Accepted manuscript

Neighbourhood exposure to fast-food and sit-down restaurants and estimated 24-hour urinary sodium excretion: A cross-sectional analysis of urban adults from the ORISCAV-LUX 2 study

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This is an Accepted Manuscript for Public Health Nutrition. This peer-reviewed article has been accepted for publication but not yet copyedited or typeset, and so may be subject to change during the production process. The article is considered published and may be cited using its DOI 10.1017/S1368980025000540

Shortened version of the title: Exposure to restaurants and urinary sodium

Acknowledgements: The authors wish to thank the nurses and participants in the ORISCAV-LUX study. In addition, the authors thank the members of the ORISCAV-LUX study group for their contribution to the study: Ala'a Alkerwi, Stephanie Noppe, Charles Delagardelle, Jean Beissel, Anna Chioti, Saverio Stranges, Jean-Claude Schmit, Marie-Lise Lair, Marylène D'Incau, Jessica Pastore, Gwenaëlle Le Coroller, Gloria A Aguayo, Brice Appenzeller, Laurent Malisoux, Sophie Couffignal, Manon Gantenbein, Yvan Devaux, Michel Vaillant, Laetitia Huiart, Dritan Bejko, Torsten Bohn, Hanen Samouda, Guy Fagherazzi, Magali Perquin, Maria Ruiz, and Isabelle Ernens.

Financial support: This research was funded in whole, or in part, by the Luxembourg National Research Fund (FNR), grant reference: C20/BM/14787166, project acronym: MET'HOOD. For the purposes of open access, the authors have applied a Creative Commons Attribution 4.0 International (CC BY 4.0) license to any Author Accepted Manuscript version arising from this submission.

Conflict of interest: The authors have no relevant financial or non-financial interests to disclose

Authorship: Conceptualization and methodology: Marion Tharrey, Torsten Bohn, Olivier Klein, Laurent Malisoux, and Camille Perchoux. Formal analysis and investigation: Marion Tharrey and Dmitry Bulaev, Camille Perchoux. Writing, original draft preparation: Marion Tharrey. Funding acquisition: Camille Perchoux, Laurent Malisoux, Olivier Klein, and Torsten Bohn. All the authors have revised and provided critical reviews of the paper. All the authors have approved the final manuscript.

Ethical standards disclosure: This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the Luxembourg National Ethics Committee for Research (Ref: 202104/03 V2.0). All participants in the ORISCAV-LUX 1 and 2 studies provided written consent. They were then informed about the MET'HOOD project and given the opportunity to object to the use of their data.

ABSTRACT

Objective: Increased out-of-home consumption may elevate sodium (Na) intake, but self-reported dietary assessments limit evidence. This study explored associations between neighbourhood exposure to fast-food and sit-down restaurants and estimated 24-hour urinary Na excretion.

Design: A cross-sectional analysis from the ORISCAV-LUX 2 study (2016-2017). 24-hour urinary Na was estimated from a morning spot urine sample using the INTERSALT formula. Spatial access to fast-food and sit-down restaurants was derived from GIS data around participants' addresses within 800-m and 1000-meter road-network buffers by summing up the inverse of the road-network distance between their residential address and all restaurants within the corresponding buffer size. Multi-adjusted linear models were used to assess the association between spatial access to restaurants and estimated 24-hour urinary Na excretion.

Setting: Luxembourg

Participants: Urban adults age over 18 years (n=464).

Results: Fast-food and sit-down restaurants accounted for 58.5% of total food outlets. Mean 24-hour urinary Na excretion was 3564 mg/d for men and 2493 mg/d for women. Health-conscious eating habits moderated associations between spatial access to fast-food and sit-down restaurants and Na excretion. For participants who did not attach great importance to having a balanced diet, greater spatial access to restaurants, combining both density and accessibility, was associated with increased urinary Na excretion at 800 m ($\beta_{highvslow}$ = 259, 95% CI: 47–488) and 1000 m ($\beta_{highvslow}$ = 270, 95% CI: 21–520).

Conclusions: Neighbourhood exposure to fast-food and sit-down restaurants influences sodium intake, especially among individuals with less health-conscious eating habits, potentially exacerbating diet-related health disparities.

Keywords: restaurants; sodium; cross-sectional; Geographic information system; neighbourhood effect

INTRODUCTION

Poor diet quality and nutrition are major preventable risk factors for overweight and obesity, as well as for diet-related non-communicable diseases (NCDs), such as cardiovascular diseases, cancer and diabetes(1), which are the leading causes of death worldwide(2). High intake of sodium ranks as the number one dietary risk factor for NCDs, accounting for approximately 3 million deaths and 70 million disability-adjusted life years (DALYs) worldwide in 2017(1). Salt affects health by damaging target organs predominantly by raising blood pressure, but also through hormonal and inflammatory pathways, as well as by influencing immune responses and the gut microbiome(3). The burden of NCDs attributable to the excessive intake of sodium is particular high in European countries(1), where dietary habits include a high proportion of bread, bakery products, processed meats, dairy products, sauces and convenience meals, which are the leading contributors to sodium intake in most populations(4). Despite the recommendation of the World Health Organization (WHO) to keep personal salt intake to less than 2000 mg/day of sodium (equivalent to 5 g/day of sodium chloride), sodium intake in the WHO European Region is substantially above those recommended levels(5). In Luxembourg, the estimated median per capita intake of dietary sodium exceeded recommendations in 2007-2008 and continued to rise over the subsequent decade, from 2332 to 3333 mg/day(6).

