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The Relationship between the Accessibility to Food Infrastructure and Obesity among Adults in the Netherlands: A Spatial Analysis

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Background

Obesity prevalence has globally more than doubled since 1980 (Afshin et al. 2017) and changes in the food environment and system are supposed to be the main drivers for this increase (Anderson et al. 2014). Accordingly, the high availability and accessibility of unhealthy food characterised by a high proportion of fat and energy-dense may be one of the most important causes. However, for high BMI, obesity or overweight, previous research on their associations with the accessibility to food infrastructure found no clear evidence for the fact that better availability of food stores was related to better or worse health outcomes (Cummins et al. 2015, Fraser et al. 2012, Smith et al. 2010). Additionally, many studies did not use spatial data and thus not regard the fact that, e.g. the spatial distribution of food infrastructure, is not random.
Only few previous studies tried to disentangle the effects of food infrastructure on obesity by regarding effect differences between urban and rural areas. For the US, there is some evidence that there may be a positive relationship in metropolitan regions and a negative in non-metropolitan (Michimi & Wimberly 2010; Smith et al. 2010) Regarding the development of obesity prevalence in the last decades a separate analysis (stratification) for urban and rural regions might be highly relevant. That is, the obesity prevalence is higher in urban regions than in rural regions, but the prevalence in rural regions has increased much stronger than in urban spaces. Between 55% and 80% of the worldwide increase in the obesity prevalence was contributed by rural regions (NCD Risk Factor Collaboration 2019).
Our study investigated the relationship between accessibility to food infrastructure and obesity in the Netherlands using spatial analysis stratified by area of residence (urban vs rural).

Setting

Our cross-sectional study was based on all adults aged 19 or older living in private households in 2016 in the Netherlands. The spatial units of interest are neighbourhoods (six digits zip code, “wijken”). In the Netherlands, the municipalities are subdivided in 3,069 neighbourhoods, which are coherent regions without a formal status that are based on several characteristics like age, geographical barriers such as busy roads, having similar urban and/ or architectural features, or having similar functional, social or political characteristics.

Data

The neighbourhood-level data, which stem from individual data from the national registry and were aggregated to the spatial level, on food infrastructure, population and economics were obtained from Statistics Netherlands (CBS) and obesity data from the National Institute of Public Health and the Environment (RIVM).

Obesity data

Obesity prevalence was represented by the small-area proportion of obese (BMI ≥ 30) people. All spatial units with valid data on the used variables was included in our analysis (n = 2,717), from whom 1,093 were defined as urban (≥ 1,000 addresses per km²) and 1,624 as rural neighbourhoods (≤ 1,000 addresses per km²).
Because there are no direct data for obesity prevalence available at the district level, we obtained, already estimated, data on this from the RIVM. The RIVM used individual data from

the Dutch Public Health Monitor ("Gezondheidsmonitor", n = 457,153, age 19+) 2016, a national survey-database, and small-area estimators performed by generalized structured additive regression (STAR) modeling to carry out parameters via restrictive maximum likelihood (REML). 12 indicators at individual (age, sex, ethnicity, marital status), household (household type, size, capital, income, income source, and home ownership) and neighborhood (urbanisation, neighborhood code) level were used to predict the obesity, smoking and alcohol intake prevalence data for 2016 (van de Kassteele et al. 2017).

Food infrastructure data

We focused on accessibility to two different food infrastructure domains, namely i) cafeterias and fast food stores, ii) grocery and fresh food stores. Accessibility was measured by the average distance to the next food facilities in the neighbourhoods, and we related this to the prevalence of obesity (both at district level) in 2016.

Methods

First, we mapped the geographical difference in obesity. To identify and understand the overall pattern of obesity, global univariate pattern analysis was applied in a first descriptive step. Thereby, we aimed to find out whether neighbouring spatial units tend to be similar (clustered), distributed in a certain pattern (dispersed) or pattern-less (random). This spatial autocorrelation was detected by Global Moran's I ranging from -1 (perfect dispersion) to 1 (perfect clustering). Pseudo-significance was performed using 9,999 permutations. To detect and illustrate local geographical clusters we created a Local Moran's I (LISA) map.

