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Socioeconomic and sociocultural disparities in the dietary habits of adolescents in Belgium

Analysis of the "Health Behaviour in School-aged Children" Surveys

Doctoral thesis submitted by Manon ROUCHE
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FOREWORD

Dietary habits account for a significant proportion of preventable deaths and disabilities. Numerous initiatives have been put in place to raise public awareness of healthy dietary habits as part of chronic disease prevention. Moreover, diet is particularly prone to social inequalities, which can lead to social inequalities in health. In order to reduce the burden of diet-related diseases, there is a need to develop public health initiatives that reduce such inequalities or at least do not increase them. In this respect, socioeconomic and sociocultural disparities in relation to diet as well as the underlying mechanisms need to be thoroughly understood.

Adolescence is a critical transition period characterised by the acquisition of health behaviours that can continue into adulthood. During this process of existential transformation, diet plays an important role. Influenced by their school, family and peer environments, adolescents can acquire both unfavourable and health-promoting dietary behaviours. These behaviours may be a way to control their body and its transformations or to define their identity, outside of their families but in connection with their peers, for instance. Nowadays, adolescents are particularly open to new ideas and eager to impose their choices and preferences. Adolescence thus represents a window of opportunity to induce the acquisition of favourable behaviours that can be spread through adolescents' social networks and that may last a lifetime.

In this context, a research project was developed to comprehensively assess social and cultural disparities in diet among adolescents and young adults in Belgium. This project was a preliminary stage of an intervention trial aimed at reducing social and cultural inequalities in diet among this population. Funding for four years was granted by the Wallonia-Brussels Federation in the framework of the "*Action de Recherche Concertée – Projets Consolidation 2016-2020*" [Concerted Research Action - Consolidation Projects].

Within the framework of this project, two doctoral theses have been carried out. The first one, already published, had the objective of studying the socioeconomic and cultural disparities relating to the diet of adolescents and young adults living in Belgium. It was based on the data from the National Food Consumption Survey (FCS). The second, this one, used the data from the "Health Behaviour in School-aged Children" (HBSC) surveys carried out in Belgium. The differences between the studies in the populations, sampling methods, and data collection on diet and social indicators make the two theses complementary in order to achieve the global objective of the research project.

This thesis manuscript focuses on adolescents recruited in the school setting, using the HBSC surveys. The first chapter defines the framework of the thesis, including a literature review on diet disparities among adolescents, and the objectives. Methods are presented in the second chapter. Chapters 3, 4 and 5 present the three parts of analyses carried out on the HBSC survey data. The sixth and final chapter consists of a general discussion followed by a conclusion.

ABSTRACT

Diet contributes to a large proportion of preventable deaths and diseases. Adolescence is a period during which diet may particularly evolve, and therefore represents an opportunity to develop long-lasting healthy dietary behaviours. However, dietary habits are particularly subject to social variations, which may lead to social inequalities in health. Tackling them requires public health actions based on a comprehensive approach of social determinants at this life stage.

This doctoral thesis aimed to examine socioeconomic and sociocultural disparities in dietary habits among adolescents, using the repeated cross-sectional Health Behaviour in School-aged Children (HBSC) surveys conducted in French- and Dutch-speaking Belgian schools. The three specific objectives of this aim were: (i) to study the socioeconomic disparities in dietary habits of adolescents from different migration status; (ii) to determine trends in dietary disparities between 1990 and 2014; (iii) to estimate disparities in dietary habits according to the socioeconomic and migration status at both individual and contextual levels.

Firstly, different socioeconomic disparity patterns according to the migration status were observed, with narrower disparities in 1st-generation immigrants than among natives, highlighting the major role of cultural influences in immigrant populations. Secondly, the long-term trend analyses emphasised increasing disparities for healthy foods and decreasing disparities for unhealthy foods. In addition, when the consumption of a food group increased overall, disparities decreased, and vice-versa. Finally, the multilevel analyses showed that individual and school disparities were independently associated with food consumption frequencies. Furthermore, this observational assessment revealed the weak relationships between nutrition policy in schools and dietary habits. Note that in the Brussels-Capital Region, native adolescents were at higher risk of unhealthy dietary behaviours than immigrants, but the risk of unhealthy behaviours tended to be higher when, in the school, the socioeconomic index decreased, and the proportion of immigrants increased.

Overall, our analyses underlined the need to include, in addition to the socioeconomic factors, cultural components in public health actions aimed at addressing social inequalities in adolescent diet, in a multicultural context such as Belgium. Support to schools, with a greater emphasis on those disadvantaged in order to prevent increased inequalities, is needed to develop a consistent and effective nutrition policy. Finally, further studies are needed to better understand the mechanisms behind dietary disparities among adolescents, particularly those related to their migration status and broader socioeconomic environment.

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SCIENTIFIC VALORISATION

Related to the doctoral thesis

Published scientific papers

Rouche M, Dierckens M, Desbouys L, Pedroni C, Lebacq T, Godin I, Deforche B, Castetbon K. Twenty-Four-Year Trends in Family and Regional Disparities in Fruit, Vegetable and Sugar-Sweetened Beverage Consumption among Adolescents in Belgium. *Int J Environ Res Public Health*. 2021;18(9):4408.

Rouche M, de Clercq B, Lebacq T, Dierckens M, Moreau N, Desbouys L, Godin I, Castetbon K. Socioeconomic disparities in diet vary according to migration status among adolescents in Belgium. *Nutrients*. 2019;11(4):812.

Submitted scientific papers

Rouche M, Lebacq T, Pedroni C, Holmberg E, Bellanger A, Desbouys L, Castetbon K. Dietary disparities among adolescents according to individual and school socioeconomic index: a multilevel analysis. *Public Health Nutr.* [Under Review].

Oral presentations

Rouche M, Dierckens M, Desbouys L, Pedroni C, Lebacq T, Godin I, Deforche B, Castetbon K. Changes in disparities related to the family structure regarding fruit, vegetable and sugar-sweetened beverage in adolescents in Belgium between 1990 and 2014. European Association for Research in Adolescence, September 2020, Online (Porto, PT).

Rouche M, Dierckens M, Desbouys L, Pedroni C, Lebacq T, Godin I, Deforche B, Castetbon K. Changes in disparities related to the family structure regarding fruit, vegetable and sugar-sweetened beverage in adolescents in Belgium between 1990 and 2014. Public Health PhD Students' Day, November 2019, Louvain (BE).

Rouche, M, de Clercq B, Lebacq T, Dierckens M, Moreau N, Desbouys L, Godin I, Castetbon K. Socioeconomic disparities in dietary habits according to migration status among adolescents. Public Health PhD Students' Day, December 2018, Liège (BE).

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Apart from the doctoral thesis

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Pedroni C, Vandevijvere S, Desbouys L, **Rouche M**, Castetbon K. The cost of diets according to diet quality and sociodemographic characteristics in children and adolescents in Belgium. *Int J Food Sci Nutr* [In press].

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Chatelan A, **Rouche M**, Dzielska A, Lebacq L, Fismen AS, Kelly C, Zaborskis A, Kopcakova J, Tsareva A, Kalman M, Castetbon K. Trends in adolescent soda consumption in Eastern Europe between 2002 and 2018. ISBNPA, 20th annual meeting, June 2021, Online.

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Supervision of master student

Master's dissertation presented by **Kouam Kaping Armelle Vanessa** (2019/2020 academic year) : *Durée de séjour en Belgique et consommation de fruits et de boissons sucrées chez les adolescents immigrés : étude HBSC 2018*.

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LIST OF ABBREVIATIONS

24HR	24-hour dietary recall
CBE	Crossroad Banks for Enterprise
CVDs	Cardiovascular diseases
DALYs	Disability-adjusted life-years
DQI-AM	Diet Quality Index for Adolescents, including a specific Meal index
EFSA	European Food Safety Authority
FAO	Food and Agriculture Organisation of the United Nations
FAS	Family Affluence Scale
FBDG	Food-Based Dietary Guidelines
FCS	Belgian Food Consumption Survey
FFQ	Food Frequency Questionnaire
FWB	Wallonia-Brussels Federation
HBSC	Health Behaviour in School-aged Children
HCPC	Hierarchical Clustering on Principal Components
HEI	Healthy Eating Index
HPS	Health Promoting School
KIDMED	Mediterranean Diet Quality Index for children and adolescent
MOR	Median Odds Ratio
N/A	Not available
NCDs	Non-communicable diseases
OR	Odd Ratio
PAF	Population Attributable Factor
PCV	Proportional Change of Variance

POOR	Proportion of Opposed Odds Ratio
PR	Prevalence Ratio
RRR	Relative Risk Ratio
SEI	Socioeconomic index
SES	Socioeconomic status
sFFQ	Short Food Frequency Questionnaire
SHC	Superior Health Council
SSB	Sugar-sweetened beverage
T2D	Type 2 diabetes mellitus
U.K.	United Kingdom
U.S.	United States
VPC	Variance Partition Coefficient
WHO	World Health Organisation

CHAPTER I. INTRODUCTION

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1. Food-related public health issues

In the past few decades, numerous studies, such as cohort studies[1] and randomised trials,[2] have been conducted to better understand the complex relationships between food consumption and health.[3] Based on strong evidence, it has been concluded that diet may have favourable, neutral or unfavourable effects on health.[3,4] As a result of the accumulation of knowledge, learned societies and research institutions have synthesised such an evidence.[3] Among the most successful syntheses is the one carried out since 1997 by the *World Cancer Research Fund* and the *American Institute for Cancer*.[5] This continuously updated report summarises and appraises knowledge and levels of evidence on the links between food (along with physical activity and body weight) and cancer.

Following knowledge syntheses, national and international consensus have been reached on the main outlines of "healthy eating". The World Health Organisation (WHO) has taken up this consensus to call for a global commitment to reduce the heavy and growing burden of non-communicable diseases (NCDs) related to unhealthy diet and physical inactivity.[6] In this regard, WHO has issued over the years sets of recommendations for policies and action plans at various levels, based on current issues. Thus, in the 2010's, WHO released recommendations for tackling childhood obesity following its rapid increase worldwide.[7] Recently, the emergence of climate change issues has raised the importance of sustainable food production and eating habits. In 2019, based on the growing body of work on this topic,[8] the WHO and the Food and Agriculture Organisation of the United Nations (FAO) have issued guiding principles for sustainable healthy diets.[9]

1.1. Diet and health

1.1.1. Diet: a risk factor and a protective factor for health

Dietary habits account for a significant proportion of preventable deaths and disabilities in Europe and around the World.[10] In 2019, the dietary risk factors were estimated to be responsible for eight million deaths worldwide (18.9% of total deaths) and 188 million disability-adjusted life-years (DALYs) (11.6% of total DALYs) related to NCDs among all ages.[11] In Belgium, the dietary risk factors were estimated to be responsible for 13 thousand deaths (13.1% of total deaths) and 228 thousand DALYs (8.0% of total DALYs) with regards to NCDs. Dietary risks are the third leading cause of NCDs deaths and the fourth of NCDs' DALYs in Belgium. The three most important dietary risks for NCDs are diet low in whole grains, and high in red and processed meat.[11]

Yet diet may also play a role in the prevention of NCDs,[4] such as cancer, cardiovascular diseases (CVDs), or type 2 diabetes mellitus (T2D). In this regard, fruit,[4,12,13] vegetables,[4,12,13] legumes,[4,14] whole grains,[4,15] nuts,[4,14] and fish[16,17] should be consumed in adequate quantities. Indeed, while consuming these foods in insufficient quantities may increase the risk of developing NCDs,[4] consuming them in adequate quantities may decrease this risk.[8] In contrast, foods such as sugar-sweetened beverages (SSB),[4,18] crisps,[19] fries,[19] red meat[4,20] or processed meat[4,20] should be consumed in limited quantities, in order to limit the risk of developing NCDs. Because these foods do not provide key nutrients that cannot be found in other sources, they may not be consumed at all from a nutritional standpoint.

1.1.2. Main dietary guidelines in Belgium

Since 1997, the Belgian Superior Health Council (SHC) has developed dietary guidelines organised around nutrients for the population. They are mainly intended for health professionals to help the population adopt a healthy and balanced diet.[21] With the aim of issuing practical guidelines more directly to the Belgian population, these nutrient-based guidelines have been translated into food-based guidelines,[21] the first time being in 2005.[22]

In 2019, the SHC published the latest food-based guidelines, aimed at the healthy adult population.[21] The methodology used for the translation came from the guide for establishing Food-Based Dietary Guidelines (FBDG) issued in 2010 by the European Food Safety Agency (EFSA).[23] Accordingly, on the basis of the main diet-related health issues in Belgium and the foods that largely contribute to them, as well as given the current dietary habits observed in the 2014 Belgian Food Consumption Survey (FCS), the 2016 guidelines organised around nutrients were translated into a practical guideline.[21] Thanks to this methodology, these dietary guidelines give advice on foods and food groups that provide the nutrients needed to promote overall health and prevent NCDs. They focus on the foods to be encouraged at the level of the Belgian population, while taking into account the sociocultural aspects too.[21]

The 2019 food-based dietary guidelines emphasise 12 recommendations, including five "golden rules".[24] These five priorities, which are considered to have the greatest benefit for public health, have been promoted through video clips[25] and graphically represented (**Figure**

1).[26] Other recommendations include the limited consumption of SSB, and of processed and red meat, and the consumption of adequate amounts of fish and dairy products.[21]

Figure 1. *Épi alimentaire / Voedingstak* – Five priorities for eating better. *Source: Food in action, 2019.*

While dietary guidelines are national, they can be the subject of public health actions or communication at different levels. For example, nutrition labelling has been mandatory in Belgium since the 1990s as a result of a European directive.[27] In 2011, the European regulation defined the mandatory labelling information. This regulation was applied in our country from 2014.[27] Furthermore, although still voluntary in Belgium, the Nutri-Score has recently been adopted as the official nutritional logo at the federal level; this formalisation has been supported by information campaigns.[28] At last, since 2016, sugar- and artificially-sweetened beverages have been specifically subject to a regularly revised national excise duty.[29]

Alongside the federal actions, two food guides based on the national dietary recommendations have been disseminated at the regional level for several years.[30] Until recently, the latest revisions of the food pyramids were relatively similar. However, since 2017, the *Vlaams Instituut Gezond Leven* [Flemish Institute for Healthy Living] has been disseminating a simple and colourful cut-out triangle (inverted pyramid) in Flanders (**Figure 2**).[31] Conversely, the pyramid disseminated in Wallonia by a private communication company ("Food in Action") was somewhat modified during the 2020 review.[32] It is now a cut-out food pyramid (**Figure 3**) that takes health and sustainability considerations into account. Compared to the pyramid distributed in Flanders, it is more complete but also much more complex for the general public, and the foods to be consumed in sufficient quantities are less clearly highlighted.

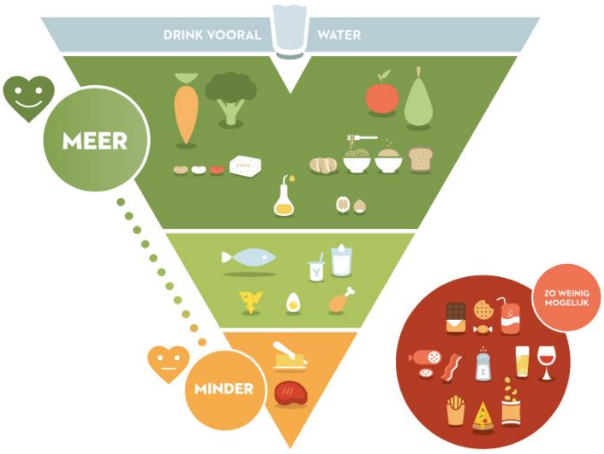


Figure 2. Cut-out triangle developed by the Vlaams Instituut Gezond Leven. *Source: Vlaams Instituut Gezond Leven, 2017*.

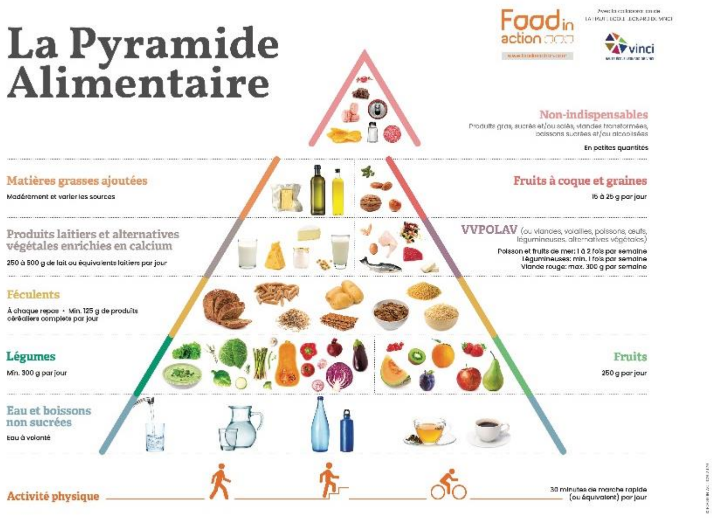


Figure 3. Cut-out food pyramid developed by Food in Action and the Haute Ecole Léonard de Vinci. *Source: Food in Action, 2020*.

Overview on adolescents

At present, the 2019 dietary recommendations around foods are not intended for the adolescent population.[21] Yet, the first version of the food-based dietary guidelines issued in 2005 were developed for adolescents aged 12 to 18.[33] Interestingly, the 2016 dietary recommendations organised around nutrients were developed for adolescents and relatively similar to those for adults.[34] In 2014 in Flanders, the *Vlaams Instituut Gezond Leven* made some food-based recommendations for 12-18-year old adolescents.[35] These recommendations, intended to Flemish, are similar to the 2019 national dietary guidelines for adults.[21,35]

Communication of dietary guidelines regarding foods are not specifically aimed at adolescents. While the cut-off pyramid disseminated in Wallonia is only intended for the adult population, the Flemish triangle is intended for the population aged over one year. Previously, the 2005 food-based guidelines intended for adolescents were disseminated through a practical guide for healthy eating, initiated by the *Plan Fédéral Nutrition Santé / Federaal Voedings- en Gezondheidsplan* [Federal Nutrition (and) Health Plan].[33] However, information in this guide was imprecise and disperse.[33]

In Belgium, actions promoting healthy eating habits among adolescents are rather scattered and may differ between regions or even at a more local level. For instance, in Flanders, the competent authorities have committed to phasing out unhealthy drinks and snacks in schools, such as sweetened drinks, with the aim of eliminating them by 2020-2021.[36] By contrast, in the Wallonia-Brussels Federation (FWB), the issue of banning vending machines in schools was included in a legislative project in 2005 and several times afterwards but was never concluded. With the support of governmental bodies, schools can promote healthy eating habits through various means such as improving the food environment or implementing educational programmes. However, such initiatives are not coordinated, and their content is not checked.

◆

Diet is a key factor in improving population health. In Belgium, a number of initiatives have been developed at the federal level and federated entities to raise public awareness of healthy dietary habits as part of the NCDs prevention. The multiplication of these initiatives may have a positive effect, as long as the messages conveyed are clear, understandable and unambiguous. However, this would require more collaboration among the federated entities in charge of health promotion and perhaps with the federal government. The initiatives currently implemented are aimed at the general population but are never targeted at specific populations, including adolescents. Yet, in addition to the content, the form of the message needs to be adapted to these specific populations. In this respect, there still is considerable room for improvement.

1.2. Social inequalities in health applied to diet

1.2.1. Origins of social epidemiology as a science

Although the development of social epidemiology methods as we know them now is fairly recent, the first pioneering works around the social conditions influencing health dates back to the 19th century. At that time, Villermé and Virchow highlighted social class and work conditions as major determinants of health.[37,38] Shortly afterwards, Chadwick pointed out that the physical environment may have a significant effect on health.[37,38] However, the assumption of social conditions was overshadowed by other theories at the end of the 19th century, including the germs theory.[38] As a result, the social variations in health had drawn less attention. Meanwhile, the improvement of the physical environment and medical advances have resulted in an increase in life expectancy. In Belgium, the life expectancy at birth was less than 50 years at the end of the 19th century, around 65 years in the 1950s, and more than 75 years at the end of the 20th century.[39]

However, how inequalities have changed over the past century in Europe is not fully clear. While it is assumed that absolute inequalities in mortality have been reduced with the increase in life expectancy, the change in relative inequalities is less clear.[40] In Europe, the interest in health inequalities resurged with the publication of the *Black Report* in 1980 in England. This was the first report to highlight the increasing health inequalities in the second half of the 20th century despite the modern welfare state. Furthermore, at the end of the 20th century, an increase in relative inequalities was observed in Western Europe despite many improvements regarding, for instance, social security and health care systems.[40] As a result, interest in the influence of socio-structural factors on health significantly increased.[38] Since then, many reports have confirmed the trends in health inequalities.[41] Among the most recent is the pioneering report *Marmot Review*, which also sets out an evidence-based strategy to address health inequalities.[42]

Meanwhile, it has become apparent that health behaviour was not only conditioned by the individual but also by society. This has increased the need for contextual analyses that consider both individual-level and contextual-level data, such as multilevel analyses. These recent findings have been the beginning of the broad development of social epidemiology. Nowadays, it is defined as the "*branch of epidemiology that studies the social distribution and social determinants of states of health*".[37]

1.2.2. Concepts related to social inequalities in health

1.2.2.1. Social inequalities in health

Social inequalities in health are considered as health differences observed across social groups.[43] There are two main approaches to defining social groups.[3] The first uses the term "social class" that refers to Marx.[3,44] A social class is a group or a category of individuals who develop a common consciousness and a sense of belonging that lead to collective action.[44] The second approach uses statistical aggregates that refer to Weber and is privileged in epidemiology.[3,44] A stratum is a group of individuals occupying similar positions, with similar prospects for development.[3,44] In practice, the way to stratify people into social groups is quite specific to societies.[43] For instance, in India, the "caste" is a meaningful distinction. The race/ethnicity and to a lesser extent social class are relevant distinctions in the United States (U.S.) although somewhat discussed.[45] In the United Kingdom (U.K.), the level of schooling achieved is a meaningful grouping.[43] In Belgium, like in other European countries, one of the most important definitions of social group is also based on education level.

Differences in health can be denominated by different terms, leading to slightly different meanings[a] behind. Throughout this thesis, we have interchangeably used "inequalities" and "disparities" to describe differences, without any *a priori* moral judgment. In other words, we do not postulate that a social group has systematically favourable dietary habits. By contrast, "inequities" are "*systematic differences in health that could be avoided by reasonable means*". Thus, it implies a moral judgment[43] and is not used throughout this work.