In response to the shift in dietary patterns influenced by the increased supply, accessibility, and marketing of energy-dense, nutrient-poor processed foods, European public policy initiatives have turned their attention to the local food environment, which encompasses 'the collective physical, economic, policy and sociocultural surroundings'(7), in order to reduce salt intake at the population level(8). Of particular concern is the rise of fast-food, which encompasses a variety of quick-service establishments, generally offering pre-prepared food with minimal table service (hamburgers, pizza chains, etc.), and sit-down restaurants, which typically include establishments where customers are seated and a member of staff takes their order. Both have been reported to offer sodium-rich foods, regardless of the type of establishment(9). A growing body of observational studies suggest that the shift towards out-of-home consumption over recent decades has contributed to increased sodium intake(10,11). However, the limited number of studies, variability in methods and reliance on self-reported dietary assessments have hindered

https://doi.org/10.1017/S1368980025000540 Published online by Cambridge University Press

the available evidence, leading to mixed results[10] and underscoring the need for more objective measurements in assessing both the food environment and sodium intake. In this regard, geographic information systems have been increasingly used in epidemiological research to examine the role of 'place' as a contextual element of different health and diet-related risk factors[12]. While some studies have found links between neighbourhood availability of and proximity to fast-food outlets, increased fast-food consumption and poorer diet quality, the overall evidence remains inconsistent[13]. The link between exposure to sit-down restaurants and diet has been even less explored[13], and to the best of our knowledge, no study has examined the exposure to fast-food and sit-down restaurants in relation to sodium intake.

It has been acknowledged that heterogeneity in the assessment of environmental exposure related to the definition of a neighbourhood, its size and the type measurements (e.g. distance, density, proportion of food outlets), is a major methodological challenge that hampers the collation and interpretation of results linking the food environment and diet[13,14]. However, it is also likely that people respond differently to their environment, depending on personal and contextual factors, potentially mitigating the association between food environment and dietary behaviour[15]. For instance, education, income, culture, pro-health behaviours and physical access to healthy food options are among many factors that could affect food habits[16]. In that regard, men and more disadvantaged populations are more inclined towards takeaway and fast-food consumption[17] and compared with women, could therefore exhibit a stronger association between exposure to fast-food & sit-down restaurants and sodium intake. Pro-health attitudes may further influence the impact of exposure to fast-food and sit-down restaurants on eating habits[18], as individuals who value healthy eating may be less inclined to dine out in order to avoid high-fat and/or high-sodium foods and maintain greater control over their diet.

The purpose of the present study was to examine the cross-sectional association between neighbourhood exposure to fast-food and sit-down restaurants and salt intake among adults from a nationwide population-based survey in the Grand Duchy of Luxembourg. As self-reported dietary assessments (e.g., 24-hour recall or diet records) generally yield inaccurate estimates of sodium intake[19], we used estimated 24-hour urinary sodium excretion based on spot urine samples. We hypothesized that greater access to fast-food and sit-down restaurants would be

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associated with higher 24-hour urinary sodium excretion. We expected associations to be stronger for men, disadvantaged populations, and/or those with less pro-health behaviours.

METHODS

Study design, data, and participants

This study uses data from the cross-sectional Observation of Cardiovascular Risk Factors in Luxembourg (ORISCAV-LUX 2) study, a nationwide population-based survey conducted from 2016 to 2017 among the adult population of the Grand Duchy of Luxembourg. Details of the study design have been previously published[20]. Briefly, ORISCAV-LUX 2 was a follow-up of the ORISCAV-LUX 1 study conducted in 2007–2009 in Luxembourg to monitor the cardiometabolic health of the population[21]. The ORISCAV-LUX 2 sample included 1558 adults aged 25–79 years recruited according to different random sampling strategies. Participants from the first national survey (ORISCAV-LUX 1) were recontacted. This first wave was a nationally representative sample of 1432 subjects aged 18–69, created by random sampling stratified on age, sex and district from the National Health Insurance Register (IGSS)[21]. A sample of 660 participants enrolled in the first wave agreed to take part in the second survey, for which three additional alternative sampling strategies were implemented to overcome the drop in the number of participants for the follow-up (second wave)[20]. All the participants filled in a self-reported questionnaire at home, followed by a nurse interview combined with anthropometric and clinical examination. In 2021, a letter was sent to the 660 participants who participated in both waves (ORISCAV-LUX 1 and 2), asking for their agreement for secondary data analyses, using their data and address coordinates to extract information regarding the environmental characteristics of their residential neighbourhood at both time points. In response to this, 633 (96.6%) gave informed consent. From this sample, we excluded participants living in rural municipalities (n=122), as they were little exposed to fast-food and sit-down restaurants (**Figure 1**), as well as those self-reporting chronic conditions (heart failure, myocardial infarction, cerebrovascular accident or cancer) (n=47), resulting in a final sample of 464 participants.