Second, we were interested in the bivariate associations (co-location) between obesity and the food infrastructure domains. For this purpose, Bivariate Moran's I and Local Moran's I (BiLISA) were used to investigate the simultaneous occurrence and thus co-location in both obesity and the food infrastructure. The Bivariate Global Moran's I served as a measure regarding the association between proportion of obesity prevalence at a given location and the predictor value in neighbouring regions. By applying BiLISA we detected and visualised hotspots/ clusters (High-High), cold spots/ clusters (Low-Low) and discordant (High-Low or Low-High) clusters. To ensure the robustness of the obtained clusters, 9,999 permutations were used to assess the pseudo-significance.

Third, we aimed to assess whether the accessibility to food infrastructure have an effect on obesity prevalence, even when controlled for population composition and lifestyle. Multivariate spatial error models were estimated separately for urban and rural neighbourhoods and controlled for different confounders related to population composition, SES and lifestyle (age, sex, ethnicity, social welfare recipients, income, alcohol intake, smoking).

Bivariate and multivariable geographically weighted regressions (GWR) were then estimated to find out spatial variation of the effects of the food infrastructure on the prevalence of obesity.

Results

When considering spatial autocorrelation obesity prevalence showed clear spatial patterns of obesity prevalence (Figure 1). That is, neighbouring regions seem to have a similar obesity prevalence (clustering). Among the 2,717 Dutch neighbourhoods, the average prevalence of obesity was a bit higher in urban neighbourhoods (14.61%) than in rural neighbourhoods (14.14%) in 2016. Small area obesity at the neighbourhood level showed a highly significant spatial pattern among both urban (Moran's I = 0.648) and rural (Moran's I = 0.667) neighbourhoods (Table 1). By applying LISA, we found mainly high-high (n = 317) and low-low obesity clusters (n = 426) (results not shown). High-high clustering for obesity prevalence was mainly present in the rural regions, whereas low-low clusters were mainly identified among urban

neighbourhoods. In the multivariable spatial error models, we found that among urban neighbourhoods the distance to both food infrastructure domains, namely to cafeterias and fast food stores as well as to grocery and fresh food stores were positively associated with the prevalence of obesity (Figure 1). However, among rural neighbourhoods the distance to both food infrastructure domains was negatively associated with obesity prevalence.
When investigating geographically effect variation in bivariate models predicting obesity prevalence by accessibility to food infrastructure only, we did not find a clear urban/ rural pattern found in the multivariable spatial error models. However, when controlling for the population composition and lifestyle confounders the urban/ rural pattern became much clearer for the Netherlands (Figure 2).

Conclusion

We extended previous studies by exploring the relationship between accessibility to food infrastructure and obesity prevalence in a European country (Netherlands), using spatial analysis stratified by urban and rural regions. Our findings suggest, confirming previous results from the US, that there are different relationships between accessibility to food infrastructure and obesity prevalence in urban and rural neighbourhoods. We hypothesise that the urban pattern found (higher distance to food infrastructure = higher obesity prevalence) relies on a positive social selection effect (segregation) in the way, that obese people relocate more likely to urban outskirts characterised by worse accessibility to food infrastructure, and healthy people reside in/ relocate to the more prosperous urban neighbourhoods. Despite this, in the rural neighbourhoods our observation of higher distance to food infrastructure related to lower obesity prevalence seems to be a potential causal effect of the accessibility to food infrastructure on obesity. That is, higher distances to (unhealthy) food seem to prevent people of having an unhealthy nutrition and becoming obese subsequently.

In the context of the worldwide severe increase of obesity, particularly in rural regions, our findings give some further evidence for a special research and policy attention on rural regions to avoid detrimental infrastructure effects on health resulting in increasing social and health inequalities.

