people would think that I don't have money. That's how I thought. Some colleagues also said: 'you should not be ashamed, even if all your groceries are premium brands, it's all the same'. It's just another package, just look, it's all the same. I used to buy Cornflakes of 3 euros while I could also get Cornflakes of 1 euro*."
>
> Participant 10

Non-basic needs like a holiday with the family or visiting family abroad were important motivators for saving money.

Financial perception

Healthy foods (e.g., fruit and vegetables) were perceived to be generally more expensive compared to less healthy foods (e.g., sweets and snacks), making choosing unhealthy options tempting.

"*Well then you go and look and the healthy things are actually really expensive. Yes then you are inclined, […] we better take a sausage roll, you almost want to say that*."

Participant 3

Some participants felt discontented about that and indicated that lowering healthy food prices would be a great help in achieving healthier eating behavior in the population.

"*But the worst help there is are all those sweets in the shops. Those are cheap and the ones that you need are expensive. That is the worst thing they can have. And then some people think: 'Yes, that is cheap?' That is why we have a lot of children with obesity here, too many children. Children from 4 years and older, some children are only 5, all teeth are rotten. Wherever you go, [for] 50 cents you have a bag full of candy. You are not going to have a bag full of vegetables for 50 cents. You do not have that. So if you turn that mentality around, it would be better.*"

Participant 5

However, it was mentioned that using the right strategies (e.g., coping strategies for dealing with a limited budget like buying frozen vegetables) it was possible to buy healthy foods despite having a limited budget. Participants generally felt in control over their grocery shopping behavior and felt this was not greatly influenced by external factors. Participants demonstrated a conscious attitude towards their financial situation, as reflected in their coping strategies for dealing with a limited budget, knowingly buying products that were a bit more expensive if they lasted longer, and prioritizing basic needs over luxury needs.

Financial stress

Despite their generally low incomes, participants overall felt relatively comfortable with their financial situation. As described above, various coping strategies were applied to cope with a limited budget and financial stress. Besides, some participants indicated that money was not the most important thing in their lives. For example, health was considered much more important.

"*For me, money is not everything. For me it is that I can get up every day, that I can breathe every day, that I thank my god. Every day of my life because*

not everyone can do that and I think that's the best you can do as a person, especially when you get up. Because we cannot buy that, not with any money."

Participant 5

However, as also indicated in the theme about mental health, financial stress was a barrier for healthy eating behavior, as participant 8 indicated about the time when she was in debt:

"*I did not really buy healthy food then, I just bought what was cheap. I only want to live because you are in the cramp, it's not possible, it's difficult*."

Participant 8

Regarding basic needs like food and clothes, participants clearly prioritized their children over themselves. For example, participants mentioned to rather skip a meal themselves than that the child would be short on something.

"*I do not care because I prefer [caring for] them [children] rather than myself. I can do with a few slices of bread and peanut butter and then I go to sleep. But they can't*."

Participant 6

Food insecurity was mostly mentioned in reference to the past or to others and not to the participants' own current experiences, i.e., mentioning past experiences of having insufficient money for food due to debts, or knowing others that were unable to afford sufficient food. Interestingly, participant 1 was classified as food insecure according to the previous questionnaire, but during the interview he specifically mentioned not to worry about going hungry:

"*So, you always have to pay close attention and put everything in order when it comes to finances. For the rest just happy. I mean, my family also. I mean, I'm not worried about, for example, that I'm going to starve, not that*."

Participant 1

He made a clear link with the quantity aspect of food security for himself and his family:

"*Healthy eating for me and my family means ensuring that there always is food. Yes. That is first of all healthy, that you have to eat. And secondly, yes,*

that you pay attention to your diet."

Participant 1

Existing and proposed solutions to reduce food-related financial strain

Participants were familiar with several existing resources to reduce financial strain or improve eating behavior, like several foundations, allowances, debt assistance, dieticians, the Food Bank, and local initiatives. They generally had a positive attitude towards these resources, which were perceived as a welcome helping hand, although some indicated that they would rather not need it. Conceptually the Food Bank was appreciated, but the actual content of the food parcels distributed by the Food Banks was criticized. Participants mentioned that the distributed products were not suitable for preparing a meal and were sometimes rotten or past the expiry date. If bread was provided it was sometimes stale. Suggested improvements for the content of the food parcels were to provide more fresh products like fruit, vegetables, potatoes and other products that can be used to prepare a proper meal. It was further deemed desirable that social contacts would be promoted and facilitated by Food Banks or other organizations, for example by facilitating getting together for a coffee and conversation.

"*The only thing they [Food Banks] don't have is social contacts*."

Participant 6

Other proposed solutions to reduce financial strain and improve dietary habits were providing free meals for those in need, increasing healthy food supply in the neighborhood (specifically limiting unhealthy snacks at supermarket checkouts and decreasing the number or fast-food outlets) and lowering healthy food prices.

"*What would help me? To eat healthier? If the store prices of those things drop a little, that would be super helpful. Not just for me but for many people*."

Participant 5

Barriers for using resources included feeling ashamed, thinking not to belong to the target group, not being eligible for the desired resources, finding it too difficult to register for resources or not knowing where to find the right information. Further, dietary advice provided by dieticians was mentioned to be insufficiently suitable for different cultural backgrounds:

> "*For dietary advice, it's just hard in such a neighborhood as this because you have different cultures. […] I also experienced that at the dietician, yes okay I do get the dietician, but I don't eat all that. And you can't expect that if it is in your roots not to eat certain things that you just change it*."
>
> Participant 3

Several participants felt that resources like Food Banks and allowances were often misused by people who did not need it and that people who actually needed help not always asked for or accepted help.

Discussion and conclusions

The current study aimed to provide better insight in the needs and perceptions regarding healthy eating among parents living in disadvantaged neighborhoods in the Netherlands at risk of experiencing food insecurity. Overall, participants showed relatively adequate nutrition knowledge and awareness of the importance of healthy eating behavior for optimal mental and physical health. Nevertheless, participants indicated various social, environmental and financial barriers to healthy eating behavior.

Comparison with previous literature

Consistent with previous research (32), participants acknowledged the importance of healthful eating for chronic disease prevention and overall health. Weight maintenance and child weight maintenance through healthful eating and physical activity was a recurring topic. This finding is in contrast with a previous study (33) that found that participants recognized the importance of improving health habits for themselves but not for their children. Our participants were clearly highly aware of the importance of child weight control, but nevertheless child overweight was a common concern among participants.

Some studies confirm the association between lower nutrition knowledge and lower SES (18, 34) and low (but not very low) food security (35), whereas others indicate adequate nutrition knowledge in these groups (36, 37), which is in line with our findings. Nevertheless, participants generally had a suboptimal diet quality and physical activity level, suggesting that a lack of knowledge was not the driving factor influencing eating behavior. This is in line with various psychological theories related

to health behavior, all consisting of multiple constructs indicating that a variety of factors influence the eventual health behavior (38).

Participants voiced several social, environmental and financial barriers to healthy eating behavior. Social barriers included unhealthy foods offered at social gatherings, bad exemplary roles of others, lacking social support for adopting healthier eating habits, and cultural customs that were associated with overeating and unhealthy food products. Social and family relations are shown to influence eating behavior (39). Especially children were noted to play an important role in family food habits (39), which is in line with the views of our participants. Therefore, it is important to consider child influences when developing interventions to improve eating behavior among families at risk of food insecurity. In line with previous studies (34, 40), lack of time to prepare or cook a meal was another perceived barrier for healthy eating.

Environmental barriers for a healthy eating and lifestyle behavior included an unfavorable food environment (e.g., an abundance of fast-food outlets). A systematic review on environmental factors and obesogenic dietary intakes showed that the food environment (i.e. less access to supermarkets or greater access to takeaway outlets) was consistently associated with higher overweight prevalence, and mixed results were found for the association between the food environment and dietary behaviors (41). Living in a disadvantaged neighborhood may act as a barrier for healthy eating behavior through increased access to takeaway outlets, thereby increasing the ease of making unhealthy choices (41). Further, perceived lack of safety was mentioned as a barrier to outdoor activities like physical activity and child outdoor play. Previous research among low-SES women also indicated unsafe neighborhood environments as barrier for physical activity (42). Also in line with this study (42), despite the generally low income of this study population and of our participants, costs were not discussed as a barrier for physical activity.

Financial considerations were mentioned as a barrier for healthy eating in two ways. Firstly, some believed that healthy foods were too expensive. Strikingly, this perception will probably only intensify because of the recent national tax increase, which came into force on January 2019 (20). As the interviews were conducted before January 2019, we were not able to assess the impact of the tax increase on price perceptions and eating behavior in our study. Therefore, future studies should focus on the effects of the tax increase on eating behavior, especially in low-SES groups. The perception that healthy foods are expensive is in line with previous studies indicating financial

considerations as important barriers for health behavior among low-SES groups (33, 40, 43-45), although participants were resourceful in finding ways to save money and get healthy foods. Secondly, in line with previous studies (46-48), financial stress and poor mental health were associated with poorer eating behavior. Interestingly, while most participants had low incomes and 7 participants were previously classified as food insecure (12), participants had an overall positive attitude towards their financial situation and barely mentioned personally experiencing food insecurity at the present. Participants did mention experiencing food insecurity in reference to the past or to others. This might be due to feelings of discomfort or shame when disclosing personal experiences with food insecurity during an interview (49).

To improve healthy eating behavior among people at risk of food insecurity, participants perceived that changes were needed at the governmental and community and social level. Suggested changes at the governmental level included improving existing resources, for example improving the quality and healthfulness of the Food Bank parcel content. Opposite to the perceptions of our participants, most participants of another Dutch study were satisfied with the food parcels and perceived them as healthy (50), even though their content did not conform to Dutch nutritional guidelines (14). Another proposed governmental intervention was decreasing healthy food prices. Previous studies consistently show that food taxation and subsidies can effectively improve population dietary behavior (22), suggesting that subsidizing healthy foods might be a very promising intervention. This makes the recent decision of the Dutch government to increase food taxes (20) highly undesirable. Suggested changes at the community and social level included promoting and facilitating social contacts in the neighborhood as this was currently lacking according to some participants. The importance of eating in a social context was also highlighted in a previous study among charity-run soup kitchen users (36). Facilitating social contacts could for example be done at Food Banks by providing a suitable location for social interaction. This might also reduce shame and stigmatization associated with Food Bank use, as this was indicated as a barrier for Food Bank use in previous literature (51, 52) and in our study.

Methodological considerations

This study deepens the understanding of needs and perceptions of parents at risk of experiencing food insecurity. Our qualitative, open interview approach enabled identifying important themes regarding healthy eating behavior in this difficult to reach target population. Our analyses confirmed some of the themes that were expected to play a role in healthy eating behavior based on our previous study and

the literature (e.g., family influences) and deepened knowledge on these topics. Additionally, some less anticipated themes emerged during the interviews (e.g., influence of the food environment and importance of social contacts). Our results may not be representative for a national sample of people at risk of food insecurity because we only recruited participants from the current study on food insecurity in disadvantaged neighborhoods in The Hague, The Netherlands (12). Also, participants volunteered to be interviewed which may have led to a sample with a larger-than-usual interest in nutrition. However, the included participants varied in terms of migration background and other characteristics. Also, thematic saturation for all themes was reached, suggesting that the sample size was sufficient for the aims of our study.

Implications

Nutrition knowledge and motivation to improve healthy eating behavior were relatively high among participating parents at risk of food insecurity, yet they indicated various social, environmental and financial barriers to healthy eating behavior. Therefore, interventions aimed at improving eating behavior in this unique population should not merely focus on nutrition education but take into account a wider range of social, environmental and financial factors. Because our study population consisted specifically of families with young children living in or near disadvantaged neighborhoods, the identified themes, barriers and interventions may not be generalizable to other populations at risk of food insecurity. Therefore, future studies are needed to confirm the needs and perceptions regarding healthy eating behavior in other populations at risk of experiencing food insecurity, e.g., young or elderly populations, childless people, and people with other migration backgrounds. Suggested interventions to improve eating behavior and reduce food-related financial stain that were identified in our study include facilitating social contacts (thereby potentially enhancing social support for both financial and food-related issues), improving existing recourses (e.g., Food Bank parcel content), culture-specific dietary advice, parenting training focused on handling child food choice influences, and improving the neighborhood food environment. Also, financial and mental issues should be addressed prior to focusing on improving eating behavior. Further, possibilities for subsidizing healthy foods or taxing unhealthy foods in the Netherlands should be explored as a potentially promising intervention to improve eating behavior.

List of abbreviations

BMI Body Mass Index

IRR Inter Rater Reliability

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Additional material Chapter 4

Additional Table 1. Food insecurity status assessment

Statement/ question
I (or other family members) worried whether my (or our) food would run out before I (or we) got money to buy more. [1]
The food that I (or we) bought just didn't last, and I (or we) didn't have money to get more. [1]
I (or we) couldn't afford to eat balanced meals. [1]
In the last 12 months, did you (or other adults in your household) ever cut the size of your meals or skip meals because there wasn't enough money for food? [2]
How often did this happen in the last 12 months? [3]
In the last 12 months, did you ever eat less than you felt you should because there wasn't enough money for food? [2]
In the last 12 months, were you ever hungry but didn't eat because there wasn't enough money for food? [2]
In the last 12 months, did you lose weight because there wasn't enough money for food? [2]
In the last 12 months, did you (or other adults in your household) ever not eat for a whole day because there wasn't enough money for food? [2]
How often did this happen in the last 12 months? [3]
I (or we) relied on only a few kinds of low-cost food to feed my (or our) child/children because I was (or we were) running out of money to buy food. [1]
I (or we) couldn't feed my (or our) child/children a balanced meal, because I (or we) couldn't afford that. [1]
My (or our) child was/children were not eating enough because I (or we) just couldn't afford enough food. [1]
In the last 12 months, did you ever cut the size of your child's/ any of the children's meals because there wasn't enough money for food? [2]
In the last 12 months, did your child/ children ever skip meals because there wasn't enough money for food? [2]
How often did this happen in the last 12 months? [3]
In the last 12 months, was your child/were your children ever hungry but you just couldn't afford more food? [2]
In the last 12 months, did your child/ any of the children ever not eat for a whole day because there wasn't enough money for food? [2]

[1]Answer options: Often true/ Sometimes true/ Never true/ I don't know
[2]Answer options: Yes/ No/ I don't know
[3]Answer options: Almost every month/ Some months but not every month/ Only 1 or 2 months/ I don't know

Additional Table 2. Diet quality score components, dietary guidelines and scoring per component

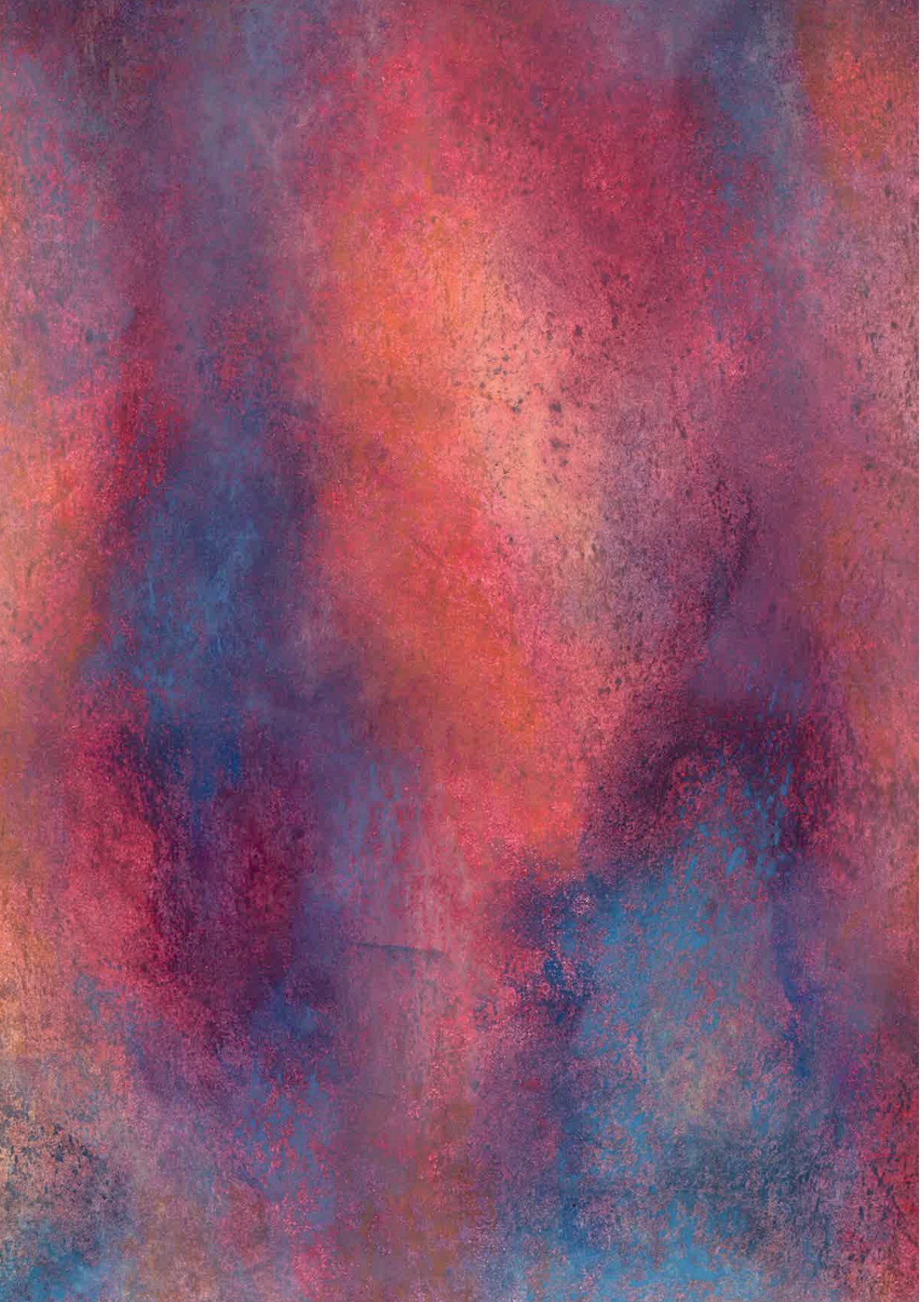
Component	Recommendations by the Health Council of the Netherlands[1] and/ or the Netherlands Nutrition Centre[2]	% contribution to component score	Units	Score		
				0	5	10
Vegetables	Eat at least 200 grams of vegetables daily	100	Grams/ d	0	*Continuous*	≥200
Fruit	Eat at least 200 grams of fruit daily	100	Pieces/ d	0	*Continuous*	≥ 2
Fish	Eat one serving of fish weekly, preferably oily fish	50	Servings/ w	0	<1	≥ 1
		50		No fish consumed	Lean or both lean and fatty fish	Mostly fatty fish
Bread	Replace refined cereal products by whole-grain products	50		Mostly white bread	Both white and brown/ whole-grain bread	Mostly brown/ whole-grain bread
	Women: 4-5 brown/ whole-grain sandwiches daily	50	Sandwiches/ d	0	*Continuous*	≥ 4
	Men: 6-8 brown/ whole-grain sandwiches daily		Sandwiches/ d	0	*Continuous*	≥ 6
Oils and fats	Replace butter, hard margarines and cooking fats by soft margarines, liquid cooking fats, and vegetable oils	50		Butter, hard margarines	Both butter, hard margarines and oils and soft margarines	Oils and soft margarines
		50		Butter on bread or bread is not buttered at all	Semi-skimmed butter or hard margarine on bread	Diet margarine on bread
Sweet and savory snacks	For products outside the Wheel of Five: choose an item from the daily selection no more than three to five times per day, and something from the weekly selection no more than three times a week	25	Sweet snacks (larger serving)/ w	≥ 3	<1 to 2	Not consumed
		25	Sweet snacks (small serving)/ d	> 3	*Continuous*	Not consumed
		25	Savory snacks (larger serving)/ w	≥ 3	1 to 2	Not consumed
		25	Savory snacks (small serving)/ d	> 3	*Continuous*	Not consumed

[1]Health Council of the Netherlands. *Guidelines for a healthy diet 2015* (Richtlijnen Goede Voeding 2015). The Hague 2015.
[2] Netherlands Nutrition Center. *Wheel of Five guidelines* (Richtlijnen Schijf van Vijf). The Hague 2016.

Additional Table 3. Topic list and example questions

Topic	*Example question*
General/ introductory topics	
Birthplace and culture	When and where were you born?
	For how long have you been living in the Netherlands
Household composition	What does your family look like?
	Who lives at your home?
Living conditions	Where do you live/ which neighborhood?
	What do you think of the neighborhood where you live?
	What kind of house do you have?
Specific topics	
Healthy eating	What is healthy eating for you?
	What do you think of healthy eating?
Skills	What do you think about cooking a healthy meal?
	What do you find easy or difficult when cooking a healthy meal?
Influences on eating and food purchasing	What influences how you eat or what kind of foods you buy?
Healthy lifestyle	What can you tell about health and nutrition?
	What impact does your health have on what you eat?
	How does your weight affect what you eat?
	How do you think about exercise and health?
Eating in a social context	Do other people influence what you eat? Who are they?
	How do they (reference to previous question) affect what you eat?
	What can you tell about eating and coming together with people, for example on parties or social gatherings?
Neighborhood	How does the neighborhood where you live affect what you eat?
	What kind of temptations (for you/ for the children) are there in your neighborhood?
Cultural influences on eating	What influence does your culture have on your eating habits?
Family	What does healthy eating mean for your children (for you as a parent)?
	How important is this (reference to previous question)?
	How do you ensure that your children eat healthy?
	What would you like to teach your children about food and health?
Upbringing	What do you find easy or difficult when raising your child?
	What barriers do you experience when raising your child?
Financial status	Would you describe your own financial status?
	How do you influence that in daily life?