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24-hour urinary sodium excretion

As around 90% of daily sodium intake is excreted in the urine throughout the day[22], the measurement of 24-hour urinary sodium excretion is considered the gold standard for assessing dietary sodium intake[19,23]. However, the collection of complete 24-hour urine Na excretion is tedious and not feasible in large epidemiological studies due to the high participant burden and cost. Therefore, spot urine samples have been identified as an appropriate alternative to measure population salt intake[24]. In the ORISCAV-LUX 2 survey, morning fasting spot urine samples were collected. Participants were invited to go to the nearest to their home Ketterthill laboratory (LKT, an accredited commercial laboratory) nearest to their home for sample collection. Samples were then transported to the LKT central facility to be processed and shipped daily to the Integrated BioBank of Luxembourg (IBBL, Dudelange, Luxembourg) for storage. The INTERSALT formula developed in the Western population was used to estimate total 24-hour urinary sodium from a spot urine sample[25], providing a more practical alternative to time-consuming complete 24-hour urine collection. This validated equation takes into account the sodium (Na), potassium (K) and creatinine concentrations of spot urine samples, and individual characteristics such as age, sex, geographical region and body mass index (BMI) to approximate daily sodium intake (**Supplementary Table 1**)[25]. As total urinary creatinine excretion remains relatively stable throughout the day and is hardly impacted by food intake, correcting for its concentration aids in considering the urinary output volume that can be variable during the day. The correction with potassium is typically carried out as an inverse relation between sodium intake and potassium intake – and therefore excretion – was observed. Hence, the combined equation provides, on the population level, a good approximation of total daily sodium excretion.

Exposure to fast-food and sit-down restaurants

Food outlet data

Data collection and reporting were carried out in accordance with the Geo-FERN reporting framework (**Supplementary Table 2**). The list of food outlets was obtained from the Luxembourg business directory data coordinated by the National Institute of Statistics and Economic Studies of the Grand Duchy of Luxembourg (STATEC 2017). The directory contains

https://doi.org/10.1017/S1368980025000540 Published online by Cambridge University Press

each entity's name, address and economic activity code according to the NACE Rev. 2 classification[26] of all registered businesses in the country. Restaurants were selected using the NACE codes 56.1 (restaurants and mobile food service activities). As fast-food and sit-down restaurants are not classified under a specific NACE code, we referred to the Atlas du Luxembourg, which provides a typology of restaurants in Luxembourg (including the name and type of cuisine) allowing us to differentiate fast-food and sit-down restaurants. The *Atlas du Luxembourg* (2009) was used as a reference, and an update was made for the second wave (2017) based on the type of restaurant/cuisine and information collected on the web. Fast-food restaurants were classified on the basis of i) their classification in the 2009 Atlas of Luxembourg, ii) the name of the restaurant/chain (e.g., McDonald's, Burger King, KFC, etc.), and iii) the impossibility for the customers to order food while seated at their table, iv) their designation as "fast-food restaurants" on food delivery websites, when available. We validated our classification by cross-referencing it with Open Street Map (2017) and amenities datasets provided by the Spatial Development Observatory from the Ministry of Housing and Spatial Planning of the Grand Duchy of Luxembourg.

Exposure measurements

To account for both density and proximity, we computed the spatial access to fast-food and sit-down restaurants, which we previously found to be a relevant metric to capture the healthiness of food environments in Luxembourg[27]. For each participant, spatial access to fast-food and sit-down restaurants was calculated by summing the inverse of the road-network distance in meters (m) between residential address and all restaurants within a predefined road-network buffer. Higher values indicate that participants live closer to a larger number of restaurants[28]. The further away the fast-food and sit-down restaurants are from participants' residences, the less accessible these restaurants become. The variable is defined as follows:

Spatial access to fast-food and sit-down restaurants (m^{-1}) = ∑(1/street network distance fast-food and sit-down restaurants in the road network buffer)

Spatial access measurements were calculated at 800 and 1000 m road-network buffer size around each participant's residential address. The reason for using these buffer sizes was twofold: First, 800 and 1000 m buffer sizes are a commonly-used metric for defining residential neighbourhood

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food environments (equivalent to a 15 to 20 minute walk)[29], second, smaller buffer sizes were deemed too small as they could lead to an excessive number of participants without exposure to fast-food and sit-down restaurants, while larger buffer sizes are more likely to be travelled by car and therefore are not a realistic representation of the proximity within neighbourhoods.

Participants' residential addresses and food outlet addresses were geolocated with the georeferenced addresses database (BD-Addresses), provided by the Administration of Cadastre and Topography (ACT), using ArcGIS (Version 9.3.1; ESRI, Redlands, CA, USA, 2010). The road network was obtained from the BD-L-TC topo-cartographic database (2015 version) provided by the Administration of Cadaster and Topography (Luxembourg City, Luxembourg).

Covariates

To guide the identification of potential confounders, we constructed a directed acyclic graph (DAG) as shown in **Supplementary Figure 1**. DAGs are visual representations that depict a priori causal assumptions regarding the relationships between variables[30].

Individual-level covariates were obtained from the self-administered questionnaire, and include: sex, age, country of birth (Luxembourg, European country, or non-European country), resource perception (difficult, easy or refuse to answer), educational level (no diploma, secondary education or higher diploma), work status (employed, not employed, stay-at-home parent, disabled/retired), marital status (married/living with partner, single/never married or divorced/widowed), presence of a child in the household (yes or no), attitude towards healthy eating (great or enough/little importance) and attitude towards weight management (great or enough/little importance). For the latter two variables, participants were asked about the importance they placed on respectively having a balanced meals and maintaining a normal weight for good health. The response options included 'great importance', 'enough importance', 'little importance', and 'no importance' (which no participant selected). 'Enough importance' and 'little importance' were combined to differentiate those who attached great importance to having a balanced diet from those who did not.