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Table 1. Overview of the used variables and descriptive statistics

Variable	Unweighted mean (SD)		Weighted mean (SD)		Univariate Moran's I (clustering)		Bivariate Moran's I (co-location)	
Region	Urban	Non-urban	Urban	Non-urban	Urban	Non-urban	Urban	Non-urban
Outcome								
Obesity prevalence (%, BMI ≥ 30)	14.61 (3.04)	14.14 (2.44)	9.59 (7.28)	11.50 (5.50)	0.648***	0.667***	-	-
Predictor Variables								
Distance to next canteen (km)	0.58 (0.30)	1.88 (1.52)	0.41 (0.35)	1.49 (1.09)	0.299***	0.225***	0.097***	0.072***
Distance to the next café (km)	0.93 (0.68)	0.64 (0.61)	0.93 (0.68)	1.67 (1.20)	0.454***	0.325***	0.037*	0.005
Distance to the next grocery store (km)	0.60 (0.32)	1.70 (1.38)	0.42 (0.35)	1.37 (0.97)	0.264***	0.162***	0.132***	0.041**
Distance to the next restaurant (km)	0.64 (0.37)	1.49 (1.15)	0.46 (0.40)	1.20 (0.82)	0.287***	0.140***	0.165***	0.080***
Confounders								
Males (%)	49.27 (2.01)	50.78 (1.70)	48.59 (23.48)	42.35 (18.95)	0.145***	0.073***	0.003	0.007
People aged 45 to 64 (%)	27.55 (4.39)	31.98 (4.05)	12.38 (4.39)	26.58 (12.23)	0.330***	0.200***	0.161***	0.080***
People aged 65 and older (%)	18.42 (7.33)	19.69 (4.71)	15.67 (12.38)	16.52 (8.21)	0.256***	0.289***	0.135***	0.067***
Non-western immigrants (%)	14.26 (11.87)	2.53 (2.84)	8.12 (8.96)	2.55 (3.04)	0.522***	0.201***	0.076***	-0.040**
Social welfare recipients (%)	2.31 (0.55)	2.09 (0.90)	1.51 (1.16)	1.67 (0.96)	0.402***	0.264***	0.278***	0.171***
Average yearly net income per inhabitant (*1,000 euros)	25.37 (5.71)	24.82 (4.04)	16.29 (12.32)	21.45 (10.50)	0.474***	0.528***	-0.395***	-0.198***

Alcohol intake (% not more than one glass of alcohol per day)	41.87 (7.24)	37.89 (5.26)	27.26 (20.42)	31.55 (14.78)	0.608***	0.709***	0.442***	0.323***
Smoking (% of current smokers)	22.67 (4.60)	18.52 (2.76)	14.38 (10.87)	15.33 (7.20)	0.525***	0.559***	0.072***	0.392***

*** P < 0.001, ** P < 0.01, * P< 0.05

Figure 1. Obesity prevalence z-standardized by neighbourhoods (spatially lagged by row-standardized weights)