1.2.2.2. Social gradient in health and other types of relationships with health

Social inequalities cannot be reduced to the extremes of the social hierarchy, such as "rich" *vs.* "poor".[3] They cover the whole of society.[3] In addition, a social gradient can be observed, such that the higher the position in social hierarchy, the lower risks of morbidity and mortality.[37] A social gradient in health may be observed throughout the range of level of education, income or occupation. For instance, in Europe, the mortality rates are greater among the low than the mid, and among the mid than the highly educated.[50] However, the social gradient is not limited

[a] Note that there is an ambiguity in the meaning of those terms. While it can be inverted across continents,[46] for some languages a single word exists to cover all meanings.[47] Work is ongoing on the clarification of these terms,[43,48] but the ambiguity persists. As a matter of fact, the WHO defines "*inégalités*" [inequalities] in French[49] in the same way as "inequity" in English.

to socioeconomic indicators. It can be observed throughout the range of social groups, such as migration status (see **Chapter III**, **section 2**).

In addition to the social gradient reflecting a linear relationship, a U- or J-shaped relationship can sometimes be observed (**Figure 4**). For instance, a U-shaped relationship has been observed between occupational status and risk of mortality. Individuals with a low or a high occupational status may have a higher risk of mortality than those with an intermediate one.[51] This can be explained by a strenuous physical occupation for those at the bottom of the hierarchy and a stressful occupation for those at the top.[52] A similar U-shaped relationship between certain health behaviours and health is also observed. For example, an adequate level of physical activity is beneficial for cardiac morbidity, but low and extreme levels may have a detrimental effect on such morbidities.[53]

In other instances, a J-shaped relationship has been observed. Among non-smokers, the lowest mortality risk was observed for individuals with a body mass index of 20-22 after more than 20 years of follow-up.[54] Underweight individuals have a higher mortality risk than normal body weight individuals, and a similar risk to overweight individuals. Moreover, this risk increased substantially with obesity. In fact, underweight individuals are particularly at risk of developing respiratory diseases, while overweight individuals are at risk of developing T2D and a wide range of NCDs.[54]

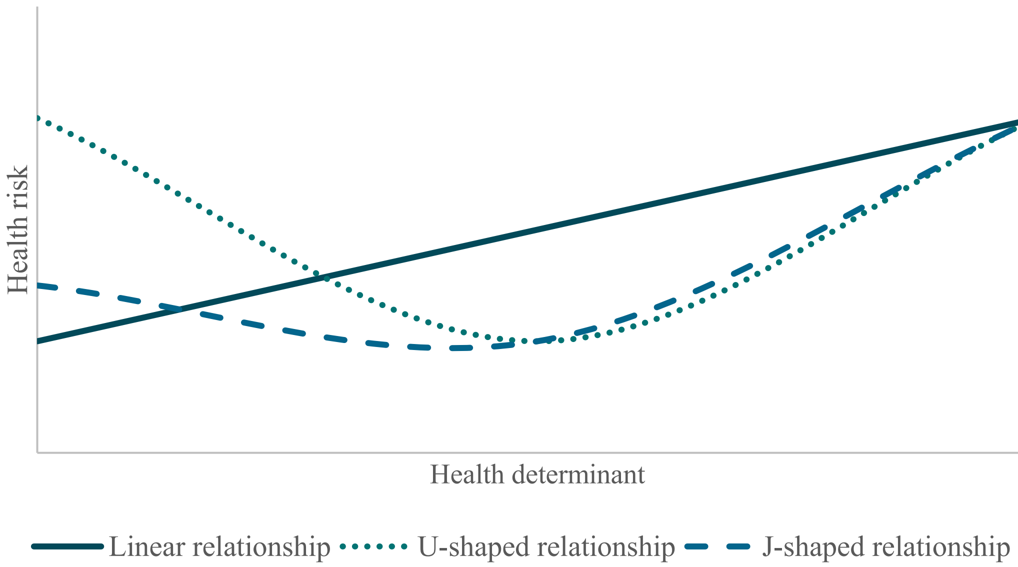


Figure 4. Types of relationship between a health determinant and a health risk.

1.2.2.3. Social determinants of health inequalities

Social determinants of health inequalities are defined as "*contexts, social norms, social structures, and their determinants*".[55] Three main pathways have been highlighted to explain the causal process (**Figure 5**).[55] First, health may determine social position, in a perspective known as "social selection" (pathway A on **Figure 5**). Thus, healthier individuals would move towards a better social position.[55] For instance, a healthy individual may have access to the entire educational system while a sick or disabled individual may experience difficulties. However, this is not considered to be the main contributor of health inequalities.[40]

The main explanation of health inequalities[40] is likely to be the "social causation" (pathway B).[40] This perspective implies that inequalities in health are raised by the differential distribution of more specific health determinants across social groups.[40,56] These include the health system, material, psychosocial and behavioural factors.[40,56] Even if people with higher socioeconomic status can, for example, benefit from better treatment or better prognostic factors, access to the health care system does not contribute significantly to health inequalities in Western Europe.[56] Material factors are related to "conditions of economic hardship" and "damaging conditions in the physical environment".[56] Psychosocial factors include "stressful living circumstances" or lack of social support. Regarding behavioural factors, the most important health-related behaviours are smoking, diet, alcohol consumption and physical activity. A differential distribution of these behaviours contributes to explain social inequalities in health. For instance, the median contribution (calculated as part of a systematic review)[57] to socioeconomic differences in all-cause mortality can be up to one-third for tobacco and one-fifth for alcohol, physical activity, and diet, depending on the socioeconomic indicator used.[57] In addition, the median contribution to socioeconomic differences in cardiovascular diseases can be up to more than half for alcohol, one-fourth for diet, one-fifth for tobacco and one-tenth for physical activity.[57]

Lastly, the timing of exposures may influence health (pathway C) through different mechanisms.[55] First, an exposure at a specific period has lifelong effects, the so-called "critical periods" model.[56] Second, health factors may accumulate gradually over the life course ("accumulation of risk" model).[56]

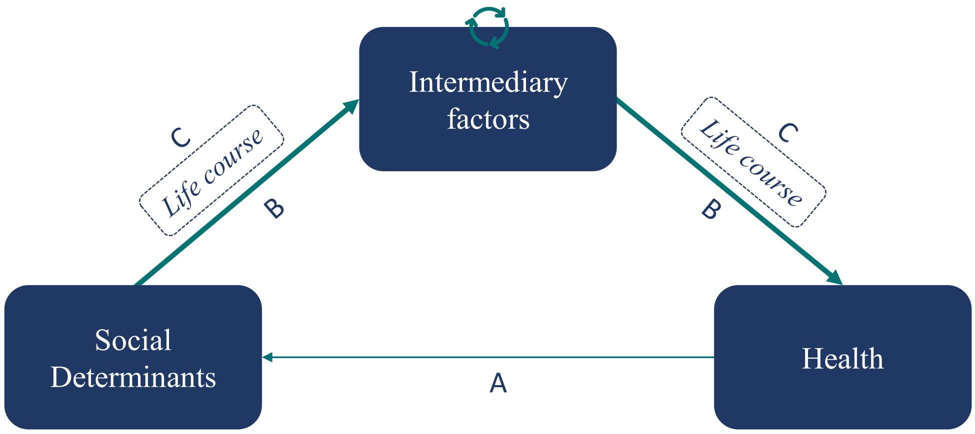


Figure 5. Diagram illustrating the main pathways of generation of health inequalities from social environment.

◆

Social inequalities in health have a longstanding interest. Today, reducing health inequalities has become a major but still a challenging public health issue. However, a clear understanding is necessary to develop effective public health initiatives. These initiatives must cover the entire social structure and all periods of life, especially critical periods. Comprehensively addressing those determinants is needed to reduce inequalities but implementation of effective actions in "real life" is highly challenging.

1.2.3. Main indicators of social position

Many indicators can reflect social status and therefore social inequalities in health.[58] There is no single best indicator, universally applicable. Each indicator measures different aspects of the social hierarchy.[3] Some of them are specific to periods of life.[58]

The choice of the indicators should be adapted to the research question. However, it also depends on the feasibility to collect such information in the surveys. It is also necessary to consider the theoretical framework for a correct interpretation.[3] Two main groups of indicators are described below with examples based on their relationships with diet: socioeconomic position indicators and sociocultural position indicators. Following their presentation, we will address their application to the adolescent population.

1.2.3.1. Socioeconomic position

Socioeconomic position refers to the "*social and economic factors that influence what positions individuals or groups hold within the structure of a society*".[58] In the literature, the terms "status" and "position" are often used interchangeably. However, they refer to different theories.[59] Socioeconomic status refers to the "prestige- or rank-related characteristics" whereas socioeconomic position includes actual resources in addition to status.[59] Nevertheless, throughout this work, we have used both terms indifferently, without intending to refer to either theory.

Socioeconomic position is mostly captured by indicators such as education, income and occupation. More rarely but still important, subjective indicators and ecological indicators may be used. Other indicators are used to a greater or a lesser extent, such as housing or wealth, however, these are not developed below.

Education

Due to its robust association with health,[60] education is a frequently used indicator around the world.[37] In short, it mirrors the overall knowledge of individuals. Depending on the context, it is referred to as either years of schooling (continuous variable) or degree credentials (categorical variable).[37] While the years of schooling implies that every year contributes similarly to the socioeconomic position, the degree credentials imply that the socioeconomic position is determined by a specific achievement.[58] However, education as understood above does not consider the quality of education. Although complex to measure, the quality of education might be important, especially in studies including a sociocultural dimension.[37] Interestingly, the indicator has methodological advantages relatively to the others, such as ease of measurement or high response rate.[58] It is also more stable (especially in adults) and less sensitive in the contentious sense than other indicators,[58] including in Belgium. However, education cannot be directly compared between individuals from different birth cohorts or from different countries.[58]

Different mechanisms are potentially involved in its association with health. First, it is an important determinant of occupation and income,[37] discussed further below. In addition, education may improve long-term health through a well-educated social network. For instance, peers may influence patterns of adolescents' diet. Finally, schooling is a place to acquire knowledge relevant for health. In addition to factual and specific knowledge, schooling may form long-lasting cognitive and emotional skills for healthy behaviours.[37] Thus, education is strongly associated with health literacy, which refers to a set of "*competencies related to accessing, understanding, appraising and applying health information*".[61] As a result, higher educated individuals are likely to have a better grasp of the health promotion messages regarding dietary behaviours.[58] For instance, they may better understand and assimilate nutritional information on products through labelling.[3]

Income

The income of an individual or a household is the indicator of socioeconomic position that most directly measures material resources.[58] However, asking about income is sensitive and people may be reluctant to disclose accurate information,[58] leading to a high rate of non-response. One way to partially address this issue is to ask people to place themselves within predefined income categories, although absolute income provides a much more precise information. In addition, it can be converted into a relative indicator, such as levels of poverty. Ideally, income should be disposable income (i.e. reflecting what can be spent) and not, for example, gross income (i.e. ignoring debts or loans).[58] It is worth noting that income is a dynamic indicator, with sudden changes possible in a short period of time and its effect accumulates over the life course.[3] Income is also life stage dependent and follows a curvilinear trajectory with age.[58] As a result, it is not suitable for certain periods of life.[58]

Pathways between income and health can be direct or indirect but also reverse.[58] Firstly, it provides "*better access to the means to produce good health*".[37] Thus, income gives access to better quality material resources,[58] such as better quality foods. It also helps to access services that may improve health directly through health services or indirectly through education. In addition, income fosters self-esteem and social standing.[58] Furthermore, it partly determines the budget allocated to each aspect of daily life, including the food budget.[3] It should be noted, however, that this budget is also determined by other aspects, such as food prices.[62,63] Finally, health may in turn influence income[58] through loss of income due to sick leave, work loss or care costs.

Occupation

Occupation is a well-established indicator in health studies.[58] It characterises working relations and conditions. In addition to the different type of occupations, the reasons for unemployment also deserve attention.[58] Indeed, social conditions of students may differ greatly from those seeking a job, for instance. Interestingly, numerous national classification schemes have been developed to group individuals according to occupation and implies specific aspects of the socioeconomic position.[3] Among others, we can mention the British (i.e. Registrar-General's Social Class) and the French (i.e. *Professions et Catégories Socio-professionnelles*

[Professions and Socio-professional Categories]) nomenclatures. Nevertheless, they may not apply to other national contexts.[3]

Occupation possibly influences health through different mechanisms. First, it strongly determines income, discussed earlier. In addition, occupation reflects social standing, which can give certain privileges, such as access to education, also discussed earlier. Occupation also defines the social networks, which may also influence diet. Finally, it may determine the social environment, including the food environment.[58] Each occupation also has a different working pace,[3] which can have an impact on the time spent preparing the meal or eating it.

Ecological indicators

Ecological indicators can either be used to measure the socioeconomic conditions of an area or as proxies for unavailable individual indicators.[64] In the latter case, the more socioeconomically heterogeneous the area, the higher the potential misclassification. This can, therefore, lead to an incorrect estimate of the association with health outcomes and behaviours. Ecological indicators can be aggregated from individual level or small area data, through administrative databases. Typically, the aggregate measures, such as proportion of unemployed or proportion of highly educated individuals, are combined into a composite score.[64]

Ecological indicators used as a measure of the socioeconomic conditions of an area can have an independent influence on individual socioeconomic indicators of health[64] and health behaviours.[65] However, it remains unclear if the association between ecological indicators and health outcomes or health behaviours are related to "*the socioeconomic characteristics of where people live, independently of the characteristics of the people living in these areas*".[64] This lack of clarity is partly due to the fact that ecological indicators are mostly constructed from aggregates of individual level data.[64]

Overview on adolescents

Studying socioeconomic disparities in adolescents' dietary habits is quite challenging. Indeed, collecting data on these three classic indicators of socioeconomic position can be tricky in adolescent self-report studies.[3] Adolescents, especially younger ones, may not know or be willing to give their parents' occupation, education or income.[58] Therefore, indicators, such as the Family Affluence Scale, have been developed specifically for adolescents and can be used to reflect their social position. In addition to other objective indicators like parental working status, subjective indicators can also reflect the socioeconomic position of adolescents. As long as these subjective indicators relate to what they think and not to what their parents think, they may be adapted to this population.

Family Affluence Scale

Developed by the Health Behaviour in School-Aged Children (HBSC) network, the Family Affluence Scale (FAS) is a "*brief assets-based measure of family wealth that was designed for use in adolescent surveys*".[66] The assets-based measures are an alternative to parents' income and consists of directly asking for the family's material conditions of an acceptable standard of living. One of the main issue of the FAS is that it should reflect the "*societal patterns of consumption and lifestyles of families with adolescents*".[66] It must therefore be culturally sensitive, but also cross-nationally adapted to the very variable contexts across the European countries that participate in the HBSC surveys and over time.[66] Hence, its revision is regularly discussed within the network.

The FAS was firstly developed in the 1990s[66] and has been revised twice since then. The first version (FAS I) included three items: number of cars, number of vacations and having your own bedroom. The second version of the FAS (FAS II) was developed in 2002 and additionally includes computer ownership. For the most recent revision (FAS III), the item "number of vacations" was refined by "holidays abroad" and two new items were added: owning a dishwasher and number of bathrooms. The latter version also has the advantage of including several anchored items for cross-national comparability.[66]

The validity and reliability study regarding FAS III has shown that income is sufficiently but not perfectly associated with family wealth,[66] which is not surprising. Indeed, there are multiple sources of family affluence. For example, if we refer to the FAS questions, some occupation positions offer a company car or substantial discounts on household appliances. The house or car can also be inherited. The relevance of this indicator to the evolution of socioeconomic conditions is currently under discussion. Similarly, the item on holidays abroad is questionable, as people may prefer to go to the country where they live or return to their country of origin (without even speaking about the ongoing restrictions due to the Covid-19 pandemic).

The specific pathways between FAS and health or diet have not been enough documented so far. However, based on the results of the validation and reliability study, it can be assumed that the mechanisms are similar to those of classical indicators of socioeconomic position, especially those of income.

Working status

The parental working status provides information on whether or not the parents are working, regardless of the type or the environment of work. While the parental occupation indicator focuses mainly on employment, the working status indicator emphasises mainly on unemployment. In this respect, two categories can be distinguished: unemployed parents who are actively seeking for a job and those who are not seeking for a job (homemakers, disabled parents, students…).[67] This more precise categorisation allows a better understanding of the effects on health, but it is also more likely to lead to a higher non-response rate than simple distinction between employment and unemployment.

To some extent and in most situations, family income can be considered as proportional to the number of working parents. Thus, working status can influence health through mechanisms similar to those of income. In addition, people who do not work may suffer from a lack of material resources, loss of self-esteem and social isolation that can affect the whole family.[64] Unemployment can also be a source of conflict and stress in the family,[67] which can negatively influence health and health behaviours. Finally, the parental working status may reflect the time parents have available for education or for everyday life, for example preparing meals. In this respect, unemployed parents who are not actively seeking for a job are likely to have more time than employed parents or those seeking for a job, to be involved in the family life, at least in theory.

Subjective indicator

Subjective indicators refer to "*an individual's perception of his/her place in the socioeconomic structure*".[68] Individuals assess their subjective position according to different criteria, specific to each one if the question does not give any indication of reference points. For instance, they can rely on their own characteristics, including education, or on their social environment,[68] proximal or distal. As a result, subjective indicators mainly reflect the relative position perceived by the individual in the society. An advantage of this type of measure is that they rarely cause problems with knowledge or understanding among adolescents.[3] As a matter of fact, the subjective socioeconomic position is assessed in HBSC surveys by asking adolescents the following question: "*How well off do you think your family is?*".[67]

At present, subjective indicators are not sufficiently mobilised to review the different pathways with health or diet. However, subjective indicators could reflect dimensions of the socioeconomic position other than those captured by objective indicators and that fall outside conventional hierarchies, especially for youths.[3] Therefore, subjective and objective indicators might be independently associated with health outcomes.[69] Subjective position may influence health by psychosocial factors, which may lead to risky behaviours for instance. It can reflect ability or choices in the budget use to purchase resources,[70] such as healthy or accessory foods.

1.2.3.2. Sociocultural position

In addition to the socioeconomic position, the sociocultural position can be used to describe the social position. The sociocultural position indicators related to the origin and geographic setting are described below.

Race/ethnicity, nationality, place of birth

Sociocultural position indicators related to the origin include race, ethnicity, nationality, and place of birth. Unlike socioeconomic position indicators, they are generally used alone. The use of a particular sociocultural indicator depends mainly on what is meaningful for the research's objectives but also, and above all in some circumstances, on what is ethically acceptable to collect.

Race and ethnicity are mainly used in Anglo-Saxon countries, especially in the U.S.[43] Although often defined and conceptualised in different ways,[43] these concepts mainly refer to a notion of social construct[b], the social identity.[72] Beyond the numerous definitions, a large number of ethnicity/race categories can be listed. Examples can be given such as "non-Hispanic blacks",

[b] In French-speaking countries, "race" mainly refers to a biological construct. Therefore, it is rarely used since it makes no scientific sense. Furthermore, Unesco has recommended the term "ethnic group" to deal with the different notions of construction across scientists.[71] Consequently, the two terms are often used together to refer to the social construct. However, the term related to "ethnic group" is not universally accepted by scientists, especially French-speaking ones, and is therefore infrequently used.

"Whites/Caucasian" or "Asians".[45,72] Nevertheless, terms used are mostly pejorative, stigmatising and depersonalising, leading to adverse consequences to communication.[45] In addition, there is a lack of clarity on methods of categorisation. They can be based on self-identification or be assigned by investigators, generating misclassification.[45] At last, the retained categories are often specific to the societal context, making comparisons between studies complex. Still, relatively homogeneous groups in terms of some cultural dimensions are expected to be found with this type of classification, even if highly heterogeneous behaviours cannot be excluded.

Although much rarer, sociocultural position can also be defined using nationality,[73] an administrative dimension. The nationalities are then frequently grouped into two: nationals and non-nationals. The group of non-nationals can then be broken down according to the nationality. However, nationality is not granted in the same way in different countries, complicating the comparison of studies. For instance, some countries rely on the principle *jus sanguinis* (right of blood) while others on the principle *jus soli* (right of soil). Moreover, while some countries prohibit multiple citizenship, others may allow it, with or without conditions, such situations changing over time.

Another sociocultural indicator related to the origin is the country of birth of the individual and that of its previous generations. This information is mostly used to define "migration status".[74] Three main groups can be identified: "native-born" (with native background) ; "second-generation immigrants" (native-born population with at least one foreign-born parent); "first-generation immigrants" (foreign-born population).[74] This grouping has the advantage of enabling to compare the results of the different studies, regardless of the country where the study is carried out. Nonetheless, groups are obviously heterogeneous in terms of culture. Categories relating to immigrants can be made more precise by declining according to the regions of birth, such as the continent, the length of stay in the country or the age of arrival. Such information allows to distinguish between recent and non-recent immigrants, and immigrants who arrived at a more or less young age, for instance.

It is worth noting that the migration history of Belgium is particular and thus deserves to be summarised. Initially an emigrating country, Belgium has gradually become an immigrating country with a first significant wave of immigrants at the end of the First World War.[75] First, Italians came to Belgium for heavy industry and then for mining. Following the labour migration agreement of 1956, many Spaniards immigrated in Belgium. In the meantime, there was a migration of Portuguese and Greeks. Later, a massive low-cost labour force was recruited from Turkey and Morocco. With the economic crisis of 1970s, migration has been restricted to family reunion. Meanwhile, political refugees have increased. Lastly, as a consequence of historical colonial ties, an African community dominated by the Congolese community developed.[75] In recent years, the European institutions in Brussels – the *de facto* capital of the European Union – have attracted many young and highly-qualified expatriates.

In the last population census, 42% of the population of Brussels was born abroad whereas 14% of the population of Wallonia and 10% of Flanders were born abroad.[76] In 2019, 10% of immigrants in Belgium were born in Romania, 9% in France, 6% in Morocco, 5% in the Netherlands, 3% in Italy, and the same proportion in Bulgaria, in Poland, in Afghanistan, in Spain, in India and in Turkey, and 2% or less in other countries.[77] There is no recent official data on the country of birth of immigrants by region, but by nationality (to be distinguished with the country of birth as explained above). In Wallonia, in order of importance, we have Italians, French, Germans, Moroccans, Spaniards, Romanians, Portuguese, Turks, Dutch and Congolese.[78] In Brussels, the French come first, followed by the Moroccans, Romanians, Italians, Spaniards, Poles, Portuguese, Bulgarians, Germans and Congolese.[79]

To sum up, immigrants in Belgium mainly come from Europe and in a lesser extent, North Africa, with a very large variety of origins. The reasons behind migration have changed over the years and therefore, immigrants' profiles may highly differ, especially between Brussels and the rest of Belgium.