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Neighbourhood-level covariates include neighbourhood socioeconomic status (SES) and the healthiness of the retail food environment. Patterns of neighbourhood SES were derived by principal component analysis (PCA), based on six variables : percentage of unemployment, percentage of blue-collar workers, monthly gross total wage (in euros), percentage of domestic community receiving the guaranteed minimum income supplementary allowance, percentage of the domestic community receiving cost-of-living allowance, and average housing sales prices (in euros per m²). Considering eigenvalues >1 and a breakpoint in the Scree test, two factors explaining >80% of total variance were retained. The first factor represents relatively deprived neighbourhoods with high loadings on receiving minimum income and cost-of-living allowances and low loading on monthly total wage. The second factor describes higher neighbourhood SES with high loadings on average housing sales prices and blue-collar workers and low loading on unemployment (**Supplementary Table 3**). Details regarding the extraction of the factors have been described elsewhere[27]. The healthiness of the retail food environment was assessed in 800 m and 1000 m road network buffers around the participant address by the modified Retail Food Environment Index (mRFEI)[31], a commonly-used indicator to assess the relative density of healthy food retailers. The mRFEI (range: 0-100) was calculated as the ratio between the number of healthy food retailers—that is supermarkets and specialized shops selling fresh fruit and vegetables (greengrocers and open markets)—and the total number of food retailers within each participant's neighbourhood[31], including healthy food retailers plus small grocers, convenience stores (which are located at petrol stations in Luxembourg), bakeries, butchers, fishmongers and restaurants. **Supplementary Table 4 shows** details of the methods and sources. The final mRFEI was categorized into tertiles.

Statistical analysis

The sociodemographic characteristics of the population were compared between men and women via a two-sample t-test for continuous variables (following assessment of normality and homogeneity assumptions) and Fisher's exact tests for categorical variables. To handle missing values, Multiple Imputation by Chained Equations was employed using Fully Conditional Specification method[32]. All the variables used in the present study were incorporated in the imputation model[33]. The number of imputed datasets generated was set equal to the percentage of incomplete cases[34]. Imputation was performed using the *mice* R package. A total of 20 imputed datasets were created and used in subsequent analyses.

We used general linear models (PROC GLM procedure in SAS, SAS Institute, Inc., Cary, North Carolina) to assess the association between spatial access to fast-food and sit-down restaurants and estimated 24-hour urinary sodium excretion. Spatial access to fast-food and sit-down restaurants was categorized into low, intermediate or high, based on tertiles. A significant interaction between age and sex (F-test, $p<0.0001$) was observed in all imputed datasets, and was therefore added to the models. First, two models with increasing levels of adjustment were tested. Model 1 was adjusted on individual-level covariates and Model 2 was further adjusted on neighbourhood-level covariates. Estimates (β) and 95% confidence intervals (CI) from the 20 imputed datasets were summarized using PROC MIANALYZE in SAS. Then, effect modifications by sex, age, individual SES and neighbourhood SES, as well as pro-health behaviours were investigated by adding multiplicative interaction terms with spatial access to fast-food and sit-down restaurants. We only retained statistically significant interaction terms according to a type III test (F-test, p-value <0.05), comparing the models with and without interactions. The assumption of normality and homoscedasticity of the residuals was checked visually for each set of imputed data. Measurements of skewness (±1) and kurtosis (±2) also showed no sign of deviation from normality.

Multiple imputations were performed in R version 4.3.1. All statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA), and a two-tailed p-value <0.05 was considered as statistically significant.

Sensitivity analyses

To disentangle the specific role of each type of restaurant on urinary sodium levels, we ran a model considering solely sit-down restaurants. Given the high number of participants with no exposure to fast-food restaurants (**Supplementary Table 5**), it was not possible to run a model including only fast-foods outlets. We therefore ran sensitivity analyses on the association between presence of fast-food restaurants, count of sit-down restaurant and count of fast-food and sit-down restaurants and estimated 24-hour urinary sodium excretion. Presence of fast-food restaurants was dichotomized into yes vs. no, while count of sit-down restaurant and count of

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fast-food and sit-down restaurants were categorized into low, intermediate or high, based on tertiles. We also tested sensitivity to the imputation by running the analyses on the non-imputed data (complete case analysis).

RESULTS

Study population

Mean (SD) urinary excretion of Na was 3564 (744) mg/d for men and 2493 (862) mg/d for women. Men and women had similar sociodemographic characteristics except for work status, as women were more likely to be unemployed or a stay-at-home parent (**Table 1)**.

Exposure to fast-food and sit-down restaurants

For 2017, we counted 213 fast-food and 1335 sit-down restaurants, primarily located in urbanized municipalities (**Figure 1**), accounting for 58.5 % of the total food outlets in the country (data not shown). The median number of fast-food and sit-down restaurants combined within the participants' residential neighbourhood were 3 at 800 m and 4 at 1000 m, with a median shortest distance of 495 m (**Supplementary Table 5**). Spatial access to fast-food and sit-down restaurants was greater in dense cities (Luxembourg and Esch-sur-Alzette), followed by former mining areas in the southern region of the country (**Supplementary Table 6**). The median (IQR) of spatial access to fast-food and sit-down restaurants, as well as tertiles are shown in **Supplementary Table 5**.

