Food insecurity, dietary quality and health in the Netherlands

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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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Accepted for publication, *BMJ Open*

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**
	$R^2_{\text{optimism-corrected}}$: 0.063 $RMSE_{\text{optimism-corrected}}$: 9.09			$R^2_{\text{optimism-corrected}}$: 0.092 $RMSE_{\text{optimism-corrected}}$: 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 $_{\text{optimism-corrected}}$ (95%CI)	0.64 (0.59; 0.71)	0.69 (0.62; 0.73)
Nagelkerke's $R^2_{\text{optimism-corrected}}$	0.096	0.14
MCS (dichotomous score)[a]		
C-statistic $_{\text{optimism-corrected}}$ (95%CI)	0.65 (0.55; 0.68)	0.70 (0.61; 0.73)
Nagelkerke's $R^2_{\text{optimism-corrected}}$	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))