Overall, the aforementioned indicators are of interest because they contain a strong cultural dimension. However, depending on the country and social context, they reflect different notions and imply different pathways to health inequalities. For example, being immigrant or of a certain ethnic group may have different consequences in Europe than in the U.S. Nevertheless, we do not develop the mechanisms specific to the American context, not relevant to this work. The mechanisms that can only be applied to the European context are developed below. Some syntheses discussed their scope,[72,75] particularly in relation with the paradox observed between the low socioeconomic position and high life expectancy of the adult immigrant population.[75]

Among the mechanisms that can globally apply to all three indicators are biological and genetic differences as a partial explanation for differences in health.[72,75] Although often limited to the simple description of differences between racial/ethnic groups due to criticism of race as a biological construct, the presence of protective or cancer predisposing genes has been observed in some populations. In addition, health inequalities may be better explained by sociological or psychological effects.[72,75] On the one hand, racial and ethnic minority groups may have negatively experienced racism and discrimination.[72] In addition to generating stress, racism may limit access to resources. These include a lower access to educational opportunities (and we have addressed earlier the role of education), but also a lower access to resources that would support the attainment of better health status, such as neighbourhood with a healthy food supply.[72] On the other hand, immigrants may positively benefit from "social capital" or "social networks"[75] referred to above. Finally, culture itself is likely to influence health behaviours, including dietary habits.[75] For instance, the attitudes towards life or body are part of cultural tradition,[75] implying different health behaviours across culture. In addition to different smoking or alcohol habits, differences related to diet, such as food purchase, conservation, preparation or pattern (quality, quantity or timing), can be noted.[75] However, it appears that these differences in behaviour, and therefore health between groups, would reduce over time through the acculturation process.[80–82]

Lastly, many hypotheses specific to immigrants have been proposed to explain health inequalities resulting from the migrant mortality advantage, such as the healthy-migrant effect or the "salmon bias" hypothesis.[75] The healthy-migrant effect refers to a selection process in the population of origin. Under this assumption, individuals who immigrate are in a better health than those who do not. This selection process is considered to be so strong that immigrants would be healthier than the host population.[75] However, this explanation for the migrant mortality advantage is refuted, as immigrants are generally younger than the overall host population and therefore just not ill yet.[83]

It has also been argued that the mortality advantage is attributable to a selective return migration among less healthy immigrants, referred to as "salmon bias" hypothesis.[75] In this instance, less healthy and older immigrants tend to return to their birth country with a desire to die there, leaving behind a healthy population in the host country.[84] One of the issues is that deaths abroad do not contribute to national statistics. If the second out-migration is not registered, individuals are rendered "statistically immortal". Consequently, errors in numerators and/or denominators are generated in the national mortality data, resulting in the artificially lower mortality among immigrants.[84]

Therefore, these hypotheses would not be a sufficient explanation for health inequalities observed between immigrants and natives. While the salmon bias is mainly the result of a statistical artifact, the selection process plays a role with regard to the country of departure and not to the host country. In fact, the migrant mortality advantage behind health inequalities is likely to be due to the interplay between lifestyle, dietary intake and health system.[75]

Acculturation process

Based on the Gordon model[c], during the acculturation process, an individual is partially or fully "*acquiring, retaining, and/or relinquishing behaviours and values of his or her original culture and the host culture*".[85] By definition, acculturation is not a linear but a dynamic, multidimensional and complex process involving, among others, social position. Therefore, in regard to diet acculturation, immigrants do not only increase the local foods (i.e. of the host country) and decrease the traditional foods (i.e. of country of origin). For example, they can find new ways to consume traditional and local foods,[85] resulting in original dietary behaviours. However, while some advocate the "best of both worlds" hypothesis (i.e. taking the best, leaving the worst),[75] it appears that changes in immigrants' dietary behaviour can be both healthier and less healthy.[85]

Diet acculturation can be measured using single-item measures, acculturation scales or food-based assessments.[85] The last two measures provide a rather accurate picture of the acculturation process. However, they are often developed for specific populations. Therefore, they are not always appropriate when studying immigrants from very variable origins. Although giving less precise information, single-item measures are simple and factual, facilitating their inclusion in non-specific populations, particularly those aimed at adolescents. Among these measures are the length of residency in the host country and country of origin, and the migration generation.[85]

[c] There is currently no standard definition of acculturation.[85] There are several theories put forward such as that of Robert Park or Milton Gordon. Robert Park's theory reflects the experience of many European immigrants but not of physically or culturally distinct immigrants. In addition, he considers the stages of the process to be irreversible,[85] which seems to us extreme.

Space and place

In addition to individual characteristics, the geographical setting where one lives matters for health.[86] Two geographical indicators are to be distinguished: space and place. Space "*deals with measures of distance and proximities*" of exposure sources.[43] In contrast, place "*refers to membership in political or administrative units*", such as region or school district.[43] These concepts are often treated as exchangeable since people in the same place are often very close to each other in space.[43] Nevertheless, some may belong to the same place and be far away or, conversely, be close but belong to different places.

Differences in health can be explained by mechanisms specific to space, place or both. Space can provide information about exposure to pollutants, but also proximity to health services[43] or various food environments[3] (e.g. fast food, vending machine, fresh fruit and vegetable market). Each place can implement specific public health initiatives and determine exposure within the population.[43] In Belgium, health promotion is under the responsibility of regions since the sixth reform of the State[d], leading to different exposures between their inhabitants. Food pyramids are an example of this situation (see **section 1.1.2**). In addition, organisation and accessibility of services, such as health services or food supply, can be specific to places.[3] Finally, health inequalities may be caused by a social-interactive mechanism.[88] In addition to social networks, behaviours may be changed through contact with neighbours.[88] Four culturally different countries and with different dietary habits surround Belgium, which can lead to different dietary habits from one region to another.

[d] Belgium is Federal State composed of federated entities.[87] The Federal State has three Regions that are based on territory: Flemish Region, Walloon Region and Brussels-Capital Region. There are also three language-based communities, namely the Flemish Community (composed of inhabitants of the Flemish Region and the Dutch-speaking inhabitants of the Brussels-Capital Region), the French Community (composed of inhabitants of the Walloon Region and the French-speaking inhabitants of Brussels-Capital Region) and the German-speaking Community (composed of German-speaking inhabitants of the Walloon Region). Each of these federated entities has its own powers as defined by the Federal State. Reforms have been carried out over the years, with changes in powers within the federated entities.[87] Health promotion is one example of a power shift in authority.

Overview on adolescents

Adolescents are not particularly reluctant to answer questions about sociocultural position, at least in Europe. Nevertheless, there may be a relatively large amount of missing data for migration status. Indeed, to determine it, the parents' country of birth is required. However, adolescents, and especially younger ones, may not be informed. Conversely, race and nationality of the parents are generally not asked for.

Adolescents spend a lot of time at school, where they are independent of their parents, making it an important place and space. It is therefore important to make a clear distinction between school space and place and that of the residence, as they can be very different. The advantage of school-based surveys is that sampling procedures usually make it possible to find out the place of the school, which usually results in reliable information and no missing data.

◆

Many sociocultural and socioeconomic factors are involved in social inequalities in health. These may play a direct or indirect role through health behaviours, such as diet. Although often interrelated, sociocultural and socioeconomic indicators are not interchangeable. Indeed, each of them is independently linked to health (and diet) through mechanisms of its own. Thus, each indicator provides complementary information for understanding and tackling social inequalities. Moreover, studying disparities among adolescents requires indicators adapted to this population. Persistent social inequalities, combined with changes in the socioeconomic and sociocultural position and environment of individuals over time, underline the current relevance of research on the social determinants of inequalities.

1.3. Adolescent diet: main issues and disparities

1.3.1. Adolescence, a key period for the acquisition of dietary behaviours

Adolescence is the transition period between childhood and adulthood,[89] defined by the WHO as the period between 10 and 19 years of age.[90] Changes in biological growth and major social role transitions have led to an expanded and more inclusive definition to consider adolescence as the period from 10 to 24 years of age.[89] This period is characterised by a rapid biological maturation, psychosocial, cognitive, and emotional development.[91]

These changes are translated into evolving health behaviours,[92–94] including dietary habits. Although their awareness of the long-term effects of such behaviours is rising, adolescents' risk perception remains low.[93] This can therefore result in the acquisition of unhealthy behaviours,[93] including inadequate dietary habits. Furthermore, there is growing evidence that behaviours initiated during this period are strongly likely to track into adulthood.[92,95] Therefore, adolescence should be seen as "*the years of laying down the foundations for health that determine health trajectories across the life course*".[93]

During this period characterised by upheavals, diet takes an important place in the adolescent's life.[96] It is experienced as a means of regulating and controlling his/her body and its transformations, defining his/her identity, and differentiating himself/herself from his/her family while identifying with a peer group.[96] Adolescent's dietary behaviours can therefore be shaped by several factors,[94] perhaps specific to this period of life.

Because of the biological changes it undergoes, the body becomes a central concern for the adolescent.[96] Moreover, as their relationship with the body constantly evolves, adolescents are looking for new role models. In a body image conscious society, adolescents adopt overvalued practices of body (e.g. dieting or physical exercises) and shape (weight, height) control to mirror these role models.[96] While in some cultures, thinness is promoted, others emphasise overweight, leading to various body images and practices. This quest for the culturally ideal body combined with genetic, developmental, psychological and sociocultural factors can lead, in extreme situations, to eating disorders,[97] with significant short- and long-term consequences.

The socio-relational environment of adolescents plays an important role in their dietary behaviours.[96] With regard to the family environment, each member of the family may contribute. Parents usually transmit rules and values that lead to healthy or unhealthy dietary behaviour.[96] Beyond the sociocultural and socioeconomic characteristics of their members, families may also be constrained by the parents' time and energy, especially single parents. Moreover, siblings may influence dietary behaviours through two opposite phenomena. On the one hand, siblings can serve as role models for both healthy and unhealthy dietary behaviour, leading to an imitation of siblings.[98] On the other hand, adolescents may want to differentiate themselves from their siblings and thus behave differently.[98] In addition, adolescents can help prepare meals, which can be time consuming with large siblings, but such a siblings can also be a socioeconomic barrier to healthy eating.

Besides, during this transition period, adolescents are likely to distance themselves from their parents and family environment, although they often remain financially dependent on them.[96] As adolescents gain independence, they become more and more influenced by peers and other influences such as media,[95] especially in building their identity.[96] They become closer to peers who essentially share their interests and values, and who can become role models for adolescent's eating habits. In addition, peers represent an opportunity to differentiate themselves from family dietary habits. In some situations, escaping parental control, adolescents feel free to consume unhealthier foods, such as fattier or sweeter foods. However, the group effect can also lead to positive behaviours by encouraging their peers to eat healthily.[96]

Moreover, the school environment is an important determinant[94] since adolescents spend a large part of their daily life there. In addition to being a meeting place between peers, schools can transmit values related to diet, in particular through the canteen menu or the vending machines.[96] Beyond food availability, schools can set up projects and activities that promote healthy dietary behaviours, as well as nutrition education. In addition, school courses, such as biology classes, are a fruitful way to learn about health behaviour issues.

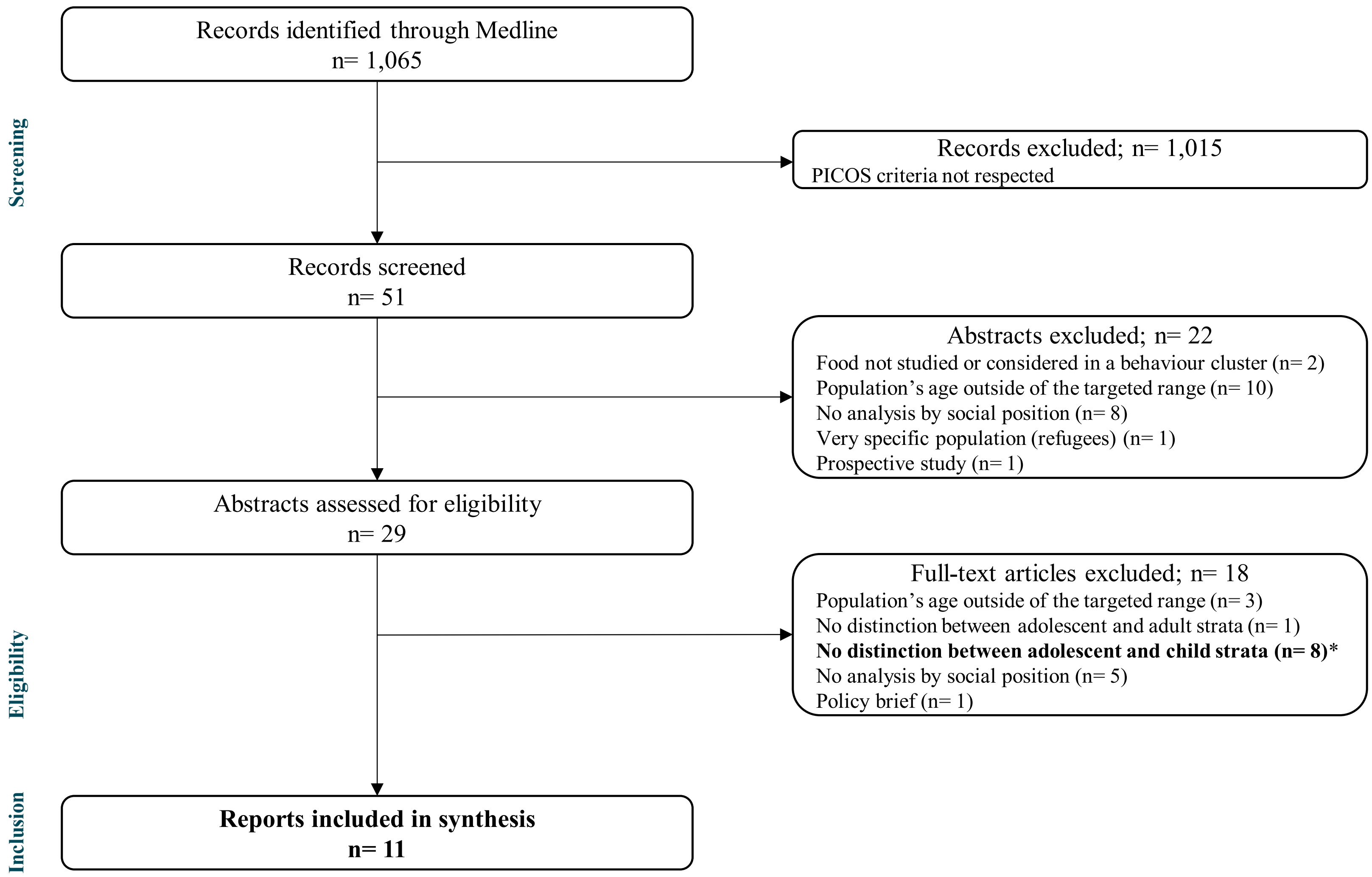
1.3.2. Updating knowledge on dietary disparities in adolescents

A systematic review on diet disparities has recently been undertaken[99] as part of the underlining project of this doctoral thesis. The objective of this review was "*to explore how diet (overall and by food group) differs according to socioeconomic and cultural characteristics of adolescents and young adults from high-income countries*".[99] This work confirmed the socioeconomic gradient previously observed among adults. However, the findings have highlighted a lack of high-quality studies and the need to examine more carefully population sub-groups, such as immigrants.[99]

Following this systematic review, a knowledge update has been carried out in the framework of this doctoral thesis. The research syntax (**Appendix A**) was based on the systematic review mentioned above, using Medical Subject Headings (MeSH) keywords but was adapted to the population, i.e. adolescents. As the objective was to follow up on the systematic review, articles published between 1 January 2018 and 31 December 2020 were evaluated. Targeted studies aimed to examine individual diet according to the social position of adolescents. The Population, Intervention, Comparison, Outcomes and Study design (PICOS) inclusion and exclusion criteria were adapted from the systematic review[99] and are presented in **Table B-1** (**Appendix B**).

A total of 1,065 additional articles were identified. Reasons for the exclusion of records are presented in **Figure 6**. Among the 29 abstracts assessed for eligibility, ten met all the eligibility criteria and were kept. In addition, eight articles that did not distinguish between adolescents and children were reviewed and described if they provided information additional to the previous review.

The summary results of the systematic review are presented first. These are followed by a description of the results of the new studies by type of outcome: dietary patterns, scores and food groups. The direction of association is described for all indicators except for ethnicity, which is context-specific. Emphasis has been placed on the frequencies of consumption of the food groups and the social indicators used in this work; the related results are displayed by food groups in **Table 1**.



*These articles were included and thus described if they provided information additional to the previous review.

Figure 6. Flowchart showing selection of reports included in the literature review.

1.3.2.1. Dietary patterns

Disparities in dietary patterns were studied based on different types of dietary patterns that can generally be classified as "healthier" or "unhealthier". A sufficient number of studies conducted on dietary pattern disparities related to parental education level was identified during the systematic review. The related conclusion was that healthier patterns generally were associated with a high parental education level, especially maternal, while unhealthier patterns were associated with lower levels of education.[99] Regarding parental occupation, healthier patterns were also consistently related to a high level (e.g. white *vs.* blue collar)[100]; however, there was no clear conclusion for unhealthier patterns.[99] Only investigated once, being unemployed was found to be associated with healthier patterns while working was found to be related to unhealthier patterns.[101] Since these results of the systematic review, no new studies on any of these indicators have been identified.

Income was not sufficiently studied to draw conclusions.[99] One recently published study conducted in Canada addressed income but without distinguishing children and adolescents. It was found that the percentage of individuals with a "pasta" pattern, a "rice" pattern or a "white bread" pattern was lower in the highest income quintile than in the other four quintiles.[102] To date, disparities in dietary patterns related to FAS and contextual socioeconomic status have not been addressed and those related to family structure are unknown.

Finally, dietary patterns according to ethnicity and migration remain understudied to establish conclusions. From the systematic review, findings regarding ethnicity were mixed, with unhealthier patterns observed both in "whites" and "non-whites";[99] since then, this issue has not been addressed. The previously mentioned Canadian study, which examined income, also investigated migration status that was not addressed before; compared to all other grain-based patterns and "no grain" pattern (i.e. less than one serving of grain-based foods per day), the lower percentage of natives (*vs.* immigrants) was found in the "rice" pattern.[102]

1.3.2.2. Nutritional and dietary scores

Social disparities were studied using several scores adapted to adolescents, such as the KIDMED index (Mediterranean Diet Quality Index for children and adolescent)[103] or the DQI-AM (Diet Quality Index for Adolescents, including a specific Meal index).[104] The systematic review revealed that a higher dietary score was consistently associated with a higher parental education level, especially maternal.[99] The conclusions to be drawn about occupation were less straightforward, although a higher dietary score was usually found among those with a higher occupation.[99] Few studies examined income; so far, the results of the different indicators are mixed.[99] While household income was not found to be associated with dietary score,[105] a higher dietary score was observed when father had an income.[106] In addition, dietary score was shown in a study to increase with FAS categories.[107] No studies on any of the above-mentioned indicators were identified for the knowledge update, which did not allow the conclusions to be reinforced. Contextual socioeconomic level as such was not addressed at all, but socioeconomic level based on individual socioeconomic characteristics and geographical region type was found not to be associated with the Healthy Eating Index (HEI) in Portugal.[108] Family structure has not been addressed regarding diet scores up to now.

Lastly, findings from the systematic review regarding migration status were contradictory, with a higher diet score among natives (*vs.* immigrants) or a more favourable score among 1st- and 2nd-generation immigrants (*vs.* 3rd-generation immigrants).[99] These results could not be reinforced as the migration status has not been investigated since then. While no study on ethnicity was eligible for the systematic review, a recently published U.S. study indicated that the HEI tended to differ by ethnicity.[109]

1.3.2.3. Food groups (**Table 1**)

In this section on food groups, only the results for fruit and vegetables, dairy products, SSB and salty and sweet energy-dense foods, which are the main food groups analysed in this thesis, are presented. Given the few and heterogenous reports on other food groups like meat,[99] these food groups have not been further investigated and are not presented.

Fruit and vegetable

The “vegetable” group usually includes raw, cooked or canned vegetables, and the “fruit” group includes fresh, whole or dried fruit. The systematic review pointed out that higher intake and daily frequency of fruit were consistently associated with a higher parental education level.[99] Similarly, daily vegetable frequency was related to a higher education level. However, results regarding vegetable intake were inconsistent, considering that non-significant and significant associations were reported.[99] Since then, a recently published Belgian study has reinforced the conclusion by finding that the mean daily consumption of fruit and vegetables increased with the level of parental education among 10-13 year olds and was higher among those with a high level of education (postgraduate *vs.* secondary or lower education) for the 14-17-year-old stratum (**Table 1**).[110]

Conclusions on parental occupation are complex to draw because of the small number of studies and the mixed findings. While consumption of fruit systematically increased with occupation level, vegetable consumption was found to increase with parental occupation level in one study and not to be associated in another.[99] Since the systematic review, occupation was investigated in three studies,[110–112] including the one mentioned above,[110] and concluded that consumption of fruit and/or vegetables increased with parental occupation level (**Table 1**). More specifically, a higher mean of fruit and vegetable consumption was observed among managerial or academic professions of parents (*vs.* manual worker) among the 14-17-year-old stratum in Belgium.[110] In Ireland, adolescents with parents in managerial, professional or technical occupations (*vs.* those whose parents are non-manual, skilled manual, semi-skilled or unskilled) are more likely to have a higher frequency of fruit or vegetable consumption.[111] In addition, a higher frequency consumption of vegetables was observed among adolescents with white-collars parents (*vs.* those with manual white collars parents, parents having a manual job or being inactive) in Denmark.[112]

Finally, findings regarding income were not consistent; some of the studies found a higher intake among those with a higher household income while others found no association.[99] Studies investigating FAS allow more robust conclusions to be drawn albeit to be confirmed: a higher daily fruit and vegetable consumption was associated with a higher FAS.[99] All these results could not be strengthened by more recent studies.