Spatial access to fast-food and sit-down restaurants and estimated 24-hour urinary Na excretion

No significant associations were found between spatial access to fast-food and sit-down restaurants, and 24-hour urinary Na excretion in the total population (**Table 2**). Analyses revealed a significant interaction term between attitude towards healthy eating and spatial access to fast-food and sit-down restaurants at 800 m (F-test, p-value <0.05: 95% of imputed datasets) and 1000 m (F-test, p-value <0.05: 90% of imputed datasets). For participants who did not attach great importance to having balanced meals only, a greater exposure to fast-food and sit-down restaurants was associated with higher 24-hour urinary Na excretion at 800 m ($\beta_{intermediate}$ = 358, 95% CI: 136–580; β_{high} = 259, 95% CI: 20–499) and 1000 m ($\beta_{intermediate}$ = 268, 95% CI: 47–488;

https://doi.org/10.1017/S1368980025000540 Published online by Cambridge University Press

β_{high} = 270, 95% CI: 21–520), as shown in **Figure 2**. Detailed coefficients are presented in **Supplementary Table 7.** There was no significant association between spatial access to fast-food and sit-down restaurants and 24-hour urinary Na excretion for participants who reported more health-conscious eating habits. Sex, individual SES and both factors of neighbourhood SES did not moderate the associations between spatial access to fast-food and sit-down restaurants and estimated 24-hour urinary Na excretion (data not shown).

The results were consistent when running the analyses on the non-imputed dataset (**Supplementary Table 8; Supplementary Figure 2**). Sensitivity analyses performed only for sit-down restaurants showed similar results (**Supplementary Table 9)**. Additionally, a significant interaction term was observed between neighbourhood SES (Factor 2) and spatial access to sit-down restaurants and at 800 m and 1000 m (F-test p-value <0.05: >75% imputed datasets). After categorizing Factor 2 into tertiles to facilitate visual representation of the interaction, we found that a greater exposure to sit-down restaurants was associated with a greater 24-hour urinary Na excretion at 800 m ($\beta_{intermediate}$ = 384, 95% CI: 101–667; β_{high} = 302, 95% CI: 22–583) and 1000 m ($\beta_{intermediate}$ = 334, 95% CI: 48–621; β_{high} = 286, 95% CI: 0.7–571) for participants in the upper tertile of Factor 2 but not the lower tertile (**Supplementary Figure 3**). Sensitivity analyses performed on presence of fast-food restaurants only, counts of sit-down restaurant only, and counts of fast-food and sit-down restaurants showed no associations except for the presence of fast-food restaurants only (**Supplementary Table 10**). The presence of fast-food restaurants in an 800 m road network buffer was inversely correlated with 24-h urinary Na excretion (p-value=0.036). This finding may be explained by the fact that the (road) distance to the outlet and their density in the buffer were not considered as a covariate, as compared to spatial access. When the spatial access to fast-food and sit-down restaurants is used instead, the observed trend inverts – the association between spatial access and 24-h urinary Na excretion becomes positive.

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DISCUSSION

To our knowledge, this is the first study to investigate the association between neighbourhood exposure to fast-food and sit-down restaurants, and urinary Na excretion. Using data for urban adults from a nationwide population-based survey and spot urine samples, we found that the mean daily Na intake as estimated by the INTERSALT formula, exceeded the WHO recommendation of 2000 mg/day of Na intake for both men and women. Greater neighbourhood exposure to fast-food and sit-down restaurants was associated with higher estimated 24-hour urinary Na excretion, though only among participants who did not report attaching great importance to having balanced meals. Sex, individual SES and neighbourhood SES did not moderate the associations between spatial access to fast-food and sit-down restaurants, and estimated 24-hour urinary Na excretion.

To date, only a limited number of studies have explored the effects of objective exposure to the food environment on Na intake, yielding inconclusive findings. In the UK, analyses of large-scale objective commercial purchasing data revealed no significant association between density and distance to restaurants and takeaway outlets, and purchases of foods and drinks high in fat, salt and sugar; however, Na intake was not studied in isolation[35]. In the USA, no association was found between the modified Retail Food Environment Index (mRFEI) (measuring the relative density of healthy and less healthy food retailers) and Na intake, although it is notable that sit-down restaurants were not encompassed by the analysis[36]. In Japan, a study conducted on female dietetic students showed no association between various metrics of neighbourhood food store availability and urinary Na excretion[37]. Our study contributes to this strand of literature by investigating the specific role of neighbourhood exposure to restaurants in urban settings. We found no clear evidence of any association between exposure to fast-food and sit-down restaurants, and urinary Na excretion in the total sample. Sensitivity analyses on presence and spatial access to sit-down restaurants only, yielded similar results, while we observed an unexpected negative association between the presence of fast-food restaurant in an 800 m buffer from the residence and urinary Na excretion (association not sustained at 1000 m). These findings, in conjunction, may suggest that presence (vs. absence) of restaurant is not fully capturing the mechanisms of accessibility, yielding contradictory findings. The sole presence of fast-food restaurants in the neighbourhood is not necessarily linked with higher Na excretion

https://doi.org/10.1017/S1368980025000540 Published online by Cambridge University Press

levels, and the distance to those restaurants needs to be considered, since it demonstrates to strongly alter the effect size and direction.