Stress/ financial stress	How does stress affect what you eat or what food you buy?
	What impact do your finances have on how stressed you feel?
Food costs	What role does money play in what you eat or what food you buy?
	How do you take into account food costs?
	How do you take into account offers?
Priorities	What do you find important or what do you pay attention to when spending your money?
	What do you find important or what do you pay attention to when buying groceries?
Nutrition and health	Does eating have an impact on your health?
	How do you notice that (reference to previous question)?
	How do you describe your own health?
	Does your health status influence where or how you buy your groceries?
	Does your physical health prevent you from for example going to the market to buy groceries?
Help	What could help you to eat healthier?
	What can people with a limited budget help to have sufficient and healthy food to eat?
	How can the municipality help?
	Which help from the municipality / which foundations do you know?
	What can for example the school or supermarket do to make healthy eating easier?
	What do you think of receiving vouchers to get fruit and vegetables at the market?
	What do you think of the Food Bank?
Rearrangement of the neighborhood	If you could rearrange the neighborhood you live in, how would you do that?
	What would you like to remove from the neighborhood or add to the neighborhood?
Closing topics	
Future	How would you like your future to look like?
Unaddressed topics	Is there anything else you would like to address in this interview?



CHAPTER 5

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

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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 take-

away 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**).

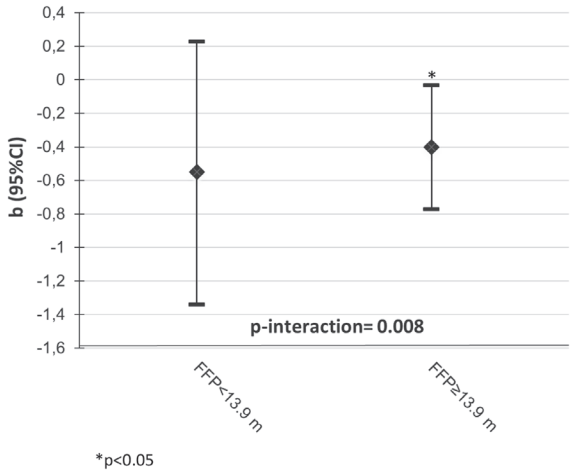

Figure 1. Stratified results for the association between food insecurity score and dietary quality (clustered by district, adjusted for age, sex, migration background, household size, marital status, household income, and educational level), split at the median fast-food outlet proximity (FFP) per 10m: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

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Additional material Chapter 5

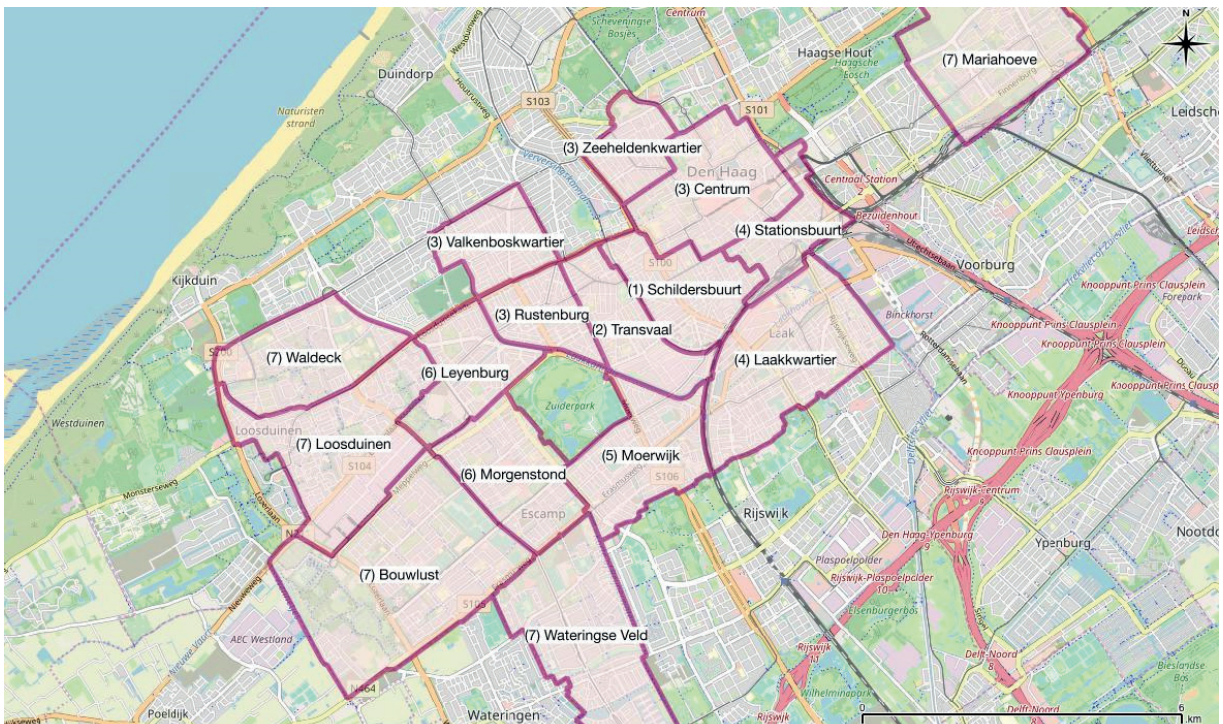


Figure S1. Locations (green-yellow dots) where fast-food is sold in The Hague, according to the Locatus database (selected for the following branches: fast-food, grillroom/kebab and delivery/take out). The six disadvantaged neighborhoods are highlighted in purple.

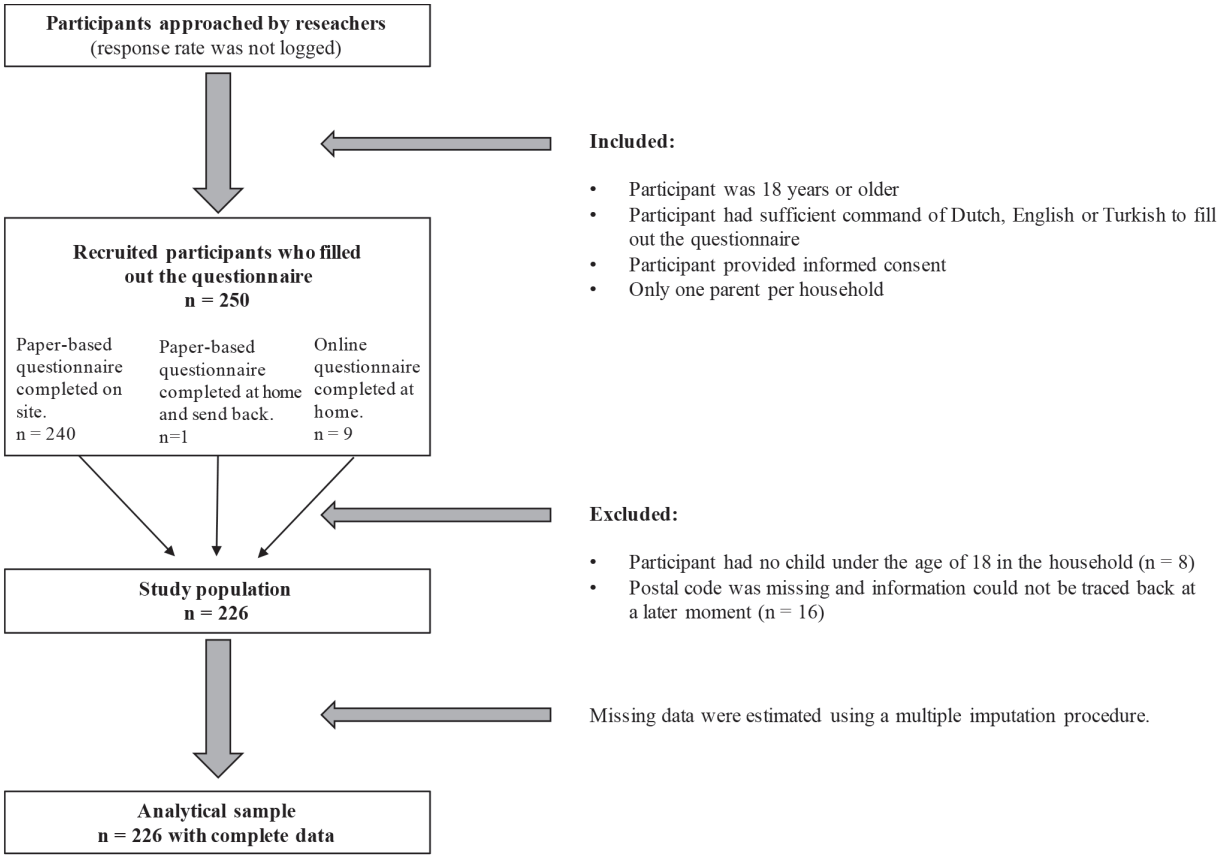
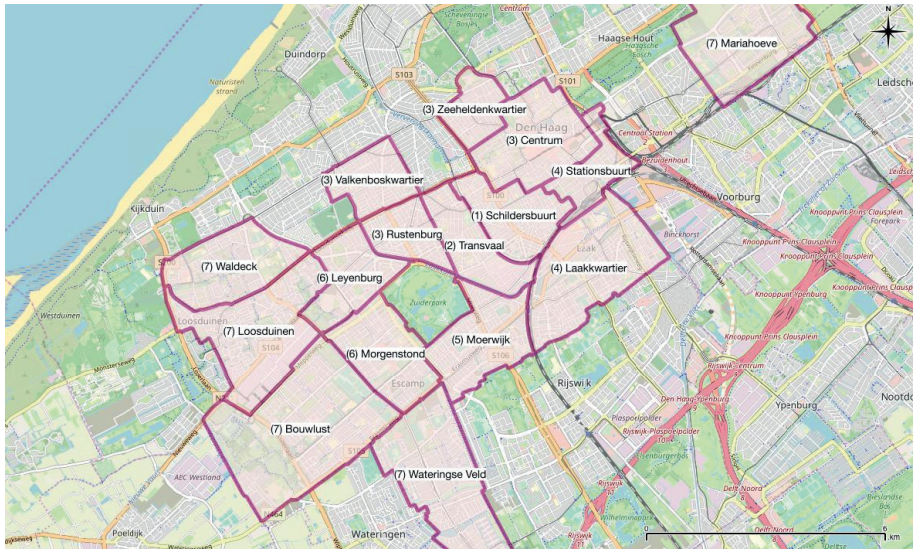


Figure S2. Flow chart presenting recruitment, inclusion and exclusion of participants

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

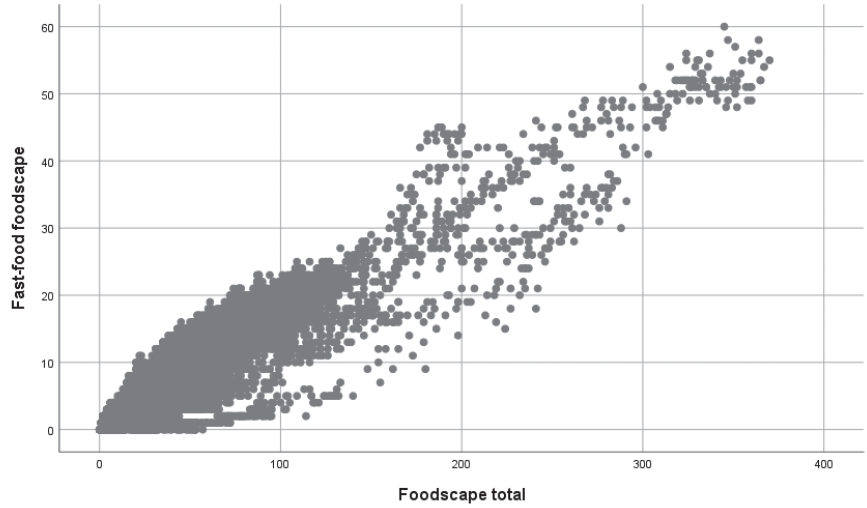
** Not applicable with only 1 district in this cluster.*

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



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**).

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)

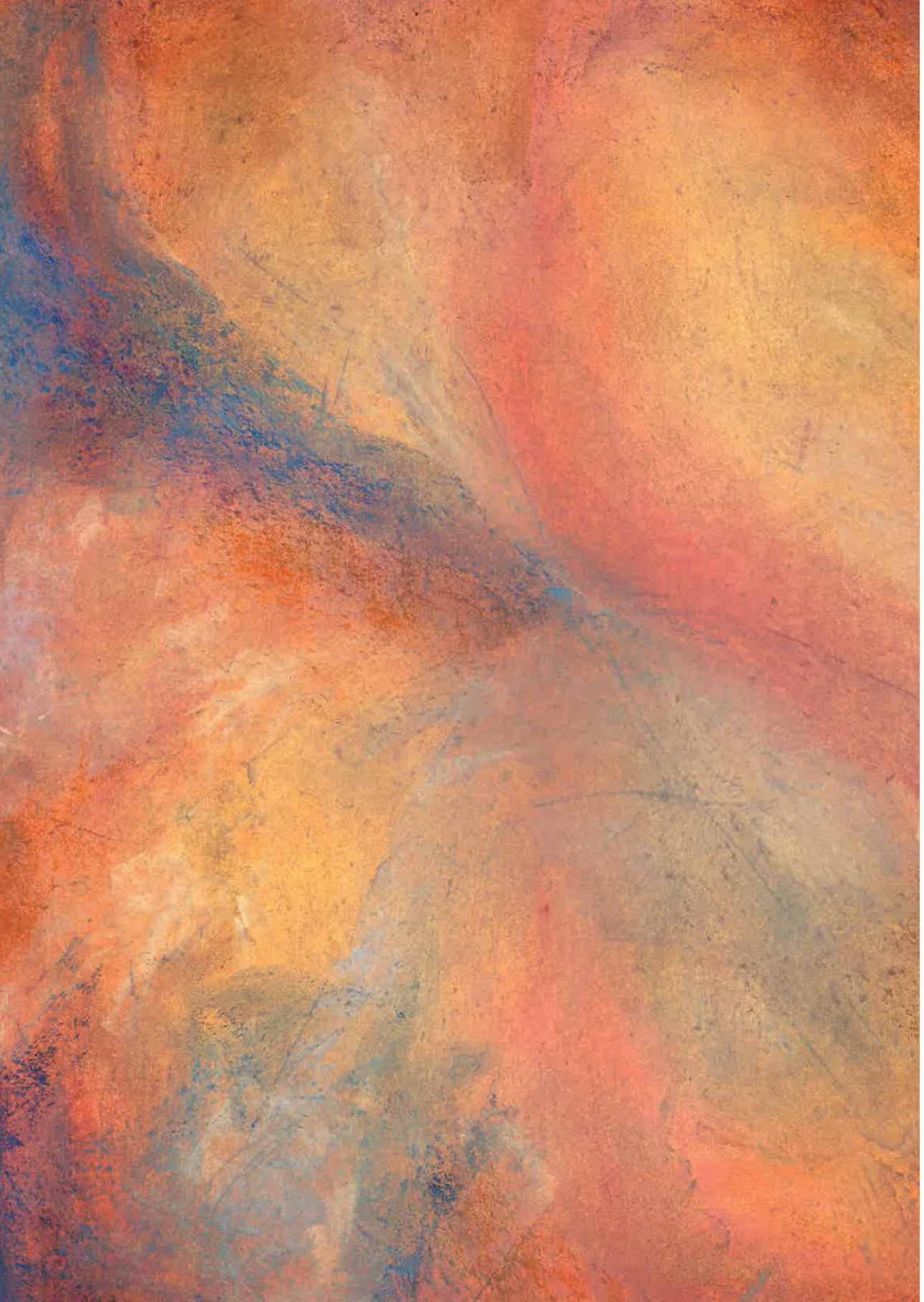
	Outcome			
	Food insecurity score (continuous)			
	Crude model		Adjusted model	
	β	95% CI	β	95% CI
FFD (within 500 m)	-0.026	-0.099; 0.047	-0.029	-0.086; 0.028
FFP (per 10 m)	-0.01	-0.045; 0.025	-0.001	-0.033; 0.032
	Food insecurity status (dichotomous)			
	Crude model		Adjusted model	
	OR	95% CI	OR	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

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



CHAPTER 6

Extending the theory of planned behavior for explaining dietary quality: The role of financial scarcity and food insecurity status

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Abstract

Objective: To examine whether an extended Theory of Planned Behavior (TPB) that included finance-related barriers better explained dietary quality.

Design: Cross-sectional survey.

Participants: 1033 participants were included from a Dutch independent adult panel.

Main Outcome: Dietary quality.

Analysis: Five TPB models were assessed: the traditional TPB; a TPB that included also direct associations between attitude and subjective norm with dietary quality; a TPB that additionally included financial scarcity or food insecurity; and a TPB that additionally included financial scarcity and food insecurity simultaneously. Structural relationships among the constructs were tested to compare the explanatory power.

Results: The traditional TPB showed poorest fit, the most extended TPB (including both financial scarcity and food insecurity) showed best fit. All 5 structure models explained ~42-43% of the variance in intention, however, the variance in dietary quality was better explained by the extended TPB models including food insecurity and/ or financial scarcity (~22%) compared to the traditional TBP (~7%), indicating that these models better explained differences in dietary quality.

Conclusions and Implications: These findings highlight the importance of taking into account finance-related barriers for healthy eating like financial scarcity or food insecurity for better understanding individual dietary behaviors in lower socioeconomic position groups.

Introduction

Poor dietary behavior is a major contributor to chronic disease morbidity and mortality worldwide (1) and dietary behavior is generally poorest amongst socioeconomically disadvantaged groups (2). Determinants of unfavorable dietary behavior amongst these groups remain poorly understood, however, and a better understanding is needed to achieve healthier dietary behavior and reduce diet-related disparities.

One of the most commonly used models for understanding health behaviors such as dietary behavior is the Theory of Planned Behavior (TPB) (3). According to the TPB, behavior is influenced by the intention to perform the behavior. This intention is influenced by the positive or negative evaluation of the behavior (i.e., attitude), the perceived social pressure and expectations to perform the behavior (i.e., subjective norm), and the perceived control over the behavior (i.e., perceived behavioral control). Besides the indirect influence of perceived behavioral control through intention, it can also directly influence the behavior. A more favorable attitude, subjective norm, and perceived behavioral control towards the behavior would lead to a stronger intention to perform the behavior. This intention in turn influences the likelihood that the behavior is actually performed (3, 4).

A systematic review conducted by McEachan et al. (2011) confirmed that the TPB is a suitable model for explaining intention and behavior across a range of health behaviors such as physical activity and sexual reproductive behavior (5). Dietary behavior, however, is complex because it is also driven by contextual factors such as perceived psychological stress (6). Indeed, the potential of the TPB to explain dietary behavior seems to be limited (4). This indicates that factors other than attitude, subjective norm, perceived behavioral control and intention may play an important role in motivating dietary behavior. Socioeconomically disadvantaged groups generally have poorer dietary quality (2), and studies that elaborate on this association show that financial resource-related matters influence the intention to eat a healthy diet as well as the actual eating behavior itself (7, 8). For example, financial stress, impaired mental health and perceived high costs of healthy food were mentioned as barriers for healthy eating (7)

Extending the TPB by including these factors may help to better explain dietary behavior and differences therein for people of different socioeconomic positions (SEPs). Differences in dietary quality that are related to SEP may be partially

explained by the generally higher costs of healthier diets and lower healthy food availability in low-SEP neighborhoods (2). Other factors, however, also constitute resource constraints and influence dietary behavior among low-SEP individuals (9). Following the conceptual framework proposed by Laraia et al. (2017), poverty indeed influences healthy food purchasing power, but also influences insecurities (including food insecurity) and biobehavioral mechanisms (including stress, sleep, and cognitive burden). Especially these insecurities trigger hormonal responses (i.e., stress-, appetite-, and hunger-regulating hormones) that shape eating behavior. These factors create a scarcity mindset, which (together with a poverty-induced reduced purchasing power) adversely influences dietary behavior and diet quality (9).

Food insecurity is a complex and multidimensional phenomenon, that reflects a limited or uncertain access to adequate food that meets dietary needs and food preferences for an active and healthy life (10). Food insecurity may for example include (anxiety and worries about) not having enough (healthy) foods, (perceived) social exclusion, and the inability to acquire food in socially acceptable way. Research shows that the impact of food insecurity on (mental) health and stress, may also lead to a tendency to consume unfavorable, highly palatable foods (9, 11). Indeed, both national and international research has shown that food insecurity is associated with poorer dietary quality (12, 13).

Financial scarcity can be defined as the subjective experience of having less financial resources than needed (14). Studies have shown that experienced financial scarcity can have negative psychological consequences. For example, it impedes executive functions (15) and increases depression and anxiety (16, 17). Moreover, having limited resources can lead to a self-reinforcing cycle between causes and consequences of poverty, also known as a "poverty trap" (18). When resources are scarce, (potential) problems loom larger and seize attention, and because of the greater engagement in trying to solve these problems, scarcity leads to neglect of other (potential) problems and longer-term goals including health (19, 20). Hence, experienced financial scarcity, and the uncertainties and stress that are associated with it, may impede cognitive control functions that are needed for healthy food choice. As described by Beenackers et al. (2017), financial strain is associated with unhealthy behavior, partially mediated by lower self-control (21). This helps explain the difficulty of eating healthy when experiencing financial scarcity.

