Food insecurity status is of added value in explaining poor health: a cross-sectional study among parents living in disadvantaged neighbourhoods 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 1 child living at home, living in or near disadvantaged neighbourhoods 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 health (Physical Component Summary: PCS) and mental health (Mental Component Summary: MCS), 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 mean square 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 to 0.71) to 0.69 (95% CI 0.62 to 0.73) for PCS and from 0.65 (95% CI 0.55 to 0.68) to 0.70 (95% CI 0.61 to 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 (ie, age, educational level, income, living situation, employment status and 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.

Strengths and limitations of this study

- Socioeconomic risk factors such as 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 generalisable 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.

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 healthcare provider), and reduce healthcare
costs (referred to as the Quadruple Aim). 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 utilisation. 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. 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.

Many factors have been identified as risk factors in the association between lower SEP and poor health. 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) often proves to be limited. Therefore, we hypothesise 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.

Food insecurity can be defined as an insufficient physical and economic access to adequate food that meets dietary needs and food preferences. Food insecurity is a public health concern facing low-income regions, including Europe: a large global study found a food insecurity prevalence of 25% across 39 European countries. Food insecurity can be considered as an adverse health outcome in itself, but also a determinant of poor health, and food insecurity is associated with increased healthcare utilisation and costs, even when socioeconomic factors are taken into account. 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. 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 among others also induces psychosocial stress.

Therefore, we hypothesise 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 urbanised disadvantaged neighbourhoods in the Dutch city The Hague. Participants were actively recruited at various public places, such as community centres, in four preselected disadvantaged neighbourhoods, based on criteria already in use by the Dutch Government to identify disadvantaged neighbourhoods. Participants were eligible for the study if they were living in or near one of the selected disadvantaged neighbourhoods; were aged ≥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.

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 email 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). 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 with the best SF-36 scale in an adult population. 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 et al. 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 SD of 10 in the general US population, as described in the SF-12 scoring guide.
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). The original USDA-HFSSM was translated from the English to the Dutch language based on the translation by Neter et al who applied the translation and back-translation technique. In the survey, conditions and behaviours 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 dichotomised into ‘food secure’ (FS: 0–2 affirmative responses), and ‘food insecure’ (FI: 3–18 affirmative responses), according to the USDA standards.

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 categorise age, Body Mass Index (BMI), household income, educational level, employment status, living situation and migration background, is described elsewhere.

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, diabetes mellitus (participants could additionally specify whether it was type 1 or 2) and anaemia (in the previous 12 months). Additionally, obesity status was included (ie, BMI >30 kg/m²). 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. Food insecurity score and food insecurity status (FS/FI) 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, for which a conservative power calculation was performed based on obesity prevalence. For the current study, we compared 150 FS to 49 FI 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 SD of 8.3–11.3. For reliable exploratory 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.

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 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 standardised 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 standardised 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.
(R²) and the root mean square error (RMSE). R² presents the proportion of variance in the dependent variable that can be explained by the independent variables. R² 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 R² 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 healthcare 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 (ie, 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 R².26

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 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 R² is an adjusted version of the Cox and Snell R² so that it ranges from 0 to 1. It can be interpreted similarly to the R² as described above, that is, 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 R².

**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 (ie, statistical optimism).27 All performance measures (ie, R², RMSE, the C-statistic and Nagelkerke’s R²) 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.26 28

**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 online supplemental 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 V.25.0 (IBM). 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 with 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 with FS participants, FI 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 (online 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

| Characteristics                          | 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)* (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)) | | | |
| 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† (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/m²) (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 (%))           |                          |                               |                         |
| Obesity                                 | 62 (31.2)                | 39 (26.2)                     | 23 (46.0)               |
| High blood pressure                     | 14 (7.0)                 | 8 (5.4)                       | 6 (12.0)                |

Continued
The dichotomous food insecurity status was a strong individual covariate explaining both poorer PCS and MCS in the unadjusted models: FI participants had a 5.79 (95% CI 2.89 to 8.68) points higher PCS and a 4.67 to 10.54) points higher MCS compared with FS participants (table 2).

Multivariable models explaining poor physical and mental health status

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

The optimism-corrected R² 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 R² 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 with the models not including food insecurity score, as indicated by lower optimism-corrected RMSEs (table 3).