Importantly, we discovered that greater exposure to fast-food outlets and sit-down restaurants was associated with higher urinary Na excretion only among participants who did not attach great importance to eating balanced meals, providing a novel insight into the moderating role of health-conscious eating habits in the relationship between the food environment and Na intake. It is well know that out-of-home food consumption can be affected by various individual experiences, behaviours and attitude(17). In particular, nutrition-related health consciousness has been recognized as an important factor shaping behaviours in terms of restaurant selection(38,39) food choice(40) and healthy eating(41,42). Our findings suggest that being in the immediate environment of fast-food and sit-down restaurants could encourage poorer dietary habits, particularly among those who are already at greater risk of having less healthy diets, raising concerns about the potential role of the local food environment in increasing diet-related health disparities.

Sex, age and individual SES did not moderate the association between exposure to restaurants and estimated Na excretion, yet they are known as important factors affecting patterns of eating out-of-home food consumption(17,43). Existing research suggests that men, younger adults and socio-economically disadvantaged populations are more inclined to opt for fast-food outlets, while women with higher socioeconomic characteristics may be more likely to frequent sit-down restaurants(17,43). It is likely that combining fast-food outlets and sit-down restaurants may have attenuated the moderating effect of socio-economic factors on the overall association. In line with this hypothesis, we found that spatial access to only sit-down restaurants was associated with higher Na excretion for participants living in higher SES neighbourhoods, reinforcing the idea that individuals with higher socioeconomic characteristics may be more likely to frequent this type of restaurants. An expanding body of literature indicates that there are neighbourhood disparities in the food environment, with individuals living in more deprived neighbourhoods having an increased likelihood of facing the double burden of individual deprivation and greater exposure to less healthy environments(15). Conversely, our study raises questions about the potential effect of the increase in the number of sit-down restaurants in the downtown areas of dense cities (generally affluent neighbourhoods) on the salt consumption of local residents.

Interestingly, importance attached to maintaining a normal weight for good health did not moderate the association between exposure to fast-food and sit-down restaurants, and Na intake. This finding is consistent with the results of a previous study, suggesting that healthy food choice motives and concern about consuming too many calories are better predictors than weight control in the formation of healthy eating attitudes[44].

Sodium levels in major fast-foods and chain restaurants are high, but with great variability between companies and countries[45–47]. Yet obtaining data for private restaurants is challenging, as recipes vary widely between establishments and chefs. The persistence of the associations, even when analyses were restricted to sit-down restaurants, nevertheless raises concerns regarding the Na content of restaurant meals. Member states of the WHO European Region have demonstrated significant leadership and progress in efforts to reduce population-level salt consumption, with about half of the countries reporting that they have fully implemented national policies on salt reduction[8]. However, these policies have not been implemented in Luxembourg. As recent data from the National Institute of Statistics of Luxembourg reveals a 56% increase between 2019 and 2022in average household spending on eating out, and home delivery in particular[48], our results call for greater policy attention to develop national salt reduction strategies targeting the food service sector.

The strengths of this study include a nationwide sample, the use of objective measurements for both exposure and outcome variables, and adjustment for a large set of potential confounders. In particular, the INTERSALT formula is widely used in population-based studies for its simplicity and reliance on spot urine samples, which do not require strict participant adherence, compared with 24-hour collections. It also adjusts for urine dilution using both potassium and creatinine concentrations, improving Na intake estimation accuracy. This study also has some limitations. First, the cross-sectional design limits the ability to establish causality. Second, the drop in the number of participants between the two waves may limit the generalizability of our findings to the general population. Nevertheless, we previously found no differences in mean age and sex proportion between the population of the ORISCAV-LUX 1 study and those who also took part in ORISCAV-LUX 2[27]. This suggests that national representativeness for these variables was retained, even though participants in the second wave were slightly better educated[27]. Third, the INTERSALT formula relies on spot urine samples collected at a single time point, and this may not capture day-to-day variability in Na intake with full accuracy. The time of the day, hydration status, food intake and other factors can introduce measurement error and affect the reliability of Na intake estimates[49]. Fasting morning urine samples (probably not the first morning urine, as participants had to travel to the closest laboratory) were collected, thus limiting the risk of measurement error in Na excretion. However, Mann *et al.*, found that the Na/creatinine ratio of a late afternoon/early evening urine sample, obtained near the midpoint of a 24-hour collection strongly correlated with the actual 24-hour Na excretion, and therefore morning samples may be more likely to underestimate 24-hour Na excretion[49]. Fourth, spatial access measurements did not allow for the assessment of which aspect of exposure (density or proximity) is more relevant in the association with the outcome. Although evidence indicates that availability (i.e. density) measurements may produce larger and more significant effect sizes than accessibility (i.e. proximity) measurements, both provide distinct and complementary perspectives on spatial exposure and therefore should be studied conjointly[13]. Last, our analysis was limited to the residential environment, thus disregarding individuals' exposure to restaurants during daily mobility. Notably, research has shown a significant correlation between exposure to takeaway food outlets in the work neighbourhood, takeaway food consumption and body mass index[50]. How restaurant environment influence Na intake should be further investigated in future research using activity space-based measurements.