Although perceived food insecurity and financial scarcity are closely related (22), they represent separate constructs. Financial scarcity reflects a perceived shortage of money in general and control over the financial situation, whereas food insecurity reflects a perceived inadequate access to food specifically, thereby also capturing psychosocial stress related to a perceived inadequate access to food. As both constructs are associated with unfavorable eating behavior, extending the TPB by including food insecurity and financial scarcity may be promising for better explaining dietary behavior and differences therein for people of different SEPs. Therefore, in the current study, we aim to assess whether extending the TPB with barriers related to financial scarcity and food insecurity better explains dietary quality.

Methods

Study Population and Data Collection

Data for this cross-sectional study were collected in December 2020 through online questionnaires sent to a Dutch independent panel that operates in line with ISO standards (23). We included adults living across the Netherlands including both rural and urban areas, with oversampling on a relatively low SEP: approximately four-fifth of the sample was selected to have a lower SEP. This was based on three combinations of their income and educational level: 1) below mode income + low educational level; 2) mode income + low educational level; or 3) below mode income + intermediate educational level. Questionnaires were available in the Dutch language. The study was reviewed by the Medical Ethics Committee of Leiden University Medical Center and confirmed not to be subject to the Medical Research Involving Human Subjects Act (WMO) (P17.164).

Variables and Measurements

Dietary intake and dietary quality.

Dietary intake was assessed using an adapted version of the Dutch Healthy Diet Food Frequency Questionnaire (DHD-FFQ) (24). Based on the dietary intake, adherence to the current dietary guidelines (25, 26) was assessed for the following components: vegetables; fruit; legumes; unsalted nuts; fish; grain products; dairy; tea; coffee; oils and fats; sugar containing beverages (SCBs); savory snacks; and sweet snacks. Each component was assigned a score ranging from 0 to 10, with higher scores indicating

better adherence to the dietary guidelines (**Supplemental Table 1**). All component scores were summed, resulting in a total dietary quality score with a theoretical range from 0 to 130 points.

Constructs of the theory of planned behavior.

Psychosocial factors related to dietary behavior were assessed based on the constructs of the TPB (3). Items were selected in a multiple step process. First, we selected general constructs based on the TPB (3). Second, we applied the specific health behavior of interest -dietary behavior- to these general constructs. For the construct subjective norm, we included items reflecting subjective norm regarding healthy eating in general. For the other constructs, we included items regarding healthy eating in general, and specifically regarding fruit and vegetable consumption and snack and fast-food consumption. For each construct, multiple items were included to reflect that particular construct. Specific items per construct are presented in **Supplemental Table 2**.

Attitude towards healthy eating; fruit and vegetable consumption; and snacks and fast-food consumption was assessed based on 24 items. Attitude was assessed using 7-point Likert scales ranging from positive to negative (e.g., I think healthy eating is… good for me (1 point), bad for me (7 points)). These scores were then reversed, so that higher scores indicate a more positive attitude towards the eating behavior in question.

Subjective norm regarding healthy eating was assessed based on 6 items (e.g., my family and/ or friends think it would be good if I eat healthy/ more healthy in the next 3 months) using 7-point Likert scales ranging from strongly disagree (1 point) to strongly agree (7 points), so that higher scores indicate a stronger perceived subjective norm regarding healthy eating.

Perceived behavioral control was assessed based on 8 items (e.g., I feel in control about eating healthy/ more healthy in the next 3 months) using 7-point Likert scales ranging from strongly disagree (1 point) to strongly agree (7 points), so that higher scores indicate a stronger perceived behavioral control.

Intention to eat healthy was assessed based on 5 items (e.g., I intend to eat healthy/ more healthy in the next 3 months) using 7-point Likert scales ranging from strongly disagree (1 point) to strongly agree (7 points), so that higher scores indicate a stronger intention to eat healthy.

Financial scarcity and food insecurity.

Financial scarcity was assessed based on the short version of the Psychological Inventory of Financial Scarcity (PIFS), a validated scale showing good validity and reliability (van Dijk, W., van der Werf, M., van Dillen L. *The Psychological Inventory of Financial Scarcity (PIFS): A Psychometric Evaluation*. 2021). The PIFS assesses experienced financial scarcity, and captures four aspects of this subjective experience: appraisals of insufficient financial resources and lack of control over one's financial situation, in addition to responses concerning financial rumination and worry, and a short-term focus. The scale included 5 statements (e.g., I am constantly wondering whether I have enough money) for which participants could indicate to what extent they agreed with the statements on 7-point Likert scales ranging from strongly disagree (1 point) to strongly agree (7 points), so that higher scores indicate a higher perceived experience of financial scarcity.

Food insecurity status was assessed using the 6-item United States Department of Agriculture Household Food Security Survey Module (USDA-HFSSM). This original survey was previously translated from the English to the Dutch language by Neter et al. (2014), using the translation and back-translation technique (27). Affirmative responses to questions addressing food insecurity-related conditions were summed, resulting in a food insecurity score ranging from 0 to 6. The food insecurity score was dichotomized into 'food secure' (0 affirmative responses: high food security) and 'food insecure' (1-6 affirmative responses: marginal, low and very low food security), according to current international recommendations to count marginal food insecurity as part of food insecurity (28).

Sociodemographic covariates.

Age, sex (male/ female), country of birth, marital status, educational level, employment status, income, smoking status, height, and weight were assessed. Body Mass Index (BMI, kg/m^2) of the participants was calculated from their self-reported weight and height, and classified into normal weight (BMI $<25\,kg/m^2$), overweight (BMI 25–30 kg/m^2) and obese (BMI $\geq 30\,kg/m^2$), using the WHO cut-off points (29). Country of birth was categorized into 'Netherlands' and 'other'. Educational level was categorized into low (upper secondary education or lower), intermediate (post-secondary – short cycle tertiary education), and high (Bachelor or higher education). Income was categorized into minimum income, below mode income, and mode income or higher (mode income refers to the income that is most commonly earned

in the Netherlands). Smoking status was dichotomized into current smoker (yes/ no). Employment status was dichotomized into currently employed (yes/ no). Further, we included the livability index (30) as a measure of the livability of the neighborhood ranging from poor (1) to outstanding (9). This index is based on 50 indicators which can be further divided into the following underlying six dimensions: housing stock; public space; level of facilities; (social/ economic) population composition; life structure and social cohesion of the population; inconvenience and safety (30). The livability index was linked to the dataset based on 4-digit postal code of the participants.

Statistical Analyses

Population characteristics for the total study population and split by food insecurity status and financial scarcity status were presented using descriptive statistics. Linear regression analyses were conducted to assess associations between food insecurity, financial scarcity, attitude, subjective norm, perceived behavioral control, intention, and dietary quality, both crude and adjusted for age, sex, income, educational level, employment status, marital status, country of birth, and livability index.

Exploratory factor analysis (EFA) was conducted to obtain the variable sets that best explained the underlying constructs (i.e., attitude, subjective norm, perceived behavioral control, intention, and financial scarcity). Items with component loadings above 0.3 were retained. For the EFA we used one-half of the dataset (n=517), for the CFA (described hereafter) we used the other half of the dataset (n=516). As described by Boateng et al. (2018), a sample size of over 500 is sufficient for factor analysis. They describe a sample size of 500 as very good for factor analyses, and suggest that, as a rule of thumb, the ideal ratio of respondents to items is 10:1 as, which is achieved in our study (31).

Five TPB models were assessed: the traditional TPB and 4 extended TPB models; a TPB that included also direct associations between attitude and dietary quality, and between subjective norm and dietary quality; a TPB that additionally included financial scarcity or food insecurity; and a TPB that additionally included financial scarcity and food insecurity simultaneously (**Supplemental Figure 1**). To compare the explanatory power of these models, structural relationships among the constructs were tested using structural models.

As recommended by Anderson and Gerbing, a two-step procedure with the maximum likelihood estimation method was applied (32). In the first step, Confirmatory

Factor Analysis (CFA) was conducted to assess the goodness-of-fit of the model, and the reliability and validity of the constructs (i.e., attitude, subjective norm, perceived behavioral control, intention, and financial scarcity). In the second step, the hypothesized structural relationships (i.e., paths) among the latent constructs were tested using structural equation models. All models were adjusted for age, sex, income, educational level, employment status, marital status, country of birth, and livability index. Model fit was assessed using absolute, parsimonious, and incremental indices: we assessed the Chi^2 to df ratio (Chi^2/ df), Comparative Fit Index (CFI), the root mean square error of approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR) (33). Model fit was deemed acceptable if Chi^2/ df $\leq$ 5; CFI $\geq$ 0.90; RMSE $\leq$ 0.10; and SRMR $\leq$ 0.080. Further, explained variance was assessed for intention, dietary quality, and the overall model.

CFA and path analyses were conducted using Stata version 16.1 (StataCorp,2015. Stata Statistical Software. College Station, TX:StataCorp LP). All other statistical analyses were performed using IBM SPSS statistics version 25.0 (IBM Corp., 2012, Armonk, NY). A two-sided p-value of 0.05 was considered statistically significant.

Results

Factor Analyses for Model Constructs

The variable sets that best explained the underlying constructs (i.e., attitude, subjective norm, perceived behavioral control, intention, and financial scarcity) following the EFA were retained, resulting in 14 items for attitude towards healthy eating and fruit and vegetables (2 items removed), 7 items for attitude towards snacks and fast-food (1 item removed), 4 items for subjective norm regarding healthy eating (2 items removed), 8 items for perceived behavioral control over healthy eating (no items removed), 5 items for intention to eat healthy (no items removed), and 5 items for financial scarcity (no items removed). Remaining items had a high internal consistency/ reliability, indicated by Cronbach's alpha ranging from 0.83 to 0.94 (**Supplemental Table 2**).

A Confirmatory Factor Analysis (CFA) was applied for the remaining items (i.e., the items that were not excluded following the EFA) within the constructs, showing moderate model fit (Chi^2/df = 3.74; CFI = 0.80, RMSEA (95%CI) = 0.094 (0.091; 0.098); SRMR = 0.086) and an explained variance of 99% for the overall model (**Supplemental Table 3**). In the analyses, we used the average scores of the remaining items for each construct.

Participant Characteristics

A total of n=1033 participants with oversampling on a relatively low SEP were included in the current study. Participants had a mean age of 55.5 (± 16.4), an approximately equal percentage of men and women were included, and the vast majority of participants was born in the Netherlands (96.7%) (**Table 1**). Most participants had an income below the mode Dutch income or lower (66.8%). Mean livability index was 6.7 (± 1.26) out of 9. Approximately one-quarter of participants were obese and mean dietary quality score was 70.3 (± 15.3) out of 130 (**Table 1**).

Participants generally did not perceive a strong subjective norm regarding healthy eating (4.3 ± 1.2). Participants overall showed a positive attitude towards healthy eating and fruit and vegetable consumption (4.8 ± 0.9) and a negative attitude towards snacks and fast-food consumption (2.9 ± 1.1). Participants generally felt confident about their ability to eat healthy, as reflected by a mean perceived behavioral control of 5.0 ± 1.0. Participants generally intended to eat healthy (4.7 ± 1.1) (**Table 1**).

Compared to participants not experiencing financial barriers, people experiencing food insecurity or financial scarcity generally reported a stronger perceived subjective norm regarding healthy eating, a less positive attitude towards healthy eating and fruit and vegetable consumption, and particularly food insecure participants reported a lower perceived behavioral control (**Supplemental Table 4**).

Table 1. Population characteristics for the total population (n=1033)

Characteristics	
Age (mean ± SD)	55.5 ±16.4
Age range (minimum-maximum)	18 - 88
Sex (n (%) male)	542 (52.5)
Country of birth (n (%) Netherlands)	999 (96.7%)
Marital status (n (%))	
Cohabiting with children	202 (19.6)
Cohabiting without children	408 (39.5)
Single with children	101 (9.8)
Single without children	285 (27.6)
Other	37 (3.6)
Educational level (n (%))	
Low (upper secondary education or lower)	469 (45.4)
Intermediate (post-secondary – short cycle tertiary education)	506 (49.0)
High (Bachelor or higher education)	58 (5.6)
Paid employment (n (%) yes)	429 (41.5)
Income (n (%))[1]	
Minimum	130 (12.6)
Below mode income	560 (54.2)
Mode income or higher	251 (24.3)
Don't know/ don't want to answer	91 (8.9)
Livability index (range1 (poor) to 9 (outstanding) (mean ± SD))[2]	6.7 ±1.26
Score 6 or lower	437 (42.4)
Score 7 or higher	594 (57.6)
Lifestyle factors	
Current smoker (n (%) yes)	183 (17.7)
BMI (mean ±SD)[3]	26.8 ±5.0
Weight status (n (%))	
Normal weight	404 (39.1)
Overweight	370 (35.8)
Obesity	259 (25.1)
Dietary quality (range 0-130) (mean ± SD)	70.3 ±15.3
TPB constructs (7-point Likert scales (mean ± SD))	
Subjective norm	4.3 ±1.2
Attitude healthy eating and fruit and vegetables	4.8 ±0.9
Attitude snacks and fast-food	2.9 ±1.1
Perceived behavioral control	5.0 ±1.0
Intention	4.7 ±1.1
Finance-related barriers	
Food insecurity score (range 0-6 (mean ±SD))	0.4 ±1.2
Financial scarcity (7-point Likert scale (mean ± SD))	2.6 ±1.5

TPB: Theory of Planned Behavior
[1] Income categories refer to the following amounts of annual gross income: Minimum <14.100 euro; Below mode income 14.100-36.500 euro; Mode income or higher >36.500 euro.
[2] Livability index: n=1031
[3] BMI (Body Mass Index): n=984

Associations Between Food Insecurity, Financial Scarcity, Attitude, Subjective Norm, Perceived Behavioral Control, Intention, And Dietary Quality

A higher food insecurity score (i.e., stronger experienced food insecurity) and a stronger experienced financial scarcity were associated with a lower dietary quality score (β = -1.51, 95%CI= -2,30; -0.73, p <0.001 and β = -1.60, 95%CI= -2,57; -0.94, p <0.001, respectively) after adjustment for sociodemographic variables (**Table 2**). Further, a more positive attitude towards healthy eating and fruit and vegetable consumption, a more negative attitude towards snacks and fast-food consumption; higher perceived behavioral control; and higher intention to eat healthy were associated with a higher dietary quality. No significant association was found between subjective norm and dietary quality. A more positive attitude towards healthy eating and fruit and vegetable consumption; a more negative attitude towards snacks and fast-food consumption; a higher perceived subjective norm; and a higher perceived behavioral control were associated with a higher intention to eat healthy. Experiencing financial scarcity or food insecurity were not significantly associated with intention. People experiencing food insecurity or financial scarcity had a less positive attitude towards healthy eating and fruit and vegetable consumption, perceived a stronger subjective norm for healthy eating, and perceived lower behavioral control (**Table 2**).

Table 2. Associations between food insecurity, financial scarcity, attitude, subjective norm, perceived behavioral control, intention, and dietary quality

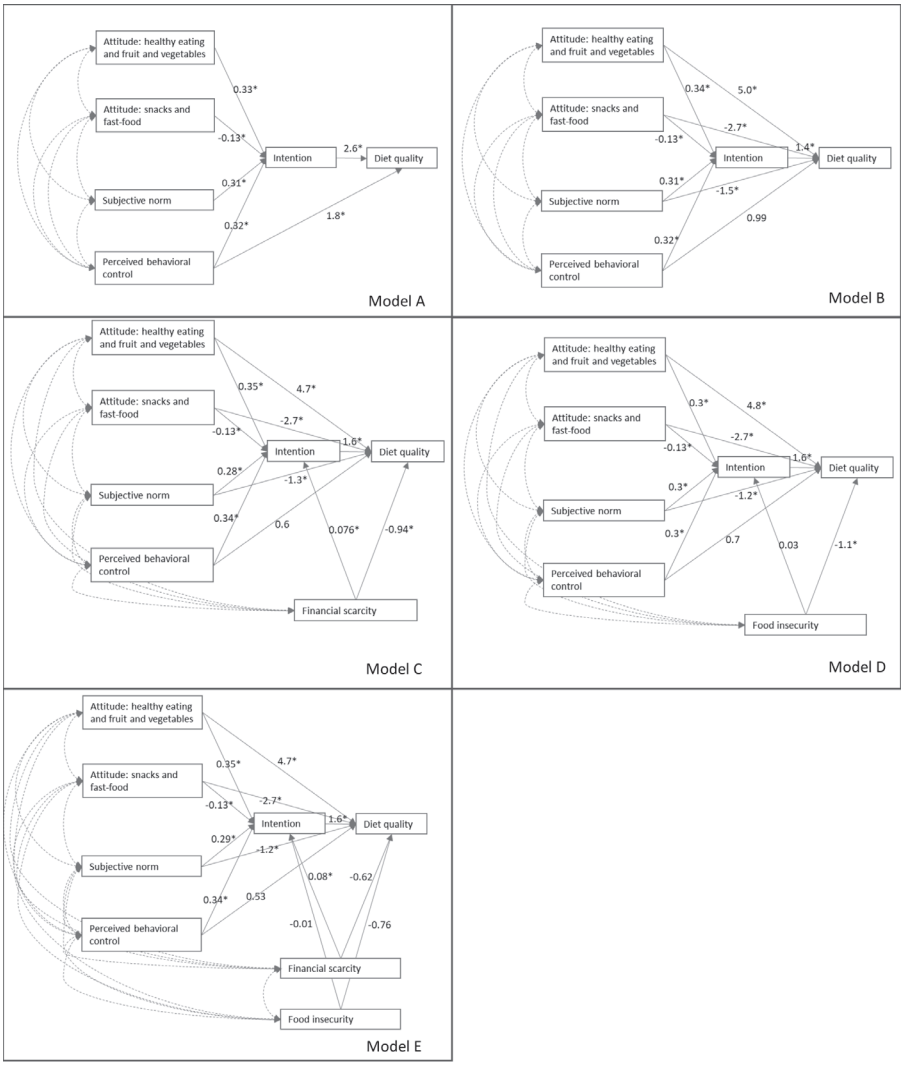
	Crude			Adjusted[2]		
	β	95%CI	p-value	β	95%CI	p-value
Outcome: dietary quality						
Food insecurity score	-1.94	-2.71; -1.18	0.000	-1.51	-2.30; -0.73	0.000
Financial scarcity	-1.81	-2.45; -1.18	0.000	-1.60	-2.27; -0.94	0.000
Subjective norm	-0.65	-1.44; 0.15	0.110	-0.069	-0.89; 0.76	0.870
Attitude healthy eating and fruit and vegetables[1]	6.56	5.58; 7.55	0.000	6.36	5.37; 7.35	0.000
Attitude snacks and fast-food[1]	-3.90	-4.72; -3.08	0.000	-3.05	-3.95; -2.15	0.000
Perceived behavioral control	3.25	2.35; 4.14	0.000	3.34	2.44; 4.24	0.000
Intention	3.24	2.41; 4.06	0.000	3.41	2.57; 4.24	0.000
Outcome: intention						
Food insecurity score	0.006	-0.050; 0.062	0.837	-0.015	-0.07; 0.04	0.610
Financial scarcity	0.001	-0.045; 0.047	0.957	-0.01	-0.06; 0.04	0.794
Subjective norm	0.37	0.31; 0.42	0.000	0.39	0.33; 0.45	0.000

Attitude healthy eating and fruit and vegetables[1]	0.54	0.47; 0.61	0.000	0.55	0.48; 0.62	0.000
Attitude snacks and fast-food[1]	-0.17	-0.23; -0.11	0.000	-0.21	-0.27; -0.14	0.000
Perceived behavioral control	0.50	0.44; 0.56	0.000	0.52	0.46; 0.58	0.000
	Outcome: attitude healthy eating and fruit and vegetables[1]					
Food insecurity score	-0.10	-0.14; -0.06	0.000	-0.10	-0.14; -0.05	0.000
Financial scarcity	-0.13	-0.16; -0.09	0.000	-0.12	-0.16; -0.08	0.000
	Outcome: attitude snacks and fast-food[1]					
Food insecurity score	0.013	-0.04; 0.07	0.648	-0.01	-0.07; 0.05	0.725
Financial scarcity	0.029	-0.02; 0.08	0.207	0.03	-0.02; 0.08	0.190
	Outcome: subjective norm					
Food insecurity score	0.18	0.12; 0.24	0.000	0.14	0.08; 0.20	0.000
Financial scarcity	0.13	0.08;0.18	0.000	0.10	0.05; 0.15	0.000
	Outcome: perceived behavioral control					
Food insecurity score	-0.14	-0.20; -0.09	0.000	-0.15	-0.21; -0.10	0.000
Financial scarcity	-0.16	-0.20; -0.12	0.000	-0.17	-0.22; -0.13	0.000

[1] Attitude scores were reversed (i.e., higher scores reflect a more positive attitude)
[2]Adjusted: adjusted for age, sex, income, educational level, employment status, marital status, country of birth, and livability index

The TPB And Extended TPB

Path analyses for the models explaining dietary quality showed that all associations between the constructs constituting the traditional TPB (Model A) were statistically significant ($p < 0.05$) and in the expected directions: a more positive attitude towards healthy eating and fruit and vegetable consumption; a more negative attitude towards snacks and fast-food consumption; a stronger perceived subjective norm; and a stronger perceived behavioral control were positively associated with a higher intention to eat healthy, and intention was positively associated with dietary quality (β=2.6, 95%CI = 1.62; 3.56, $p < 0.001$) (**Figure 1**). In the extended TPB, where financial scarcity and food insecurity score were added to the model (Model E), similar effect estimates were observed for most associations. Notably, a higher experienced financial scarcity was associated with a slightly higher intention (β = 0.08, 95%CI = 0.036; 0.12, $p <0.001$) and not statistically significantly associated with lower dietary quality (p = 0.086). A higher food insecurity score (i.e., stronger experienced food insecurity) was not significantly associated with intention nor with a lower dietary quality (p = 0.069) (**Figure 1**).