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 to 0.71) to 0.69 (95% CI 0.62 to 0.73) and Nagelkerke’s R² 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 to 0.68) to 0.70 (95% CI 0.61 to 0.73) and Nagelkerke’s R² from 5.4% to 11.0%, an improvement of 5.6% (table 4).
stratification to identify populations at increased risk of poor health.

In line with previous literature, our results show that experiencing food insecurity is associated with poorer physical and mental health. The differences between FS and FI 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 et al. Food insecurity may be linked to poor health through multiple potential pathways such as shifting towards less expensive, lower-quality foods and elevated levels of depression and (chronic) stress. Also, impaired adherence to medical recommendations due to budgetary constraints may play a role, for example having to choose between food and medicine. 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. 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.

As described by Predmore et al, addressing social determinants of health within healthcare organisations contributes to achieving the Triple Aim. With regard to predictive risk modelling, one of their proposed applications is ‘social predictive modelling and case finding’ by incorporating social risk factors, 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, 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. Screening for food insecurity status has value beyond better identification of people at risk of poor health, because it also helps making healthcare 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. Multiple tools are currently available for screening for food insecurity, ranging from very short, one-item screening tools

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

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

*PCS and MCS scores range from 0 to 100, higher scores indicate a poorer health
†Indicates a p<0.05; ‡ indicates a p<0.01; *** indicates a p<0.001
‡ISCED 2=lower secondary education; ISCED 3=upper secondary education
PCS, Physical Component Summary; MSC, Mental Component Summary; ISCED, International Standard Classification of Education
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 |
|------------------|--------------------------------------------------------|------------------------------------------------------|
|                  | Standardised β | β-coefficient | 95% CI       | Standardised β | β-coefficient | 95% CI       |
| **PCS**          |               |               |              |               |               |              |
| Age (years)      | 0.17          | 0.20          | 0.028 to 0.38† | 0.16          | 0.19          | 0.019 to 0.37† |
| Educational level* |             |               |              |               |               |              |
| Low (≤ISCED 2)   | Reference     |               |              | Reference     |               |              |
| Higher (≥ISCED 3) | 0.026         | 0.27          | −2.61 to 3.14 | 0.029         | 0.55          | −2.27 to 3.38 |
| Household income |               |               |              |               |               |              |
| Above basic needs budget | Reference |               |              | Reference     |               |              |
| Below basic needs budget | 0.18      | 3.60          | 0.41 to 6.79† | 0.14          | 2.70          | −0.49 to 5.89 |
| Living situation |               |               |              |               |               |              |
| Single           | 0.13          | 2.91          | 0.006 to 5.82 | 0.13          | 2.65          | −0.20 to 5.50 |
| Employment status |               |               |              |               |               |              |
| Currently employed | Reference |               |              | Reference     |               |              |
| Currently not employed | 0.059 | 1.12          | −1.87 to 4.10 | 0.052         | 0.98          | −1.94 to 3.90 |
| Migration background |             |               |              |               |               |              |
| Western          | Reference     |               |              | Reference     |               |              |
| Non-Western      | 0.044         | 1.11          | −2.38 to 4.59 | 0.040         | 1.02          | −2.40 to 4.44 |
| Food insecurity score (0–18) | Not included | 0.21          | 0.68          | 0.22 to 1.14** |
|                  | **R²**optimism-corrected: 0.063 |               |              | **R²**optimism-corrected: 0.092 |               |              |
|                  | RMSEoptimism-corrected: 9.09 |               |              | RMSEoptimism-corrected: 9.05 |               |              |
| **MCS**          |               |               |              |               |               |              |
| Age (years)      | 0.12          | −0.15         | −0.34 to 0.051 | 0.11          | 0.13          | −0.061 to 0.32 |
| Educational level‡ |             |               |              |               |               |              |
| Low (≤ISCED 2)   | Reference     |               |              | Reference     |               |              |
| Higher (≥ISCED 3) | −0.048       | 0.95          | −2.076 to 3.97 | −0.028        | −0.56         | −3.48 to 2.36 |
| Household income |               |               |              |               |               |              |
| Above basic needs budget | Reference |               |              | Reference     |               |              |
| Below basic needs budget | 0.083    | −1.67         | −5.13 to 1.78 | 0.023         | 0.46          | −2.91 to 3.83 |
| Living situation |               |               |              |               |               |              |
| Married/partner  | Reference     |               |              | Reference     |               |              |
| Single           | 0.10          | −2.07         | −5.17 to 1.03 | 0.082         | 1.72          | −1.27 to 4.71 |

