Contextual correlates of dietary behaviours in adults across Europe

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Chapter 8

General Discussion

SUMMARY OF MAIN FINDINGS

The general objective of this thesis was to explore how individual-level and environmental-level factors are associated with dietary behaviours in Europe, and how methodological decisions on the definition of exposure to the food environment may influence these associations. In this section, the three overall research questions stated in the general introduction are re-visited, and the findings from each chapter are summarized providing answers to the research questions. In this general discussion section, these findings are put into perspective based on research from others.

1. How are different individual social-cognitive factors associated with dietary behaviours in adults from five European countries?

In Chapter 2, the association between perceived barriers to healthy eating and dietary behaviours in adults across five urban regions in Europe was explored. We found that individuals who perceived any of the barriers to healthy eating included in the study were less likely to report healthier dietary behaviours, such as frequent consumption of vegetables, fruit, fish, breakfast and home-cooked meals, and were more likely to report fast food consumption compared to individuals who perceived no barriers to healthy eating. Strongest inverse associations were found for the barriers 'lack of willpower', 'time constraints' and 'taste preferences' with the consumption of vegetables and home-cooked meals. Associations between barriers to healthy eating and dietary behaviours often differed by socio-demographic factors and urban regions. For example, the associations between various barriers and lower intake of fruit and vegetables were somewhat more pronounced among younger participants and women.

2. How does the definition of measures of exposure influence the relation between the food environment and dietary behaviours in a European adult population?

In Chapters 3 and 4, we explored challenges related to the definition of exposure to the food environment while analysing different relations between the food environment and dietary behaviours. In Chapter 3, in order to test the independent and combined association of access to grocery stores and restaurants and

frequency of home cooking, we used an exposure measure ('spatial accessibility') that accounts for both 'availability' and 'accessibility'. Adjustment for the broader food environment (i.e., accounting for the presence of food retailers other than those used as the exposure measure), was also taken into account in separate models. We showed that, in a study population of adults from different urban areas in Europe, highest access to restaurants was associated with lower frequency of home cooking while no independent association was found between access to grocery stores and frequency of home cooking. We found no evidence for interaction, e.g., stronger effect sizes for a combined association between access to grocery stores and access to restaurants and home-cooking, as compared to the independent associations.

In Chapter 4, we explored the influence of type and variety of food retailers while testing the associations between food environment and dietary patterns. Simpler and more complex measures were compared. However, the use of more complex and relative measures of exposure to the food environment did not provide stronger associations with dietary patterns than simpler absolute measures. We found some indication that absolute and relative measures of exposure assess different aspects of the food environment, however, given the lack of significant findings in this study, this needs to be further explored.

3. How does the study area, and the distribution of food retailers across it, influence the relation between the food environment and dietary behaviours?

In Chapters 5, 6, and 7, we addressed common challenges related to the definition of the study area and the distribution of food retailers across 'neighbourhoods'. In Chapter 5, various ego-centred and territorial neighbourhood definitions were compared in exploring associations between the density of restaurants and home-cooking. As described in Chapter 5, in an adult population in the Netherlands, no significant association between the food environment and home-cooking was observed, which was different from the earlier finding in a study population from different countries in Europe (Chapter 3). Although in the Dutch study, exposure in terms of density of restaurants was different according to different neighbourhood definitions, we found no evidence that the definition of the area under study influenced this association. However, whether the area under study is important for determining exposure to other aspects of the food

environment, among different populations and/or other behaviour and health outcomes should be further investigated.