*p<0.05

Figure 1. Path analyses for the models explaining dietary quality. Double (dashed) arrows indicate correlations, single arrows indicate beta coefficients.

Model A: traditional TPB; Model B: Model A that included also direct associations between attitude and dietary quality, and between subjective norm and dietary quality; Model C: Model B that additionally included financial scarcity; Model D: Model B that additionally included food insecurity; Model E: Model B that additionally included financial scarcity and food insecurity

All models were adjusted for age, sex, income, educational level, employment status, marital status, country of birth, and livability index

Fit indices of the 5 models explaining dietary quality (outlined in **Supplemental Figure 1 and Figure 1**) showed poorest fit for the traditional TPB (Model A: Chi^2/ df = 11; CFI = 0.75; RMSEA (95%CI) = 0.10 (0.091; 0.12); SRMR = 0.049), and best fit for the most extended TPB including financial scarcity and food insecurity (Model E: Chi^2/ df= 3.3; CFI = 0.95; RMSEA (95%CI) = 0.050 (0.035; 0.065); SRMR = 0.018) (**Table 3**). All 5 structure models explained approximately 42-43% of the variance in intention, however, the variance in dietary quality was better explained by the extended TPB models including food insecurity and/ or financial scarcity (Model C, D and E: 21.6 - 21.9%) compared to the traditional TBP (Model A: 7.3%) (**Table 3**). The explained variance of the overall model (i.e., how much of the variance in included variables is explained by the total model) improved from 42.5% to 52.3% between model A and E (**Table 3**).

Table 3. Fit indices of models used to explain diet quality based on the theory of planned behavior (TPB).

	Model A*	Model B*	Model C*	Model D*	Model E*	Norm values
Fit index						
Chi^2 / df	11.09	3.84	3.42	3.49	3.31	≤ 5
CFI	0.749	0.941	0.950	0.948	0.953	≥0.90
RMSEA (95%CI)	0.104 (0.091; 0.117)	0.055 (0.041; 0.070)	0.051 (0.036; 0.066)	0.051 (0.037; 0.067)	0.050 (0.035; 0.065)	≤ 0.10
	P close=0.000	p close = 0.262	p close 0.437	P close=0.407	p close=0.490	
SRMR	0.049	0.022	0.019	0.019	0.018	≤ 0.080
Explained variance						
R^2 intention	0.418	0.418	0.427	0.419	0.427	
R^2 dietary quality	0.073	0.209	0.216	0.216	0.219	
R^2 overall model	0.425	0.510	0.522	0.515	0.523	

*Model A: traditional TPB;
*Model B: Model A that included also direct associations between attitude and dietary quality, and between subjective norm and dietary quality;
*Model C: Model B that additionally included financial scarcity;
*Model D: Model B that additionally included food insecurity;
*Model E: Model B that additionally included financial scarcity and food insecurity
All models were adjusted for age, sex, income, educational level, employment status, marital status, country of birth, and livability index

Discussion

Results of our study showed that dietary quality was better explained by the extended TPB including financial scarcity and/ or food insecurity compared to the traditional TPB: explained variance in dietary quality was approximately 7 percent for the traditional TPB, whereas the extended TPB showed an explained variance in dietary quality of 22 percent. The extended TBP thus accounts for more variance in dietary quality, indicating that this model better explains differences in dietary quality. However, based on our findings, including both food insecurity and financial scarcity simultaneously is not necessary for explaining differences in dietary quality. These findings highlight the importance of taking into account finance-related barriers for healthy eating like financial scarcity or food insecurity to better understand individual dietary behaviors in lower SEP populations.

Our results showed that the traditional TPB had a limited ability to explain dietary quality, a finding that has been confirmed by others as well (4). For example, previous research among Australian pregnant women, and a study among a sample of the general population in the UK, both showed that the TPB framework is well able to explain intention to eat healthy, but explains little variance in actual eating behavior (34, 35). Consistent with these findings, our results showed that the traditional TPB had a reasonable ability to explain intention to eat healthy, whereas the traditional TPB poorly explained dietary quality.

These observations may be explained by the underlying assumption of the TPB that dietary behavior is under an individual's volitional control, implying that dietary decisions are made willingly and rationally. This is partially accounted for by including perceived behavioral control over healthy eating in the TPB (36). However, clearly, dietary behavior is influenced by contextual factors and availability of resources, and the assumption of having volitional control over dietary behaviors does not hold for individuals experiencing finance-related barriers for healthy eating as reflected by food insecurity and financial scarcity. Additionally, previous studies show that factors such as attitude and subjective norm can also directly influence eating behavior (e.g. (37)). We therefore also explored including direct associations between attitude and subjective norm with dietary quality, and results of our path analyses showed that these direct associations were indeed significant and that including these direct associations improved the explained variance in dietary quality. Extending the traditional TPB by additionally including financial scarcity and/ or food insecurity,

further improved explained variance in dietary quality. The observed improvement in explained variance in dietary quality from 7 to 22 percent is considerable when taking into account the complex nature of dietary behavior (4).

Our regression analyses showed an association between experiencing food insecurity and poorer dietary quality, which is in line with previous studies (12). Our results indicate that food insecurity is directly associated with dietary quality, but not with intention to eat healthy, which is in line with a previous study reporting no differences in intention to eat healthy between food secure and food insecure individuals (38). This suggests that the generally poorer dietary quality among people experiencing food insecurity is not the result of a lack of intention to eat healthy, but may rather be induced by stress, psychosocial barriers, or financial barriers (9, 11).

Comparable to our findings on food insecurity, our regression analyses showed that experiencing financial scarcity was not significantly associated with intention. In contrast, our path analyses including all TPB constructs and food insecurity did indicate that experiencing financial scarcity was associated with a slightly higher intention to eat healthy. Based on literature, one would expect that (financial) scarcity has a negative impact on the ability to focus on longer-term goals, and thus would lead to a lower intention to eat healthy (19). Therefore, one the one hand, our path analyses results should be interpreted with caution as this association is not confirmed by theory nor by the results of the individual association. On the other hand, this contrasting finding may also be explained by the inclusion of the TPB constructs in the model. The model showed significant negative covariances for financial scarcity with attitude towards healthy eating and fruit and vegetable consumption and perceived behavioral control, and a positive covariance with subjective norm (data not shown). It may be speculated that other constructs related to subjective norms influence the positive association between financial scarcity and intention to eat healthy. For example, people living in poverty may have a higher intention to eat healthy to comply to social norms because of fear for social exclusion. Indeed, previous studies have shown that besides social norms, social exclusion is also an important determinant that needs to be taken into account when addressing health behavior (39).

In line with previous literature (12, 21), our findings indicate that experiencing financial scarcity or food insecurity is associated with a lower dietary quality in the regression analyses and path analyses, although in the path analyses of the most

extended TPB model including both financial scarcity and food insecurity we did not observe a significant association between these variables and dietary quality. A possible explanation for this finding is that food insecurity and financial scarcity are closely related, thereby each explaining part of the association of the other variable with dietary quality.

Although our results showed that the extended TPB improved the explained variance in dietary quality considerably, it should be noted that other factors that were not included in the current study expectedly also play an important role, as still a large part of the variance in dietary quality was not well explained by the extended TPB model in the current study. Nevertheless, the presented findings further our understanding on dietary behaviors and food choices, and underline the importance of taking finance-related barriers like financial scarcity and food insecurity into account when aiming to better understand dietary behavior or to improve dietary quality among lower-SEP populations.

The findings of the current study should be interpreted in light of its limitations. Firstly, all data were self-reported, which may have led to misclassification or biases such as recall bias and social-desirability bias (40). To validate our findings, more objective measures would be valuable, especially for the dietary intake assessment. Further, questionnaires were offered in the Dutch language only and no help could be provided as questionnaires were completed online and anonymously, thereby excluding non-Dutch speaking and illiterate people. This may explain the disproportionately high number of participants born in the Netherlands. This may have led to an underestimation of food insecurity prevalence in our study, as previous literature indicates that food insecurity prevalence is generally higher among ethnic minority groups (41). Also, the high number of participants born in the Netherlands, together with oversampling on lower SEP individuals, limits the generalizability of our results. It should further be noted that not all model fit statistics were above the norm values. Specifically, for the model that included the items within the constructs that remained after the EFA, we found a CFI of 0.8, whereas a norm of 0.9 or higher is considered in methodological literature (42). However, we found high internal consistency/ reliability for the constructs. Furthermore, our extended TPB models, which were the main focus of our study, all had CFI values above the norm values. Our study is further limited by its cross-sectional design, not suitable for drawing conclusions about causality. Also, no temporal order of the paths between the

TPB constructs could be confirmed in our study. We have partly overcome this by including the food insecurity status of before the COVID-19 pandemic, reflecting the food insecurity status preceding the dietary behavior. However, a longitudinal study design assessing dietary intake at al later timepoint than the other TPB constructs would have been preferred and would improve the ability to establish causal pathways leading to dietary quality.

Strengths of the current study include the relatively large sample size, and our inclusion of participants living across the Netherlands, including both rural and urban districts. Further, TPB constructs were assessed based on a large number of items and the retained items showed good validity and reliability. Further, financial scarcity and food insecurity were assessed based on validated scales.

In conclusion, our results indicate that variance in dietary quality is better explained by an extended TPB including financial scarcity and/ or food insecurity compared to the traditional TPB. These results highlight the importance of taking into account finance-related barriers for healthy eating like financial scarcity and food insecurity for better understanding individual dietary behaviors, and further our understanding on dietary quality and food choices especially in the context of lower SEPs. These findings may contribute to achieving healthier dietary behavior and reduce diet-related disparities.

Implications for research and practice

Dietary behavior is complex, and therefore the potential of the TPB to explain dietary behavior seems to be limited. Our results showed that including financial barriers such as financial scarcity or food insecurity in the extended TPB improved the explained variance in dietary quality considerably, however, our findings suggest that other factors that were not included in the current study expectedly also play an important role, as still a large part of the variance in dietary quality was not well explained by the extended TPB model in the current study. Therefore, future studies may consider including other potential important factors for explaining dietary quality in lower-SEP populations, or consider a mixed methods approach to better understand important factors determining dietary behavior from an individual perspective. All in all, the present findings underline the importance of taking into account finance-related barriers like financial scarcity or food insecurity when aiming to better understand dietary behavior or to improve dietary quality among lower-SEP populations.

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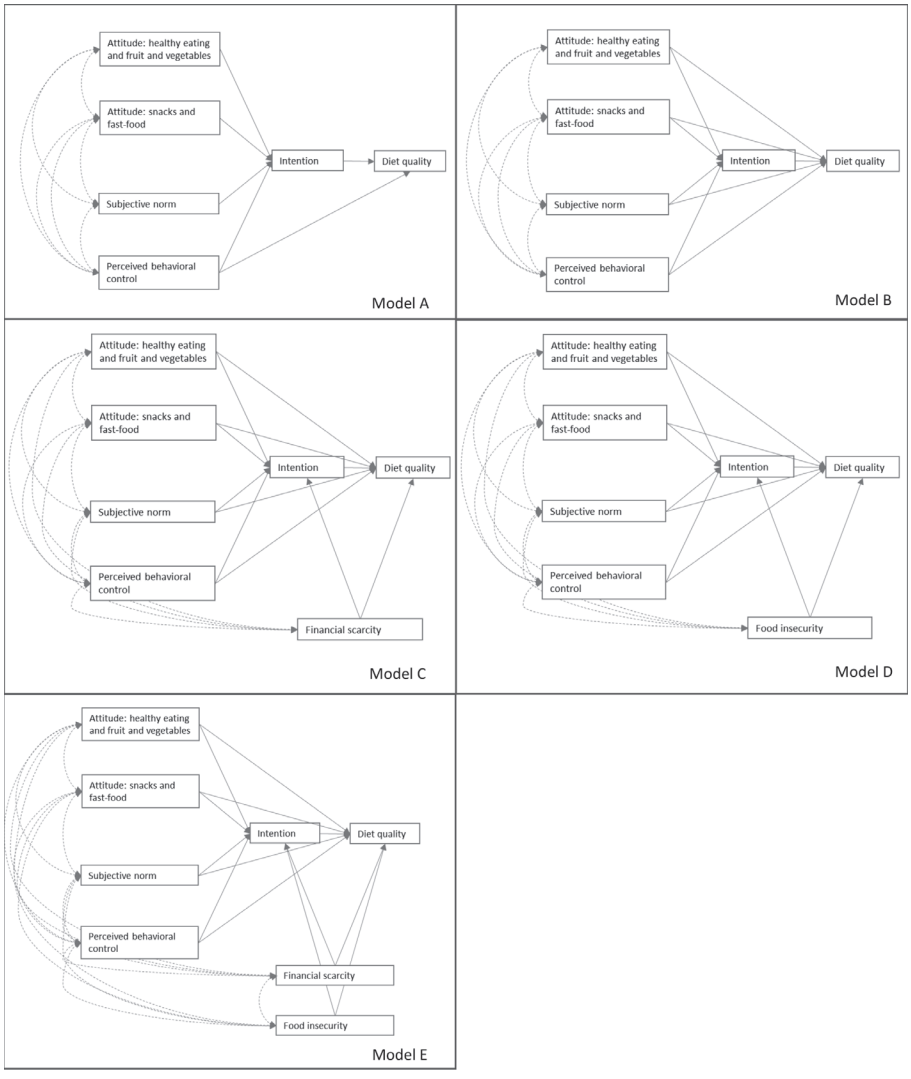
Additional material Chapter 6

Supplemental table 1 Dietary components with associated current national dietary recommendations, contribution percentages and scoring per component

Dietary component	Dietary recommendations by the Dutch Health Council and/or the Netherlands Nutrition Centre	% contribution to the dietary component score	Units	Dietary component score		
				Minimum score		*Maximum score*
				(=0 points)	*5 points*	*(=10 points)*
Vegetables	Consume at least 200 grams of vegetables daily	100	g/d	0	*Continuous*	≥200
Fruit	Consume at least 200 grams of fruit daily	100	p/d	0	*Continuous*	≥ 2
Legumes	Consume one serving legumes a week	100	g/w	0	*Continuous*	≥ 135[1]
Unsalted nuts	Consume at least 15 grams of unsalted nuts daily	100	g/d	0	*Continuous*	≥ 15
Fish	Consume one serving of fish weekly, preferably fatty fish	50	s/w	0	<1	≥ 1
		50	-	No fish consumed	Lean or both lean and fatty fish	Mostly fatty fish
Grain products	Consume at least 90 grams of whole grain products daily	50	g/d	0	*Continuous*	≥ 90
		50	-	Mostly refined	Both refined and whole grain	Mostly whole grain
	Replace refined grain products by whole grain products					
Dairy	Consume 2-3 servings of dairy daily	50	s/d	0	*Continuous*	≥ 2
			-	Full fat dairy products	Both whole dairy products and (semi)-skimmed dairy products	(Semi)-skimmed dairy products
		50				
Tea	Consume 3-4 cups of green/black tea a day	100	s/d	<1 **AND** mostly green/black tea <3 **AND** both herbal tea and green/black tea	1 to 2 **AND** mostly green/black tea ≥ 3 **AND** both herbal tea and green/black tea	≥ 3 **AND** mostly green/ black tea

			-	Not consumed		
				Mostly herbal tea		
Coffee	Replace unfiltered coffee by filtered coffee	100	-	Boiled coffee, cafetière coffee, Greek coffee, Turkish coffee	Vending-machine coffee[2], coffee from cups and espresso	Not consumed or filter coffee, coffee from pads and instant coffee
Oils and fats	Replace butter, hard margarines and cooking fats by soft margarines, liquid cooking fats, and vegetable oils	50		Butter, hard margarines		Oils and soft margarines
		50	-	Butter on bread or bread is not buttered at all	Semi-skimmed butter or hard margarine on bread	Diet margarine on bread
SCBs	Minimize consumption of sugar-containing beverages.	100	s/d	≥ 1	<1	0
Savory snacks	For products outside the Wheel of Five: consume an item from the daily selection no more than three to five times per day, and something from the weekly selection no more than three times a week	50	lrg s/w	≥ 3	<1 to 2	0
		50	sml s/d	> 3	*Continuous*	0
Sweet snacks	For products outside the Wheel of Five: consume an item from the daily selection no more than three to five times per day, and something from the weekly selection no more than three times a week	100	s/w	≥ 3	<1 to 2	0

Abbreviations: SCB, sugar-containing beverages; g/d, grams per day; p/d, pieces per day; s/w, servings per week; s/d, servings per day; lrg s/w, large servings per week; sml s/d, small servings per day.
[1]The Netherlands Nutrition Centre indicates that one serving of legumes corresponds to 135 grams of legumes
[2]Vending-machine coffee can be either filtered coffee or unfiltered coffee. Since the filter used by the vending- machine is not known, the cafestol level is assumed to be moderate



Supplemental Figure 1: Conceptual models used to explain diet quality based on the theory of planned behavior (TPB).
Model A: traditional TPB;
Model B: Model A that included also direct associations between attitude and dietary quality, and between subjective norm and dietary quality;
Model C: Model B that additionally included financial scarcity;
Model D: Model B that additionally included food insecurity;
Model E: Model B that additionally included financial scarcity and food insecurity

Supplemental Table 2. Internal consistency/reliability and factor loadings of model constructs (n=517)

	Factor loadings					
	1	**2**	**3**	**4**	**5**	**6**
Subjective norm (Cronbach's alpha=0.913)						
Most people who are important to me think it would be good if I eat healthy/ more healthy in the next 3 months.				0.900		
My child thinks / children think it would be good if I eat healthy/ more healthy in the next 3 months (if applicable).				0.861		
My family and / or friends think it would be good if I eat healthy/ more healthy in the next 3 months.				0.917		
It is expected of me to eat healthy/ more healthy in the next 3 months.				0.620		
Most people who are important to me eat healthy themselves						
Most people who are important to me, think healthy eating is important						
Perceived behavioral control (Cronbach's alpha= 0.909)						
I am convinced that I can eat healthy/ more healthy in the next 3 months if I want to.		0.635				
I feel in control about eating healthy/ more healthy in the next 3 months.		0.726				
I am convinced that I can eat healthy/ more healthy in the next 3 months, even if I have little money		0.693				
I am convinced that I can eat a lot of fruit and vegetables in the next 3 months, even if I have little money		0.695				
I am convinced that I can eat few snacks and/ or fast-food in the next 3 months, even if I have little money		0.731				
I am convinced that I can eat healthy/ more healthy in the next 3 months, even if I have little time		0.817				
I am convinced that I can eat a lot of fruit and vegetables in the next 3 months, even if I have little time		0.846				
I am convinced that I can eat few snacks and/ or fast-food in the next 3 months, even if I have little time		0.801				
Attitude healthy eating and fruit and vegetables (Cronbach's alpha= 0.944)						
I think eating healthy/ more healthy is: good for me – bad for me	0.697					
I think eating healthy/ more healthy is: easy – difficult	0.612					
I think eating healthy/ more healthy is: tasty – not tasty	0.682					
I think eating healthy/ more healthy is: important – not important	0.709					
I think eating healthy/ more healthy is: cheap-expensive						
I think eating healthy/ more healthy is: nice – stupid	0.634					
I think eating healthy/ more healthy is: possible - impossible	0.666	-0.386				
I think eating healthy/ more healthy is: positive - negative	0.694	-0.308				
I think eating fruits and vegetables is: good for me – bad for me	0.753					

I think eating fruits and vegetables is: easy - difficult	0.726				
I think eating fruits and vegetables is: tasty – not tasty	0.806				
I think eating fruits and vegetables is: important – not important	0.837				
I think eating fruits and vegetables is: cheap – expensive					
I think eating fruits and vegetables is: nice – stupid	0.745				
I think eating fruits and vegetables is: possible - impossible	0.781				
I think eating fruits and vegetables is: positive - negative	0.831				
Attitude snacks and fast-food (Cronbach's alpha= 0.832)					
I think eating snacks and fast-food is: good for me – bad for me				0.413	
I think eating snacks and fast-food is: easy - difficult				0.662	
I think eating snacks and fast-food is: tasty – not tasty				0.862	
I think eating snacks and fast-food is: important – not important				0.475	
I think eating snacks and fast-food is: cheap- expensive					
I think eating snacks and fast-food is: nice – stupid				0.745	
I think eating snacks and fast-food is: possible - impossible				0.656	
I think eating snacks and fast-food is: positive - negative				0.586	
Intention (Cronbach's alpha= 0.900)					
I intend to eat healthy/ more healthy in the next 3 months		0.396			0.745
I intend to eat a lot of fruits and vegetables in the next 3 months	-0.307	0.429			0.627
I intend to eat few snacks and/ or fast-food in the next 3 months	-0.302	0.325		0.305	0.523
I really want to eat healthy/ more healthy in the next 3 months		0.315	0.324		0.757
I expect to eat healthy/ more healthy in the next 3 months		0.398			0.783
Financial scarcity (Cronbach's alpha= 0.944)					
I often don't have enough money.			0.899		
I am constantly wondering whether I have enough money.			0.896		
I worry about money a lot.			0.914		
I am only focusing on what I have to pay at this moment			0.862		
rather than my future expenses.					
I experience little control over my financial situation.			0.859		