Continued
to more elaborate surveys. 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.36 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 centres (as these centres 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.37 This may also call for referral to resources across domains, such as the social domain (ie, 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 (while incorporating the needs and preferences of this population and the healthcare provider that performs the screening). Together, these actions are expected to contribute to the Quadruple Aim by improving experienced quality of care (as underling 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-term and long-term mortality risk and higher healthcare 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.30

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 the inability to acquire food in socially acceptable ways or places when needed.43 Fo...
The (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 syndrome (ie, two or more mutually enhancing health conditions that cluster within a specific population, in light of socioeconomic inequality and inequity that enhances this adverse interaction). 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 10% 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. This suggests that besides food insecurity, other factors such as lifestyle behaviours 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.

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. This can lead to optimistic estimates of model performance (ie, 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.

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. Conceptualising health from a broader, multidimensional and positive perspective (eg, ‘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. 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.

### 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)** |                                                          |                                                     |
| C-statistic (optimism-corrected (95% CI) | 0.64 (0.59 to 0.71) | 0.69 (0.62 to 0.73) |
| Nagelkerke’s $R^2$ (optimism-corrected) | 0.096 | 0.14 |
| **MCS (dichotomous score)** |                                                          |                                                     |
| C-statistic (optimism-corrected (95% CI) | 0.65 (0.55 to 0.68) | 0.70 (0.61 to 0.73) |
| Nagelkerke’s $R^2$ (optimism-corrected) | 0.054 | 0.11 |

*The PCS and MCS scores were dichotomised into scores below 50 and scores above 50.

PCS, Physical Component Summary; MSC, Mental Component Summary.
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 generalisable to the general Dutch population. Previous studies indicate that women are more at risk of food insecurity and its accompanying health consequences, 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 with large-scale food insecurity screening surveys such as those annually conducted by the USDA. 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 optimise the allocation of available resources to the people most in need.