In Chapter 6, we analysed recent changes in the Dutch 'foodscape', i.e., the availability of different food outlets distributed across Neighbourhoods in the Netherlands. In particular, we focused on whether these trends were dependent on the level of SES and urbanisation of the neighbourhoods under study. This chapter demonstrated that even within a relatively short period of time the Dutch foodscape underwent considerable changes. Data from 2004 to 2018 showed a clear increase of 120% and 35% in the availability of food delivery and restaurants, respectively, and a decrease of 26% in the availability of local shops. Among the lowest SES neighbourhoods, availability of supermarkets and convenience stores increased by 58% and 10% respectively, while a decrease of 45% in the availability of supermarkets and of 29% in the availability of convenience stores were observed for the highest SES neighbourhoods. Food delivery outlets increased substantially in all neighbourhood SES strata. When assessing different urbanisation levels, a similar pattern was observed: food delivery places increased in general and the availability of supermarkets and convenience stores increased in the highest urbanised neighbourhoods and decreased in the lowest. In general, the Dutch foodscape has changed towards a higher availability of convenience and ready-to-eat foods; such foods have been found to be associated with less healthy diets.

Finally, in Chapter 7, we explored the association between exposure to the food environment and the consumption of ultra-processed foods in an elderly population in the Netherlands. A comprehensive approach was applied to define exposure to the food environment. We used both measures of availability and proximity to different types of food retailers within different buffer sizes. Furthermore, we used more complex methods for deriving exposure variables, such as street network distances and kernel density estimates. We found evidence that higher exposure to different types of food retailers was associated with lower consumption of ultra-processed foods. The use of different buffer sizes did not influence the associations much. However, since the availability of different food retailers varies depending on the type of food retailer (e.g., there are many more restaurants than supermarkets in a neighbourhood), the definition of a buffer size seems to be important while analysing different food retailers. For instance, as there are usually not many supermarkets in a neighbourhood, too small buffer sizes cannot capture sufficient variation in the exposure to that particular food retailer.

INTERPRETATION OF MAIN FINDINGS AND RECOMMENDATIONS FOR FUTURE RESEARCH

The use of 'simple' measures of exposure to the food environment (e.g., only proximity or availability) have been suggested as one of the potential explanations for the inconsistent findings in the literature to date on the relation between the food environment and dietary behaviours [1, 2]. We sought to account for the complexity of the food environment by deriving more complex exposure measures, accounting for the broader food environment and using innovative ways to define study areas. However, regardless the measure or method used, the studies in this thesis did not provide convincing evidence for a link between the geographically measured food environment and diet.

The use of simple measures of exposure may fail to reflect the complexity of exposure to food retailers. For example, the use of a proximity measure such as the distance to the closest fast-food restaurant ignores the potential presence of several other fast-food restaurants in the vicinity, which may influence one's food choice. The use of a density measure, in turn, may capture this array of options of fast food retailers, while ignoring the construct of proximity. Therefore, while both measures may capture relevant aspects of the food environment, a combination of measures is likely to be a better option. An example is the *spatial accessibility measure* based on a 'potential accessibility index', which includes functions of the weighted inverse distance to destinations within a specific area, thus taking into account both proximity and availability [3]. Therefore, by deriving more complex measures we meant to incorporate more than one construct of access while deriving exposure to the food environment. In Chapters 3 and Chapter 4, we used methods previously proposed in the literature to derive a spatial accessibility measure that accounted for both availability and accessibility. However, the use of such measures is not without limitations. Deriving a measure based on a function of the weighted inverse distance demands much computational work as first the distances to all food retailers available in the neighbourhood have to be calculated and in a second stage the inverse weights are applied. Furthermore, the interpretation of such measures is not straight forward and results from this thesis did not indicate them to be superior to other simpler measures tested. However, earlier published systematic reviews suggest that more complex measures of

exposure are needed [2, 4]. In light of our findings and considering previous published studies, I would argue for the use of more complex measures that are less laborious to be derived and are easier to interpret, such as kernel density estimates. Kernel density calculates the counts of food retailers across the study area from a determined origin, by including a distance function in the calculation of the measure. Points clustered closer to the origin receive higher weights than those closer to the boundary of the delimited area [5, 6].