The contextual socioeconomic level is not yet sufficiently studied regarding disparities in fruit and vegetable consumption. However, this issue was recently addressed in two studies.[108,111] In Ireland, non-daily consumption of fruit or vegetables was highlighted to be more frequent in disadvantaged schools (definition based on socioeconomic demographic characteristics of pupils).[111] In addition, socioeconomic level based on individual characteristics and geographical type of area was associated with a higher intake of fruit and vegetables in Portugal.[108] There was a lack of studies examining disparities related to family structure, but recently, it was not found to be associated with fruit and vegetable intakes.[110]

Following several studies on the subject, it can be argued that fruit and vegetable consumption varies according to ethnicity,[99] which was confirmed by the recently published Canadian study.[113] Migration status is still too rarely studied and has not been the subject of a recent study. Nevertheless, a higher consumption of these foods was previously found in immigrants compared to natives.[114]

Dairy

The "dairy" group mainly includes milk, yoghurt and cheese with or without taking into account fat and sugar content. Socioeconomic disparities in dairy consumption tended to be non-significant but were not sufficiently investigated to definitively support this conclusion.[99] Disparities related to parental education levels were observed, as well as for income, for some but not all dairy product consumption. Parental occupation was not found to be associated with any dairy product consumption.[99] The FAS, the family structure and the contextual socioeconomic level were not addressed in dairy consumption disparities among adolescents. The conclusions cannot be strengthened following the knowledge update, as no new study has been issued on this subject.

Finally, disparities related to migration status are not yet clarified due to a lack of studies. Findings from the systematic review regarding ethnicity were inconsistent as it was found that dairy product consumption both differed and did not differ by ethnic groups.[99] Since then, the Canadian study has found differences in consumption according to the ethnic group.[113] In fact, adolescents of European ethnicity had a higher mean daily frequency consumption of cheese and yoghurt, as well as milk, while those of Asian ethnicity had the lowest consumption of cheese and yoghurt and Indigenous adolescents the lowest consumption of milk.[113]

Sugar-sweetened beverages

In most of the studies relating to dietary disparities, SSB were defined as sugary, soft and diet drinks, with some also including fruit juices. Findings regarding disparities related to parental educational level in SSB consumption were robust[99] and confirmed with the recent literature;[115] higher consumption was observed among those with a lower level. During the systematic review, only one identified study addressed occupational status and found no association with SSB consumption.[116] Since then, two studies have been carried out,[110,111] but the related disparities remain unclear. In Belgium, maternal occupation was not found to be associated with SSB mean intake.[110] Conversely, daily SSB consumption was higher among adolescents with semi-skilled or unskilled parents (*vs.* those with parents in managerial, professional or technical occupations) in Ireland.[111] Only one study in the systematic review addressed income and found no association with consumption.[116] Since then, a study has addressed household income in Norway and also found no association with mean frequency consumption.[115] The FAS was rarely studied, and conclusions were mixed. Indeed, a higher consumption of SSB was observed among adolescents with a low FAS,[116] but a recently published U.S. study highlighted a non-significant association with weekly consumption.[117] Another recently published study provided some initial results on the socioeconomic environment and found that daily frequency consumption of SSB was higher in disadvantaged Irish schools.[111]

In the initial systematic review, no study addressed disparities related to the family structure. Since then, no disparities were found in Belgium and in the U.S.[110,117] However, a recent study conducted in eight European countries found family structure-related disparities among adolescents together with children.[118] It showed a lower SSB intake among those living in a two-parent biological family configuration than among those in a two-parent blended/adoptive family configuration for boys and among those in a single-parent family configuration for girls.

Finally, ethnicity was found to be consistently associated with SSB consumption,[99] which was further confirmed by the recent literature coming from the U.S. and Canada.[113,117] Disparities related to the migration status were inconclusive but were only addressed twice, once at the time of the systematic review[114] and once at the time of the knowledge update.[110] A higher consumption was found among both immigrants (*vs.* natives) in Balearic Islands [114] and natives (*vs.* immigrants born outside EU) in Belgium.[110]

Salty and sweet energy-dense food

The salty and sweet energy-dense food group generally included fatty, salty and sweet snacks, and fast food in the retained studies. Higher consumption of energy-dense food was almost systematically associated with a lower parental level of education[99,119] and a lower FAS.[99] However, results from the systematic review regarding parental occupation level and income were mixed, making it difficult to draw conclusions.[99] Nevertheless, although no new selected study has investigated income-related disparities, parental occupation level were studied in two new studies. In Ireland, consumption of crisps was more frequent among adolescents with semi-skilled or unskilled parents (*vs.* those with parents in managerial, professional or technical occupations).[111] In Spain, consumption of sweets and pastries was more frequent among adolescents with an unemployed father (*vs.* those with a working father).[119]

None of the studies in the systematic review addressed socioeconomic environment and family structure, and the recent literature is inconclusive. While it was found that being in a disadvantage school was associated with a higher daily consumption of energy-dense foods in Ireland,[111] the socioeconomic status, based on individual and area characteristics, was not found to be conclusively associated with these foods in Portugal.[108] Regarding family structure, a lower consumption of sweets and pastries was observed among adolescents living in blended and in two-biological parent families (*vs.* one-parent family) in Spain.[119]

No conclusion can be drawn on ethnicity and migration status due to the small number of studies on the subject. However, the recent Canadian study reported ethnic disparities in crisps and fries but not in sweets, pastries and ice cream consumption.[113] In addition, a previously published study on Balearic Islands found that immigrants generally had higher energy-dense food consumption than natives.[114] No new study could be identified on this subject to update knowledge.

To summarise, the literature review highlighted clear disparities according to the level of education and, to a lesser extent, of parental occupation. Conclusions regarding disparities related to other socioeconomic indicators, such as FAS or contextual socioeconomic level, still need to be reinforced with additional studies. Finally, too few studies have examined sociocultural disparities, preventing conclusions to be drawn, even if disparities have been reported here and there.

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Adolescence is a key period for present and future health. It is characterised by the acquisition of health and dietary behaviours that can last a lifetime. Moreover, many socioeconomic and sociocultural factors are involved in the social inequalities relating to adolescent diet. In the literature, socioeconomic and sociocultural disparities in adolescent diet have been identified. However, the findings need to be strengthened, especially for some aspect of the socioeconomic disparities and for sociocultural disparities. A better understanding of social disparities will help act more effectively on the social inequalities in adolescents' dietary habits.

Table 1. Food group consumption according to socioeconomic or sociocultural characteristics of adolescents.

Reference	Population, design, time of collection, country	Age range (years)	n	Diet collection method	Intake or frequency of consumption	Exposure variables (number of categories)	Associations
				Food groups: fruit and vegetable			
Desbouys, 2019[110]	FCS, cross-sectional, 2014, Belgium	10-13; 14-17	435; 460	24HR (x2)	Mean consumption of fruit and vegetables (g/d)	Household type (2)	NS
						Household education (3)	Mean increases with education in 10-13yo; lower mean for secondary or lower (*vs.* postgraduate) in 14-17yo
						Maternal occupation (6)	Lower mean among manual worker (*vs.* managerial or academic) in 14-17yo
						Country of birth (3)	Higher mean among immigrants in 14-17yo
Kelly, 2018[111]	HBSC, cross-sectional, 2010, Ireland	-14-16+	5344	sFFQ	Frequency consumption of fruit or vegetables (non-daily)	Social class (3)	% inversely decreases with social class
						Disadvantaged school (2)	Higher % for disadvantaged schools
Rasmussen, 2018[112]	HBSC, cross-sectional, 2002 to 2014 (4 surveys), Denmark	11-15	17243	sFFQ	Frequency of vegetables (less than weekly)	Occupational social class (3)	Higher % for middle and low social class, for each survey year

24HR: 24-hour dietary recall; sFFQ: short Food Frequency Questionnaire; NS: non-statistically significant.

(Continued)

Reference	Population, design, time of collection, country	Age range (years)	n	Diet collection method	Intake or frequency of consumption	Exposure variables (number of categories)	Associations
				Food group: sugar-sweetened beverages (SSB)			
Bolt-Evenson, 2018[115]	Schools, longitudinal cohort, 2001-2005-2016, Norway	Mean: 11.5, 15.5	437 (including adults)	sFFQ	Frequency of SSB (mean)	Parental education (2) Household income (2)	Age group of 15.5: mean frequency higher among low parental education NS
Chung, 2018[117]	HBSC, cross-sectional, 2009-10, U.S.	10-17	2138	sFFQ	Frequency of soft drinks (more than once a week)	Family structure (2) FAS (3)	NS NS
Desbouys, 2019[110]	FCS, cross-sectional, 2014, Belgium	10-13; 14-17	435; 460	24HR (x2)	Mean consumption (g/d) of sugary sweetened beverages	Household type (2) Household education (3) Maternal occupation (6) Country of birth (3)	NS Mean decrease with education NS Higher mean for immigrants born outside EU (*vs.* Natives)
Kelly, 2018[111]	HBSC, cross-sectional, 2010, Ireland	-14-16+	5344	sFFQ	Frequency consumption of soft drinks (daily)	Social class (3) Disadvantaged school (2)	Higher % for low social class (NS for middle) Higher % for disadvantaged schools

24HR: 24-hour dietary recall; sFFQ: short Food Frequency Questionnaire; NS: non-statistically significant.

(Continued)

Reference	Population, design, time of collection, country	Age range (years)	n	Diet collection method	Intake or frequency of consumption	Exposure variables (number of categories)	Associations
				Food group: salty and sweet energy-dense food			
Garrido-Fernandez, 2020[119]	Secondary education high school, cross-sectional, N/A, Spain	12-16+	8068	sFFQ	Consumption at schools of snacks with sweets, candy, bagged crisps, sweets and pastries (yes/no)	Mother's education (6)	Candy: higher odds when no university degree
						Father's education (6)	Candy, sweets and pastries: higher odds when no university degree
						Family type (6)	Sweets and pastries: higher when other than 1st-gen.[a] or extended [b]
						Mother's employment (5)	NS
						Father's employment (5)	Sweets and pastries: higher odds when unemployed father
Kelly, 2018[111]	HBSC, cross-sectional, 2010, Ireland	-14-16+	5344	sFFQ	Frequency consumption of sweets, chips (daily)	Social class (3)	Chips: Higher % for low social class (NS for middle)
						Disadvantaged school (2)	Chips: Higher % for disadvantaged schools

sFFQ: short Food Frequency Questionnaire; NS: non-statistically significant.
[a] 1st-generation family: parents and children; [b] extended family: grand-parents, children, grand-children.

2. Methodological issues in nutritional epidemiology: Focus on dietary behaviours

2.1. Brief overview of nutritional epidemiology issues

Interest in the relationship between diet and occurrence of disease is longstanding, but the methods used have recently evolved to become more specific.[120] Until several decades ago, the focus was mainly on deficiency syndromes, using clinico-epidemiological methods. For instance, in the mid-18th century, observations about scurvy led Lind to conduct one of the first controlled clinical trials, by giving different treatments (including citruses) to pairs of suffering men.[121] Such deficiency syndromes are usually characterised by a high frequency among those with insufficient nutrient intakes, and an almost null frequency among those with adequate intakes.[120] Another characteristic is the short latent periods, with a rapid onset of symptoms but also a rapid reversal of the clinical symptoms. As a result, experiments rather than observations were carried out.[120] In the 1970s, the focus was developed in low-income countries, with particular emphasis on stunting and wasting of children due to insufficient energy and protein intake along with multiple micronutrient deficiencies.[122] Specific diagnosis and case management methods have been elaborated accordingly.

In high-income countries, contemporary nutritional epidemiology has been focusing on the potential involvement of diet in the growing increase in NCDs incidence, such as cancer, T2D or CVDs.[120] These diseases greatly differ from deficiency syndromes. First of all, they have multiple causes most often acting in combination, such as several components of diet, physical activity and other lifestyle behaviours. Secondly, many of these diseases have a long latent period, resulting from a cumulative exposure over several years. Finally, although these diseases are currently among the most frequent causes of mortality and morbidity, their incidence is rather low in the population in comparison with the relatively high frequency of exposure to multiple risk factors. Moreover, they may result from insufficient or excessive consumption, and are more difficult to reverse.[120]

Besides, diet itself represents a complex set of highly correlated exposures.[120] With a few exceptions, all individuals are exposed to assumed causal dietary factors, as everyone eats fat and fibre, for example. Hence, most often, exposure cannot be determined as only absent or present. Furthermore, eating patterns evolve during the lifetime; in general, there is no clear change at a specific turning point in time.

Beyond the complexity of diet, individuals are generally not aware of the food contents. As a result, nutrients have to be determined indirectly either through food declaration or biochemical measurements. The features of NCDs and diet have therefore led to the development of sophisticated methods in nutritional epidemiology. One of the greatest challenges in this area is to identify practical methods for assessing diet that are reasonably accurate and relatively inexpensive given the number of subjects needed to be included in studies.

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In recent years, knowledge on the diet-health relationships has become increasingly advanced albeit not definitive, thanks to the numerous studies using elaborate nutritional epidemiology methods. Within this scope, the used methods must provide a comprehensive assessment of the diet that captures its complexity, even if specific parts are of interest for research. At present, in order to implement effective public health actions regarding diet-related diseases, a broad understanding of determinants of diet is needed. In this respect, and unlike the diet-health approach, it is not always necessary to use potential resource-intensive methods that comprehensively assess diet, including energy and nutrients. Therefore, the remainder of this section is focusing on the methods used to assess dietary habits in the context of large-scale studies among adolescents, and the issues related to these methods. The methods assessing other components of nutrition, such as nutritional status or nutrient intake, are therefore not addressed as part of this doctoral dissertation.

2.2. Dietary data collection in school-based surveys: the short Food Frequency Questionnaire

Several methods for describing adolescent diet in large-scale population surveys are theoretically available. They include 24-hour dietary recalls (24HR), food records or Food Frequency Questionnaires (FFQ).[120] Each of these methods have strengths and weaknesses. Since they all are based on declaration, no single method perfectly measures dietary exposure and is suitable for all circumstances. The method choice will depend mainly on the type of survey and on the research objective, such as the diet components of interest, the target population and its ability to participate in the collection, along with the financial and human resources available.[123]

In cross-sectional school-based surveys, the time allocated to pupils to complete surveys is relatively limited, thus restricting the length of the questionnaire. In addition, when such surveys cover a wide range of topics, the related questionnaires may become particularly long. Therefore, the inclusion of a comprehensive assessment is rather impossible and a balance between the accuracy of the diet assessment and the limited number of questions has to be found. Besides, in school-based surveys, it is complex to invite all families of participating pupils in order to obtain additional information on diet. Therefore, the chosen diet assessment methods should not require additional information from families. In view of all these circumstances, the short Food Frequency Questionnaire (sFFQ), a method based on principles quite similar to the FFQ, seems to be one of the best choices despite some actual limitations.

2.2.1. Food Frequency Questionnaire

In the 20th century, investigators searched for a method that would provide a reliable and comprehensive assessment of usual diet.[120] In this regard, a detailed dietary history interview was developed in 1947. This method included a 24HR, a menu recorded for three days and a checklist of foods consumed over the previous month. However, this long and complex method is resource-intensive (time, financial, human), which led researchers to find an alternative. Based on the dietary history checklist, the FFQ was then developed a decade later. Having become frequent in the 1980s and 1990s, FFQs are now used less and less as it is less informative than other methods whose technical improvement through online tools has made them easier to use and to treat along with an enhanced reliability.[120] Indeed, 24HR can be easily multiplied with the development of computer technology and, accompanied by a Food Propensity Questionnaire,[124] can measure usual diet with a small number of recall days.

The FFQ aims to estimate individuals' usual food consumption.[125] Individuals are asked to report how frequently they consume the foods, in a finite list, during a given period of time, for example, several months to a year.[120] In some cases, they are also requested to give information on usual servings and composition,[120] resulting in an increased burden which is not always worthwhile in view of the additional data it provides.[126]

The list of foods cannot be endless; it is defined according to the purpose of the study[120] and to the target population.[125] If the objective of the study is aetiological, then the list should be as complete as possible, even if the full variability of the population's diet cannot be reflected with a defined list.[127] However, if the objective is to study the determinants of a specific nutrient, then the list may be focused more on foods related to that nutrient. In this case, the number of foods that are not related to this nutrient can be limited as long as they allow a correct estimate of total energy intake. This limitation thus avoids having particularly long lists, which also has disadvantages. Indeed, to avoid the impairment of concentration and accuracy but to keep reliability on the estimations, the list should be of an adequate length; usually, it consists of a hundred or so items.[128] In this respect, the foods selected must be as appropriate and informative as possible, like being discriminating or consumed by a significant number of individuals.[120] The items must then be compiled in such a way as to obtain a clear and unambiguous questionnaire, since its organisation and structure can influence the interpretation of certain foods.[127]

Frequency responses usually range from five to ten options, for instance from "never" to "more than six times a day".[120] While most of the information for some foods are at the lower end of the scale, for other foods, information can be at the high end, hence the need for a sufficient number of responses covering the whole scale. In addition, each frequency category cannot be too broad to remain discriminatory and give some precise estimates.[120]

The FFQ is a tool that makes it possible to measure the usual consumption of a large number of individuals in a relatively simple, resource-efficient and easy to administer manner. The burden on respondents is considered as acceptable in most situations.[123] However, the FFQ is sensitive to measurement errors.[126] For example, the length of the list can lead to over- or under-estimating the consumption of certain foods.[120,127] Compared to other methods, the portion size is more complex to estimate as it has to be an average of a consumption that can highly varied over the given period of time. The finite list of foods without information on their characteristics (e.g. combination, cooking) is not as accurate as other methods, like 24HR.

Finally, the FFQ requires respondents to make a significant cognitive effort, since they are required to average themselves their consumption over a long period of time.[120] At last, some similar foods may be grouped together creating a complex cognitive question when the respondent consumes one of these foods frequently and the other infrequently.[126]

2.2.2. Short Food Frequency Questionnaire

The sFFQ uses the same approach as the FFQ in that individuals are asked to report the frequency of consumption of a finite list of foods over a given period of time (or "usually"), leading to an estimation of usual intake. However, the sFFQ differs from the FFQ on the food items listed. While the FFQ list is composed of detailed foods such as bananas or pears, the sFFQ list is composed of food groups like fruit. As a result, far fewer items are included than in the FFQ, making this short list of a dozen or so items a unique feature of this short instrument. Similar to the FFQ, the food list must correspond to the objective of the survey and the population surveyed. However, this short list of food groups will not allow the estimation of total energy intake.

The sFFQ allows the usual consumption of food groups to be captured with relatively few resources in large-scale surveys. The short form of the questionnaire is ideal for adolescents who can quickly lose concentration and fall into boredom. The sFFQ can be easily integrated into multi-thematic surveys working with already long questionnaires. However, this tool has actual limitations. First of all, it requires a significant cognitive effort from the respondent by asking for an average or usual consumption of food groups. In addition, the sFFQ is more imprecise than the FFQ because only the consumption of global food groups can be estimated. Finally, social desirability bias is particularly present in the sFFQ, with consumption declarations close to the well-known dietary recommendations. It is less easily detectable than with FFQ lists or other declaration methods. Thus, errors in declaration are possible, limiting the analyses of related data.

2.3. Issues related to the interrelation of the different indicators of social position in diet: the cases of effect modification and confounding

Adolescents' dietary habits are determined by a set of strongly interrelated socioeconomic and sociocultural factors discussed above. In order to better understand the relationship between these factors and dietary habits, attention should be paid to the interrelation between these factors. In some cases, the strength of the association between one indicator of social position and dietary habits may differ according to the levels of another social position indicator, referred to as an effect modification. In other cases, the association between one of the social position indicators and dietary habits may be "explained" by another indicator, which is referred to confounding when causal inference is assumed. For these reasons, the interrelationship between the social position indicators must be considered as it provides a better understanding of the underlying mechanisms of the social inequalities in dietary habits.

2.3.1. Effect modification of the social position indicators

Effect modification occurs when the magnitude of the association between the social position indicator and dietary habits differs depending on the level of another social position indicator.[129] If such an effect is present, analyses should ideally be stratified on the latter indicator to obtain strata-specific associations. This stratification thus provides meaningful information that should be used to implement public health actions.

While the literature on social position as a determinant of adolescents' dietary habits is growing,[99] there are currently still too few studies examining the interaction between indicators of social position. Yet these indicators are likely to interact between each other.[130] It is therefore worth investigating whether, for example, native adolescents with a low socioeconomic status have different dietary habits than immigrant adolescents within the same socioeconomic status. If this is the case, stratification enables to identify the groups most at risk of unhealthy dietary habits, but also those least at risk. These new social groups with specific risks of unhealthy dietary habits would thus provide meaningful information. As a result, it will help better understand the mechanisms behind the respective disparities related to socioeconomic position (socioeconomic status in this case) and sociocultural position (migration status in this case). The role of culture in relation to socioeconomic conditions within sociocultural groups may also be apprehended. Ultimately, the relevant socioeconomic and sociocultural components can be integrated into public health initiatives, increasing their effectiveness.

In the context of the social determinants of diet, several modification effects can be identified. However, even if there are several modifying effects or if modifying effects remain after the first stratification, multiple stratification is not recommended. Indeed, in addition to the substantial decrease in the sample size per stratum and therefore in the statistical power, the results may become uninformative and very complex to interpret. The choice of the variable on which the stratification is carried out should ideally be based on explanatory hypotheses.

2.3.2. Confounding in the relationship between social position and dietary habits

Factors influencing dietary habits can be described as either "proximal" or "distal" in the causal pathway.[a] Proximate factors of diet directly influence dietary habits and are therefore proximate links in the causal chain (*P* in our notation in **Figure 7**).[132] In contrast, distal factors influence dietary habits indirectly through intermediate factors that are more proximal to diet.[132] These factors are distal links in the causal chain (*D* in our notation). Socioeconomic and sociocultural determinants as studied in this work are considered to be distal factors of diet, which would influence dietary habits through more proximal causes. For example, education, occupation, FAS or migration status can influence dietary habits through social standing and networks as well as resources (see **sections 1.2.3.1** and **1.2.3.2**). Income can also determine dietary habits through self-esteem and budget (section **1.2.3.1**). Factors closer than education also include cognitive and emotional skills (section **1.2.3.1**). Finally, migration status can influence dietary habits through attitudes towards life and the body, for example (section **1.2.3.2**). Other factors can also be mentioned, such as physical activity and body mass index, provided that they are indeed determinants of dietary habits.