CONCLUSION

To the best of our knowledge, this study is the first to examine the association between neighbourhood exposure to fast-food and sit-down restaurants and Na excretion. Using a nationwide sample of urban adults, we found that greater spatial access to fast-food and sit-down restaurants was associated with higher estimated 24-hour urinary sodium excretion among participants who did not attach great importance to having a balanced diet. These findings highlight the role of health-conscious behaviours in moderating the association between the food environment and sodium intake. They suggest that pro-health attitudes may serve as a preventive factor for people with high levels of neighbourhood exposure to fast-food and sit-down restaurants. Our results underscore the need for national salt reduction strategies targeting the food service sector.

https://doi.org/10.1017/S1368980025000540 Published online by Cambridge University Press

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Table 1. Sociodemographic characteristics of the study population by sex, n=464 adults from ORISCAV-LUX 2 study

	Men (n=229)	Women (n=235)	P-value[a]
Estimated 24-hour Urinary Na excretion, mg/d	3564 (744)	2493 (862)	<.0001
Mean (SD) age, years	51.2 (11.8)	53.2 (11.6)	0.748
Resource perception, n (%)			0.895
Difficult	36 (15.7)	38 (16.2)	
Easy	153 (66.8)	155 (66.0)	
Refuse to answer	37 (16.2)	42 (17.8)	
N/A	3 (1.3)	0 (0)	
Work status, n (%)			<.0001
Employed	162 (70.8)	135 (57.5)	
Not employed/Stay-at-home parent	6 (2.6)	44 (18.7)	
Disabled or retired	58 (25.3)	55 (23.4)	
NA	3 (1.3)	1 (0.4)	
Education level, n (%)			0.589
No diploma	34 (14.8)	38 (16.2)	
High school or vocational diploma	96 (41.9)	107 (45.5)	
Higher diploma	97 (42.4)	89 (37.9)	
N/A	2 (0.9)	1 (0.4)	
Marital status, n (%)			0.150
Married/living with partner	177 (77.3)	169 (71.9)	
Single/never married	24 (10.5)	22 (9.4)	
Divorced/widowed	27 (11.8)	43 (18.3)	
N/A	1 (0.4)	1 (0.4)	
Country of birth, n (%)			0.782
Luxembourg	136 (59.4)	140 (59.6)	
European country	78 (34.1)	84 (35.7)	
Non-European country	15 (6.5)	11 (4.7)	

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Presence of a child in the household, n (%)			0.782
Yes	138 (60.3)	162 (68.9)	
No	89 (38.8)	73 (31.1)	
N/A	2 (0.9)	0 (0)	
Great importance attached to eating balanced meals for good health, n (%)			0.351
Yes	111 (48.5)	127 (54.0)	
No	113 (49.3)	108 (46.0)	
N/A	5 (2.2)	0 (0)	
Great importance attached to maintaining normal weight for good health, n (%)			0.640
Yes	99 (43.2)	109 (46.4)	
No	126 (55.0)	126 (53.6)	
N/A	4 (1.8)	0 (0)	

Na: sodium

[a] P-value from a two-sample t-test (continuous variables, equal variances), or, Welch's t-test (continuous variables, unequal variances) or, Fisher's exact test of significance of association (categorical variables).

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Table 2. Estimates (β) and 95% confidence intervals (CI) for associations of spatial access to fast-food and sit-down restaurants, and 24-hour urinary Na excretion (mg/d), by different road network buffer sizes

Tertiles of spatial access	800 m		1000 m	
	β (95% CI)	P-value	β (95% CI)	P-value
Model 1[a]				
Low	ref.	-	ref.	-
Intermediate	135.5 (-19.8, 290.9)	0.087	79.2 (-69.7, 228.1)	0.297
High	105.2 (-42.7, 253)	0.163	104 (-44.4, 252.4)	0.169
Model 2[b]				
Low	ref.	-	ref.	-
Intermediate	133.2 (-22.5, 288.8)	0.094	77.9 (-76.2, 232)	0.322
High	109.8 (-78.4, 298.1)	0.253	109.7 (-92.8, 312.2)	0.288

[a] Model 1 was adjusted for sex, age, country of birth (Luxembourg, European country or non-European country), resource perception (difficult, easy or refuse to answer), educational level (no diploma, secondary education or higher diploma), work status (employed, not employed, stay-at-home parent or disabled/ retired), marital status (married/living with partner, single/never married or divorced/widowed), presence of a child in the household (yes or no), great importance attached to eating balanced meals for good health (yes or no) and great importance attached to maintaining normal weight for good health (yes or no).

[b] Model 2 = Model 1 + tertiles of modified Retail Food Environment Index (mRFEI), as well as two scores of neighbourhood SES derived from PCA.