Supplemental Table 3. Fit indices of the constructs subjective norm, attitude towards healthy eating and fruit and vegetables, attitude towards snacks and fast-food, perceived behavioral control, intention, and financial scarcity (n=516)

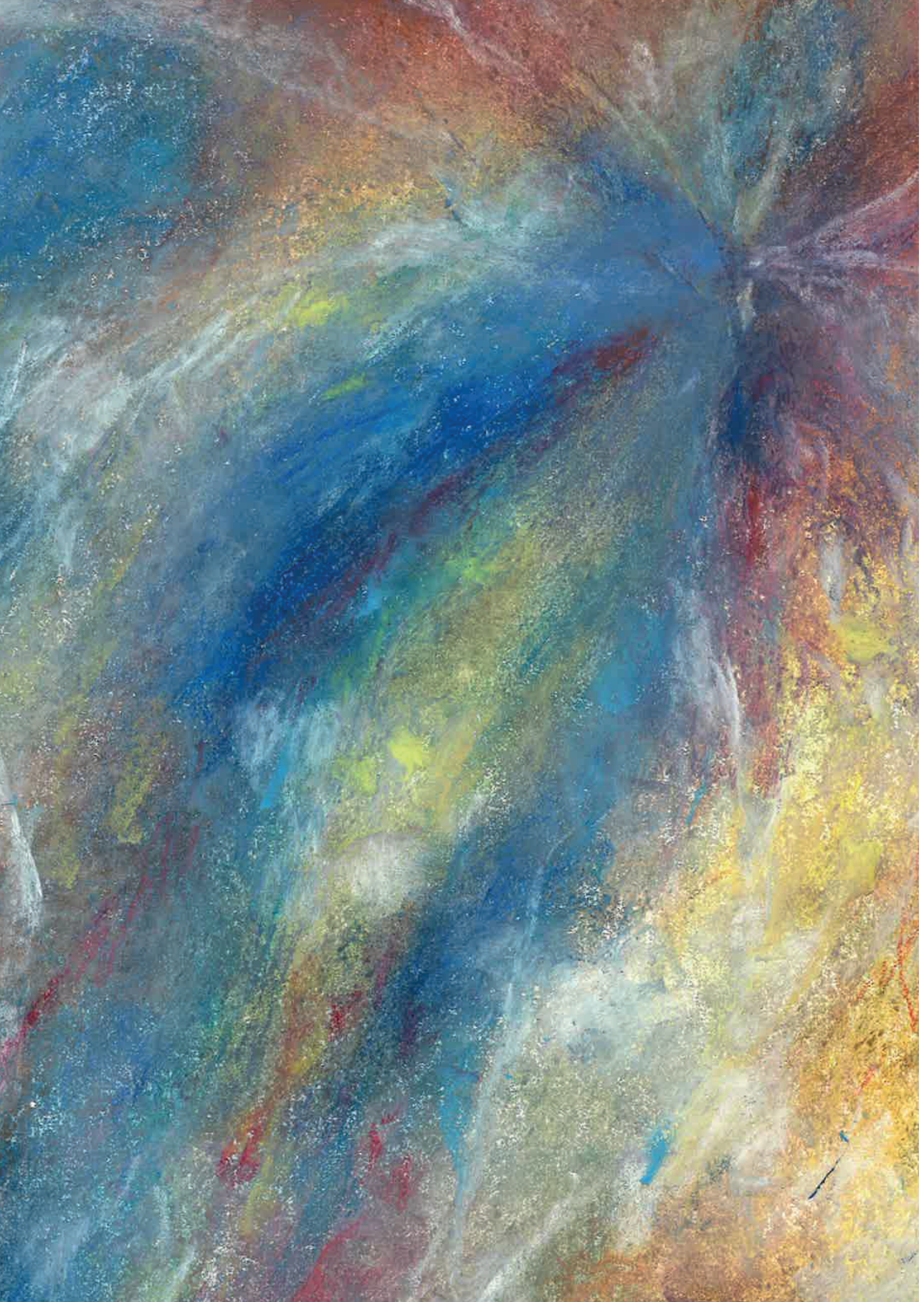
Fit index		**Norm**
Chi2 / df	3.74	≤ 5
TLI	0.790	≥0.90
CFI	0.803	≥0.90
RMSEA	0.094 (0.091; 0.098)	≤ 0.10
SRMR	0.086	≤ 0.080
Explained variance		
R^2 overall model	0.99	

Supplemental Table 4. Population characteristics for the total population and split by current food insecurity status and financial scarcity status

	Total population (n=1033)	**Food secure (n=890)**	**Food insecure (n=143)**	**No financial scarcity (Strongly disagree-neutral) (n=864)**	**Financial scarcity (somewhat agree- strongly agree) (n=169)**
Age (mean ± SD)	55.5 ±16.4	56.8 ±16.2	47.2 ±14.9	56.7 ±16.2	49.3 ±15.7
Age range (minimum-maximum)	18 - 88	18 - 88	20 - 82	18 - 88	20 - 85
Sex (n (%) male)	542 (52.5)	499 (56.1)	43 (30.1)	478 (55.3)	64 (37.9)
Country of birth (n (%) Netherlands)	999 (96.7%)	869 (97.6)	130 (90.9)	842 (97.5)	157 (92.9)
Marital status (n (%))					
Cohabiting with children	202 (19.6)	174 (19.4)	28 (19.6)	167 (19.3)	35 (20.7)
Cohabiting without children	408 (39.5)	376 (42.2)	32 (22.4)	363 (42.0)	45 (26.6)
Single with children	101 (9.8)	68 (7.6)	33 (23.1)	72 (8.3)	29 (17.2)
Single without children	285 (27.6)	240 (27.0)	45 (31.5)	232 (26.9)	53 (31.4)
Other	37 (3.6)	32 (3.6)	5 (3.5)	30 (3.5)	7 (4.1)
Educational level (n (%))					
Low (upper secondary education or lower)	469 (45.4)	414 (46.5)	55 (38.5)	411 (47.6)	58 (34.3)
Intermediate (post-secondary – short cycle tertiary education)	506 (49.0)	423 (47.5)	83 (58.0)	404 (46.8)	102 (60.4)
High (Bachelor or higher education)	58 (5.6)	53 (6.0)	5 (3.5)	49 (5.7)	9 (5.3)
Paid employment (n (%) yes)	429 (41.5)	381 (42.8)	48 (33.6)	365 (42.2)	64 (37.9)
Income (n (%))[1]					
Minimum	130 (12.6)	82 (9.2)	48 (33.6)	82 (9.5)	48 (30.2)
Below mode income	560 (54.2)	488 (54.8)	72 (50.3)	467 (54.1)	93 (58.5)
Mode income or higher	251 (24.3)	235 (26.4)	11 (11.2)	233 (29.8)	18 (11.3)
Don't know/ don't want to answer	91 (8.9)	85 (9.6)	7 (4.9)	82 (9.5)	10 (5.9)
Livability index (range1 (poor) to 9 (outstanding) (mean ± SD))[2]	6.7 ±1.26	6.75 ±1.24	6.36 ±1.34	6.7 ±1.2	6.5 ±1.4
Score 6 or lower	437 (42.4)	354 (39.9)	83 (58.0)	349 (40.5)	88 (52.1)
Score 7 or higher	594 (57.6)	532 (60.1)	60 (42.0)	513 (59.5)	81 (47.9)

Lifestyle factors					
Current smoker (n (%) yes)	183 (17.7)	133 (15.0)	50 (35.0)	140 (16.2)	43 (25.4)
BMI (mean ±SD)[3]	26.8 ±5.0	26.6 ±4.8	28.1 ±6.3	26.6 ±4.6	27.9 ±6.7
Weight status (n (%))					
Normal weight	404 (39.1)	354 (39.8)	50 (35.0)	335 (38.8)	69 (40.8)
Overweight	370 (35.8)	328 (36.9)	42 (29.4)	322 (37.3)	48 (28.4)
Obesity	259 (25.1)	208 (23.4)	51 (35.7)	207 (24.0)	52 (30.8)
Dietary quality (0-130) (mean ± SD)	70.3 ±15.3	71.2 ±15.1	64.3 ±15.2	70.9 ±15.2	66.8 ±15.5
TPB constructs (7-point Likert scales (mean ± SD))					
Subjective norm	4.3 ±1.2	4.2 ±1.1	4.9 ±1.3	4.2 ±1.1	4.7 ±1.3
Attitude healthy eating and fruit and vegetables	4.8 ±0.9	4.8 ±0.9	4.5 ±0.9	4.8 ±0.9	4.6 ±0.9
Attitude snacks and fast-food	2.9 ±1.1	2.9 ±1.1	3.0 ±1.1	2.9 ±1.0	3.0 ±1.2
Perceived behavioral control	5.0 ±1.0	5.0 ±0.97	4.6 ±1.2	5.1 ±1.0	4.9 ±1.3
Intention	4.7 ±1.1	4.7 ±1.1	4.8 ±1.2	4.7 ±1.1	4.8 ±1.2
Finance-related barriers					
Food insecurity score (range 0-6 (mean ±SD))	0.4 ±1.2	0 ±0	2.9 ±1.9	0.1 ±0.6	1.9 ±2.1
Financial scarcity (7-point Likert scale (mean ± SD))	2.6 ±1.5	2.3 ±1.2	4.6 ±1.2	2.2 ±1.0	5.0 ±0.7

[1] Income categories refer to the following amounts of annual gross income: Minimum <14.100 euro; Below mode income 14.100-36.500 euro; Mode income or higher >36.500 euro.
[2] Livability index: n=1031
[3] BMI: n=984



CHAPTER 7

General discussion

The main objective of this thesis was to improve understanding of the prevalence of food insecurity in the Netherlands and its consequences for dietary quality and health. In this chapter, we first describe and discuss the main findings presented in this thesis. Secondly, we discuss methodological considerations regarding the study design and assessment of variables. Thirdly, the implications of our research, as well as directions for future research, are discussed. Finally, an overall conclusion is presented.

Main findings

While food insecurity has previously been shown to be associated with obesity, the explanatory factors underlying this association are less clear. The study presented in **Chapter 2** therefore explored potential explanatory factors by conducting mediation analyses, which involved describing the association between food insecurity and obesity and potential mediation by sociodemographic and lifestyle factors. The findings indicated that food insecurity was associated with obesity but not with overweight, and that the food insecurity-obesity association was partially mediated by living situation, dietary quality, and smoking status. Our finding that food insecurity and obesity were associated among adults is consistent with previous literature; a systematic review and meta-analysis by Moradi et al. (2019), and a review by Te Vazquez et al. (2021), including the most recent studies on this topic, both indicate that food insecurity increases the risk of obesity, especially among women (1, 2). The mechanisms and pathways underlying this association are, however, not yet fully understood (3). **Chapter 2** advances our understanding of explanatory factors underlying the complex association between food insecurity and obesity, and as such contribute to filling one of the main research gaps in current literature on this topic: understanding the mechanisms and pathways underlying the association between food insecurity and obesity (3).

Improving health among disadvantaged groups and an ability to identify those most at risk of poor health has great potential for improving population health. Population health management is an emerging concept that aims to improve population health and includes effective risk stratification: identification of populations that are most at risk of poor health (4). Risk stratification and explaining poor health based on traditional risk factors and social determinants of health (such as employment status, educational level, and income) often yields disappointing results, indicating

that less traditional social determinants of health, such as food insecurity, might be worth considering for these purposes. In **Chapter 3** we therefore explored the value of assessing food insecurity and adding this to traditional social determinants of health when explaining poor physical and mental health: food insecurity was indeed a strong predictor of poor physical and mental health. Our results further indicated that food insecurity was of added value beyond traditional socioeconomic risk factors (i.e., age, educational level, income, living situation, employment, migration background): explained variance improved by approximately one-half for physical health and doubled for mental health. Although the association between food insecurity and poor health is well established in literature (e.g., (2, 5, 6)), our study nevertheless is among the first to investigate the added value of food insecurity status in explaining poor health. This information can contribute to effective risk stratification (by identifying populations at increased risk of poor health); to providing targeted interventions to improve their health; and to decreasing health care costs and utilization. Implementation requires information on food insecurity status to be available (for example through routine screening for food insecurity status, which is not current practice in the Netherlands) and the availability of effective interventions to reduce food insecurity and improve health. The importance of addressing social determinants of health when seeking to identify people at increased risk of poor health, which requires screening for these determinants, is recognized in recent literature (7-9). However, screening for social determinants such as food insecurity does require consideration of the health benefits, health care costs, and acceptance of screening by both the person being screened and the professional performing the screening. Furthermore, despite a growing recognition of the importance of interventions aimed at reducing food insecurity and improving health outcomes, current literature provides little high-quality research on this topic (10). A recent review indicates that health care-based food insecurity interventions (based on food-related resources or assistance provided, and on providing food or food vouchers in addition to resource referrals) may improve food security and health outcomes, but more research is warranted (10).

Advancing our understanding of factors that influence eating behavior among people at risk of experiencing food insecurity is essential when developing targeted interventions to support this population. **Chapter 4** presents narratives of people at risk of experiencing food insecurity, using a qualitative approach to gain a better

understanding of the needs and perceptions regarding healthy eating behavior among this target group. The results of this study suggested that participants possess adequate nutritional knowledge; nevertheless, participants reported various social, environmental and financial barriers to healthy eating behavior, including poor mental health, financial stress, high food prices, and an unfavorable food environment. This chapter offers some initial suggestions for interventions that may help improve eating behavior in this vulnerable population. These suggestions include lowering the price of healthy foods and improving the food environment, as high prices of healthy foods and an unfavorable food environment characterized by an abundance of fast-food outlets were among the main perceived barriers for healthy eating articulated by our participants. This is in line with a recent photovoice study by Lindow et al. (2021) on how food insecurity affected parent's eating behavior and health. This study described how healthy foods seem out of reach due to relatively high prices, whereas unhealthy foods are relatively cheap, heavily promoted and food environments contain an abundance of unfavorable food outlets, all of which represent barriers to healthy eating (11).

In **Chapter 5**, we further explored the influence of the food environment as a barrier for healthy eating among people at risk of experiencing food insecurity. In this study, we assessed the interplay between fast-food outlet exposure, household food insecurity, and dietary quality in disadvantaged districts in the Netherlands. Fast-food outlet exposure measures were calculated using Geographical Information Systems (GIS). The results of the study presented in **Chapter 5** indicated that experiencing food insecurity was associated with lower dietary quality, and that this association was moderated by fast-food outlet proximity: 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 home. This is in line with previous literature, showing substantial evidence for an association between experiencing food insecurity and lower dietary quality (12). Contrary to these studies, a recent study by Gupta and Freedman (2021) did not show a significant direct association between food insecurity and dietary quality, however, their results indicated that among people experiencing food insecurity, a greater perception of healthy food availability was associated with a better dietary quality (13). These authors argue that people experiencing food insecurity may be more constrained to the retail food choices available within their neighborhood because of limited access to transportation (13). The results of the study presented in **Chapter 5** also showed that increasing fast-

food outlet distance (i.e., increasing distance between the fast-food outlet and the participants' home) 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), whereas no association was found between fast-food outlet density and dietary quality. A recent study including over 8000 Dutch older adults also found no evidence for an association between an unhealthy food environment with a relatively high proportion of fast-food outlets and lower dietary quality (14). Overall, the evidence for an association between the food environment and dietary quality remains limited and shows inconsistent results (15). Our study contributes to the growing body of literature focused on the influence of the neighborhood fast-food environment on food insecurity and dietary quality. Taken together, this indicates that improving dietary quality by promoting healthier food environments may be especially important in areas with high percentages of food insecure households, as people experiencing food insecurity are most affected by their food environment, and because food insecurity and a high prevalence of fast-food outlets generally cluster within neighborhoods (16, 17).

The role of financial barriers in explaining dietary quality is elaborated on in **Chapter 6**. In this study, we aimed to assess whether extending the Theory of Planned Behavior (TPB) - one of the most commonly used models for understanding health behaviors such as dietary behavior – by adding barriers related to financial scarcity and food insecurity better explains dietary quality. Our findings indicate that compared to the traditional TPB and less extended TPB models, the most extended TPB (including both financial scarcity and food insecurity) showed best model fit and best explained variance in dietary quality, highlighting the importance of taking finance-related barriers for healthy eating into account when seeking a better understanding of individual dietary behaviors in populations with a lower socioeconomic position. As the literature on psychosocial factors explaining differences in dietary intake is still relatively sparse, our study represents a substantial contribution to addressing this gap in current research (18). A recent study by Ranjit et al. (2021) showed that levels of various behavioral and psychosocial mediators of dietary quality, such as self-efficacy for healthy eating, were low among people experiencing food insecurity, and that psychosocial factors (e.g., self-efficacy for healthy eating and for planning healthy meals, stage of change of fruit and vegetable consumption) appeared most effective in reducing inequalities in dietary quality (18). Although including other psychosocial factors than used in our study (i.e., self-efficacy and stage of change),

this study also stresses the importance of addressing psychosocial factors as well as systemic factors linked to food security (e.g., costs, availability, and accessibility of adequate food) when seeking to improve dietary quality in low-income populations (18).

Methodological considerations and recommendations for future research

In the following sections, methodological considerations and strengths and limitations of the study designs and assessment methods applied in this thesis are discussed, as well as opportunities for future research.

Study design

Most studies presented in this thesis used a cross-sectional, observational study design. This study design was suited to the main aim of this thesis (which was to improve understanding of the prevalence of food insecurity in the Netherlands and its consequences for dietary quality and health) and was a pragmatic choice in view of the time and budget available for our studies. Nonetheless, to put the results of this thesis into perspective, this type of study design has several limitations that should be addressed. First of all, using cross-sectional data precludes conclusions on the temporal order of the associations and paths found in our studies, as the determinants and outcomes are simultaneously assessed (19). This is especially important for the mediation and path analyses presented in this thesis, as for these types of analyses we clearly assumed a temporal order. For example, in **Chapter 2** we assumed that food insecurity preceded mediating variables, which in turn preceded obesity. We further assumed that TPB constructs, financial scarcity and food insecurity preceded dietary quality in **Chapter 6**. For the studies presented in **Chapters 3** and **5**, we assumed that the determinants preceded the outcomes of the regression analyses, although this cannot be confirmed using a cross-sectional study design. However, our aim was not to establish causal pathways, but rather to gain a better understanding of how food insecurity, dietary quality, obesity, and other factors may be associated, and which could be potential factors to take into account when developing interventions. Nevertheless, a longitudinal study design assessing outcomes of interest at a later timepoint than determinants would allow the temporal order of pathways to be determined. Furthermore, a life course perspective is preferred for future studies, as life course theory (which states that what happens

at one moment in life influences what happens later in life) helps to explain the long-lasting adverse effects of experienced food insecurity (20). Experience of food insecurity is also closely linked to Adverse Childhood Experiences (ACEs) (a concept that, amongst others, encompasses experiences of physical and emotional abuse, neglect, and household instability, for example witnessing domestic violence or experiencing parental separation), and accumulating ACEs in childhood are linked to food insecurity later in life (21, 22). This highlights the importance of a life course approach for future studies seeking to understand and alleviate food insecurity.

Other challenges of observational, cross-sectional research are precision (i.e., a lack of random error or variation in the study estimates) and validity (i.e., a lack of systematic error) (19). In observational studies, random variation arises from the participant sample (as this is always limited to a selection of the possible sample that could have been included) and assessment of variables, which can affect the precision of the study estimates. Greater precision can be achieved by having balanced groups (i.e., people with and without food insecurity), and including a sufficiently large sample, as we have strived to do in our studies. As for validity, one can differentiate between internal validity (i.e., the strength of the inferences from the study: differences in outcome arise from differences in exposure rather than from systematic errors) and external validity (i.e., generalizability of the results to a more universal population) (19). In our studies, we attempted to limit systematic errors and biases, and to include representative study populations. However, it should be noted that for the studies presented in **Chapters 2, 3**, and **5**, our sample size was relatively small and mainly included women living in a disadvantaged urban setting, even though we recruited participants at various locations and also offered help with filling in the questionnaires (which were available in different languages), both of which increased our reach within the target population. The study presented in **Chapter 6** managed to include a relatively large sample size, although it should be noted that questionnaires were only available in the Dutch language and no help could be offered with filling in the questionnaires due to the anonymous online format. This approach excluded non-Dutch speaking and illiterate people, which may explain the disproportionately high number of participants born in the Netherlands in this study. Therefore, to demonstrate external validity of our results and generalizability to the broader Dutch population, future studies should replicate our findings in different populations, places, and time periods. Furthermore, it is important that future studies approach the problem from a life course perspective

and consider specific subgroups separately, as risk of experiencing food insecurity varies between and within countries, regions, populations, and life stages.