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REFERENCES

1. Adler NE, Boyce T, Chesney MA, et al. Socioeconomic status and health. The challenge of the gradient. Am Psychol 1994;49:15–24.
2. Sikk R, Morath JM, Leape L. The quadruple aim: care, health, cost, and cost of health care. BMJ Quality & Safety 2015;24:121–7.
3. Cousins MS, Shickle LM, Banderman JA. An introduction to predictive modeling for disease management risk stratification. Disease Management 2002;5:157–67.
4. Sakhthong P, Kasemsup V, Winit-Watjanwa W. Assessment of health-related quality of life in Thai patients after heart surgery. Asian Biomedicine 2017;9:203–10.
5. Su S-W, Wang D, DjuolDjor W. Health-Related quality of life and related factors among elderly persons under different aged care models in Guangzhou, China: a cross-sectional study. Qual Life Res 2019;28:1293–303.
6. Arvidsson S, Arvidsson B, Fridlund B, et al. Health predicting factors in a general population over an eight-year period in subjects with and without chronic musculoskeletal pain. Health Qual Life Outcomes 2006;4:98.
7. Lorraine PJ, Hammock RL, Blanton JM. Predictors of self-rated health status among Texas residents. Prev Chronic Dis 2005;2:A12–A.
8. Robards J, Evandrou M, Falkingham J, et al. Marital status, health and mortality. Maturitas 2012;73:295–303.
9. Galobardes B, Lynch J, Smith GD. Measuring socioeconomic position in health research. Br Med Bull 2007;81–82:21–37.
10. Fitzpatrick T, Rosella LC, Calzavara A, et al. Looking beyond income and education: socioeconomic status gradients among future high-cost users of health care. J Fam Pract 2016;65:61–7.
11. Gregory CA, Coleman-Jensen A. Food insecurity, chronic disease, and health among working-age adults, 2017. Available: https://www.ers.usda.gov/publications/pub-detail/?pubid=84468
12. FAO. World food Summit: Rome Declaration on world food security and world food Summit plan of action.
13. Jones AD. Food insecurity and mental health status: a global analysis of 149 countries. Am J Prev Med 2017;53:264–73.
14. Pourmotabbedeh A, Moradi S, Babaei A. Food insecurity and mental health: a systematic review and meta-analysis. Public Health Nutr 2020;23:1–13.
15. Berkowitz SA, Seligman HK, Meigs JB, et al. Food insecurity, healthcare utilization, and high cost: a longitudinal cohort study. Am J Manag Care 2018;24:399.
16. Neter JE, Dijkstra SC, Visser M, et al. Food insecurity among Dutch food bank recipients: a cross-sectional study. BMJ Open 2014;4:e004657.
17. van der Velde LA, Nyns CJ, Engel MD, et al. Exploring food insecurity and obesity in Dutch disadvantaged neighborhoods: a cross-sectional mediation analysis. BMC Public Health 2020;20:1–11.
18. Vogelaar CP. Brief van de Minister voor wonen, 2007. wijken en integratie. Available: https://zoek.officielebekendmakingen.nl/kst-30995-1.html
19. WARE JE, Kosinski M, KELLER SD. A 12-item short-form health survey. Med Care 1996;34:220–33.
20. WARE JE, Keller SD, Kosinski M. SF-12: how to score the SF-12 physical and mental health summary scales: health Institute. New England Medical Center, 1995. https://www.researchgate.net/publication/242636850_SF-12_How_to_Score_the_SF-12_Psychological_and_Mental_Health_Summary_Scales. Randles-Baum R, DAlessio D, Borjer BJ. Health-Related quality of life predicted subsequent health care resource utilization in patients with active cancer. Qual Life Res 2019;28:1085–95.
22. Fleishman JA, Cohen JW, Manning WG, et al. Using the SF-12 health status measure to improve predictions of medical expenditures. Med Care 2006;44:54–63.
33 Economic Research Service. U.S. household food security survey module: three-stage design, with screensers. In: USDA, editor. 2012.
34 Statistics Netherlands (CBS). Health survey as of 2014, 2021. Available: https://www.cbs.nl/en-gb/onderzoeken/methoden/ surveys/korte-onderzoeksbeschrijvingen/health-survey-as-of-2014
35 Austin PC, Steyerberg EW. The number of subjects per variable required in linear regression analyses. J Clin Epidemiol 2015;68:627–36.
36 Steyerberg EW, Vergouwe Y. Towards better clinical prediction models: seven steps for development and an ABCD for validation. Eur Heart J 2014;35:1925–31.
37 Noma H, Shinozaki T, Iba K, et al. Confidence intervals of prediction accuracy measures for multivariable prediction models based on the bootstrap-based optimism correction methods. Stat Med 2021;40:5691–701.
38 Steyerberg EW. Clinical prediction models. Springer, 2019.
39 Hadley C, Crooks DL. Coping and the biosocial consequences of food insecurity in the 21st century. Am J Phys Anthropol 2012;149 Suppl:55:72–94.
40 Leddy AM, Weiser SD, Palar K, et al. A conceptual model for understanding the rapid COVID-19-related increase in food insecurity and its impact on health and healthcare. Am J Clin Nutr 2020;112:1162–9.
41 Fang D, Thomsen MR, Nayga RM. The association between food insecurity and mental health during the COVID-19 pandemic. BMC Public Health 2021;21:607.
42 Rao M, Afshin A, Singh G, et al. Do healthier foods and diet patterns cost more than less healthy options? A systematic review and meta-analysis. BMJ Open 2013;3:e004277.
43 Harrell FE, Lee KL, Mark DB. Multivariable prognostic models: issues in developing models, evaluating assumptions and adequacy, and measuring and reducing errors. Stat Med 1996;15:361–87.
44 Samsa G, Edelman D, Rothman ML, et al. Determining clinically important differences in health status measures. Pharmacoeconomics 1998;15:141–55.
45 Hadley C, Crooks DL. Coping and the biosocial consequences of food insecurity in the 21st century. Am J Phys Anthropol 2012;149 Suppl:55:72–94.
46 Leddy AM, Weiser SD, Palar K, et al. A conceptual model for understanding the rapid COVID-19-related increase in food insecurity and its impact on health and healthcare. Am J Clin Nutr 2020;112:1162–9.
47 Fang D, Thomsen MR, Nayga RM. The association between food insecurity and mental health during the COVID-19 pandemic. BMC Public Health 2021;21:607.