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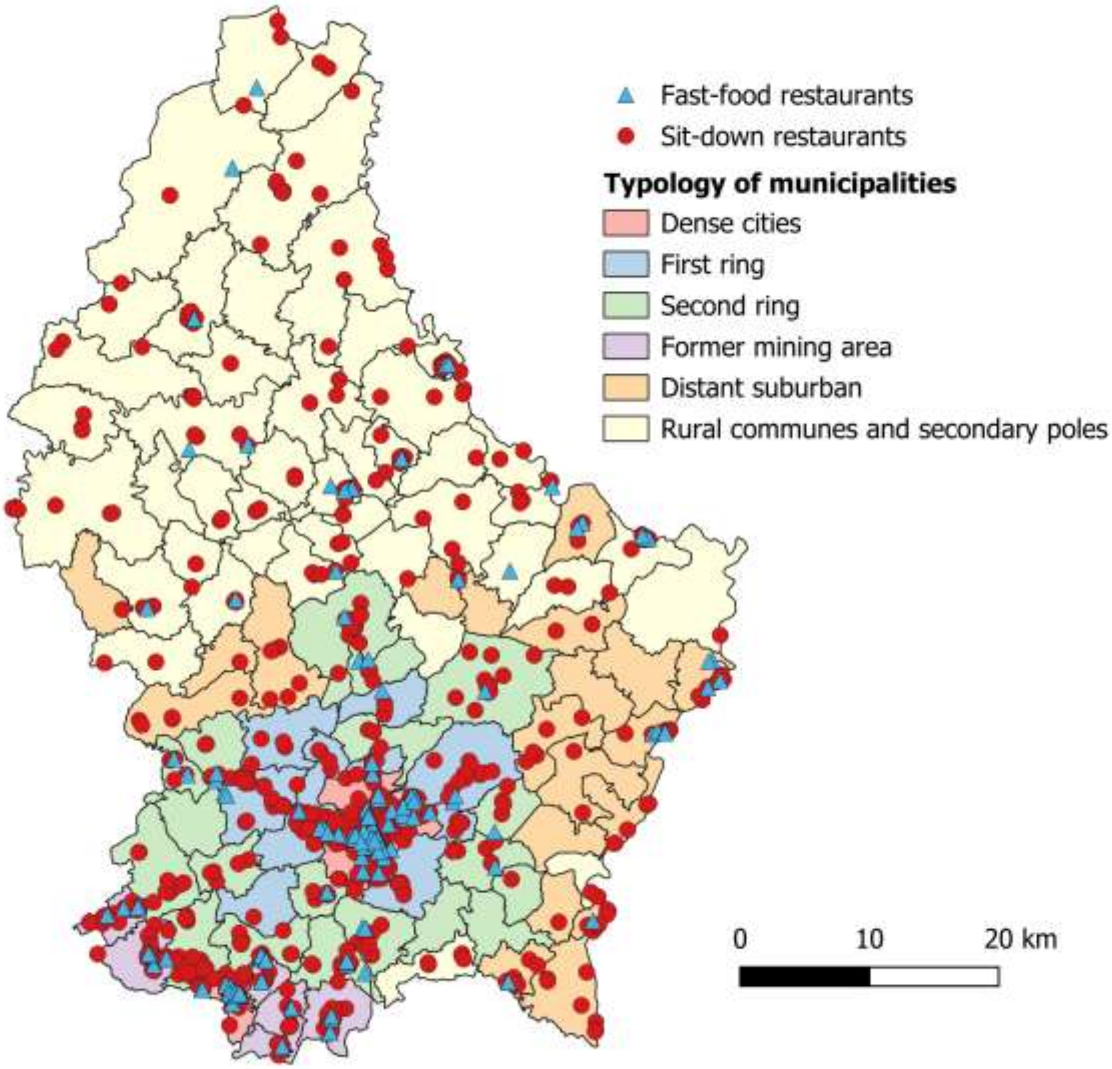

Figure 1. Map of fast-food outlets (n=213) and sit-down restaurants (n=1335) in Luxembourg in 2017 (STATEC, 2017)

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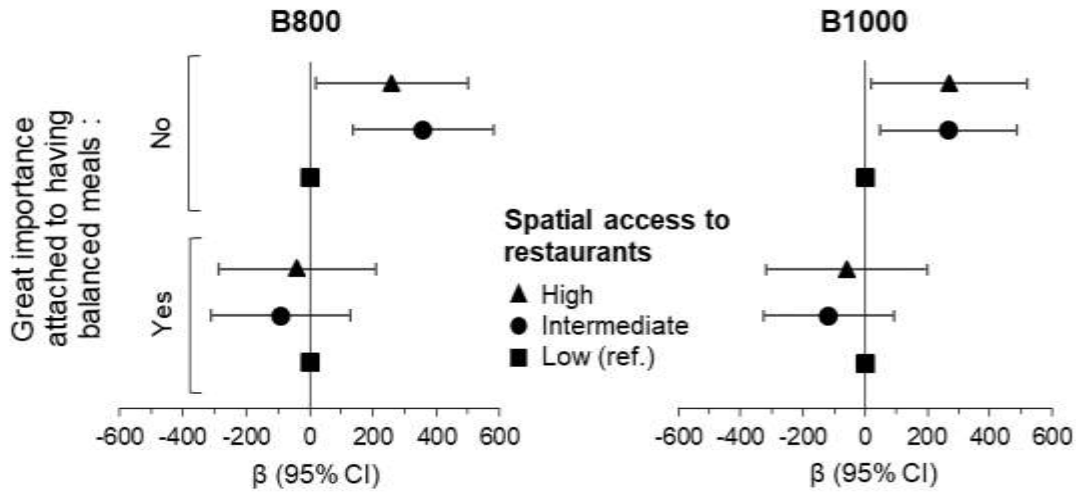

Figure 2. Estimates (β) and 95% confidence intervals (CI) for associations of spatial access to restaurants and 24-hour urinary Na excretion (mg/d), at 800 m and 1000 m, according to health-conscious eating habits. Fully adjusted model (Model 2)

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