In addition, to account for the complexity of the food environment by deriving measures that combine both constructs of availability and accessibility, we also sought to account for the complexity of the food environment by considering a variety of food retailers within the study area. For this aim, the use of relative measures has been suggested [7-11]. In Chapter 4, we derived relative measures of exposure, such as the Modified Retail Food Environment Index (mRFEI). This measure represents the proportion of food retailers that sell more healthy options in relation to the total amount of food retailers in the neighbourhood, therefore accounting for the type and variety of food retailers [12]. Since this measure is obtained from a ratio, it cannot be calculated for individuals that lived in neighbourhoods that have no food retailer present. Thus, an alternative to these measures is the use of statistical adjustment for the broader food environment. To do so, variables indicating availability/accessibility of food retailers that were not included in the exposure measure are included in the models as covariates. In Chapters 3 and Chapters 5 we presented models with and without adjustment for the broader food environment, and in Chapter 6 we presented only models that were adjusted for the broader food environment. The results of these studies indicate that relative (i.e., taking the broader food environment into account) and absolute measures seem to assess different aspects of the food environment, but no substantial differences were observed in the results from these different models. In general, we could not demonstrate that more complex and relative measures, instead of simpler, absolute measures, produce stronger associations with dietary behaviours. However, the overall lack of associations found in most analyses did not leave much room for exploring differences between absolute and relative measures. In other words, we did not find that more complex and relative measures of exposure produce stronger associations between the food environment and diet, but we did not find evidence for an association using less complex measures either. Lack of differences across models tested with or without adjustment have been found before [13]. However, a number of previous studies have found stronger associations between the food environment and diet when adjusting their analysis for the broader food

environment [7, 8, 10, 11]. In addition, testing the association between only one type of food retailer and dietary behaviours might not represent an individual's true exposure. That is because, in reality, food retailers often co-locate and are likely to influence food choices concomitantly. For instance, the presence of healthier food retailers in a neighbourhood may balance the influence that less healthy food retailers have on dietary choices [7]. Thus, considering only one type of food retailer in the analysis, while ignoring the potential influence of other food retailers may lead to residual confounding, resulting in incorrect estimates. Therefore, I believe that the broader food environment should always be taken into account. The use of relative measures such as the ratio of healthier food retailers by the totality of food retailers may be a preferred option in cases where there are only few neighbourhoods with no food retailer present. When there are too many neighbourhoods with no food retailers present, statistical adjustment may be a better option. Statistical adjustment may be done by adding the variables representing exposure to food retailers other than the food retailed used as an exposure measure as covariates to the models. However, multicollinearity between those different variables representing access to the food environment should be considered, and models should be presented with as well as without adjustment for the broader food environment.

In addition to that, due to the overall inconsistency in results from previous studies on the relation between the food environment and dietary behaviours, some have argued that comparing study results is not appropriate due to the large variety of methods used to assess exposure, and because these methods are often poorly described [14, 15]. Thus, the use of standardized measures across studies has been suggested in order to improve comparability across studies [16]. Although the use of well-described measures should be encouraged and could be valuable to advance this field of research, this should be done with caution. Because the exposure definition is dependent on the specific study context and aims, one universal/standard measure may not be appropriate for all study settings [17]. In this regard, the use of several and/or composite measures, for instance the use of a simpler density measure, street network distances and kernel density estimates, is likely to add valuable information to the evidence-base.

We also tried to account for the complexity of the food environment by comparing different and innovative ways to define study areas, including different buffer sizes (Chapters 5 and 7) and the use of a participant self-defined neighbourhood – for which we hypothesized (in Chapter 5) that a participant self-defined neighbourhood would better represent individuals' activity space and

produce stronger associations between the food environment and diet. We found large variations of area sizes and total number of food retailers across different neighbourhoods. We also had some indications that ego-centred neighbourhoods, i.e., individual buffers around residential addresses and the self-defined neighbourhoods were more alike in terms of exposure to food retailers than the exposure observed in administratively defined neighbourhoods. However, no evidence was found that the definition of the area under study influences the association of the food environment and diet. Similarly, a study from the UK analysed the association between the availability of food retailers and BMI using different neighbourhood definitions. They found differences in the number of food retailers across different neighbourhood definitions, but only minor differences were observed in the associations between food retailers and BMI [18]. Potential explanations for this lack of a difference in the associations across different neighbourhood types may of course just be an actual lack of association between the influence of the food environment in the frequency of home cooking. Nevertheless, this lack of association was only observed for the Dutch sample, while for a cross-European population we found that higher exposure to restaurants was associated with lower frequency of consumption of home-cooked meals (see Chapter 3).