Assessment of study variables

Assessment of food insecurity status

Food insecurity is an elusive and multidimensional concept, occurring when people lack consistent physical, social, or economic access to adequate food due to limited resources. Naturally, this makes food insecurity status difficult to define (as described in **Chapter 1**) and even more difficult to measure (23). Various indicators, assessment procedures and surveys are available and are used to estimate food insecurity. National-level food insecurity estimates include the Global Hunger Index (GHI) and Global Food Security Index (GFSI) (24). To assess experience-based food insecurity (i.e., indicators that "directly measure food insecurity based on the food deprivation process that food insecurity households experience") as carried out in our studies, a range of surveys are available including the United States Department of Agriculture Food Security Survey Modules (USDA FSSM), Household Food Insecurity Access Scale, Household Hunger Scale, Latin American and Caribbean Household Food Security Scale, and Food Insecurity Experience Scale (24).

In our studies we used the USDA FSSMs, which are widely used and accepted and have shown excellent predictive validity and good fit (24). For the majority of studies presented in this thesis, we used the most comprehensive (18-item) USDA FSSM, but in the study presented in **Chapter 6,** due to the already extensive questionnaires developed for that study, we chose to use the 6-item module in order to limit participant burden. Although the original USDA FSSM was only validated for use in the United States, the module has been extensively adapted and subsequently validated among various populations and settings in recent years (24). Although it has been previously used in the Netherlands (25), it should be noted that the USDA FSSM has not yet been validated specifically for the Dutch population. This indicates the need for a future Dutch validation study to assess whether the (translated) USDA FSSM is actually suitable for assessing food insecurity in the Dutch context and sufficiently covers all dimensions of food insecurity that may occur in the Netherlands.

Regardless of which specific survey is used, and although tools to measure experience-based food insecurity have been shown to provide a reliable and valid estimate of food insecurity (26), several biases associated with these tools need to be addressed.

Firstly, these tools are generally self-reported. As opposed to objective measures of nutritional status (such as anthropometric measures) or stress (such as chronic stress levels measured in hair cortisol), self-reported experience-based food insecurity tools reflect a subjective experience/perception of inadequate access to food. Different groups (for example, people of different gender, ethnic- or cultural background) may perceive and report their food insecurity experience differently (26). Furthermore, household food insecurity is often reported by one member of the household and their responses may not reflect the views of other family members. Child food insecurity status is often reported by a parent, while parents may not be reliable reporters of their children's intakes and experiences (27, 28).

Secondly, self-reported measures of food insecurity and other variables used in our studies may have been affected by biases such as social desirability bias and recall bias. For example, we used reference periods of up to 12 months for experienced food insecurity, which may have been difficult to recall in general or recall may have been affected by current food security status. It is important here to distinguish between non-differential and differential misclassification: non-differential misclassification occurs when the probability of individuals being misclassified is equal across all groups in the study, whereas differential misclassification occurs when the probability of individuals being misclassified varies between groups because the error depends on other variables (29). With regard to measurement of food insecurity, differential misclassification may have occurred if participants currently experiencing food insecurity show differences in their recall and reporting of factors such as dietary intake, financial scarcity, and psychosocial factors related to healthy eating (such as attitudes, subjective norm, perceived behavioral control, and intention) compared to food-secure people. This is not unlikely, as people currently struggling to gain adequate access to food may be more focused on food and finance-related matters, which may result in differences in reporting of these matters. As these differences may theoretically lead to biased results, replication of the study using repeated measures of food insecurity and related variables across various time points is therefore needed.

Assessment of dietary quality

As most studies described in this thesis included dietary quality (as a determinant, mediator, or outcome), it is important to address some methodological considerations regarding the assessment of dietary intake and dietary quality. To assess dietary

intake and compute dietary quality scores in our studies, we used short Food Frequency Questionnaires (FFQ) that contained only a limited range of foods. The FFQ did not allow detailed assessment of nutrient intakes and therefore our dietary quality scores could not be validated by relating them to nutrient adequacy (30). Based on previous literature describing a similar FFQ, we believe that these FFQs adequately provided an approximate ranking of subjects according to their dietary quality (31). An important consideration is that the FFQ was designed for - and therefore most applicable to - Dutch eating patterns and to a lesser extent to non-Dutch eating patterns. It should further be noted that we based our dietary quality scores on Dutch dietary guidelines, which may also be less suitable for non-Dutch ethnic groups. This could have biased our results, for example if particular foods that are more often eaten by non-Dutch ethnic groups were not included in the FFQ and therefore not considered in the dietary quality score. Depending on the healthiness of these foods, this could have resulted in both higher or lower dietary quality scores among various non-Dutch ethnic groups. Therefore, future studies should assess the appropriateness and potential need for improvement of the FFQ for non-Dutch ethnic groups. Furthermore, dietary intake was self-reported, and may therefore have been affected by biases such as social desirability bias and recall bias as described above. It would be valuable if future studies combine dietary intake as assessed using the FFQ with objective measures of dietary quality and nutrient intake such as biomarkers for vitamins and minerals obtained from urine or blood.

Assessment of the food environment

Several methodological considerations regarding food environment research have already been discussed in **Chapter 5**. Following the methodological considerations regarding the assessment of dietary intake described above, it should be noted here that it would have been valuable to obtain information on actual fast-food purchase and consumption behaviors from the participants, rather than just assess density and proximity of fast-food outlets and an indication of overall dietary quality.

Lamb et al. (2020) indicate that longitudinal studies or quasi- or natural-experimental designs (with appropriate comparison groups), including information on neighborhood choice and preference and related individual characteristics, offer the best potential to study how changes in the environment influence changes in behavior (32). As described in a systematic umbrella literature review by Sawyer et al. (2021), the food environment includes social, physical, economic, and political

factors within the dimensions of food availability, affordability, accessibility and acceptability (33), which are also essential elements of food security. They note that despite observed associations between adverse food environments and poor diets, unravelling the mechanisms underlying these associations in low-income groups remains difficult. A novel, comprehensive and promising way to study the associations between food environments, dietary intake, and poverty is from a systems dynamics perspective (33). These authors applied causal loop diagramming (a specific method within system dynamics research), resulting in an evidence-based mapping of the complex adaptive system underlying the food environment influencing dietary intake in low-income groups. This showed that an adverse food environment is shaped by multiple, interconnected feedback loops - wherein food insecurity also plays an important role - increasing accessibility, availability, affordability, and acceptability of unhealthy foods, leading to poorer dietary intake in low-income groups (33). The comprehensive and complex systems described in this study help to put our findings into perspective and highlight the importance of taking broader systems into account when seeking to identify leverage points on which interventions are more likely to have sustainable impact in terms of accessibility, availability, affordability, or acceptability of healthier food (33).

Implications and future directions

As outlined throughout this thesis, even in high-income countries such as the Netherlands, food insecurity exists and negatively impacts dietary quality and health. Food insecurity is further associated with increased healthcare utilization and costs, even when socioeconomic factors are taken into account (34). These factors make food insecurity an important issue for population health and highlight the pressing need to properly address food insecurity and its consequences. The question is, how should we address this problem? Should we screen for food insecurity in the Netherlands? And once we have identified people at increased risk of food insecurity, how can we help them to improve their dietary quality and health? These questions will be addressed below.

Should we screen for food insecurity in the Netherlands?

A growing body of literature recognizes that addressing social determinants of health is essential when seeking to improve population health and identify people at increased risk of poor health (7, 8). Assessing and addressing social determinants

of health will require screening for these determinants, and is increasingly being recognized as a priority among interprofessional health care teams across various settings and domains (9). Only when health care providers are aware of the existence of social risk factors such as food insecurity, can they address these issues and improve access to resources, if available (9).

However, despite the recognized importance, at present neither food insecurity screening nor monitoring is routinely implemented in European countries, including the Netherlands. Indirect indicators of food insecurity, such as poverty or neighborhood-level disadvantage, are not suitable for accurately capturing perceived food insecurity. Food insecurity should therefore be assessed directly at the person or household level (9). Multiple tools are currently available for this purpose, ranging from very short, one-item screening tools to more elaborate surveys (9).

In the Netherlands, monitoring could be carried out at the population level, for example through inclusion in the CBS Health Survey (a yearly survey) or the GGD Health Monitor (a 4-yearly survey), both of which focus on health- and lifestyle-related topics among the Dutch population. This could provide insight into the prevalence and fluctuations over time of food insecurity, as well as risk groups/risk regions in the Netherlands and consequences for health, all of which could help guide policy making.

Alternatively, screening could also focus on specific (high-risk) populations, for example in nonclinical settings such as community centers (focusing on people living in disadvantaged contexts). Screening could also take place in clinical settings, for example at the general practice, as most Dutch citizens regularly visit their primary care physician. In order to minimize additional time and costs for health care providers and maintain acceptability of patients and providers, short screening tools are, unsurprisingly, best suited to health care settings (7). Furthermore, screening for food insecurity should not be done in isolation: screening results should be carefully discussed and interpreted within the prior context of the patient (9). Screening could also further reinforce stereotypes and stigmatization if only targeted subgroups are included in the screening, but this can be avoided by engaging the entire practice population (35, 36).

If screening for food insecurity is to be implemented in the Netherlands, it is important to monitor acceptability and address potential barriers for both those

screened and those doing the screening. For example, addressing this sensitive issue could be uncomfortable for both those questioned and those asking the questions (35). Efforts should also be made to minimize the reinforcement of stereotypes and stigmatization due to screening, indicating that best practices when screening for food insecurity in the Netherlands should be carefully explored.

Importantly, the identification of people at risk of food insecurity should ideally be followed by referral to effective interventions or resources. This may also call for referral to resources across domains, such as the social domain (i.e., social prescribing), which in the current Dutch context is challenging due to different funding streams. Moreover, in the absence of adequate interventions or resources, screening for food insecurity could be considered unethical (35), as also addressed in other criteria for screening programs for health outcomes (37, 38).

How can we help people experiencing food insecurity?

Due to the many determinants and multidimensional nature of perceived food insecurity, no single intervention or solution can be expected to resolve this issue. Regarding possible interventions, one can distinguish between population-based approaches (targeting the whole population with the aim of favorably shifting the entire risk distribution) and high-risk approaches (targeting specific, high-risk populations with the aim of decreasing the number of people at the high-risk end of the distribution), as emphasized by the epidemiologist Geoffrey Rose (39).

The importance of addressing food insecurity is increasingly being recognized in current literature: several literature reviews have appeared recently describing interventions to address food insecurity in high-income countries (10, 40-42). However, these reviews did not yield conclusive results regarding the most effective interventions for tackling food insecurity, as few high-quality studies or evaluations are currently available. Nevertheless, the findings of these reviews generally point towards systemic, population-based 'upstream' interventions (e.g., social protection programs; policy, governance and legislation targeting determinants related to living and working conditions; or community strengthening and building social support and cohesion) as the most promising approaches to structurally address food insecurity, although interventions with a 'downstream', individual focus (e.g., providing emergency food aid such as foodbanks or changing people's food knowledge, skills or behavior) can also contribute to reducing food insecurity (10, 40-42).

As described by Geoffrey Rose, population-based interventions generally have the largest total effect (e.g., on reducing population-wide food insecurity prevalence, because the number of people at low/ intermediate risk is largest), but may offer little benefit at the individual level (e.g., the extent to which food insecurity is reduced in individual cases) (39). Therefore, one can argue that population-based and (high-risk) individual-based interventions are both needed when aiming to reduce food insecurity, and may indeed complement each other.

In the Netherlands, few interventions (either at population or individual level) are currently available to address food insecurity-related issues, and the available interventions have received little evaluation concerning their effectiveness in reducing experienced food insecurity.

However, the results of our own studies and conversations with participants yielded several suggestions for interventions. For example, although foodbanks can play an important role in alleviating acute food deprivation, they generally have a limited ability to improve overall food insecurity, for example due to inadequate amounts of nutritionally-dense foods (43). Our results and other literature suggest that an improved type of foodbank (e.g., providing more fresh and healthy foods) or an adapted form of food aid (e.g., a social supermarket and improved facilities for social contact) may better meet the needs and preferences of people experiencing food insecurity and should therefore be explored further (25, 44-46).

Our results and other literature further suggest that improving social networks and social support - included in social capital - among people (at risk of) experiencing food insecurity may be a promising strategy to reduce food insecurity and improve dietary quality and health (44, 47). For example, some of our participants perceived a lack of social support and social contacts in the neighborhood as barriers to healthy eating (44). To date, few studies have focused on intervention studies for social capital and health, and future research is warranted to improve our understanding on how social capital interventions can improve health (48). Evidence supporting interventions in the social environment (i.e., social norms and social support) to improve dietary intake is presently limited, but seems promising (49).

Another intervention proposed by our participants was to decrease prices of healthy foods and/or to increase prices of unhealthy foods (44, 45). Previous studies show that pricing interventions (such as taxes on unhealthy foods, subsidies on healthy

foods, and food subsidy programs for low-income families) can effectively improve dietary quality (50-52).

The results of our studies further highlight the need to promote healthier food environments when aiming to improve dietary quality among people experiencing food insecurity, for example by decreasing the number of unhealthy food outlets (such as fast-food restaurants), increasing the number of healthy food outlets, and a larger supply of healthy and affordable foods in supermarkets and restaurants (44, 45, 53). Although there is still considerable scope for research on food environment interventions, current evidence suggests a positive effect of these types of interventions on diet-related outcomes (54). This indicates that implementing and testing interventions to improve the food environment, and thus to improve dietary quality among people experiencing food insecurity, is well worth pursuing.

Through policy and legislation, the Dutch government plays an important role in creating an affordable and healthy food environment. Nevertheless, a recently published research report showed that the Dutch government is missing opportunities in this area and the study provided recommendations for policy improvements that are mostly in line with suggested interventions following from our studies (e.g., lowering prices of healthy foods; increasing prices of unhealthy foods; increasing the amount of healthy products in supermarkets, restaurants and other providers; and funding food assistance such as vouchers for free purchases of healthy foods for people living on a low income) (55). We naturally support these recommendations and believe they can also help improve the diets of people experiencing food insecurity. How these policy actions can best be implemented, however, remains to be determined, as current national and international laws and regulations hinder policy to lower prices of healthy foods (such as lower tax rates for fruits and vegetables) or improve the food environment (such as providing municipalities with the opportunity to ban unhealthy food outlets such as fast-food restaurants from (parts of their) community), although these possibilities are currently being explored (56). A recent study assessing the views of Dutch stakeholders regarding taxation of sugar-sweetened beverages, together with perceived barriers and facilitators to its adoption in the Netherlands, indicated that successful adoption of this tax will require several remaining challenges to be overcome: these barriers included the strong lobby against the tax, perceived public opposition, administrative load and difficulties in defining sugar-sweetened beverages (57).

In summary, reducing food insecurity and improving dietary quality and health in the Netherlands will require a range of population- and individual-based interventions. Further studies will be needed to assess the feasibility and effectiveness of these interventions in The Netherlands.

Population health management: pursuing the Triple Aim

The association between food insecurity and poor health is well established in literature (e.g., (2, 5, 6)). Moreover, food insecurity is associated with higher healthcare costs and more frequent emergency department visits and inpatient admissions (34). Food insecurity is forecasted to increase due to the current COVID-19 pandemic, thereby further increasing the risk of poor health in the short-term and long-term through several pathways, including household stress, behavioral-, and inflammatory pathways (58). Population health management is increasingly being recognized as a key concept to achieve improved population health, improved experienced quality of care, improved provider experience, and reduced healthcare costs (referred to as the Quadruple Aim) (59). The importance of screening for food insecurity and other social determinants of health and then integrating interventions to address these determinants in health care settings, as well as connecting patients to appropriate resources (such as local social support resources), is increasingly recognized and appears effective in improving poor health outcomes in adults in the United States (34, 60).

Based on evidence from the studies presented in this thesis, we advocate the development and implementation of population-based and risk group-based interventions that address food insecurity and its consequences, while incorporating the needs and preferences of this population. Particularly in the case of risk group-based interventions, appropriate screening is required and optimal forms and feasibility should be explored in the Dutch context. Together, these actions are expected to contribute to the Quadruple Aim by improving experienced quality of care (as underlying needs associated with food insecurity and its consequences can be addressed), reducing healthcare costs (which will follow from reduced food insecurity prevalence and improved health and dietary quality), improved provider experience (as their needs and preferences are also considered, allowing them to better aid their patients in need), and ultimately improved population health (61).

Conclusion

Based on this thesis, we can conclude that a considerable number of people in the Netherlands experience food insecurity. The findings described in this thesis provide insight into the consequences: food insecurity is associated with obesity, poor physical and mental health, and poor dietary quality. Our results also illuminate the role of sociodemographic and lifestyle factors, psychosocial factors and the food environment in these associations. In addition, our findings offer a clearer understanding of the perceived needs, perceptions and barriers regarding healthy eating among people at risk of experiencing food insecurity, as well as suggesting potential interventions. This thesis has shown that the issue of food insecurity needs to be better recognized and addressed in the Netherlands, for example through the development and implementation of population-based and risk group-based interventions for which appropriate screening and targeted interventions should be further explored.

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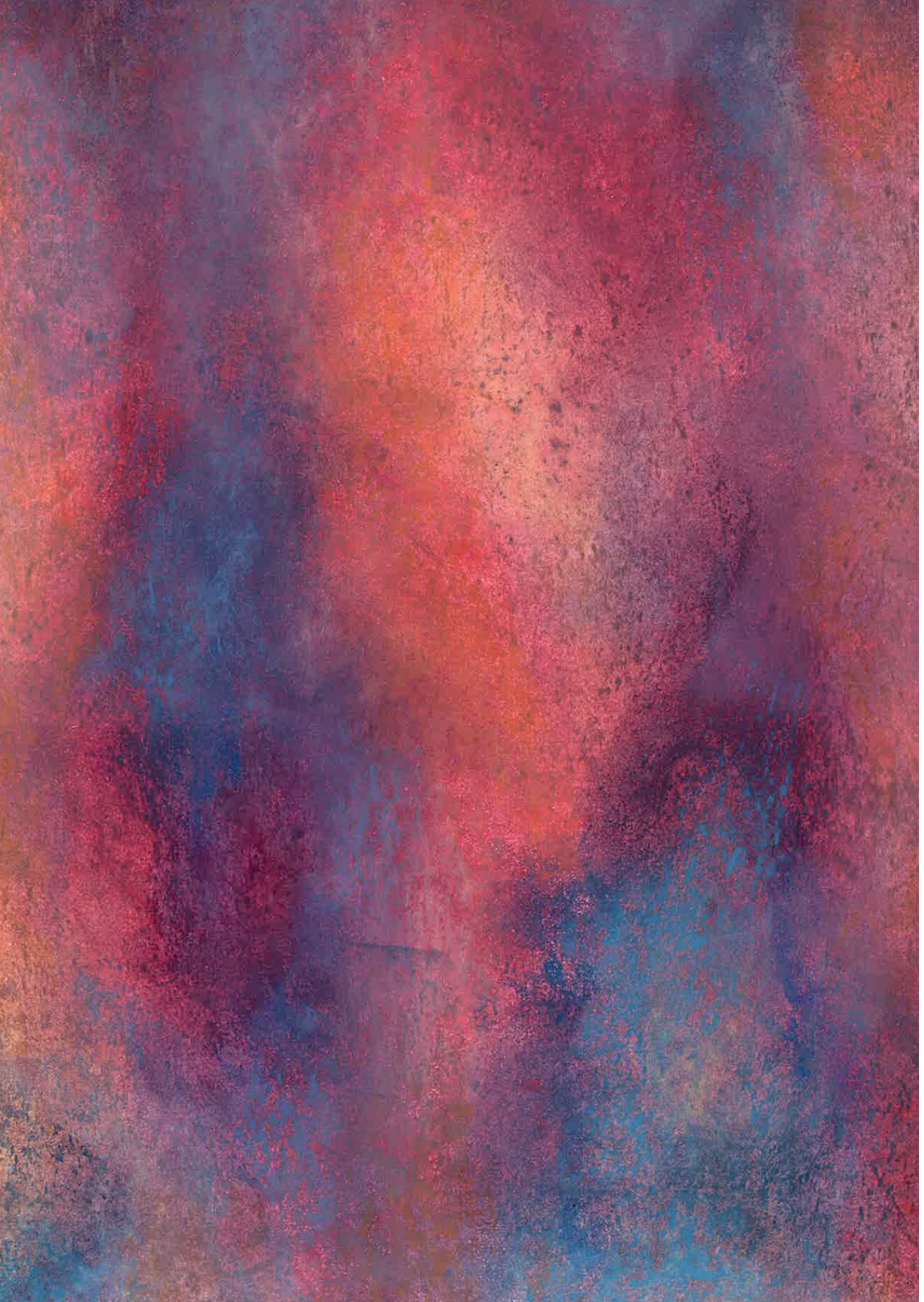


CHAPTER 8

Summary

Social inequalities in health and dietary quality are found worldwide. To identify cues that might help reduce these inequalities, it is important to concurrently address social determinants of health such as food insecurity. Food insecurity is an elusive and multidimensional concept, which occurs when people lack consistent physical, social, or economic access to adequate food because of limited resources. Besides availability and access, feelings of worry and anxiety over food supply and the inability to acquire food in socially acceptable ways are also important components of food insecurity. These components have been incorporated into the definition used by the United States Department of Agriculture, stating that food insecurity is "the limited or uncertain availability of nutritionally adequate, safe foods or the inability to acquire foods in socially acceptable ways".