In assessing the causal association between a proximal factor and diet (*P* and *O* in our notation), attention should be paid to a third factor that may confound this association (*C* in our notation). Confounding occurs when the observed association between a proximal factor and diet is due, at least in part, to a third proximal factor that is associated with the former proximal factor and causally associated with diet.[133] Thus, confounding is a causal concept and is described as a "mixing" or a "blurring" of effects.[134] Ignoring this confounding factor can lead to an erroneous estimation of the association, such as over- or underestimating. Confounding can be controlled by different methods, either during the study design with random allocation into intervention

[a] The use of the terms "proximal" and "distal" is currently being discussed as they are subject to distortion.[131] In the framework of this work, these terms are only used in relation to the causal pathway and therefore have no other meaning than those mentioned above.

groups, restriction to certain characteristics of the study population, or matching between subjects, or during analyses, through multivariable regressions.[133]

When studying socioeconomic and sociocultural disparities in dietary habits (*D* and *O* in our notation, respectively), a variation in the association between these distal factors and dietary habits can also be observed after adjustment for another factor of social position. However, unlike proximal factors, it is complex to conclude to a misestimation of the studied association and therefore to confounding. Indeed, while confounding is based on causality, social position factors are far along the causal path to dietary habits, with many intermediate factors. Due to the distal relationship, socioeconomic and sociocultural factors may not be more causal than each other in relation to dietary habits.

In fact, the variation that can be observed after the adjustment of a third factor is rather due to the interrelation of the social position factors studied. Although interrelated, these factors are associated with dietary habits through their own mechanisms, even though these factors may have commonalities. Indeed, while migration status is associated with socioeconomic status, for example, these factors are related to dietary habits differently at least in part (see **section 1.2.3**). Therefore, even if the effects are statistically "absorbed", it cannot be concluded that there are no socioeconomic or sociocultural disparities when using multivariable modelling.

Not considering a factor of social position in the study of socioeconomic and sociocultural disparities does not represent a conceptual error, since the association will not be incorrectly estimated. However, caution should be taken in order to avoid adjusting for overlapping factors and over-adjusting the relationship studied with intermediate factors like taste, preference or physical activity when it is a determinant of dietary habits, since the association obtained will not be more accurate. Over-adjustment corresponds to an "*undesirable consequence of the adjustment of an intermediate variable that lies on the causal path*" between social position and dietary habits.[135] Controlling for this intermediate variable will bias towards null the association between social position and dietary habits.[133]

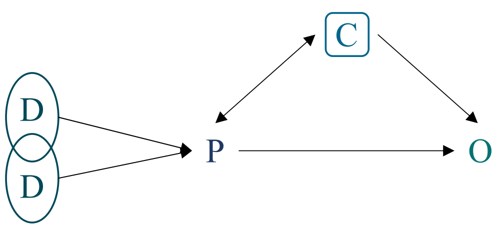

Figure 7. Directed Acyclic Graph from distal factors (D) through proximal factors (P) to dietary habits (O), with confounder (C).

◆

Among all the methods theoretically available for describing adolescent diet in large-scale surveys and in the study of social disparities related to diet, the sFFQ seems to be the most adequate tool. Indeed, its short format is an advantage for multi-thematic surveys of adolescents. Restricted to the frequency of consumption of a few food groups, certain limitations must be kept in mind, such as its relative imprecision and its susceptibility to social desirability bias. Moreover, the study of social disparities in dietary habits raises specific issues. For example, the interrelationship between different social factors may complicate the interpretation of statistical results. In addition, caution should be taken not to adjust for intermediate factors in the relationship between social determinants and dietary habits, especially without using appropriate methods. This would lead to over-adjustment and bias in the study of social disparities in dietary habits.

3. Objectives of the thesis

3.1. Main objective

The literature review highlighted socioeconomic and sociocultural disparities in dietary habits among adolescents. However, current knowledge still is too scattered. In addition, too little attention was paid to the role that certain socioeconomic and sociocultural factors can play in specific associations between an indicator of the social position and dietary habits of adolescents. Therefore, the aim of this doctoral thesis was to strengthen current knowledge by **studying socioeconomic and sociocultural disparities in dietary habits among adolescents, using the Health Behaviour School-aged Children surveys conducted in French- and Dutch-speaking schools**. This general objective was addressed in three chapters, each responding to a specific objective.

3.2. Specific objectives

Based on the 2014 French- and Dutch-speaking HBSC surveys, **chapter III** aimed:

- To describe dietary habits among adolescents from different migration backgrounds;
- To study socioeconomic disparities in dietary habits of adolescents from different migration backgrounds.

Using the 1990, 2002 and 2014 French- and Dutch-speaking HBSC surveys, aims of **chapter IV** were:

- To assess trends in the prevalence of food consumption among adolescents between 1990 and 2014;
- To determine how the dietary disparities related to the family structure and to the school region have evolved during this time period.

Based on the 2018 French-speaking HBSC survey, **chapter V** aimed:

- To estimate disparities in dietary habits according to the individual and contextual (school) socioeconomic status.

CHAPTER II. METHODS

⁂

1. The "Health Behaviour in School-aged Children" survey

1.1. General aims and objectives

The HBSC study is a repeated cross-sectional and cross-national school-based research. It focuses on adolescent health behaviours, health and well-being. Initiated in 1982, the first HBSC survey took place in 1983/1984 under the aegis of the WHO Regional Office for Europe in five countries: England, Finland, Norway, Austria and Denmark.[136] Since the second survey in 1985/1986, the HBSC WHO collaborative survey has been carried at four-year intervals in a continuously increasing number of countries in Europe and North America. In 2017/2018, 49 countries participated in the tenth round of the survey.[137]

In Belgium, the HBSC survey is conducted independently in French-speaking schools in the Wallonia-Brussels Federation (FWB), and in Dutch-speaking schools. In the French-speaking part, the first survey took place in 1986 and was initially carried out every two years before being repeated every four years from 1994.[138] Until the 2014 survey, the protocol was not submitted to any ethics committee. Nevertheless, the solicited school authorities approved and allowed to carry out the surveys. Later, the 2018 survey received the authorisation from the Ethics Committee of the Faculty of Psychology at the *Université libre de Bruxelles*. In Dutch-speaking schools, the survey started with the 1989/1990 round. It has been carried out every two years since the second survey in 1994, then at four-year intervals since the 2006 survey.[139] Data collection has been approved by the Ethics Committee of the University Hospital of Ghent.[140,141]

The HBSC surveys aim to "*gain new insight into and increase understanding of adolescent health behaviours, well-being and health in their social context*".[142] To achieve this goal, its main objectives are as follows:

- *"To contribute to theoretical, conceptual, and methodological development in the said area [health behaviour, health and well-being] of research;*
- *To monitor and to compare health behaviour, health, well-being and social contexts of school-aged children in member countries through the collection of relevant data;*

- *To disseminate findings to researchers, health and education policy makers, health promotion practitioners, school staff, parents, young people and other relevant audiences;*
- *To provide an international source of expertise and intelligence on adolescent health for public health, health education and health promotion*".[143]

1.2. Sampling

Each survey should be based on the methods drawn up within the international protocol of the survey year, to the extent possible. The priority of the survey sampling is to draw a nationally-representative estimations;[67] therefore, the methods to achieve this may differ between survey years and regions. The sampling plan targets the population of school adolescents aged 11, 13 and 15 years.[136] These ages correspond to the key periods of adolescence, that is the onset, followed by physical and emotional changes and related challenges, and the intermediate years when important life and career decisions are made.[142] If a relatively large proportion of adolescents is held back or advanced, as is the case in Belgium, continuous grades should be sampled to achieve the representativeness of the three age groups.[67]

The goal of the HBSC survey sampling in Belgium is to be representative of the population enrolled in full-time mainstream education in Dutch- and French-speaking schools, while respecting the internationally recommended minimum sample size of around 1,500 adolescents for the three target age groups.[136] Since the precise information for the first surveys that were carried out during a pre-digital period is not available, only the sampling of the surveys used in this thesis will be described.

In the French-speaking part, schools in the surveys from 1986 to 2002 were drawn from a random sample stratified for provinces, school networks and form of education.[144] From 2010 to 2018 surveys, schools were drawn from a random sample stratified proportionally to the distribution of the school population by province and education system.[145–147] In the 2018 survey, the number of schools selected in each stratum was proportional to the size of the schools (i.e. number of students) in these strata.[147] In 2018, the Brussels-Capital Region was oversampled to enable specific analyses to be carried out, as done in **Chapter V** for instance. Due to the insufficient number of participating secondary schools for this survey, a second wave of data collection was carried among the schools in the initial sample that did not participate in the first wave.[147] Within the selected schools, one class from each level from 5th primary to 6th (or 7th) secondary was randomly selected,[144–147] except in the 1986 survey for which only classes from 5th primary to 4th secondary were selected.[144] All adolescents of the selected classes were invited to take part in the survey in spring, except between 1990 and 2002 that took place in winter,[144] and the second wave of 2018[147] that took place in autumn. Overall, the number of participating schools ranged from 78 in the 1990 survey to 362 in the 2014 survey, and the number of adolescents included in the survey database ranged from 3,509 in 1990 to 14,748 in 2002 (**Figure 8**).

In the Dutch-speaking part, the schools in the 2002 and 2014 surveys were drawn from a random sample representative of school networks.[140,141] In 2002, within the selected primary schools, all adolescents in 5th and 6th primary were invited to participate; in the secondary schools, all adolescents of a randomly selected school year or about 100 adolescents in the selected school were invited to participate.[140] In 2014, classes were selected using a random sample stratified proportionally to the distribution in schools of gender, grade level and type education.[141] Afterwards, about fifty students per primary school and a hundred per secondary school were invited to participate.[141] The information regarding the sampling procedure of 1990 survey is not available and we assume that the sampling was drawn according to the international recommendations for that year.[148] For the 1990, 2002 and 2014 surveys, adolescents took part to the survey in spring (also in winter for the 1990 survey). Overall, 48, 197 and 98 schools participated in the surveys of 1990, 2002 and 2014, respectively, and 4,204, 17,299 and 9,566 observations were available in the respective databases (**Figure 9**).

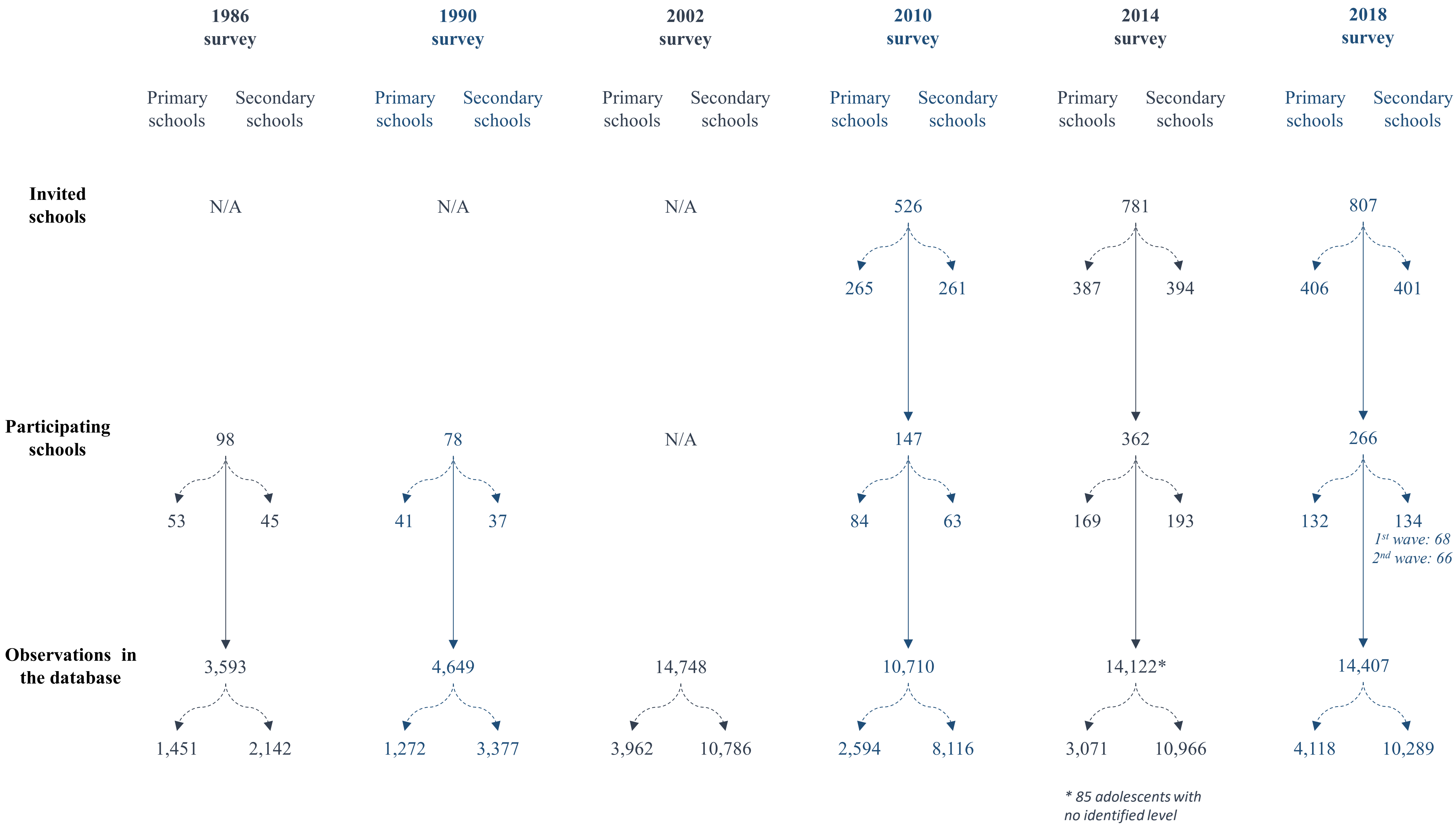

Figure 8. Flow chart of invited and participating French-speaking schools and adolescents for the HBSC surveys used in this research.

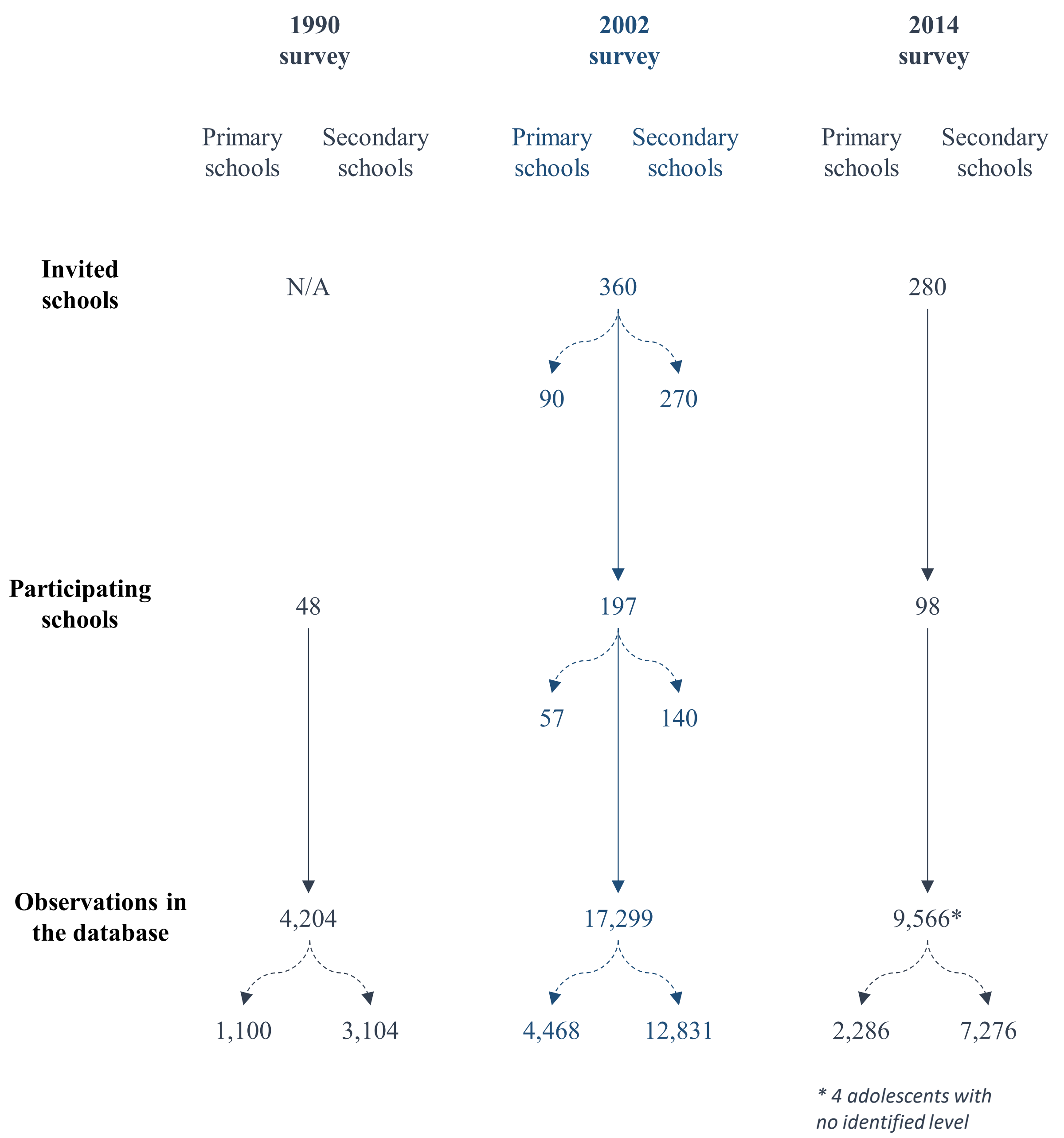

Figure 9. Flow chart of invited and participating Dutch-speaking schools and adolescents for the HBSC surveys used in this research.

1.3. Data collection

The measurement instrument of the HBSC surveys is an international standardised questionnaire, consisting of a mandatory set of questions, optional packages and national items.[67] Items are translated from English to the national language and then back-translated by a different translator in order to ensure that the same concepts are measured in all countries. All participating countries must use all the mandatory items in their questionnaire but are free to add any optional and national packages. The mandatory part concerned all age groups excepting (i) the items related to cannabis use and sexual health that are only presented to the 15-year-old adolescents, and (ii) the items considered highly sensitive in some countries. The mandatory items must comply exactly with the content and structure of the questions indicated, as far as translations will allow. Optional packages may be not presented to all age groups but should be placed after the mandatory items on the given topic area. Countries are encouraged to pilot the new questions to check clarity and translations issues, and to estimate the length of the questionnaire to ensure that sufficient time is allocated to answer the questions. Such a standardisation of the questionnaire enables to collect common data across countries, to make comparisons and to gather (cross-)national trend data with the successive surveys.[67]

In Belgium, the questionnaires in French and Dutch differ due to the respective choice of optional packages and "national" questions. Furthermore, different versions of the questionnaire have been developed per survey year, depending on the sensitivity of the questions and the specificities related to the school level. Nevertheless, such different versions of questionnaires have an impact that is deemed minimal for this work but are discussing when appropriate.

In Dutch-speaking schools, four versions were developed in 1990 and designated as follows for: primary schools; 1st and 2nd years of secondary schools; 3rd and 4th years of secondary schools; from 5th year of secondary schools. In 2002, a questionnaire was developed for primary school and another one for secondary schools. For the 2014 survey, three questionnaires were developed, i.e. for primary school, for the first two years of secondary schools and for the 3rd year of secondary schools onward.

In French-speaking schools, a single questionnaire was used in 1986. As to the other surveys used as part of this research, there were three versions, one of which being for primary schools. In 1990 and 2014,[146] a version was also designed for adolescents in the first three years in secondary schools, and another version for older adolescents. In 2002[144] and in 2010,[145] adolescents in Catholic secondary schools (only those from 1st to 4th year of secondary in 2010) received a shortened version. In 2018, a version was developed for adolescents in 1st and 2nd years of secondary school, and another for adolescents from 3rd year of secondary school onwards.[147] The different versions have had no influence on our analyses, albeit parental level of education was only asked to secondary school adolescents.

Methods of administering the questionnaire can be paper-based or online.[67] If both are used, the layout must be similar. The questionnaires in French and Dutch were paper-based,[140,141,144–147] excepting in the 2014 Dutch-speaking survey where questionnaires could also be completed online in secondary schools.[141] Envelopes for all individual questionnaires on paper were provided. In this way, each adolescent put it in the envelope after filling it at school and sealed it themselves to ensure confidentiality. For anonymity, adolescents were advised not to write their name.[67] They were informed that they could choose not to fill in the questionnaire or to skip questions if they wished to do so. No written parental (or guardian) consent was requested in Belgium so far. Instead, an opt-out consent has been chosen.[141,147]

1.3.1. Individual-level data

In addition to demographic, socioeconomic or sociocultural questions, adolescents are asked about their health behaviours, including diet. To collect information on dietary habits, a sFFQ was used throughout the surveys. Its aim is "*to assess the intake of important sources of dietary fibre (e.g. fruit, vegetable) and calcium (e.g. milk), and items of the youth food culture (e.g. soft drinks, sweets, crisps)*".[67] The reliability and relative validity of the HBSC sFFQ have been studied among several dozens of Belgian and Italian children.[149,150] The validity has been investigated first by comparing it with a food behaviour checklist and a seven-day food diary;[149] second, the FFQ completed twice seven days apart was compared with a seven-day food diary.[150] The results indicated sufficient reliability and validity for "*ranking subjects according to consumption of the individual food items*"[149] but pointed out overestimation of consumption frequencies that must be kept in mind. The HBSC sFFQs used for this work differed at some point from the validated one regarding the food list. Nevertheless, since the validation studies proceeded food item by food item, there should be no downside to have not use the same sFFQ exactly.

The layout of the sFFQ is a table including the general question, the modalities of answers and a list of food items (see **Table 2**). The sFFQ from the 2018 French-speaking survey is in the **Appendix C** as an example. The HBSC sFFQ has been revised for the 2002 survey. For this reason, the main differences in the sFFQ are between surveys prior to the 2000s and surveys in the 2000s years. In contrast to surveys prior to the 2000s, only a slight difference in terms is to be noted for the sFFQ question between the French- and Dutch-speaking surveys in 2000s (**Table 3**). Similarly, the answer modalities between the French- and Dutch-speaking surveys slightly differed since 2000s, while they differed substantially prior to 2000s (**Table 4**). Indeed, the revision of the sFFQ led to an increase in the number of answer modalities from five to seven. The order changed in the Dutch-speaking surveys and was reversed compared to the French-speaking version. As the sFFQ includes mandatory and optional items, important differences in the item proposals may happen, especially for the surveys during the 2000s years. Eleven food items were mandatory in the 1986 survey (tea, coffee, fruit, coke or other fizzy drinks, sweets, vegetables, peanuts, potato crisps, chips/fried potatoes, hamburgers or hot dogs, and dark bread) whereas only four are mandatory since the 2002 survey (fruit, vegetables, sweets (candy or chocolate) and regular soft drinks).[67]

1.3.2. Context-level data

In addition to the information collected about adolescents, countries have the opportunity to collect context-level data through a school-level questionnaire.[67] This questionnaire is completed by a school official, such as the head or a teacher. One of the main objectives of this questionnaire is to describe the main characteristics of schools, the school context and the structures and activities in schools regarding health promotion. Data on school-level were first collected in the 2006 wave by some countries.[67] In Belgium, only the 2018 French-speaking survey includes a school-level questionnaire, mostly based on the international HBSC questionnaire.