Findings in this thesis suggest that the area under study does not seem to matter for the association between density of restaurants and cooking at home within the Dutch adult population. However, due to the general lack of association found in this population, whether the area under study is important for determining exposure to other aspects of the food environment and/or other behaviour and health outcomes should be further investigated. In general, it seems that ego-centred neighbourhoods, such as buffers around individual homes, may better represent exposure than the administrative defined neighbourhoods, and should therefore be preferable. However, since there is no agreement on ideal buffer sizes, and also "the ideal buffer size" may vary for different food retailers, future research should consider the use of more than one buffer size. In addition, as individuals do not always do their groceries shopping or go out for food in their residential neighbourhoods, research on the food environment should more often consider other settings than the home environment (e.g., work- and commuting neighbourhoods). Assessing only the residential environment may underestimate the true exposure and it is likely to attenuate the estimates for a relation between the food environment and diet [19, 20]. On this regard, activity space assessed with the use of GPS trackers or wearable cameras has been suggested as an alternative to capture individual exposure at different settings. [21-24].

Another potential explanation for our inconsistent findings, especially in the studies within the Netherlands, is low variability in the exposure measures. For example, in Chapter 3, we found evidence that in a European population, higher exposure to restaurants was associated with lower frequency of home cooking. However, when we analysed similar associations among only the Dutch population, no evidence was found for an association between the food environment and home-cooking (Chapter 5). This might be due to the fact that the food environment in the Netherlands is very homogeneous and food is available everywhere. The existence of a threshold effect of exposure may also be considered. Presence of food retailers may be so evident and evenly distributed across the foodscape that it may not be possible to capture associations anymore. Therefore, the relatively low variation in exposure to the food environment makes it difficult to detect associations with dietary behaviours. In contrast, research from the United States, - a country with a more heterogeneous food environment [25, 26], shows more consistent associations [4]. The geographic location of food retailers is likely to influence dietary behaviours in the Netherlands. However, due to the lack of evidence, potentially caused by the low variation in the exposure to the geographic measured food environment, other aspects of the community environment should be considered alongside the geographic measures (e.g., indoor store audits to evaluate the quality of food products; price of foods offered, food advertisements, etcetera).

In general, despite our efforts to account for the complexity of exposures to the food environment, given the observed unexpected findings in this thesis, we probably could not sufficiently account for it with our methods and data. Currently used methods and/or data may not be appropriate enough to test the relation between the food environment and diet. The general focus on the geographical location of food retailers may be an additional explanation for our contra-intuitive findings. The largest share of studies on the community food environment to date focuses on the geographical location of food retailers [20, 4, 27, 28]. Indeed, research has suggested that the type of store, and thus the range of food products offered, may be a stronger predictor of healthy and unhealthy food availability than store location [29]. In this regard, measures combining both spatial analysis and indoor audits have been proposed. This multi-method approach evaluates availability, price and quality of foods offered at the store and at the neighbourhood level and could be adapted and applied to different contexts [30].