Food insecurity is an important issue because it negatively affects health and dietary quality. Nevertheless, food insecurity is still a relatively neglected issue in Europe. In the Netherlands, research into food insecurity remains scarce but as the prevalence of food insecurity and its consequences differ between and within countries, regions, and populations, it is especially important to improve our understanding of the situation in the Netherlands.

The overall aim of this thesis was to gain a clearer picture of the prevalence of food insecurity in the Netherlands and its consequences for dietary quality and health. The studies included in this thesis provide potential targets for interventions aimed at reducing food insecurity among affected people and families in the Netherlands.

Main findings of this thesis

While food insecurity has previously been shown to be associated with obesity, the explanatory factors underlying this association are less clear. The study presented in **Chapter 2** therefore explored potential explanatory factors by conducting mediation analyses, which involved describing the association between food insecurity and obesity and potential mediation by sociodemographic and lifestyle factors. The findings indicated that food insecurity was associated with obesity but not with overweight, and that the food insecurity-obesity association was partially mediated by living situation, dietary quality, and smoking status.

Improving health among disadvantaged groups and an ability to identify those most at risk of poor health has great potential for improving population health. Population

health management is an emerging concept that aims to improve population health and includes effective risk stratification: identification of populations that are most at risk of poor health. Risk stratification and explaining poor health based on traditional risk factors and social determinants of health (such as employment status, educational level, and income) often yields disappointing results, indicating that less traditional social determinants of health, such as food insecurity, might be worth considering for these purposes. In **Chapter 3** we therefore explored the value of assessing food insecurity and adding this to traditional social determinants of health when explaining poor physical and mental health: food insecurity was indeed a strong predictor of poor physical and mental health. Our results further indicated that food insecurity was of added value beyond traditional socioeconomic risk factors (i.e., age, educational level, income, living situation, employment, migration background): explained variance improved by approximately one-half for physical health and doubled for mental health. This information can contribute to effective risk stratification (by identifying populations at increased risk of poor health) and to providing targeted interventions to improve their health.

Advancing our understanding of factors that influence eating behavior among people at risk of experiencing food insecurity is essential when developing targeted interventions to support this population. **Chapter 4** presents narratives of people at risk of experiencing food insecurity, using a qualitative approach to gain a better understanding of the needs and perceptions regarding healthy eating behavior among this target group. The results of this study suggested that participants possess adequate nutritional knowledge; nevertheless, participants reported various social, environmental and financial barriers to healthy eating behavior, including poor mental health, financial stress, high food prices, and an unfavorable food environment. This chapter offers some initial suggestions for interventions that may help improve eating behavior in this vulnerable population. These suggestions include lowering the price of healthy foods and improving the food environment, as high prices of healthy foods and an unfavorable food environment characterized by an abundance of fast-food outlets were among the main perceived barriers for healthy eating articulated by our participants.

In **Chapter 5**, we further explored the influence of the food environment as a barrier for healthy eating among people at risk of experiencing food insecurity. In this study, we assessed the interplay between fast-food outlet exposure, household

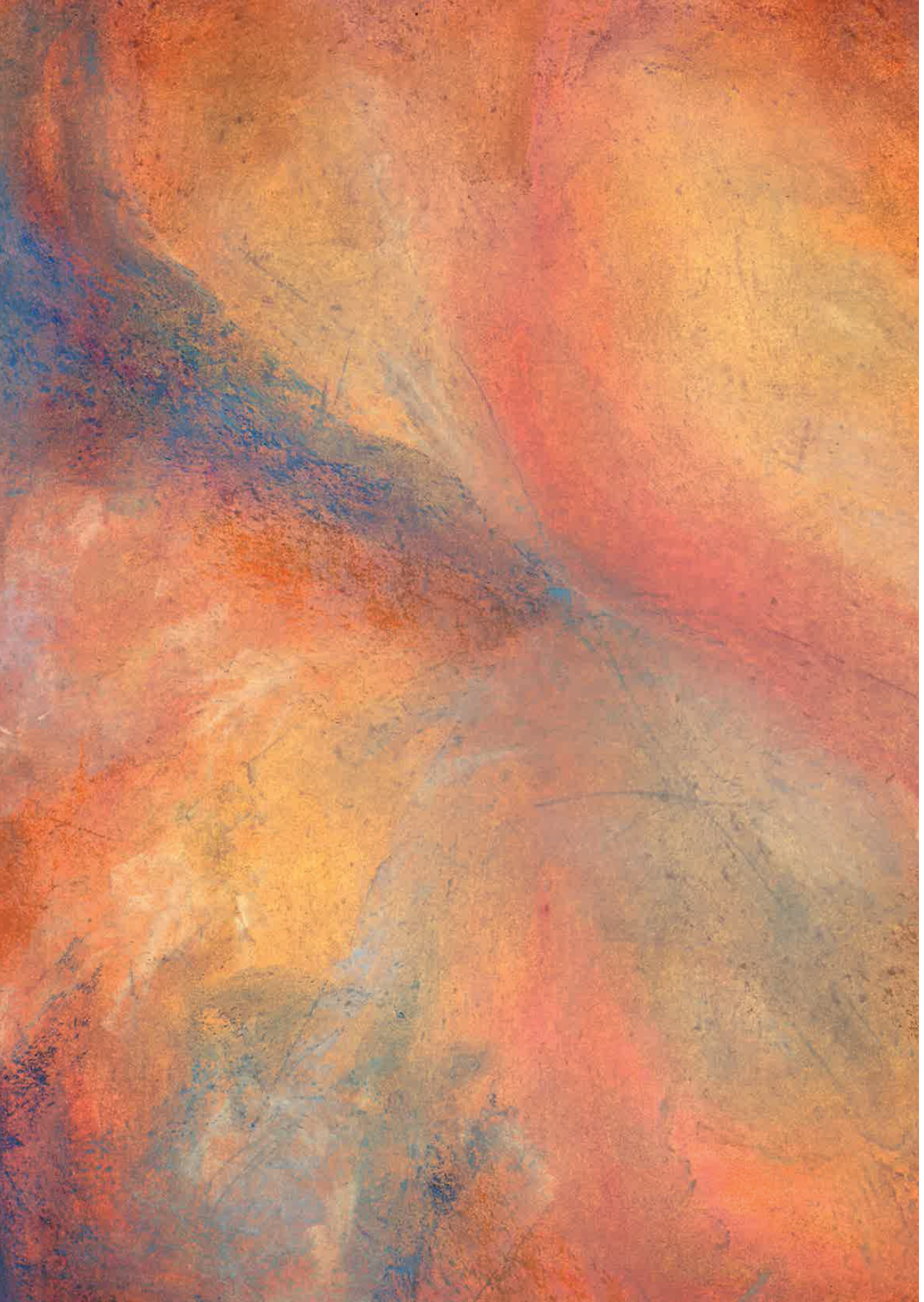
food insecurity, and dietary quality in disadvantaged districts in the Netherlands. The results of the study presented in **Chapter 5** indicated that experiencing food insecurity was associated with lower dietary quality, and that this association was moderated by fast-food outlet proximity: stratified 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 home. The results also showed that increasing fast-food outlet distance (i.e., increasing distance between the fast-food outlet and the participants' home) 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), whereas no association was found between fast-food outlet density and dietary quality. Our study contributes to the growing body of literature focused on the influence of the neighborhood fast-food environment on food insecurity and dietary quality. Taken together, this indicates that improving dietary quality by promoting healthier food environments may be especially important in areas with high percentages of food insecure households, as people experiencing food insecurity are most affected by their food environment, and because food insecurity and a high prevalence of fast-food outlets generally cluster within neighborhoods.

The role of financial barriers in explaining dietary quality is elaborated on in **Chapter 6**. In this study, we aimed to assess whether extending the Theory of Planned Behavior (TPB) - one of the most commonly used models for understanding health behaviors such as dietary behavior – by adding barriers related to financial scarcity and food insecurity better explains dietary quality. Our findings indicate that compared to the traditional TPB, the extended TPB (including financial scarcity and/ or food insecurity) showed best model fit and best explained variance in dietary quality, highlighting the importance of taking finance-related barriers for healthy eating into account when seeking a better understanding of individual dietary behavior in populations with a lower socioeconomic position. As the literature on psychosocial factors explaining differences in dietary intake is still relatively scarce, our study represents a substantial contribution to addressing this gap in current research

Conclusion

Based on this thesis, we can conclude that a considerable number of people in the Netherlands experience food insecurity. The findings described in this thesis provide insight into the consequences: food insecurity is associated with obesity,

poor physical and mental health, and poor dietary quality. Our results also illuminate the role of sociodemographic and lifestyle factors, psychosocial factors and the food environment in these associations. In addition, our findings offer a clearer understanding of the perceived needs, perceptions and barriers regarding healthy eating among people at risk of experiencing food insecurity, as well as suggesting potential interventions. This thesis has shown that the issue of food insecurity needs to be better recognized and addressed in the Netherlands, for example through the development and implementation of population-based and risk group-based interventions for which appropriate screening and targeted interventions should be further explored.



APPENDIX

Nederlandse samenvatting (Dutch summary)

List of publications

Portfolio

Curriculum Vitae

Dankwoord (Acknowledgements)

Nederlandse samenvatting (Dutch summary)

Wereldwijd bestaan er sociale ongelijkheden op het gebied van gezondheid en voedingskwaliteit. Om aanknopingspunten te vinden voor het verminderen van deze ongelijkheden, is het belangrijk om aandacht te besteden aan sociale determinanten van gezondheid zoals voedselonzekerheid. Voedselonzekerheid is een ongrijpbaar en multidimensionaal concept, dat zich voordoet wanneer mensen door beperkte middelen niet altijd fysieke, sociale, of economische toegang hebben tot adequate voeding. Naast beschikbaarheid en toegang tot voldoende voeding, zijn ook gevoelens van bezorgdheid en angst over de voedselvoorziening en het onvermogen om op sociaal aanvaardbare manieren aan voedsel te komen belangrijke componenten van voedselonzekerheid. Deze componenten zijn opgenomen in de definitie van het Amerikaanse ministerie van Landbouw, waarin voedselonzekerheid wordt omschreven als “de beperkte of onzekere beschikbaarheid van adequate, veilige voeding of het onvermogen om op sociaal aanvaardbare manieren aan voeding te komen”.

Voedselonzekerheid is een belangrijk probleem vanwege de negatieve gevolgen ervan voor de gezondheid en de voedingskwaliteit. Toch is voedselonzekerheid in Europa nog een relatief verborgen probleem. Met name in Nederland blijft het onderzoek naar voedselonzekerheid schaars. Omdat de mate van voedselonzekerheid en de gevolgen ervan verschillen tussen en binnen landen, regio’s en bevolkingsgroepen, is het belangrijk om de kennis hierover in Nederland te vergroten.

Het algemene doel van dit proefschrift was om meer inzicht te krijgen in het voorkomen van voedselonzekerheid in Nederland en de gevolgen daarvan voor de voedingskwaliteit en de gezondheid. De onderzoeken in dit proefschrift kunnen een basis vormen voor potentiële interventies om voedselonzekerheid onder mensen in Nederland te verminderen.

Belangrijkste bevindingen van dit proefschrift

Hoewel in eerder onderzoek is aangetoond dat voedselonzekerheid samenhangt met obesitas, zijn de verklarende factoren die aan dit verband ten grondslag liggen minder duidelijk. In het onderzoek dat in **Hoofdstuk 2** is gepresenteerd zijn deze potentiële verklarende factoren daarom verder onderzocht met behulp van mediatie analyses, waarin het verband tussen voedselonzekerheid en obesitas en mogelijke mediatie

door sociaal-demografische- en leefstijlfactoren is beschreven. De bevindingen lieten zien dat voedselonzekerheid wel samenhangt met obesitas maar niet met overgewicht, en dat het verband tussen voedselonzekerheid en obesitas deels wordt gemedieerd door de leefsituatie, de voedingskwaliteit en de rookstatus.

Het verbeteren van de gezondheid onder kwetsbare groepen en het kunnen identificeren van die groepen die het meeste risico lopen op een slechte gezondheid, biedt belangrijke mogelijkheden voor het verbeteren van de volksgezondheid. *Population health management* is een opkomend concept dat gericht is op het verbeteren van de volksgezondheid. Een belangrijk onderdeel van *population health management* is effectieve risicostratificatie: het identificeren van groepen die het meeste risico lopen op een slechte gezondheid. Risicostratificatie en het verklaren van een slechte gezondheid op basis van traditionele risicofactoren en sociale determinanten van gezondheid (zoals werkstatus, opleidingsniveau en inkomen), levert vaak teleurstellende resultaten op, wat erop wijst dat minder traditionele sociale determinanten van gezondheid, zoals voedselonzekerheid, het overwegen waard zouden kunnen zijn voor deze doeleinden. In **Hoofdstuk 3** onderzochten we daarom de waarde van het toevoegen van voedselonzekerheid aan traditionele sociale determinanten van gezondheid voor het verklaren van een slechte fysieke en mentale gezondheid. De resultaten lieten zien dat voedselonzekerheid inderdaad een sterke voorspeller was van een slechte fysieke en mentale gezondheid. Onze resultaten toonden verder aan dat voedselonzekerheid van toegevoegde waarde was in het verklaren van een slechte fysieke en mentale gezondheid bovenop traditioneel gebruikte sociaaleconomische risicofactoren (zoals leeftijd, opleidingsniveau, inkomen, woonsituatie, werk, migratieachtergrond): de verklaarde variantie verbeterde met ongeveer de helft voor fysieke gezondheid en verdubbelde voor mentale gezondheid. Deze informatie kan bijdragen aan effectieve risicostratificatie (door het identificeren van groepen met een verhoogd risico op een slechte gezondheid) en het aanbieden van gerichte interventies om hun gezondheid te verbeteren.

Meer inzicht in de factoren die van invloed zijn op het eetgedrag van mensen die risico lopen op voedselonzekerheid is essentieel voor het ontwikkelen van gerichte interventies om deze groep te ondersteunen. **Hoofdstuk 4** presenteert verhalen van mensen die risico lopen op voedselonzekerheid, waarbij gebruik is gemaakt van een kwalitatieve benadering om beter inzicht te krijgen in de behoeften en percepties

ten aanzien van gezond eetgedrag onder deze doelgroep. De resultaten van dit onderzoek suggereren dat de deelnemers over voldoende voedingskennis beschikken. Desalniettemin ervoeren zij verschillende sociale-, omgevings- en financiële barrières voor gezond eetgedrag, waaronder een slechte mentale gezondheid, financiële stress, hoge voedselprijzen en een ongunstige voedselomgeving. In dit hoofdstuk worden enkele eerste aanknopingspunten gegeven voor interventies gericht op het verbeteren van het eetgedrag in deze kwetsbare populatie. Deze aanknopingspunten omvatten het verlagen van de prijs van gezonde voeding en het verbeteren van de voedselomgeving, aangezien onze deelnemers aangaven dat de hoge prijzen van gezonde voeding en een ongunstige voedselomgeving, gekenmerkt door een overvloed aan fastfoodrestaurants, tot de belangrijkste barrières behoorden voor gezond eten.

In het onderzoek gepresenteerd in **Hoofdstuk 5** is de invloed van de voedselomgeving als barrière voor gezond eten onder mensen die risico lopen op voedselonzekerheid verder onderzocht. In dit onderzoek hebben we gekeken naar de wisselwerking tussen de aanwezigheid van fastfoodrestaurants, voedselonzekerheid en de voedingskwaliteit in achterstandswijken in Nederland. De resultaten van dit onderzoek lieten zien dat het ervaren van voedselonzekerheid samenhing met een lagere voedingskwaliteit, en dat dit verband werd gemodereerd door de nabijheid van fastfoodrestaurants: gestratificeerde resultaten toonden aan dat het negatieve effect van voedselonzekerheid op de voedingskwaliteit groter was voor mensen bij wie de dichtstbijzijnde fastfoodzaak dichter bij huis was gelegen. De resultaten toonden verder aan dat een oplopende afstand tot een fastfoodwinkel geassocieerd was met een iets hogere voedingskwaliteit (wat erop wijst dat het makkelijker is om een gezond voedingspatroon aan te houden als men verder van een fastfoodwinkel woont), terwijl er geen verband werd gevonden tussen de dichtheid van fastfoodrestaurants en de voedingskwaliteit. Onze studie draagt bij aan de toenemende literatuur over de invloed van de fastfoodomgeving in de buurt op voedselonzekerheid en de voedingskwaliteit. Al met al geeft dit aan dat het bevorderen van een gezondere voedselomgeving om de kwaliteit van het dieet te verbeteren vooral belangrijk kan zijn voor buurten waar veel mensen wonen die voedselonzekerheid ervaren, omdat deze mensen het meest beïnvloed worden door hun voedselomgeving, en omdat voedselonzekerheid en een hoge prevalentie van fastfoodrestaurants over het algemeen geclusterd zijn binnen buurten.

De rol van financiële barrières in het verklaren van de voedingskwaliteit wordt in **Hoofdstuk 6** verder uitgewerkt. In deze studie hebben we onderzocht of het uitbreiden van de Theorie van Gepland Gedrag (*Theory of Planned Behaviour*: TPB) - één van de meest gebruikte modellen om gezondheidsgedrag zoals eetgedrag te begrijpen - met barrières gerelateerd aan financiële schaarste en voedselonzekerheid helpt om verschillen in voedingskwaliteit beter te kunnen verklaren. Onze bevindingen tonen aan dat in vergelijking met de traditionele TPB, de uitgebreide TPB (met financiële schaarste en/ of voedselonzekerheid) de beste geschiktheidsstatistieken van het model liet zien en het beste de variantie in voedingskwaliteit verklaarde. Dit onderstreept het belang van rekening houden met financiële barrières voor gezond eten voor een beter begrip van individueel dieetgedrag in populaties met een lagere sociaaleconomische positie. Aangezien de literatuur over psychosociale factoren die verschillen in voedselinname verklaren nog steeds relatief schaars is, draagt onze studie aanzienlijk bij aan het opvullen van deze leemte in de huidige literatuur.

Conclusie

Op basis van dit proefschrift kunnen we concluderen dat een aanzienlijk aantal mensen in Nederland te maken heeft met voedselonzekerheid. De bevindingen in dit proefschrift geven inzicht in de gevolgen van voedselonzekerheid: voedselonzekerheid was geassocieerd met overgewicht, een slechte fysieke en mentale gezondheid en een lagere voedingskwaliteit. Onze resultaten geven verder inzicht in de rol van sociodemografische- en leefstijlfactoren, psychosociale factoren en de voedselomgeving in deze associaties. Daarnaast geven onze resultaten een beter inzicht in de waargenomen behoeften, percepties en barrières met betrekking tot gezond eten bij mensen die risico lopen op voedselonzekerheid. Ook geven de resultaten aanknopingspunten voor interventies. Dit proefschrift benadrukt dat voedselonzekerheid een probleem is dat in Nederland beter moet worden onderkend en aangepakt, bijvoorbeeld door de ontwikkeling en implementatie van interventies op bevolkingsniveau en voor risicogroepen, waarvoor geschikte screening of monitoring en gerichte interventies verder moeten worden onderzocht.