Table 2. General layout of the HBSC short Food Frequency Questionnaire.[67]

Question

	Frequencies						
	Freq. 1	Freq. 2	Freq. 3	Freq. 4	Freq. 5	Freq. 6	Freq. 7
Mandatory items	□	□	□	□	□	□	□
Optional items	□	□	□	□	□	□	□
National items	□	□	□	□	□	□	□

Table 3. sFFQ questions according to the survey year and region.

Surveys	Translated question	Original question
1986 and 1990 French-speaking surveys	Do you drink or eat the following foods?	Bois-tu ou manges-tu les aliments suivants ?
1990 Dutch-speaking survey	How often do you eat or drink one of the following products?	Hoe vaak eet of drink je één van de volgende produkten?
2002 and 2014 Dutch-speaking surveys	How many days a week do you usually eat or drink…?	Hoeveel dagen per week of drink jij gewoonlijk…?
From the 2002 French-speaking survey onwards	How many times a week do you usually eat or drink the following foods	Habituellement, combien de fois par semaine bois-tu ou manges-tu les aliments suivants

Table 4. sFFQ answer modalities according to the survey year and region.

Surveys	Answer modalities					
1986 French-Speaking	Several times a day	Once a day	Every week but not every day	Rarely	Never		
1990 French-speaking	More than once a day	Once a day	At least once a week	Rarely	Never		
1990 Dutch-speaking	Every day	Every week	Every month	Less than once a month	Never		
2002 French-speaking onwards	More than once per day, every day*	Once a day, every day	5-6 days a week	2-4 days a week	Once a week	Less than once a week	Never
2002 Dutch-speaking onwards	Never	Less than 1 day a week/rarely	1 day a week	2-4 days a week	5-6 days a week	Once a day and this every day	Every day, more than once

* “Several times a day every day” in the 2014 survey.

2. Analyses of dietary disparities among adolescents

2.1. Sample studied

For all analyses, the preferred strategy was to have a sample with the least amount of missing data. Firstly, only adolescents who responded to all covariates were included (complete cases). The next step differs according to the surveys analysed. For the analyses carried out on surveys up to 2014 (**Chapters III and IV**), the basis sample included adolescents who responded to the most frequently reported food consumption variable, i.e. fruit. For food consumption other than fruit, the sample size was therefore slightly smaller. For the analyses conducted on the 2018 survey (**Chapter V**), the basis sample included adolescents who responded to the sFFQ as a whole. In fact, we initially planned to use the weighting factor calculated only for adolescents who responded to the entire sFFQ. Due to the complexity of the subsequent analyses, this factor could not be reliably taken into account. However, we did not change our strategy for defining the sample afterwards.

The inclusion diagrams of adolescents in the analyses are displayed in the relative chapters. The maximum number of adolescents included for the main analyses in **Chapter III** was 19,172. For the main analyses in **Chapter IV**, the maximum number was 8,001 in 1990, 29,825 in 2002 and 21,939 in 2014. A total of 6,017 adolescents were included in the main analyses of **Chapter V**.

2.2. Reprocessing data

2.2.1. Food consumption

For the analyses carried out as part of this research, food groups to be consumed in sufficient quantities and food groups to be consumed in a limited way were considered. Fruit, vegetables, dairy products, fish and water are food groups that should be consumed in sufficient quantities, whereas crisps and fries, and SSB are those which should be consumed in limited quantities.

Categorisation of all food items was determined in order to correspond as closely as possible to the Belgian nutritional recommendations,[34] while also being determined by the original answer modalities that have evolved significantly over time. Food frequency consumption were categorised into two groups – daily and non-daily consumption – excepting for analyses on socioeconomic disparities by migration status (**Chapter III**). For this chapter, food consumption was firstly grouped in three categories: a category corresponding as far as possible to the Belgian nutritional policies; a category further away from Belgian nutritional policies; and an intermediate category. If no additional information was provided by the intermediate category, food consumption was then categorised into two groups. For all analyses, the reference category for the analyses was the most health-promoting dietary behaviour.

For composite variables (dairy; crisps and fries; SSB), initial frequency consumption for each was transformed into a monthly frequency by multiplying the initial consumption by the number of weeks (4 for analyses in **Chapter III**; 4.35 for analyses in **Chapter V**) (**Table 5**). If the answer modality was a range (e.g. "5 to 6 days a week"), the average was considered (e.g. 5.5 days a week). The differences in frequency consumption in days per month were due to the more precise multiplying factor in **Chapter V** but did not lead to important differences. Afterwards, consumption frequency per month of all items was added up to obtain the composite frequency. The food groups, variables and categorisation, as well as its corresponding consumption of days per month used for analyses are summarised in **Table 6**, **Table 7** and **Table 8**.

Table 5. Transformation of the original consumption frequencies into frequency consumption in days per month for variables making up the composite variables.

Original frequency consumption	Frequency in days per week	Frequency in days per month	
		Chapter III[a]	Chapter V[b]
More than once a day		31 days/month	31 days/month
Once a day		30 days/month	30 days/month
5-6 days per week	5.5	22 days/month	24 days/month
2-4 days per week	3	12 days/month	13 days/month
Once a week	1	4 days/month	4 days/month
Less than once a week	0.5	2 days/month	2 days/month
Never	0	0 days/month	0 days/month

[a] 4 weeks per month; [b] 4.35 weeks per month.

Table 6. Food groups, variables, and categorisation (reference category in **bold**; corresponding summed frequencies in days per month in grey) used for analyses on socioeconomic disparities by migration status (chapter III).

Food groups	Variables making up the composite variables	Categorisation		
Fruit		**> Once a day**	5-7 days a week	< 5 days a week
Vegetables		**> Once a day**	5-7 days a week	< 5 days a week
Fish		**≥ 2 days a week**	< 2 days	
Dairy products	Milk (whole milk; skim/semi-skimmed milk) Cheese Dairy products	**> Once a day** (≥ 31 days/month)	≤ Once a day (< 31 days/month)	
Crisps and fries	Crisps Fries	**< Once a day** (< 25 days/month)	≥ Once a day (≥ 25 days/month)	
Sugar-sweetened beverages	Coke or other sweetened lemonade Coke or other light lemonade	**≤ Once a week** (< 4.5 days/month)	2-6 days a week (4.5-24.5 days/month)	≥ Once a day (≥ 25 days/month)

Table 7. Food groups, variables, and categorisation (reference category in bold; corresponding summed frequencies in days per month in grey) used for analyses on long-term trend in disparities (chapter IV).

Food groups	Variables making up the composite variables	Categorisation	
Fruit		**Daily**	Non-daily
Vegetables	*In the 1989/1990 Dutch-speaking survey:* Cooked vegetables Raw vegetables	**Daily**	Non-daily
Sugar-sweetened beverages		**Non-daily**	Daily

Table 8. Food groups, variables, and categorisation (reference category in bold; corresponding summed frequencies in days per month in grey) used for analyses on contextual disparities (chapter V).

Food groups	Variables making up the composite variables	Categorisation	
Fruit		**Daily**	Non-daily
Vegetables		**Daily**	Non-daily
Dairy products	Whole milk Skim or semi-skimmed milk Cheese Yoghurt, cottage cheese	**Daily** (≥ 26.5 days/month)	Non-daily (< 26 days/month)
Water		**Daily**	Non-daily
Crisps and fries	Crisps Fries	**Non-daily** (< 26 days/month)	Daily (≥ 26.5 days/month)
Sugar-sweetened beverages	Coca and other sweetened beverages Coca light/zero and other light drinks	**Non-daily** (< 26 days/month)	Daily (≥ 26.5 days/month)

2.2.2. Individual characteristics

As part of this work, the individual information included sociocultural and socioeconomic characteristics collected through the questionnaire completed by the adolescent, namely: gender, age, migration status, family structure, siblings, FAS, perceived family wealth, parental working status and level of education. Questions related to the parental education were only asked to adolescents in secondary school while all the others were asked to all age groups.

The **age** of adolescents generally was calculated from the month and year of birth, and a given date of data collection. The day of birth was only asked for the 1986 French-speaking survey and the 2002 and 2014 Dutch-speaking surveys. For all other surveys or when data was missing for the above surveys, the day of birth was set at 15. Next, the age in completed years was categorised in two or three groups, depending on the study population.

The **migration status** was defined based on the birth country of adolescents, that of their mother and their father, along with adolescent's age of arrival in Belgium for the 2018 survey. Regardless of their country of birth, adolescents whose both parents were born in Belgium were considered to be "natives" in surveys prior to the 2018 survey. Indeed, since the age of arrival was not available for these surveys, we assumed that foreign-born adolescents were mainly born abroad "by chance" (during holidays for instance) and therefore were not strictly immigrants. In the 2018 survey, adolescents were considered as "natives" when both parents were born in Belgium, and either the adolescent was born in Belgium or arrived in Belgium before one year. In the latter uncommon instance, we also assumed that the adolescent was born abroad "by chance", without important consequences on his/her health behaviours, and therefore could be deemed as a native. For all surveys, adolescents born in Belgium who had at least one parent born abroad were considered "2nd-generation immigrants". Adolescents born abroad whose both parents were not born in Belgium were considered as "1st-generation immigrants". In the 2018 survey, foreign-born adolescents who arrived after the age of one year, and whose both parents were born in Belgium, were also considered as "1st-generation immigrants".

The **family structure** was defined by three categories: "two-parent family"; "blended family"; and "single-parent family". The questions on which the categorisation of the family structure was based have evolved throughout the surveys. Prior to the 2000s, adolescents were only asked who they were living with. From the 2002 survey, adolescents were also asked if they had a second home, and since the 2010 survey (since 2002 for Dutch-speaking adolescents) how often they lived in that home. In addition, between the 2002 and the 2014 surveys (2010 in the French-speaking part), adolescents were asked who they were living with in the second home. All these additional questions allowed us to better determine the family structure:

- Adolescents who lived with both parents and, when the question was asked, reported having no second home, were considered to be living in a "two-parent family" structure. This also applied to adolescents living with both parents who reported having a second home in which they were living less than half of the time. In this instance, the second house was assumed to be a holiday home.
- To be considered as living in a "blended family", adolescents must have reported living with a parent and a stepparent.
- Adolescents mainly living with one parent were considered as living in a "single-parent family". In addition, adolescents living with both parents and having reported a second home in which they lived half of the time were considered to be living in a "single-parent family" structure.
- The family structure of an adolescent who reported living with both parents and a stepparent or with a parent and two stepparents cannot be determined. As a result, the adolescent was randomly assigned to a single-parent or a blended family structure.
- Given the difficulties of interpretation resulting from the specificity and the heterogeneity of the living context, adolescents living in other situations such as foster care homes or with adults other than their (step)parents were not included in analyses.

Adolescent **siblings** were determined by the number of brothers, sisters, half-brothers and half-sisters. They were considered to be "single child" if they declared none of them. They were considered to have "siblings" if they had at least one brother, sister, half-brother or half-sister.

The **Family Affluence Scale** (FAS) measures the family wealth.[66] This tool is reliable and valid, as explained previously (see **section 1.2.3.1**, "**overview on adolescents**"). To get the FAS of an adolescent, a composite score is calculated based on six items (since 2014): holidays abroad the last 12 months with their family, ownership of up to two or more cars, up to three or more computers, up to three or more bathrooms, own bedroom and a dishwasher.[66] The FAS score ranged from 0 to 13 and was divided into three categories based on quintiles. The first quintile (lowest FAS scores) corresponded to adolescents with a low FAS, the second to fourth to adolescents with a medium FAS and the fifth quintile to those with a high FAS.

Adolescents were asked how they felt financially about their family, choosing from five categories ranging from “very well off” to “not at all well off”. The last two categories (i.e. “not so well off” and “not at all well off”) were merged due to the small sample size within. Thus, the **perceived family wealth** was categorised in four: “very well off”; “quite well off”; “average”; “not so/at all well off”.

The **parental working status** was defined based on whether the father and the mother were on a job or not, and if they were not working, the reasons why they were not. Initially, we used this variable for two purposes: (i) to determine the availability of parents through their presence/absence at home; (ii) to estimate their financial situation. Therefore, four categories were defined for analyses carried out with the 2014 surveys: “both parents working”; “one working parent and the other at home”; “one working parent and the other absent from home”; “no working parent”.

- Adolescents with both parents working were categorised as having “both parents working”.
- Adolescents considered as having “no working parent” were those with both parents not working, along with those with a parent not working, and who did not have or were no longer seeing the second.
- Adolescents with one working parent but no second working parent because he/she was seeking a job were categorised as having “one working parent and the other absent from home”. Those with one working parent but without a second parent were also in this category.
- Adolescents reporting to have one working parent but no second working parent because he/she was (pre-)retired, disabled, student or homemaker were categorised as having “one working parent and the other at home”. The few adolescents with a working parent but who did not know if the second parent was in a job or the reasons why he/she was not, were also taken into account in this category.

For the 2018 survey, the distinction between the presence and absence of the second parent was no longer made, mainly due to the small sample sizes in each case and the previous lack of results regarding this categorisation. The main purpose of this categorisation was to estimate their financial situation. Thus, three categories were defined: “both parents working”; “one working parent”; “no working parent”.

- Adolescents with both parents working were categorised as having “both parents working”, as in the 2014 survey.
- Adolescents considered as having “no working parent” were those with both parents not working along with those with a parent not working and no information about the second parent.
- Adolescents with one working parent and no information about the second parent or a non-working second parent were considered to be having “one working parent”.

Secondary-school adolescents were asked about their mother’s and father’s **level of education** in 2018. When the adolescent lived in a two-parent family, the highest level of education was considered. For adolescents living in a single-parent or blended family, the level of the parent with whom the adolescent lived mattered. However, if we could not identify the parent with whom the adolescent lived most of the time, the highest level of education between the two parents was considered. Given the high number of missing data, an additional category was created as “undetermined”. The “primary or lower” level of education and the “secondary” level of education were merged due to the small sample size of the former. Therefore, the level of education was categorised in three: “post-secondary education”, “secondary or lower education” and “undetermined”.

2.2.3. School characteristics

As part of this work, contextual data include information about schools on the region, the socioeconomic index (SEI), the proportion of immigrants, the selling food at school, the topics related to health or health promotion explicitly addressed in the school mission statement and the purpose of food projects. The school region was available for all surveys (sampling information). The school SEI and the proportion of immigrants, used for the 2018 survey, were extracted from official data for the former and from the individual HBSC data for the latter. The remaining contextual data were gathered through the 2018 school-level questionnaire. Since very few schools sold food and the nutrition-related characteristics of schools differed greatly between primary and secondary schools, analyses including school-level data other than school region were only carried out on adolescents from secondary schools.

The **region** of the school was determined based on the postcode of the school and categorised in two (“Wallonia”; “Brussels-Capital”) or three (“Flanders; “Wallonia”; “Brussels-Capital”), depending on whether or not the Dutch-speaking survey was included in our analyses.

The **socioeconomic index (SEI)** of a school is officially used to determine the allocation and use of resources, and additional periods allocated in the context of differentiated teaching for schools.[151] First, the school SEI is calculated based on individual characteristics of its population: per capita income, level of education, unemployment rates, labour force activity and social assistance rates, and occupational activities. Schools are then increasingly classified, from the lowest to the highest socioeconomic index. Afterwards, in primary and secondary schools separately, based on the cumulated school population, schools are distributed into 20 classes (1: lowest socioeconomic schools; 20: highest socioeconomic schools), each comprising exactly 5% of the total population. As a result, some schools may belong to two classes.[151] For the purposes of our analyses, only one class of the two classes was considered, i.e. the higher class. Based on the quartiles, three categories were defined.[151] The first quartile corresponded to schools having a "low socioeconomic index" (classes 1 to 5), the second to schools of "medium socioeconomic index" (classes 6 to 10), and the last two quartiles to schools with a "high socioeconomic index" (classes 11 to 20). In fact, low-SEI schools are 100% beneficiaries of resources and additional periods granted. Medium-SEI schools are 50-75% beneficiaries under certain conditions. No resources and no additional periods are granted to high-SEI schools.

Due to its correlation with the school region, the **proportion of immigrants** per school was only used for analyses carried in the Brussels-Capital sample. This variable was determined by dividing the number of immigrants by the number of immigrants and natives participating in the survey. Missing information on migration status was not included in the denominator, resulting in no missing data for this variable. The proportion of immigrants per school in Brussels-Capital ranged from 50.0% to 100%. It was categorised into terciles. The first tercile corresponded to schools with a "low proportion of immigrants" ([50.0-67.3%[), the second to schools with a "middle proportion of immigrants" ([67.3-91.2%[) and the third to schools with a "high proportion of immigrants" ([91.2-100%]). Exploratory findings highlighted a high correlation between the proportion of immigrants per school (MIG) and the school socioeconomic index (SEI). Therefore, a composite variable **SEIxMIG** was created, with five categories: "high SEI, low MIG"; "medium SEI, low MIG"; "medium SEI, middle MIG"; "low SEI, low or middle MIG"; "low SEI, high MIG". For the low SEI schools, low and middle MIG were merged due to the small sample size of the low MIG in low SEI schools (n= 10). Combinations not mentioned actually did not exist.

Through the school-level questionnaire, schools were asked whether **topics related to health or health promotion were explicitly addressed in the school mission statement** (yes/no). Schools were also asked whether the **purpose of food projects** was to increase the consumption of fruit and vegetables, whole grains… (yes/no); to limit the consumption of sweets, crisps, sugary drinks… (yes/no); to include fruit or vegetables at school events (yes/no). They additionally were asked whether adolescents could buy or not certain products when they had access to food buying places inside the school. **The selling food at school** comprised: bottles of water; sugar-sweetened drinks, fruit drinks that are not 100% pure juice, or so-called sports drinks (Aquarius®, Gastorade®…); flavoured milk; chocolate, sweets, cookies, cakes or ice cream; crisps or fries; fruit; vegetables or salads; filled sandwiches; pizzas or burgers; whole grain bread or other whole grain products. All of these elements were grouped into three, using a classification method preceded by the Multiple Correspondence Analysis (MCA). The three groups represented schools that sold: (1) few foods; (2) mainly health-impairing foods; (3) lots of foods (see **Chapter V**, **section 2**).

2.3. Statistical analyses

General outline of statistical analyses is presented by chapter hereafter, and more details are given in the corresponding chapter when necessary. The global analysis strategy is summarised below. Throughout the analyses, the reference categories were assumed to be the most favourable category in terms of health.

All analyses were performed using Stata/IC 14® (StataCorp, College Station, TX, USA), except for MCA and clustering which were performed using R software. Statistical significance of all tests was set at 0.05 unless other specifications.

2.3.1. Migration status as an effect modifier of the association between socioeconomic status and dietary habits – Chapter III

Preliminary analyses strongly guided the analyses presented in **Chapter III**. First, they revealed a significant number of interactions. These interactions were first evaluated on the basis of the overall *P* value of the two-way term based on dummy independent variables, which was included in the univariate and multivariate models. In the case where the overall *P* value was less than 0.1, we explored the consistency of the differences in association across population sub-groups. These results, combined with the literature and *a priori* hypotheses, led us to stratify our analyses by migration status. Next, stratified analyses conducted on the food groups categorised into three revealed that the intermediate category of some groups did not provide additional information. Some food groups were subsequently categorised into two. Thereby, the analyses of **Chapter III** to determine dietary disparities: (i) focused on food groups categorised into two or three, and (ii) were stratified by migration status.

Multilevel analysis, outlined in **Appendix D**, was required to handle the hierarchical structure of the 2014 HBSC data resulting from sampling plan (adolescents [level 1] nested in classes [level 2], in turn nested in schools [level 3]).[152] Such a structure can result in correlated or non-independent data. Thus, we might expect that two randomly-selected adolescents from the same class and the same school should be more alike regarding food frequency consumption than two adolescents from different classes and schools.[153] In other words, characteristics of the class and the school, particularly in terms of nutrition, might influence adolescent dietary habits. However, we assumed that influence of the class characteristics on dietary habits were marginal compared with those of schools. Therefore, only the school level was considered in multilevel analyses.

The first step before performing multilevel analyses is to determine whether dietary habits actually differ between schools or not. Hence, a likelihood ratio test comparing the one-level model to the two-level random intercept model[a] is performed.[154] When the null hypothesis of no group difference is rejected (*P* value significant), the two-level model is retained. A significant test implies that the more complete (i.e. two-level) model fits better than the less complete (i.e. one-level) model. However, to make the results easier to interpret and to be consistent, multilevel models were carried out for all food groups, including those for which there was no group difference. Nevertheless, the lack of contextual data did not make possible to further investigate the possible school effect. In fact, there was no school-level questionnaire available for the 2014 survey, which was only developed from the 2018 survey.

The strategy adopted here for the multilevel analyses was to carry out a series of models. The first model (*null* model) is an empty model that consists of the school-specific random effect without any independent variables. Associations between independent variables (socioeconomic characteristics) and a given food consumption were then evaluated by univariate regression (model 1). Finally, multilevel binary logistic regression was performed for food groups with consumption frequencies in two categories (odds ratio (OR) and 95% CI); multilevel multinomial logistic regression was used for food groups with consumption

[a] School residuals u_j are not fixed and are considered to vary across schools

frequencies falling into three categories (relative risk ratio (RRR)[a] and 95%CI). All covariates with a *P* value < 0.20 in the univariate analyses were included in the initial multivariable regression model. Manual backward stepwise selection was used to determine the final model (model 2), consisting of iteratively removing the predictor with the highest *P* value, and higher than 0.05. In order to facilitate comparisons of findings between migration groups, a socioeconomic predictor significantly associated with food consumption in a given migration status group was retained for all other migration status groups.

Finally, additional analyses were performed to estimate the role of immigrants' geographical origin on disparities. Further stratifying analyses on the origin of immigrants was not relevant since the sample size of some categories were already small. Therefore, we opted to subsequently adjust analyses on the origin of immigrants. Nevertheless, it should be noted that the categories remain very heterogeneous and do not allow a meaningful interpretation of the effect modification of the migration status.