A larger focus on understudied aspects of the food environment, which goes beyond a predominant attention to the geographic location of food retailers,

is therefore recommended. Among many other aspects, we can cite for example, ambient odours, food advertisement and price of foods. Research has suggested that ambient odours may influence energy intake by helping locate food sources and stimulating the appetite [31]. There is growing evidence for an influence of food advertising on adult food choices, and among children and adolescents, the evidence on the purchasing, consumption and taste preferences is substantial [32-35]. The cost of food is a major determinant of food choice [36], and research has indicated that adherence to dietary guidelines may be dependent on both the price of foods and the geographic access to food retailers [37]. Additional non-geographical aspects of the food environment that may influence dietary behaviours include information on the type and use of stores, the perceived food environment and the use of food retailers, which might be a key to address inconsistencies in the literature.

A limitation in food environment research that goes hand in hand with the predominant focus on the geographic location of food retailers, is the underlying assumption that when a food retailer is available it is actually used by the study participants. Because this assumption is not always true, it generates a gap between the assumed and actual individual exposure. In this sense, research has found more consistent associations between the perceived food environment and dietary behaviours than when using objective measures [4]. It may be that the perceived food environment reflects the actual use of a food retailer. Therefore the actual use of food retailers may be important additional information to understand the relation between exposure to the food environment and diet. Indeed, individuals' perception of the food environment may be different from what is objectively measured [38]. It has been suggested that the perception of the food environment might mediate associations between the objectively measured food environment and individual behaviours [39]. For example, previous research has found that access to fast food restaurants was not associated to body weight. However, the perceived availability of fast food restaurants was associated with fast food consumption and body weight when participants also reported to use those food retailers [40]. Therefore, the relation between the food environment and diet may be mediated by individual level factors related to food choice, such as taste preferences, food preparation skills, use of food retailers and the individual perception of the food environment [27, 39]. Therefore, a further exploration of an indirect relation of the food environment and diet accounting for these factors is recommended.

Implications for theory

Given the weak evidence for an association between the food environment and dietary behaviours demonstrated in this thesis and by others, as summarised in systematic reviews [4, 15, 20, 27], a re-evaluation of theoretical models used in food environment research is needed. Although any model is by definition a simplified representation of reality, current theoretical models may be too simplistic and fail to account for the complexity that exists while defining exposure to the food environment and linking it to diet. The field needs to move towards embracing other methods and combining exposure domains, including aspects of availability, accessibility, affordability, acceptability, and accommodation.

Theoretical socio-ecological models sometimes propose a broader definition of the (food) environment, including aspects from different environments (e.g., home, work or school settings); information on type of foods offered in stores price and promotions; and the potential influence of the media and marketing on food choices [41]. In order to advance current theoretical models and to encourage researchers to focus on various domains of the food environment, more specific concepts could be developed and incorporated in such models. These concepts could stress the importance of considering not only the community food environment, but combining it with information from in-store audits to evaluate the quality and price accessibility of foods offered [16, 20], and apply it to different relevant environments. More individual level determinants such as perceptions of the food environment and use of food retailers could be included in current theoretical models. The focus of this thesis and of a large body of research is on the community food environment, which may include aspects of availability, accessibility, affordability, acceptability, and accommodation. From those five dimensions, availability and accessibility are often determined by the geographic location of food [20, 4, 27]. However, findings from this thesis demonstrate that the geographic location of food retailers alone may not be sufficient to capture exposure to unhealthy aspects of the food environment, especially in countries with a high population density and a homogeneous foodscape. An example is the association found for the food environment and home cooking in a cross-European population that was not found in a sample of adults in the Netherlands. Theoretical models on the community food environment could evolve to not only focus on the geographical location of food retailers, but also include a multi-method approach and/or composite measures of exposure. For instance, the objectively measured food environment may be combined with measures of the perceived food environment and use of food retailers. Aspects of affordability (price of foods),

acceptability (perceptions of individuals on their environment), and accommodation (how the food environment adapts to individuals' demands) should be emphasised in current theoretical models focused on the community food environment. Indeed, previous research has shown that only geographic location of food retailers may not be enough to capture aspects of food choice and therefore identify associations with diet and obesity [42-44]. Instead, type of store, especially characterised by costs of foods, have been shown to be a stronger predictor. For instance, individuals considering the cost of food may travel further to shop in more affordable supermarkets [42]; and lowest economic accessibility, more than geographic accessibility, to supermarkets have been associated with lower adherence to dietary guidelines [37].