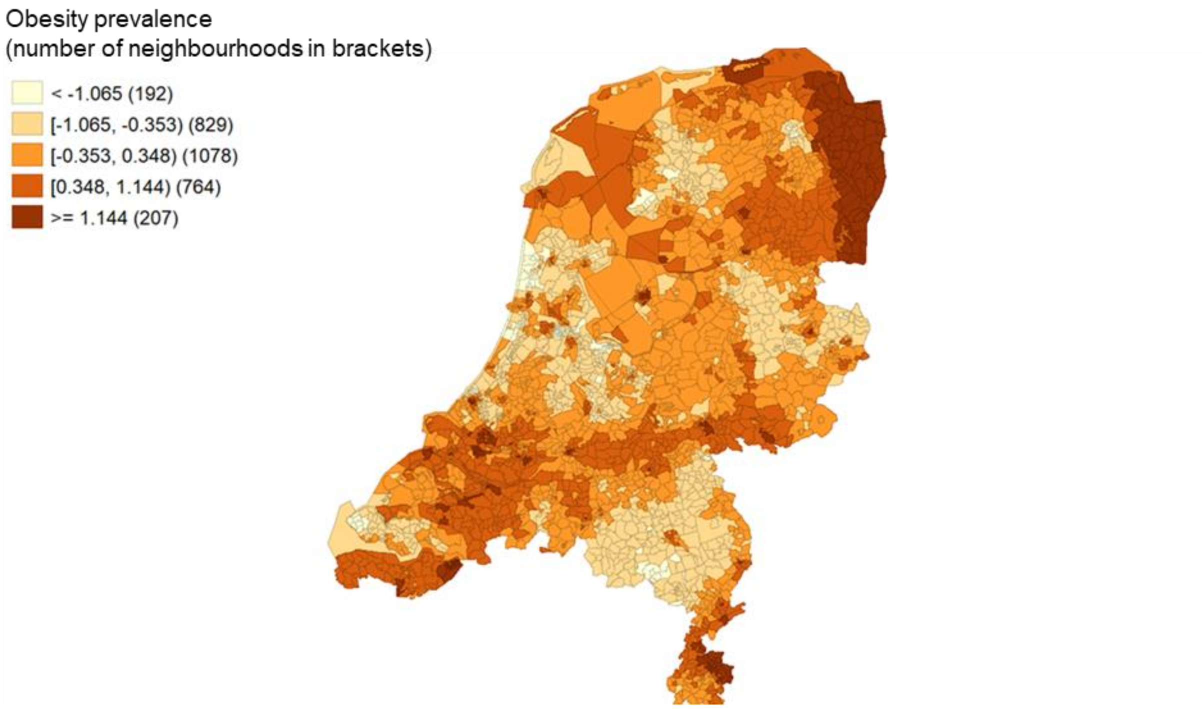

Figure 2. Associations between accessibility to cafeterias & fast food stores as well as grocery & fresh food stores and obesity prevalence

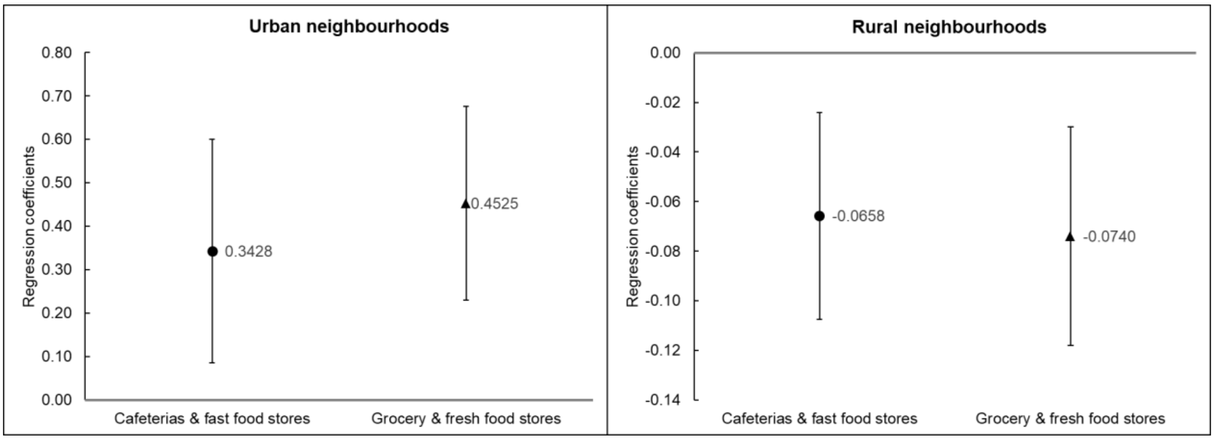

Figure 2. Geographically effect variation of the association between accessibility to food infrastructure and z-standardised obesity prevalence using GWRs