2.3.2. Long-term trends in dietary disparities – Chapter IV

Studying trends in inequalities over a long period of time is challenging. First, it considerably limits the choice of variables to be studied due to several changes in the items collected throughout the surveys. In addition, it requires a measure that helps to compare these inequalities over time. For this purpose, we have used the Relative Index of Inequality (RII) and the Slope Index of Inequality (SII).[60] The use of these measures facilitates the comparison of inequalities at different points, such as time or place, by considering the population size and the relative position of groups. Furthermore, these aggregate measures of the magnitude of inequalities take into account the whole distribution and not only the extreme groups,[60] allowing the situation of intermediate groups to be considered. In short, the RII and the SII are used to quantify the gradient of inequality related to a characteristic in relative and absolute terms, respectively.[60]

The RII and SII are complementary in the results interpretation. All relative differences being equal, an absolute difference can be much higher when frequency of unfavourable food consumption is high compared with a situation where the frequency is low.[155] Moreover, absolute and relative differences can move in opposite directions, meaning that the absolute difference may decrease over the time while relative difference increases. Therefore, both

[a] RRR are interpreted similarly to OR but they differ on one point: not one but several categories are compared to the same reference category.

measures should be considered to better understand the trends in inequalities. In addition, the interpretation of the RII and SII must be related to the Population Attributable Factor (PAF).[156] Indeed, changes in inequalities may result from a shift in the population structure. Thus, an increase over time in RII and SII could be due to an upward shift in the population, with an increase in the proportion of the population at the top of the hierarchy. If this is the case, then the PAF should decrease over the same time period.[156]

All the analyses of **Chapter IV** were stratified by survey year. Firstly, the categories of the different characteristics studied (i.e. family structure, school region and migration status) were ranked based on prior hypothesis.[110,157] Subsequently, a modified-ridit transformation[158,159] was applied to obtain a ranking score x_i between 0 and 1. The ranks x_i were determined as follows:

$$\frac{c_i + c_{i-1}}{2}$$

where c_i the fraction of the population in the class *i* or lower ($c_0 = 0$ and $c_i = 1$).[159]

According to this formula, the scores x_i=*0* and x_i=*1* correspond to hypothetical categories. Based on the ranking of the categories, a score of 0 corresponds to the so-called hypothetical best-placed category, i.e. those who should have the lowest prevalence of unfavourable dietary habits. Conversely, a score of 1 corresponds to the so-called hypothetical worst-placed category, i.e. those who should have the highest prevalence of unfavourable dietary habits.

For each food group, crude RII and SII were estimated first. Secondly, RII and SII were adjusted for all the independent variables. Trends over time in RII and SII were estimated by including a two-way interaction term modified-ridit score by survey.[160] In the case where the evolution of RII and SII was quadratic, a test for quadratic trend was performed (including survey year squared in the two-way interaction term).

For these analyses, we opted for a Poisson regression rather than a logistic regression. The prevalence ratios (PR) obtained using Poisson regression are more interpretable and easier to understand than OR in cross-sectional studies. Namely, OR cannot be interpreted as PR given that OR can strongly overestimated PR.[161] Nevertheless, a disadvantage of Poisson regression is that it is not yet sufficiently developed in the usual statistical software and cannot be used properly with some advanced statistics methods, such as multilevel analyses (**Chapters III** and **V**). In this **Chapter IV**, the structure of the data could not be taken into account because the older databases did not reliably include class or school information.

2.3.3. Individual and school socioeconomic disparities in dietary habits – Chapter V

Preliminary analyses revealed that contextual variables, especially food sold at school, were rarely associated with food group consumption (data not shown). We then assumed that the school environment as a whole could influence dietary habits, but the magnitude of each health promotion action was much less impacting. Therefore, we performed an MCA, outlined in **Appendix E**, to study the associations between all the school variables' categories.[162]

First of all, we carried out an MCA on all the contextual variables (see **section 2.2.3**). This MCA enabled to distinguish six groups that could be summarised into two following the two principal components: food sales *vs.* all other contextual variables (data not shown). Then, we calculated two scores according to the two summarised groups by assigning a weight (i.e. coordinates on the axis) to each variable. Again, scores were rarely associated with food consumption (data not shown). Finally, such results added to the literature suggested that structural and contextual variables related to health promotion should be considered separately and that the foods sold should be considered together using clustering.

Before performing clustering, missing data were imputed using R, to avoid not including a whole school in the subsequent analyses. Then, an MCA was performed on *foods available at schools* and was intended to be the preliminary step to hierarchical clustering.[162] Indeed, one solution to avoid instability[163] is to first transform categorical variables into quantitative variables before performing a hierarchical clustering.

Clustering method, an unsupervised classification[a], aims to classify patterns[b] into clusters based on similarity.[164] Among the numerous methods,[164] we have chosen to perform a Hierarchical Clustering on Principal Components (HCPC). As suggested by its name, this method is performed on *principal components* that were obtained through the MCA.

To create the clusters, the agglomerative method used consists in beginning with each school belonging to a distinct group.[164] Then, the schools are merged given their similarity until all the schools are in the same group. The method of merging follows the Ward's criterion[164] and aims to minimise the increase in within-group inertia, the inertia being defined as the squared Euclidean distance between schools.[166]. The number of clusters to retain was chosen based on

[a] Groups are not known *a priori*
[b] A pattern consists of a vector[164] such that obtained by the MCA[165]

the change in inertia along with the interpretability of the clusters. Thus, Q clusters were retained when Q minimised the criterion $\frac{\Delta(Q)}{\Delta(Q+1)}$, with $\Delta(Q)$ the between-inertia increase.[167] According to this, four clusters should have been selected for analyses in **Chapter V**, but these were not easily interpretable. As a result, we have reduced the number of clusters to three.

Multilevel analyses were performed to handle the data structure (adolescents < classes < schools). Preliminary analyses confirmed that dietary habits were not influenced by class characteristics in addition to those of schools (data not shown). Therefore, only the school level was considered in analyses of **Chapter V**.

As for **Chapter III**, a succession of models was carried out. The first model (model 1), also known as the *null* model, is an empty model that consists of the school-specific random effect without any independent variables. In the second model (model 2), individual-level variables were added up to the model 1 estimating the school effect. Then, a third model (model 3) was performed and consisted in evaluating the school-level variables (including clusters) together with the individual-level variables and the school effect. Among others, this strategy allowed to describe the change in the group effect explained by the variables at the individual- and school-levels.

In models 2 and 3, the slopes of all the independent individual-level variables can be allowed to vary across schools, leading to a very complex and difficult to estimate model. Hence, if the effect of a variable is not different from one group to another, it is not necessary to use a random slope. To determine whether the slope should be fixed or random, a likelihood ratio test is performed,[168] comparing a first model with a fixed slope nested in a second with a random slope. The random slope model is retained when the *P* value is statistically significant, meaning that this model fits better than the fixed slope model. We allowed all the independent individual-level variables to vary in turn across schools in models 2 and 3. However, no *P* value of the likelihood ratio test was significant. Therefore, all the independent individual-level variables were fixed across schools. Note that contextual variables, which are specific to schools, may also vary and could be considered at a higher level, i.e. level 3. However, we did not use such a level in our analyses.

Measures and interpretation of multilevel analyses

In contrast to chapter III, the analyses in this chapter went beyond the simple consideration of the within-cluster correlation, in particular by including school-level variables. In addition to specific measures for multilevel analyses that are necessary to understand the hierarchical data, school-level measures are needed to properly interpret the results. Two main types of measures can be distinguished in multilevel analyses: the measures of association between the food frequency consumption (our topic) and the independent variables, such as the OR, and the measures of components of variance and of heterogeneity, such as the variance partition coefficient.[153] The latter measures help better evaluate the general contextual effects.[153]

The logit of the **intercept** β_0 is the probability of having a food frequency consumption detrimental to health at an average school (model 1) for an adolescent of reference (model 2) and a school of reference regarding school characteristics (model 3).[153] An "average school" means a school whose random effect is equal to zero. An adolescent and a school of reference mean that individual and school covariates, respectively, equal to zero too.[153]

The interpretation of the **Odds Ratio** is conditional on other independent variables and school-specific random effect, leading to a within-school interpretation.[153] Therefore, the OR of X_{ij} in model 2 determines the association between variable X_{ij} and the food frequency consumption, adjusted on the other independent variables for adolescents within the same school. Nevertheless, the interpretation of the OR of Z_j (school-level independent variables) is problematic because, by definition, the value of the school-level variable is constant for all individuals in the school. Therefore, in order to properly assess the association between the food frequency consumption and the school-level variables, another measure is presented: the Proportion of Opposed Odds Ratios (POOR).[153]

The **Proportion of Opposed Odds Ratios** is the proportion of pairwise OR "with the opposite direction to the overall OR".[169] A pairwise OR means an OR comparing two adolescents "*whose values of a school-level independent variable differs by one unit but who have identical value for other individual- and school-level independent variables*".[153] The values of the POOR range between 0 and 50% and provide information on the homogeneity of the association.[153] The closer to zero the POOR, the more homogeneous the association. Conversely, the closer to 50%, the more heterogeneous the association. For instance, a POOR equals to 0% means that the direction of the association is the same for all schools, albeit the strength may differ. A POOR of 50% implies that it is not possible conclude to an association between the given variable and dietary habits.

The **Variance Partition Coefficient** (VPC) is the proportion of the residual variation in food frequency consumption that is attributable to systematic difference between schools,[153] i.e.

between-group variations. The VPC values range from 0 to 1. The closer the VPC value is to one, the more adolescents from the same school have the same frequency of food consumption. Conversely, if the VPC is close to zero, adolescents from the same school would be no more alike regarding food consumption than those coming from a theoretical simple random sample of the population. Interestingly, since the individual-level variance is fixed when using latent variable formulation in binary logistic regression, a scale correction factor was applied to the variance of models 2 and 3, resulting in a corrected VPC.[153]

The **Median Odds Ratio** (MOR), a measure of heterogeneity, is the median of the set of OR that could be obtained by comparing two random adolescents from different schools with the same values for the independent variables (characteristics): one at higher risk of having an unhealthy food frequency consumption and one at lower risk.[153] Therefore, in half of comparisons, the odd of having a food frequency consumption detrimental to health would be less than the MOR for an adolescent at the school at higher risk, compared to another adolescent attending a school at lower risk.[153] One feature of interest of this measure is that it is directly comparable with the measures of association of individual- and school-level variables. This makes it possible to determine whether the magnitude of the effect of clustering (contextual effect) is smaller or greater than that of the individual or school characteristics.[153]

The **Proportional Change in Cluster Variation** (PCV) quantifies the variation explained by a multilevel model (e.g. model 2 or model 3).[153] The PCV allows to describe the change in the group effect explained by the variables at the individual- and school-levels.

CHAPTER III. SOCIOECONOMIC DISPARITIES IN ADOLESCENT DIET: MIGRATION STATUS AS A MODIFIER

⁂

1. Introduction

The literature review pointed to growing evidence that in high income countries, adolescents' diet varies according to their social position, despite some limitations regarding several food groups.[99] Numerous studies consistently found an association between socioeconomic status and dietary habits of adolescents.[170,171] However, research remains very scattered in terms of sociocultural position. Until now, studies mainly conducted in the U.S. oriented towards ethnic groups,[172,173] making the transposition of the findings to Belgium complex and doubtful. With regard to migration status, studies are even rarer,[114,174] like among adults.[82] Nevertheless, it has been shown that immigrant adolescents tend to gradually mimic the diet of native-born adolescents[114,174] through an acculturation process. However, this research was mainly carried out in particular contexts (such as in Balearic Islands)[114] or concerned only immigrants of limited origins.[174] In view of all these results, the first objective of this chapter was **to estimate the dietary habits of adolescents living in Belgium according to their migration status**, i.e. natives, 2nd-generation immigrants or 1st-generation immigrants (see definition **Chapter II**, **section 2.2.2**).

While studies on the association between social position and diet have multiplied in recent times, none of them focused on the interplay of indicators, particularly between socioeconomic position and sociocultural background. Yet a modifying effect of sociocultural background on the association between socioeconomic position and health has already been observed in adults[175] and adolescents.[130] It is therefore to be expected that migration status may modify the association between socioeconomic indicators and adolescents' dietary habits. Thus, the second objective of this chapter was **to estimate the socioeconomic disparities in the dietary habits in adolescents of different migration status**.

These two main objectives have been addressed in the paper presented in **section 2**. The analyses presented in this paper were based on data for adolescents aged 10 to 19 years from the French- and Dutch-speaking surveys of 2014. The supplemental materials of the paper are presented in **appendices F-H** of the doctoral thesis: (i) multilevel logistic regression models that related to the main results in the main text, but presented in a figure form (**Appendix F**); (ii) multilevel logistic regression stratified by geographical origin of immigrants (**Appendix G**); and (iii) comparison between the characteristics of adolescents included in the analyses and of those eligible but not included (**Appendix H**).

To summarise the main findings related to these objectives, a migration gradient in the dietary habits of adolescents was actually highlighted. Specifically, favourable frequency consumption gradually increased (for healthy food, such as vegetables or fish) or decreased (for unhealthy food, like crisps and fries) from natives to 2nd-generation immigrants, and from 2nd-generation immigrants to 1st-generation immigrants. Moreover, several socioeconomic disparities were identified in dietary habits of adolescents. These were mainly observed in natives and, to a lesser extent, in 2nd-generation immigrants. Even more limited socioeconomic disparities were found among 1st-generation immigrants.

These findings raise the question of whether these migration-related differences in socioeconomic disparities between adolescents are more driven by the culture or by the socioeconomic conditions. In order to help address this issue, insight into the description of socioeconomic characteristics of the immigrant adolescents in Belgium, in comparison with natives, is required. Besides, Belgium has a special migration history, with countries of origin and reasons for immigration varying greatly over the years.[75] Studying the changes in immigrant characteristics would help document whether history is reflected in the characteristics of the HBSC adolescents, and therefore whether the 2014 survey stood out from the others. Thus, complementary analyses were carried out and aimed **to describe the socioeconomic characteristics of adolescents according to their migration status and throughout the survey years** (**section 3.1**).

Furthermore, the migration gradient in the dietary habits of adolescents observed in the published paper suggests a process of acculturation, as mentioned above.[114,174] The issue of dietary acculturation deserves more attention among 1st-generation immigrant adolescents. Indeed, these adolescents can be distinguished on many characteristics that can have an impact on such a process, like, among others, the proportion of their life spent in the host country. Although too little investigated, we assumed that the higher the proportion of time spent in Belgium by 1st-generation immigrants, the closer they are to the dietary consumption of 2nd-generation immigrants and natives who have spent their whole life in Belgium. In this respect, additional analyses aimed to **determine the food consumption of adolescents according to the proportion of their past life in Belgium**. These additional analyses came from a Public Health master's thesis developed during the academic year 2019-2020 and were based on the 2018 HBSC survey conducted in French-speaking schools (**section 3.2**). They should therefore be considered as an exploratory illustration of this hypothesis.

2. Published paper: "Socioeconomic disparities in diet vary according to migration status among adolescents in Belgium"

nutrients

MDPI

Article

Socioeconomic Disparities in Diet Vary According to Migration Status among Adolescents in Belgium

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Abstract: Little information concerning social disparities in adolescent dietary habits is currently available, especially regarding migration status. The aim of the present study was to estimate socioeconomic disparities in dietary habits of school adolescents from different migration backgrounds. In the 2014 cross-sectional "Health Behavior in School-Aged Children" survey in Belgium, food consumption was estimated using a self-administrated short food frequency questionnaire. In total, 19,172 school adolescents aged 10–19 years were included in analyses. Multilevel multiple binary and multinomial logistic regressions were performed, stratified by migration status (natives, 2nd- and 1st-generation immigrants). Overall, immigrants more frequently consumed both healthy and unhealthy foods. Indeed, 32.4% of 1st-generation immigrants, 26.5% of 2nd-generation immigrants, and 16.7% of natives consumed fish ≥two days a week. Compared to those having a high family affluence scale (FAS), adolescents with a low FAS were more likely to consume chips and fries ≥once a day (vs. <once a day: Natives aRRR = 1.39 (95%CI: 1.12–1.73); NS in immigrants). Immigrants at schools in Flanders were less likely than those in Brussels to consume sugar-sweetened beverages 2–6 days a week (vs. ≤once a week: Natives aRRR = 1.86 (95%CI: 1.32–2.62); 2nd-generation immigrants aRRR = 1.52 (1.11–2.09); NS in 1st-generation immigrants). The migration gradient observed here underlines a process of acculturation. Narrower socioeconomic disparities in immigrant dietary habits compared with natives suggest that such habits are primarily defined by culture of origin. Nutrition interventions should thus include cultural components of dietary habits.

Keywords: migration status; dietary habits; food frequency questionnaire; socioeconomic disparities; adolescents

1. Introduction

High consumption of foods such as chips and fries [1] and sugar-sweetened beverages (SSB) [2] might be associated with increased noncommunicable diseases (NCD); by contrast, adequate consumption of fruits, vegetables [2,3], fish [2], and dairy products [4] might reduce NCD and all-cause mortality. Furthermore, it has been estimated that up to two-thirds of NCD social inequalities may be explained by dietary disparities [5,6].

In addition, evidence indicates that dietary habits during adolescence may continue into adulthood [7–9]. To implement effective prevention of NCD throughout the lifetime, disparities in adolescent eating behavior warrant elucidation. However, information on this topic is scarce in Western countries. Although several studies have pointed out the association between dietary habits and socioeconomic status (SES) among adolescents [10,11], SES may not explain all observed variations.

Among other determinants of dietary habits, migration status may play a role [12,13]; however, published studies are rare, even among adults, and are often oriented towards a specific ethnic group [12,13]. Studies on health related to migration have revealed a mortality advantage in immigrants compared to natives, despite the lower SES of most immigrants [14]. This paradox could be explained by the "healthy-migrant effect", i.e., positive self-selection, and an unhealthy return-migration effect, also known as the "salmon-bias hypothesis" [14]. However, these selection processes are subject to caution; "beneficial cultural and behavioral factors", like dietary habits, may be the most plausible explanation for this paradox [14]. The immigrant health advantage may also tend to wear off with length of stay in the host country, mostly due to an acculturation process [15,16], wherein foreign individuals partially integrate behaviors and cultural aspects of the host population while maintaining their roots [17]. This has been highlighted in some adult dietary studies and suggests gradual adaptation to the natives' eating habits according to years spent in the host country [18]. In adolescents, dietary habits varying according to migration status (including a gradient across migration generations) might also be expected, but such investigations have thus far been limited [19,20].

An effect modification between migration status and socioeconomic characteristics was emphasized in a previous study on adult self-rated health: A gradient was revealed across social classes in natives, which was not the case for immigrants from poor countries [21]. Similarly, in adolescents, a clear gradient throughout family affluence categories was observed for health-related quality of life in natives but not in immigrants [22]. Therefore, a possible effect modification of migration status on socioeconomic characteristics should be considered when evaluating disparities in dietary habits.

The aim of this study was to estimate socioeconomic disparities in dietary habits of school adolescents from different migration backgrounds. We first hypothesized that adolescent immigrants have healthier dietary habits than natives and that food consumption frequencies increase or decrease gradually according to the migration generation, related to an acculturation process. Secondly, we assumed that migration status might modify the association between socioeconomic characteristics and dietary habits in adolescents.

2. Materials and Methods

Research was carried out using data from the "Health Behavior in School-Aged Children" (HBSC) survey conducted in 2014 in Belgium. The cross-national HBSC survey takes place every four years in around 40 countries in Europe and North America under the aegis of the World Health Organization (WHO) Regional Office for Europe. Its goal is to produce comprehensive indicators supporting implementation of health prevention and promotion policies and interventions. Questionnaires are self-administrated in the classroom, and anonymity and data confidentiality are guaranteed [23].

Belgium has a regionalized administration in which wide demographic variations are observed, including those concerning migration. In 2014 in Belgium, this study was carried out separately in French- and Dutch-speaking schools covering the three regions, Wallonia, Flanders, and Brussels, with the latter including both French- and Dutch-speaking schools.

This survey was carried out according to guidelines articulated in the Declaration of Helsinki. For French-speaking schools, the survey was approved by school authorities. This protocol was not submitted to a medical ethics committee in view of the topics and methods used for data collection (Belgian law of May 7, 2004 and Advisory Committee on Bioethics of Belgium, opinion n°40, 12/2/2007). For Dutch-speaking schools, the study was approved by the ethics review committee of the University Hospital of Ghent (project EC/2013/1145). Following advice from school authorities, no written consent was requested for French-speaking schools; for the Dutch-speaking schools, consent was passive. Adolescents were clearly informed about survey content and about their full right to refuse to fill out the questionnaire or answer specific questions. All procedures used during data collection enabled confidentiality and anonymity.

2.1. Sampling

The French- and Dutch-speaking surveys were conducted on a random sample stratified proportionally with the school networks and included public and private schools. In addition, in the French-speaking part, the sample was stratified proportionally with the province (n = 6); in the Dutch-speaking part, it was stratified proportionally with the form of education (ordinary, general, technical, vocational, art secondary education, and non-native newcomer classes).

In all regions, schools were first randomly selected based on an official list. Next, classes from fifth grade elementary school (corresponding to adolescents aged ± 10 years) to the final grade of the secondary school (corresponding to adolescents aged ± 18 years) were selected in each grade among the schools that agreed to participate in the study. All adolescents from selected classes were invited to participate on a voluntary basis. In French-speaking schools, classes were randomly selected. In Dutch-speaking schools, distributions of gender, grade, and form of education from the previous survey were used as temporary proxies to select classes.

In 2014, 781 schools in the French-speaking schools and 208 schools in the Dutch-speaking schools were invited to participate. Among these schools, 168 in the French- and 98 in the Dutch-speaking areas actually participated, corresponding, respectively, to a participation rate of 21.5% and 47.1%.

In total, 23,552 questionnaires were collected (Figure 1). Since, in Dutch-speaking schools, adolescents aged 20 or over were not questioned, only adolescents 10 to 19 years old were included in the joint database (n = 23,031). The basis sample included all participants who responded to all covariates and to the food consumption variable that was most frequently filled in, i.e., fruits. Thus, the maximum number of adolescents included in the analyses was 19,172 (Figure 1). For food consumption other than fruits, the sample size was slightly lower.

2.2. Measures

Food Frequency Questionnaire. Food data were collected using a validated short food frequency questionnaire (FFQ) [24,25] that included a total of 22 food groups (17 in the Dutch part, 18 in the French part, including 13 in common). Seven answer categories were proposed: "more than once a day"; "once a day"; "5–6 days a week"; "2–4 days a week"; "once a week"; "less than once a week"; and "never".