Furthermore, besides socio-ecological models, it may be valuable to consider novel frameworks that may serve as a better model to represent the complex relations between the food environment and diet. Complex adaptive system approaches may be useful to understand any health problem that presents characteristics of positive or negative feedback loops [45]. For example, in food environment research, a positive feedback loop may be represented by the availability of healthy foods that reinforces a healthier diet and thereby generates a demand for more healthy foods. Because feedback loops are a characteristic of many public health problems and traditional quantitative methods of data analysis cannot account for them, effects found using traditional methods may be wrongly estimated [45]. Therefore, it is very likely that public health problems that are caused by a multitude of factors, such as obesity, will not be solved with simple, single measures. A shift in the way scientific evidence is generated, has been proposed. This new model of evidence for public health should move from simple individual-level interventions to multiple, complex, population-level actions [46]. To build such models collaboration between experts in the field that allows an understanding of what systems models are needed for specific contexts. Furthermore, input from citizens is also essential in order to understand how environmental and socioeconomic factors may affect their food choices.

Implications for policy and practice

Political decisions that may affect population health are made continuously, and often without a scientific evidence underlying these decisions. An example is the looser regulations of agricultural pesticides in lower and middle

income countries than in higher income countries [47]. Although many of those products are potentially harmful for health, governments in some countries may approve their use without extensive scientific evidence to prove safety in the long term. While weighting such decisions, economic factors may play a heavier role, or it may be that economic policy makers do not take health into consideration at all. Even when there is political disposition to take health-related scientific evidence into account, it may be that the available evidence is based on studies that, by using inadequate methods of analysis, may fail to demonstrate relevant effects on the population level [46], delaying political decisions that favour public health actions to take place. In this context, the fact that findings from this thesis did not show convincing evidence for a link between the geographically measured food environment and diet does not imply that the food environment is not important for dietary behaviours. Rather, it is more likely that, despite our efforts to try to capture the complexity of exposure to the food environment, we probably could not sufficiently account for that with our methods and data. In fact, our analysis of changes in the Dutch foodscape showed that the foodscape can change in a short period of time, and this change is happening towards offering a higher supply of convenience and ready-to-eat foods, which may lead to unhealthier diets (Chapter 6).

Despite the lack of consistent evidence, the potential influence that the food environment exerts on dietary behaviour is well accepted by researchers in the field, and the fact that the body of evidence is not robust does not necessarily have to prevent public health policies and interventions to be implemented. An example of a successful upstream policy with effects on dietary behaviours in the population is the sugar taxation. Sugar taxes are policies implemented in different countries that by taxing products rich in sugar, especially sugar sweetened beverages, aim to reduce the consumption of those products and consequently to reduce the prevalence of non-communicable diseases [48]. It is worthy to note that those policies were proposed on the bases of convincing evidence from the harmful effects of sugar sweetened beverages on NCDs, and not because there was convincing evidence of the effects of such tax on reducing the prevalence of NCDs. By definition, policies have to be first implemented and only then they can be evaluated. Therefore, this may be the way to go in relation to the food environment as well. Policies are needed that limit the spread of food retailers offering unhealthier foods, coupled with policies encouraging food retailers to make healthier foods more accessible. In fact, other upstream policies aiming to achieve an impact on population health are being considered in some contexts. Examples include the ban on marketing of unhealthier foods directed to children [49] and

zoning bans of fast food retailers [50]. Promoting higher availability of healthier foods may also be an effective strategy towards a healthier food environment. Strategies may include price promotion of healthier foods in supermarkets and inclusion of healthier options in food retailers traditionally selling unhealthier foods, such as convenience stores and takeaways outlets.