List of publications

International publications

2021 ***Effectiveness of the Beyond Good Intentions Program on Improving Dietary Quality Among People With Type 2 Diabetes Mellitus: A Randomized Controlled Trial***
van der Velde LA, Kiefte-de Jong JC, Rutten GE, Vos RC.
Frontiers in Nutrition.
doi: 10.3389/fnut.2021.583125

2020 ***The interplay between fast-food outlet exposure, household food insecurity and diet quality in disadvantaged districts***
van der Velde LA, Zitman FM, Mackenbach JD, Numans ME, Kiefte-de Jong JC.
Public Health Nutrition.
doi: 10.1017/S1368980020004280

2020 ***Exploring food insecurity and obesity in Dutch disadvantaged neighborhoods: a cross-sectional mediation analysis***
van der Velde LA, Nyns CJ, Engel MD, Neter JE, van der Meer IM, Numans ME, Kiefte-de Jong JC.
BMC Public Health.
doi: 10.1186/s12889-020-08611-x

2020 ***Comparing saliva and urine samples for measuring breast milk intake with the 2H oxide dose to-mother technique among children 2–4 months old***
Matsiko E, Hulshof P, **van der Velde L**, Kenkhuis M, Tuyisenge L, Melse-Boonstra A.
British Journal of Nutrition.
doi:10.1017/S0007114519002642

2019 ***Needs and perceptions regarding healthy eating among people at risk of food insecurity: a qualitative analysis***
van der Velde LA, Schuilenburg LA, Thrivikraman JK, Numans ME, Kiefte-de Jong JC
International Journal for Equity in Health.
doi: 10.1186/s12939-019-1077-0

2019 ***Diet quality in childhood: the Generation R Study***
van der Velde L A, Nguyen AN, Schoufour JD, Geelen A, Jaddoe VW, Franco OH, Voortman T.
European journal of nutrition.
doi: 10.1007/s00394-018-1651-z

2019 ***Factors associated with early introduction of complementary feeding and consumption of non-recommended foods among Dutch infants: the BeeBOFT study***
Wang L, van Grieken A, **van der Velde LA**, Vlasblom E, Beltman M, L'Hoir MP, Boere-Boonekamp MM, Raat H.
BMC Public Health.
doi: 10.1186/s12889-019-6722-4

Bibliography available online at ORCID: https://orcid.org/0000-0002-7666-1572

Manuscripts

Food insecurity status is of added value in explaining poor health: a cross-sectional study among parents living in disadvantaged neighborhoods in the Netherlands
van der Velde LA, Steyerberg EW, Numans ME, Kiefte-de Jong JC.
Accepted for publication, *BMJ Open*

Extending the theory of planned behavior for explaining dietary quality: The role of financial scarcity and food insecurity status
van der Velde LA, van Dijk WW, Numans ME, Kiefte-de Jong JC.
Provisionally accepted, *Journal of Nutrition Education and Behavior*

The Food Environment Around Primary Schools in a Diverse Urban Area in The Netherlands: Linking Fast-Food Density and Proximity to Neighborhood Disadvantage and Childhood Overweight Prevalence
Smagge, BA, **van der Velde, LA,** Kiefte de Jong, JC
Under review, *Frontiers in Public Health*

Food insecurity in the disadvantaged neighborhoods: a socioecological examination
Janssen, JM, **van der Velde, LA,** Kiefte de Jong, JC
Submitted for publication

National publications

Articles

2021 ***Veranderingen in ervaren voedselzekerheid en eetgedrag in Nederland sinds de COVID-19-uitbraak [Changes in perceived food insecurity and eating behavior in the Netherlands since the COVID-19-crisis]***
Van der Velde LA, Numans ME, Kiefte-de Jong JC
TSG - Tijdschrift voor gezondheidswetenschappen
doi: 10.1007/s12508-021-00311-0

2018 ***Onzichtbare honger? Voedselonzekerheid in de Haagse Krachtwijken [Invisible hunger? Food insecurity in disadvantaged neighborhoods in The Hague]***
Van der Velde LA, Numans M, Middelkoop BJ, Kiefte-de Jong JC.
Epidemiologisch Bulletin
Available at: https://www.ggdhaaglanden.nl/over/publicaties-en-onderzoeken/epidemiologisch-bulletin/epidemiologisch-bulletin-2018.htm

Book chapter

2020 ***Overgewicht en obesitas bij kinderen [Overweight and obesity in children]*** (book chapter)
Vos RC, Kiefte-de Jong JC, **van der Velde LA**
Informatorium voor Voeding en Diëtetiek – Supplement 106 – december 2020.
doi: 10.1007/978-90-368-2596-2_4

Portfolio

Courses and training

2021 Basic Qualification for Teaching (BKO) course: *Guiding workgroups*
LUMC

2021 Basic Qualification for Teaching (BKO) course: *Developing study assignments*
LUMC

2021 Basic Qualification for Teaching (BKO) course: *Assessment*
LUMC

2021 Workshop: *How to create impact with your research in an online society*
Epidemiology congress WEON

2021 Workshop: *Dealing with Stress and Perfectionism*
LUMC

2020 Nutritional leadership workshop: *How to stay visible in an online world?'*
De Nederlandse Academie van Voedingswetenschappen (NAV)

2020 Brightspace training
Leiden University

2020 5-day online summer school *Population Health Management*
LUMC

2019 Course on guiding students performing their '*Critical Appraisal of a Topic'* (CAT) project
LUMC

2019 KNAW masterclass for postdocs and Phd-students: *Interdisciplinary perspectives on the food environment and public health*
The Royal Netherlands Academy of Arts and Sciences [De Koninklijke Nederlandse Akademie van Wetenschappen (KNAW)]

2019 Course: *Methods in Social Epidemiology*
University of Antwerp

2019 Course: *Scientific Writing for PhDs*
Leiden University

2018 Course: *Open interview and qualitative data analysis for PhDs*
Leiden University

2018 Course: *Effective communication with low-literate people*
Pharos

2018 Course: *Presenting skills for PhDs*
Leiden University

2018 BROK Course
NFU

2017 Course: *Time management and self-management for PhDs*
Leiden University

2017 Spring course: *Population Health Management: Epidemiology and Methods*
LUMC

International and national congress attendance and presentations

2021 *Nutritional Science Days*
Oral presentation: Extending the theory of planned behavior for explaining dietary
quality: The role of financial scarcity and food insecurity status
Chair of the session on eating behaviour, pregnancy and children
De Nederlandse Academie van Voedingswetenschappen (NAV)

2021 Conference Nutrition Disparity Network: *Values and Nutrition Equity*
Wageningen University and Research (WUR) & Edema-Steenberg Foundation

2021 Annual Dutch Epidemiology Conference WEON: *Science in an online society*
Pre-conference workshop attendance on how to create impact with your research in an online society

Netherlands Epidemiological Society [in Dutch: Vereniging voor Epidemiologie (VvE)]

2021 Work conference LUMC-Campus The Hague
Oral presentation on food insecurity research project
LUMC-Campus The Hague

2020 Conference Nutrition Disparity Network: *Collective action on nutrition disparity*
Wageningen University and Research (WUR) & Edema-Steenberg Foundation

2020 Career event symposium of the Vereniging voor Epidemiologie (VvE) Netherlands Epidemiological Society (in Dutch: Vereniging voor Epidemiologie (VvE))

2020 NAV Public lecture by Prof. dr. Marianne Geleijnse: *Healthy eating: about beliefs and evidence* [in Dutch: 'Gezond eten: over geloven en bewijzen']
De Nederlandse Academie van Voedingswetenschappen (NAV)

2020 Third Annual Conference: *Lifestyle as Medicine: Person empowered lifestyle medicine*
Lifestyle 4 Health (Het Nederlands Innovatiecentrum voor Leefstijlgeneeskunde)

2020 Work conference LUMC-Campus The Hague
Oral presentation on food insecurity research project
LUMC-Campus The Hague

2019 CEPHIR seminar: *An integrated approach to poverty: more room for healthy behaviors?* [in Dutch: Een integrale aanpak van armoede: meer ruimte voor gezond gedrag?]
Academische Werkplaats Publieke Gezondheid in de regio's Rotterdam Rijnmond, Zeeland en Zuid-Holland Zuid: Centre for Effective Public Health In the larger Rotterdam area (CEPHIR)

2019 NAV public lecture by Prof. Dr. Gerjan Navis: *Nutrition and medicine: reinventing the dream team!* [in Dutch: Voeding en Geneeskunde: reinventing the dream team!]
De Nederlandse Academie van Voedingswetenschappen (NAV)

2019 Conference Nutrition Disparity Network: *From Differences to Potential*
Oral presentation: Needs and perceptions regarding healthy eating among people at risk of food insecurity: a qualitative analysis
Wageningen University and Research (WUR) & Edema-Steenberg Foundation

2019 Annual Dutch Epidemiology Conference WEON on *healthy ageing*
Poster presentation: Exploring food insecurity and obesity in Dutch families: a mediation analysis
Netherlands Epidemiological Society (in Dutch: Vereniging voor Epidemiologie (VvE))

2019 *FENS 13th European Nutrition Conference* in Dublin, Ireland
Poster presentation: Needs and perceptions regarding healthy eating among people at risk of food insecurity: a qualitative analysis
Poster presentation: Exploring food insecurity and obesity in Dutch families:a mediation analysis
Federation of European Nutrition Societies (FENS)

2019 *Nutritional Science Days*
Oral presentation: Needs and perceptions regarding healthy eating among people at risk of food insecurity: a qualitative analysis
Chair of the session on biomarkers of health and disease
De Nederlandse Academie van Voedingswetenschappen (NAV)

2019 Work conference LUMC-Campus The Hague: *From preconception to toddler: the first 1000 days* [in Dutch: Van preconceptie tot peuter: de eerste 1000 dagen]
Assisted in the practical implementation of the conference (e.g. workshop preparation, participant registration)
LUMC-Campus The Hague

2019 *CBS Knowledge Symposium*
LUMC

2019 Symposium: *Money, Stress and Behaviour* [in Dutch: Geld, Stress en Gedrag]
Nibud/ Leiden University

2019 Work conference LUMC-Campus The Hague
Oral presentation & **Workshop** on food insecurity research project
LUMC-Campus The Hague

2018 FEAM/ALLEA Symposium: *Health inequalities - an interdisciplinary discussion of socioeconomic status, health and causality*
Hosted by the Royal Netherlands Academy of Arts and Sciences (KNAW)

2018 Symposium: *Implementing: thinking and doing* [in Dutch: Implementeren: denken én doen]
Academische Werkplaats Publieke Gezondheid Noordelijk Zuid-Holland (AWPG-NZH) & SAMEN

2018 *Nutritional Science Days*
Oral presentation The relation between food insecurity and obesity and its potential mediators
Chair of the session on elderly and physical functioning.
De Nederlandse Academie van Voedingswetenschappen (NAV)

2018 Voeding Nederland congress '*De Eetprikkel*'
Poster presentation Food insecurity in The Hague: Characteristics of food insecure families in The Hague [in Dutch: *'Voedselonzekerheid in Den Haag: Karakteristieken van voedselonzekere families in de Haagse krachtwijken'*]
Selected for the plenary poster pitch for the best posters.
Voeding Nederland

2018 NAV public lecture by Prof. dr. Martijn Katan: *How does nutrition become a science again?* [in Dutch: Hoe wordt voeding weer een wetenschap?]
De Nederlandse Academie van Voedingswetenschappen (NAV)

2018 Work conference LUMC-Campus The Hague
Oral presentation on food insecurity research project
LUMC-Campus The Hague

2017 *Healthy Food Congress*

2017 Opening Symposium of the Amsterdam Centre for World Food Studies (ACWFS)
Amsterdam Centre for World Food Studies (ACWFS)

Selection of other meetings and presentations

2021 NAV Autumn forum: *The food environment*
Oral presentation (pitch) on the publication '*The interplay between fast-food outlet exposure, household food insecurity and diet quality in disadvantaged districts*'
De Nederlandse Academie van Voedingswetenschappen (NAV)

2020 *Haagse Praat* (the internal referral meeting for professionals within the GGD Haaglanden)
Oral presentation on food insecurity in The Hague
GGD Haaglanden

2020 Discussion meeting: *Direct Giving*
Municipality of The Hague [in Dutch: Gemeente Den Haag]

2020 IVO In-depth session: *Gender in research*
IVO Institute

2019 NAV Autumn forum: *Nutrition labels*
De Nederlandse Academie van Voedingswetenschappen (NAV)

2019 Capita selecta meeting clinical epidemiology: *The do and don'ts of validation of prediction models*
LUMC

2019 Leiden Leadership Lunch: *Public Leadership in Debt Relief* [in Dutch: Publiek Leiderschap in de Schuldhulpverlening]
Leiden University

2019 LUMC Knowledge day [in Dutch: LUMC Wetenschapsdag]
Oral presentation on food choices and eating behavior
LUMC

2018 The Hague Knowledge day [in Dutch: Haagse Kennisdag]
Municipality of The Hague [in Dutch: Gemeente Den Haag]

2018 Pop-Up College at the Haagse Markt on healthy eating
Assisted with program development and implementation
Leiden University/ Haagse markt

2017-2019 Attended the Upbringing meeting [in Dutch: Opvoedingsoverleg] multiple times.
These meetings focus on upbringing and nutrition
Oral presentation: Voedselzekerheid in Haagse krachtwijken

2017 Attended the Workgroup dietary habits [in Dutch: Werkgroep Voedingsgewoonten (WeVo)].
These meetings focus on ongoing research about nutrition and health

2017-2022 Science lunch presentations at LUMC, department of Public Health and Primary Care
Regular attendance
LUMC

2017-2022 Coffee & Research presentations LUMC-Campus The Hague
Oral presentations (multiple) and weekly attendance
LUMC-Campus The Hague

Teaching activities

2021 Course: *Nutrition and Public Health*
Lectures on food choices, dietary intake assessment methods, body composition, nutrition and non-communicable diseases.
Workgroups on dietary intake assessment methods and nutrition and non-communicable diseases
Assignment grading
Leiden University College (LUC)

2021 Theme day healthy eating at Schoonhovens college
Lecture on healthy eating (theme day opening for all second grade students vwo | havo | mavo)
Schoonhovens college

2021 Course: *Social Determinants of Health*
Course coordinator (responsible for the course planning and communication, lecture planning, assignment development and grading)
Leiden University College (LUC)

2021 5-day summer school *Population Health Management*
Interactive lecture: Behaviour and Population Health Management
LUMC

2020 IMC Weekendschool
Interactive lectures (4 times) on nutrition and a healthy lifestyle for 7th and 8th grade students
IMC Weekendschool, a Sunday school for motivated children from socio-economically disadvantaged neighborhoods

2020 Course: *Nutrition and Public Health*
Lectures on food choices, dietary intake assessment methods, body composition, nutrition and non-communicable diseases.
Workgroup on food choice and dietary intake assessment methods
Assignment grading
Leiden University College (LUC)

2019 Course: *Nutrition and Public Health*
Lectures on food choices, body composition, and nutrition and non-communicable diseases.
Assignment grading
Leiden University College (LUC)

2019 Work conference LUMC-Campus The Hague
Workshop on food insecurity
LUMC-Campus The Hague

2019 Weekend school MOVE Foundation
Lecture on nutrition and health for 8th grade students of the Weekend school
MOVE Foundation/ Boerhaave museum

2018 Symposium: *Implementing: thinking and doing* [in Dutch: Implementeren: denken én doen]
Workshop on food insecurity in The Hague
Academische Werkplaats Publieke Gezondheid Noordelijk Zuid-Holland (AWPG NZH) & SAMEN

2017 Family day of the Vobis Foundation
Workshop on a healthy lifestyle
Vobis Foundation/ Stichting Hindustani

Student supervision

2021 B. Smagge. Student Leiden University College.
Project title: 'The Food Environment Around Primary Schools in a Diverse Urban Area in The Netherlands: Linking Fast-Food Density and Proximity to Neighborhood Disadvantage and Childhood Overweight Prevalence'

2021 M. Nikolova & I. Behimehr. PRE-University students.
Project title: 'Barriers and facilitators for adopting a plant-based diet and development of an intervention to facilitate a plant-based diet'

2020-2021 R. Wortelboer. Student Leiden University College.
Project title: 'Evaluation of a community fridge initiative in The Hague (the Vers & Vrij initiative)'

2020 E. Todelo & J. Boelema Robertus. Students Statistics and Data Science, Leiden University.
Project title: 'The added value of food insecurity on predicting poor health'

2020 J. Janssen. Student Health Sciences, VU Amsterdam.
Project title: 'Food insecurity in the disadvantaged neighborhoods in The Hague, the Netherlands: Does it predict diet quality?'

2020 E. van Ooteghem. Medical student, LUMC.
Project title: 'Food frequency questionnaire to assess diet quality: a validation study'

2019 F. Zitman. Epidemiology student, EpidM (Department of Epidemiology & Biostatistics, Amsterdam UMC - location VUmc)
Project title: 'Fast-food foodscape moderates the association between food insecurity status and dietary quality in disadvantaged districts in The Hague'

2019 G. Scholten. Student Health Sciences, VU Amsterdam.
Project title: 'Effectiveness of the Beyond Good Intention program on diet quality among a pre-selected group of type 2 diabetes patients after two and a half years follow-up: a Randomized Controlled Trial.'

2019 J. Addison. Student Leiden University College.
Project title: 'Local healthy food prices and food insecurity in The Hague, the Netherlands'

2018 M. Engel. Student Health Sciences, VU Amsterdam.
Project title: 'Food security and the consumption of fruit, vegetables and fish in disadvantaged neighborhoods in The Hague'

2018 E. de Schrijver. Student Leiden University College.
Project title: 'Psychosocial, financial and environmental determinants of food insecurity among households living in disadvantaged neighborhoods in The Hague: A Qualitative analysis'

2018 L. Schuilenburg. Medical student, LUMC.
Project title: 'Psychosocial and financial determinants of food insecurity among households living in disadvantaged neighborhoods in The Hague'

2017 K. Kloss. Psychology student, Leiden University.
Project title: 'Psychological aspects of food insecurity'

2017 C. Nyns. Medical student, LUMC.
Project title: 'Food security in disadvantaged families in The Hague'

Societal impact

2021 ***Tweede prijs voor artikel over blootstelling aan fastfood restaurants, voedselonzekerheid en voedingskwaliteit***
News items published by Academische Werkplaats Publieke Gezondheid Noordelijk Zuid-Holland (AWPG-NZH). Published on December 6, 2021. Available at: https://www.awpgnzh.nl/tweede-prijs-voor-artikel-over-blootstelling-aan-fastfood-restaurants-voedselonzekerheid-en-voedingskwaliteit/

2021 ***Specialist in beeld: Laura van der Velde. Meer aandacht voor voedselonzekerheid is hard nodig***
Article published in *Nederlands Tijdschrift voor Voeding & Diëtetiek*, a professional magazine of the Dutch Association of Dieticians for dieticians and other professionals involved in nutrition. Published on September 14, 2021.

Available at: https://ntvd.media/artikelen/meer-aandacht-nodig-voor-voedselonzekerheid/

2021 ***Veranderingen in voedselzekerheid en eetgedrag sinds COVID-19 crisis***
News items published by Academische Werkplaats Publieke Gezondheid Noordelijk Zuid-Holland (AWPG-NZH). Published on September 1, 2021. Available at https://www.awpgnzh.nl/veranderingen-in-voedselzekerheid-en-eetgedrag-sinds-covid-19-crisis/

2021 ***Laura van der Velde wint de Young Professional Award 2021***
News items published by Academische Werkplaats Publieke Gezondheid Noordelijk Zuid-Holland (AWPG-NZH). Published on August 29, 2021.
Available at https://www.awpgnzh.nl/laura-van-der-velde-wint-de-young-professional-award-2021/

2021 ***LUMC vriendenboekje Laura van der Velde***: 'Ook in Nederland voedsel onzekerheid'
Film interview aimed at spotlighting LUMC-researchers. Online on YouTube on August 12, 2021
Available at https://www.youtube.com/watch?v=f-ZbGpObRxQ

2021 ***De passie van: NAV-lid Laura van der Velde***
Article published in *VoedingNU*, an independent magazine focused on food, nutrition and health. Published on July 6, 2021.
Available at: https://www.voedingnu.nl/artikelen/de-passie-van-nav-lid-laura-van-der-velde

2020 ***Update promotieonderzoek naar voedselzekerheid in Haagse achterstandswijken***
News items published by Academische Werkplaats Publieke Gezondheid Noordelijk Zuid-Holland (AWPG-NZH). Published on September 24, 2020. Available at https://www.awpgnzh.nl/update-promotieonderzoek-naar-voedselzekerheid-in-haagse-achterstandswijken/

2020 ***Het onderzoek van… Laura van der Velde. Voedselonzekerheid in Nederland***
Blog published at the website of *I'm a Foodie*, an evidence based food collective. Published on August 26, 2020.
Available at: https://www.iamafoodie.nl/voedselonzekerheid-in-nederland/#

2018 Multiple news items following the publication of the first results of our food insecurity research project, amongst others published online by Omroep West, AD, Nu.nl, Leidsch Dagblad, and HP De Tijd

2018 ***Radio interview Omroep West***
Radio interview about the first results of our food insecurity research project. Broadcasted on November 30, 2018

Awards and prices

2021 Publication prize 2020/2021 (2nd place) for the publication '*The interplay between fast-food outlet exposure, household food insecurity and diet quality in disadvantaged districts'*
De Nederlandse Academie van Voedingswetenschappen (NAV)

2021 Young Professional Award
Voeding Nederland

2019 Nomination LUMC best poster prize
LUMC

Curriculum Vitae

Laura van der Velde was born on the 19th of January 1991 in The Hague, the Netherlands. She obtained her VWO diploma at *De Vrije School Den Haag*. Thereafter, in 2011, she moved to Wageningen to start her bachelor's and master's studies *Nutrition and Health* at Wageningen University and Research (WUR), including the Minor *Sports, physical activity and health* at Vrije Universiteit Amsterdam. For her master's thesis, she moved to Rwanda for 3 months to conduct research on breastfeeding practices. Thereafter, she conducted a research internship on dietary quality in childhood at Erasmus MC, at the department of Epidemiology (ErasmusAGE). This project resulted in her first scientific publication. After obtaining her master's degree, she was employed as a junior researcher at Erasmus MC, at the department of Public Health. In April 2017 she started her PhD project at the LUMC-Campus The Hague, department of Public Health and Primary Care. Initially she combined these two jobs, then from 2018 onwards she started working fulltime at the LUMC-Campus The Hague. Her PhD project was conducted under the supervision of Prof. dr. Jessica Kiefte-de Jong and Prof. dr. Mattijs Numans, and focused on food insecurity, dietary quality and health in the Netherlands.

During her employment at the LUMC-Campus The Hague, she was involved in multiple grant applications. She was also involved in teaching in various courses and settings, mainly focused on socioeconomic inequalities, nutrition and health. In 2019, 2020 and 2021 she was co-teacher in the course *Nutrition and Public Health*, and in 2021 she coordinated the course *Social determinants of health,* both at Leiden University College. Recognizing the importance of a healthy lifestyle early in life, she has also actively sought opportunities to contribute to educate youth on this topic. For example, she provided workshops and lectures on healthy eating and lifestyle behaviors for youth (and their parents) at schools, Weekend schools and the LUMC Science day.

Laura received the Young Professional Award 2021 (awarded by Voeding Nederland) and received the second place NAV publication price 2020/2021 for her publication entitled '*The interplay between fast-food outlet exposure, household food insecurity and diet quality in disadvantaged districts'.*

From April 2021 onwards, she works as a postdoctoral researcher at the LUMC-Campus The Hague, where she is involved in several projects with a main focus on nutrition, lifestyle and health inequalities.

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