LIMITATIONS, STRENGTHS AND METHODOLOGICAL CONSIDERATIONS

As any scientific work, the studies included in this thesis need to be seen in light of some limitations. The predominantly cross-sectional design of the studies included in this thesis do not allow for a distinction between a causal association of the food environment and dietary behaviours and potential selection effects. For instance, it remains uncertain whether a high availability of food retailers such as restaurants or food delivery outlets reflect the demand of residents for such services, or individuals interested in those facilities would choose to live in areas with such facilities available. In addition, the SPOTLIGHT survey, on which some studies included in this thesis are based, had a low response rate (around 10%). Although this is a common problem for population-based studies [44], it may have led to a selection bias, such that only the more motivated and health conscious individuals accepted to take part in the survey. However, in the studies using the European SPOTLIGHT survey, the number of men and women; lower and higher educated individuals; and age groups were well balanced, which also contributes to a higher external validity [26]. The use of self-reported nutritional data, as used throughout this thesis, is a common limitation in nutritional epidemiology. In addition to that, as demonstrated by the systematic review from Kirkpatrick et.al. (2014), most studies analysing the relation between food environment and diet make use of short, crude questionnaires for dietary assessment. This is a considerable source of bias on assessing food intake and may undermine findings, being one potential explanation for the inconsistency found in food environment research [51]. In the studies using SPOTLIGHT data, dietary measures were based on a series of basic food frequency questions, therefore, these measures may not have been sufficiently sensitive to detect meaningful associations. On the other hand, it is a strength that in the EPIC-NL study, a comprehensive validated food frequency questionnaire was used to collect dietary data, which contributes to

internal validity of this particular study and addresses a common limitation in food environment research (i.e., the general use of short questionnaires for dietary assessment). Additional strengths are that we recruited a large sample across different countries in Europe as well as in the Netherlands, which contributes to higher external validity and enables comparisons across urban regions. The analysis done for this thesis generally used a comprehensive statistical approach which was guided by theory, evidence, and where appropriate, explicit hypotheses. Because food environment exposure is dependent on neighbourhood SES and population density, in the SPOTLIGHT study, we performed neighbourhood sampling based on these two neighbourhood characteristics. When relevant, in order to minimize bias resulting from residential self-selection [52], we adjusted our models for variables related to neighbourhood choice, and the broader food environment. However, the many unexpected and inconsistent associations may be an indication that some level of residual confounding might have occurred. When applicable, and assuming that missing values were missing at random, we sought to overcome potential bias due to missing data or complete case analysis by performing multiple imputation on all variables in the analysis [53-56]. A general strength of this thesis is that we accounted for different types of exposures to the food environment by analysing the independent and combined effects of food retailers; used indices accounting for the variety in the food environment; explored innovative measures of exposure to the food environment; and explored different ways of defining a neighbourhood.

CONCLUSIONS

In this thesis we explored how individual and environmental factors were associated with a variety of dietary behaviours in Europe and how various methods and measures of exposure to the food environment influenced these associations. In general, we did not find convincing evidence for a link between the geographically measured food environment and diet in European adults. In addition, despite our efforts to capture the complexity of exposure to the food environment using a range of methods such as deriving more complex absolute and relative measures of exposure to the food environment, exploring different neighbourhood definitions and adjusting our analysis for the broader food environment (i.e., accounting for the variety of food retailers within the study area), we could not demonstrate that such methodological decisions influenced

the associations under study. However, the fact that we did not find strong evidence for a link between the food environment and dietary behaviours in this European population does not imply that a true relation does not exist. Instead, it is more likely that with the methods and measures we used, we could not capture this complex relation. Future research should move from the strong focus on the geographic availability of food retailers to embrace other understudied aspects of the food environment such as quality of foods offered in stores, economic accessibility, and food advertisement. An indirect effect of the food environment should also be explored as the relation between the food environment and diet may be mediated by individual level factors related to food choice, such as taste preferences, food preparation skills, use of food retailers and the individual perception of the food environment.

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