Migration status. Adolescents born abroad and whose parents were not both born in Belgium were considered "1st-generation immigrants". Adolescents born in Belgium and who had at least one parent born abroad were considered "2nd-generation immigrants". Adolescents whose parents were born in Belgium were considered to be "natives".

Geographical area of origin. Based on countries of origin of adolescents for 1st-generation immigrants and of parents for 2nd-generation immigrants, five categories were defined for complementary analyses: (1) Europe; (2) America; (3) Asia; (4) Middle East and North Africa; (5) Sub-Saharan Africa. For 2nd-generation immigrants, in the particular case where the parents were from two different geographical areas, the category was randomly chosen between the mother's and the father's area of origin.

Family affluence. The family affluence scale (FAS) is composed of six items and has been validated in Europe [26]. The FAS score ranged from 0 to 13 and was divided into three categories after ridit analysis transformation—"low", "medium", and "high"—corresponding, in the national sample, to the 20% of adolescents with the lowest FAS scores, the 60% of adolescents with the intermediate score, and the 20% of adolescents with the highest FAS scores, respectively.

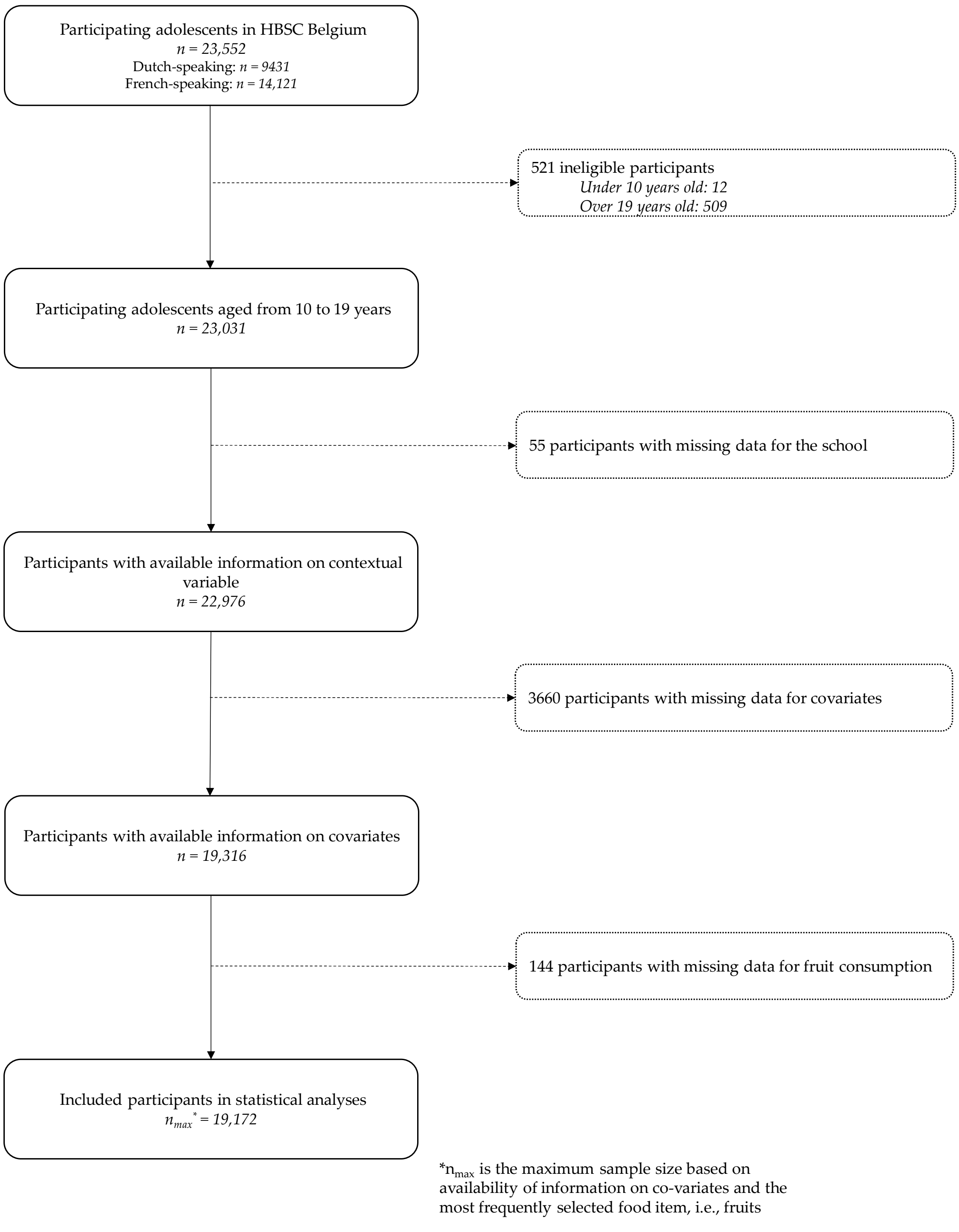


Figure 1. Inclusion diagram of adolescents in Belgium, "Health Behavior in School-Aged Children" (HBSC), 2014.

Parental working status. Based on parental employment and reason for parental unemployment, four categories were defined: (1) Adolescents with both parents working; (2) adolescents with parent(s) not working (those with a parent not working and without a second parent were placed in this category (n = 365)); (3) adolescents with one working parent and the other at home (housewife/husband, pre-retired, disabled or student); (4) adolescents with one working parent and the other "absent" from home (seeking a job, or adolescent not living with the second parent).

In addition, gender, age, family structure, siblings, and school region were taken into account in the analyses.

2.3. Statistical Analyses

2.3.1. Reprocessing Data

For all food items, categorization was defined so as to correspond as closely as possible to Belgian nutritional policies [27] but was also determined by the original answer modalities. Food consumption was first divided into three categories: A category corresponding as closely as possible to the Belgian nutritional policies, a category further removed from Belgian nutritional policies, and an intermediate category. If the intermediate category did not provide additional information, categorization was reduced to two categories. Frequency of *fruit and vegetable consumption* was classified into three categories: ">once a day", "5–7 days a week" (low frequency), and "<5 days a week" (very low frequency). Frequency of *fish consumption* was classified into: "≥two days a week" and "<two days a week" (low frequency). Milk (whole and semi-skimmed/skimmed), cheese, and other dairy product frequencies were transformed into consumption per month of 30 days and added up to obtain frequency of *dairy consumption*; this was then divided into total consumption of 31 days or more, which corresponded to consumption ">once a day", or else to consumption "≤once a day" (low frequency). Consumption of chips and fries and SSB was similarly processed. Frequency of *chips and fries* consumption was classified into: "<once a day", strictly corresponding to consumption under 25 days, and "≥once a day" (high frequency). Frequency of *SSB consumption* was classified into: "≤once a week", corresponding to total consumption under 5 days, "2–6 days a week" (high frequency) and "≥once a day" (very high frequency), corresponding to a total of 25 days or more.

2.3.2. Modeling

Due to a significant effect modification of migration status on several covariates for each food group analyzed, analyses were stratified by migration status. Since individuals were nested within schools, multilevel models were used. In each model for each food group, the school effect was controlled and estimated. The "null" model referred to the estimation of the school effect. Associations between covariates and a given food consumption were then evaluated by univariate regression, corresponding to "model 1". Multilevel binary logistic regression was performed for food groups with consumption frequencies in two categories (odds ratio (OR) and 95% CI); multilevel multinomial logistic regression was used for food groups with consumption frequencies falling into three categories (relative risk ratio (RRR) and 95%CI). The reference category was assumed to be the most favorable category in terms of health. All covariates with a p value < 0.20 were included in the initial multivariable regression model. Manual backward stepwise selection was used to determine the final model: It consisted of iteratively removing the predictor with the highest p value, and higher than 0.05. Following removal, confounding was evaluated with a tolerance threshold for variation of OR and RRR set at 10%. If variation was greater than 10%, the variable was then retained in the model. In order to facilitate comparisons between migration strata, a predictor significantly associated with food consumption in a given migration status group was retained for all other migration status groups. The results of the regressions are graphically presented and available as supplementary tables (Supplementary Tables S1–S6).

In order to estimate the role of the immigrants' geographical area of origin on socioeconomic and sociodemographic disparities, the same modeling was carried out only in immigrant adolescents and adjusted for the geographical area of origin.

Colinearity and fitting of models were verified. Statistical significance of tests was set at 0.05. All analyses were performed using Stata/IC 14® (StataCorp, College Station, TX, USA).

3. Results

The sample of 19,172 school participants included 69.6% natives, 22.0% 2nd-generation immigrants, and 8.4% 1st-generation immigrants. In univariate analyses, differences in sociodemographic and socioeconomic characteristics were observed according to migration status (Table 1).

Table 1. Sociodemographic and socioeconomic characteristics of the sample overall and by migration status—HBSC, Belgium, 2014.

Variables	Sample	Natives	2nd-Generation Immigrants	1st-Generation Immigrants	p value
	(n = 19,172) %	(n = 13,353) %	(n = 4214) %	(n = 1605) %	
Gender					<0.001 [†]
Boys	50.6	51.5	47.5	51.7	
Girls	49.4	48.5	52.5	48.3	
Age					<0.001 [¥]
10–12 years	28.8	29.6	28.7	22.5	
13–16 years	50.2	49.9	50.6	51.4	
17–19 years	21.0	20.5	20.7	26.1	
Family structure [a]					<0.001
Two parents	66.4	66.1	67.9	65.0	
Blended family	14.1	15.8	9.9	12.0	
Single-parent family	19.5	18.1	22.2	23.0	
Family Affluence Scale [a]					<0.001
High	19.4	20.6	17.0	16.4	
Medium	63.7	66.1	59.8	53.6	
Low	16.9	13.3	23.2	30.0	
Parental working status [a]					<0.001
Both parents working	68.4	76.1	51.9	47.0	
One working, the other at home	17.4	13.4	27.8	23.7	
One working, the other not at home	8.1	7.2	8.5	14.0	
None working	6.1	3.3	11.8	15.3	
Siblings					<0.001 [†]
Single child	9.3	9.8	7.5	10.5	
Siblings	90.7	90.2	92.5	89.5	
School Region					<0.001
Brussels-Capital	11.4	3.4	29.2	31.7	
Wallonia	46.6	48.7	43.0	38.2	
Flanders	42.0	47.9	27.8	30.1	
Geographical area of origin					<0.001 *
Europe			43.7	59.8	
America			3.0	6.7	
Asia			7.3	7.7	
Middle East and South Africa			36.0	13.1	
Sub-Saharan Africa			10.0	12.7	

[a] For details, see *Methods* section, [†] Nonsignificant difference between natives and 1st-generation immigrants, [¥] Nonsignificant difference between natives and 2nd-generation immigrants, * Comparison between 1st- and 2nd-generation immigrants.

Irrespective of migration status, one adolescent out of five ate fruits (17.2%) or vegetables (18.8%) >once a day and fish ≥two days a week (20.2%) (data not tabulated). Eight pupils out of ten (79.6%) ate dairy products >once a day. Nearly half of the adolescents (43.7%) drank SSB ≥once a day; fewer than one-eighth (12.2%) ate chips and fries ≥once a day (data not tabulated).

Immigrants significantly more often ate fruits (>once a day and 5–7 days a week), vegetables (>once a day) and fish (≥two days a week) than did natives (Figure 2). In addition, immigrants significantly more often consumed SSB (≥once a day), and chips and fries (≥once a day) than natives. Moreover, the proportion of 2nd-generation immigrants having low or very low intake of vegetables, fish, chips and fries was significantly at an intermediate level, i.e., higher (or lower) than that of natives, and lower (or higher) than that of 1st-generation immigrants. However, a significant difference in dairy product consumption was observed only between 2nd-generation immigrants and natives (Figure 2).

In immigrants only, and compared with immigrants from a European country, statistically significant differences in food consumption frequencies were found in those from the Middle East and North Africa areas, and from sub-Saharan Africa, for vegetable, fish, dairy, chips and fries, and SSB (Supplementary Table S7). Immigrants from America also slightly differed regarding SSB and chips and fries consumption, and those from Asia for chips and fries consumption. Overall, estimates of the SES characteristics were not modified by the addition of origins in the modeling except only for siblings in 1st-generation immigrants for chips and fries consumption (data not shown).

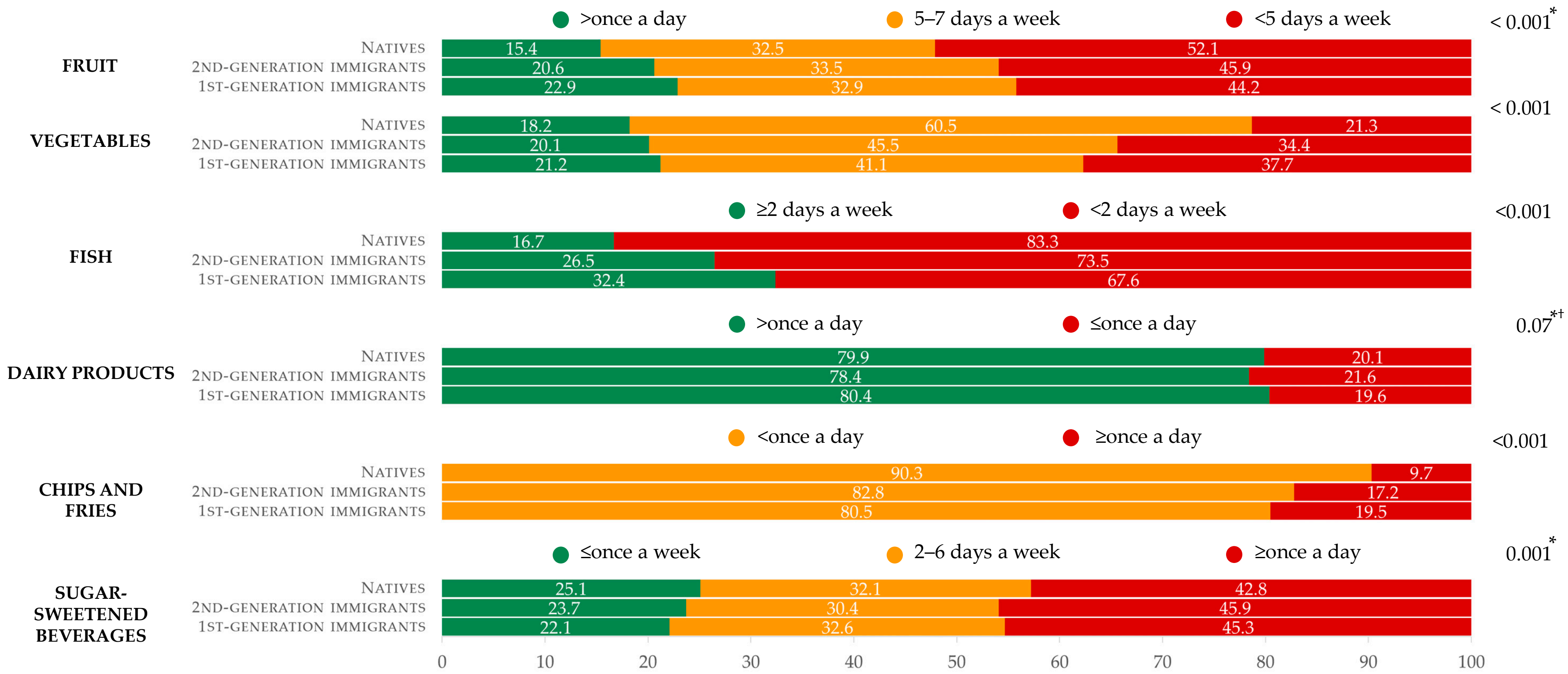


Figure 2. Distribution of food consumption frequencies by migration status in the sample, HBSC, Belgium, 2014. Favorable, moderately favorable, and unfavorable behaviors are represented, respectively, in green, orange, and red. * Nonsignificant difference between 2nd- and 1st-generation immigrants, † nonsignificant difference between natives and 1st-generation immigrants.

3.1. Fruit Consumption (Reference Category: >Once a Day)

In all migration strata, the likelihood of very low fruit consumption frequency (<5 days a week) significantly decreased with the FAS (except in 1st-generation immigrants: NS for medium FAS vs. high FAS) (Figure 3). In addition, natives having a medium FAS were more likely to eat fruits 5–7 days a week (low frequency) than those with a high FAS. Native adolescents in blended families were more likely to declare very low or low fruit consumption compared to adolescents with two parents; native adolescents in single-parent families also had greater odds of very low frequency. There was no significant association with parental working status. In all migration strata, adolescents in Flanders were significantly more likely to declare low or very low fruit consumption than adolescents in Brussels-Capital (Figure 3).

Moreover, age was significantly associated with fruit consumption frequency in all migration strata (Figure 3). This was also the case for gender in natives and 2nd-generation immigrants, whereas the existence of siblings was associated with fruit consumption frequency only in natives. The school effect upon the very low fruit consumption of all migration groups was significant, as was its effect upon the low frequency found in natives (Figure 3).

3.2. Vegetable Consumption (Reference Category: >Once a Day)

In natives and 1st-generation immigrants only, the odds of very low vegetable consumption frequency (<5 days a week) decreased with FAS (Figure 4). The same applied to low frequency (5–7 days a week) in natives. In 2nd-generation immigrants, adolescents having a medium FAS were more likely to declare very low or low vegetable consumption than those with a high FAS; in addition, adolescents having a low FAS were more likely to eat vegetables <5 days a week.

Compared with adolescents with two parents, native adolescents from a single-parent family were at greater odds of consuming vegetables <5 days a week (Figure 4). Native adolescents with two working parents were more likely to declare a low frequency than adolescents with one parent who worked and the other who stayed at home. Moreover, 2nd-generation immigrants with both working parents were less likely to declare a very low frequency. Compared with adolescents in Brussels-Capital, adolescents in Flanders were more likely to eat vegetables 5–7 days a week in all migration strata; in addition, immigrants in Flanders were more likely to declare a very low frequency, whereas 2nd-generation immigrants in Wallonia were less likely to do so (Figure 4).

Gender was significantly associated with vegetable consumption frequency in all migration strata. This was also the case for age in natives and 2nd-generation immigrants, while the existence of siblings was associated only in natives. The school effect was significant only in natives (Figure 4).

3.3. Fish Consumption (Reference Category: ≥Two Days a Week)

In natives and 2nd-generation immigrants, the likelihood of eating fish at low frequency (<two days a week) decreased with FAS. Moreover, low fish consumption was more frequent in adolescents from blended families than in those having two parents (Figure 5). Compared with adolescents with one working parent and the other who stayed at home, 2nd-generation immigrants with no working parents were less likely to eat fish at low frequency. In 1st-generation immigrants, adolescents whose parents both worked were more likely to declare low fish-eating frequency. For all migration strata, compared with Brussels-Capital, adolescents in Flanders and Wallonia were significantly more likely to declare low frequency (Figure 5).

In addition, gender was significantly associated with fish consumption frequency in natives and 2nd-generation immigrants. The school effect was significant in natives and 2nd-generation immigrants.

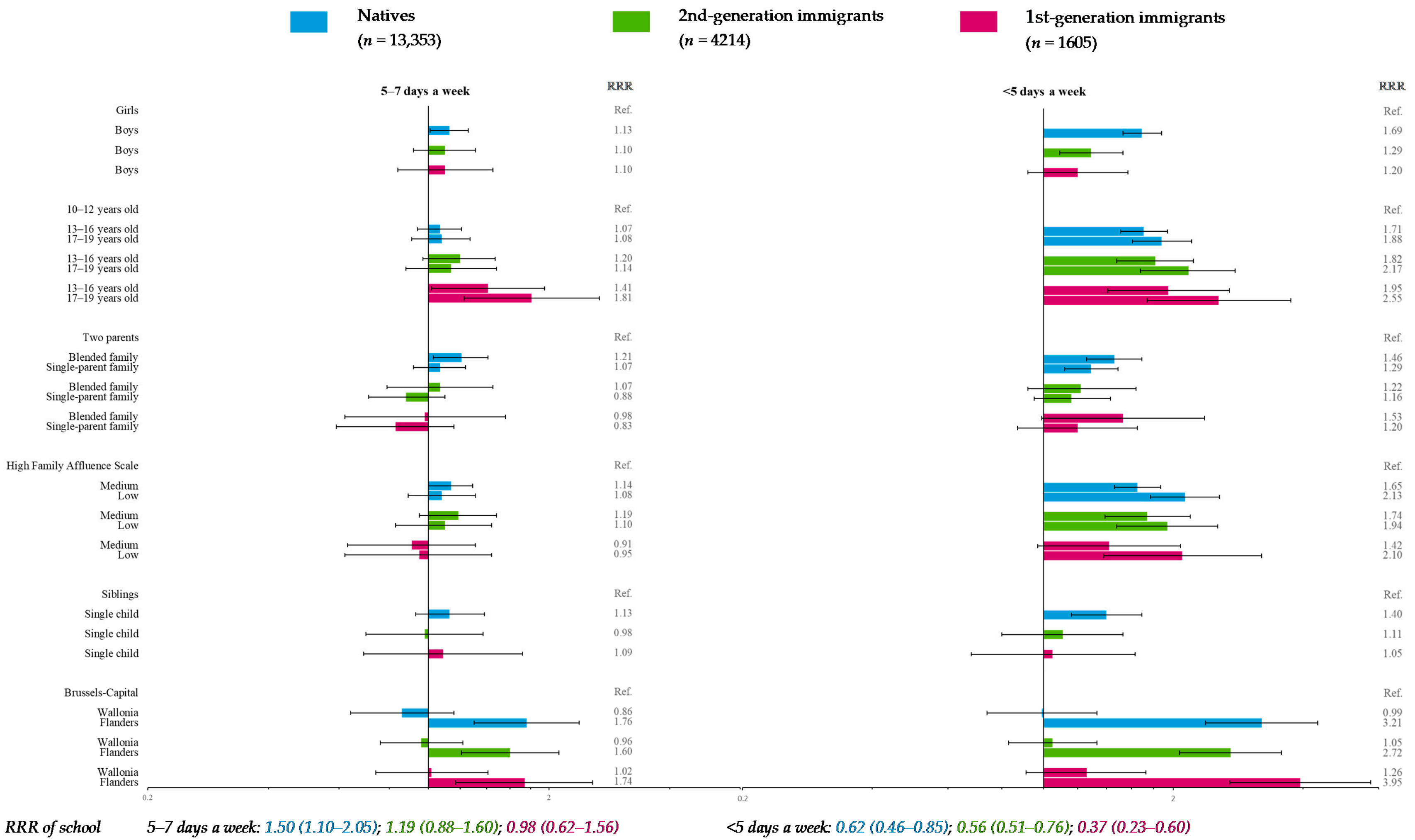
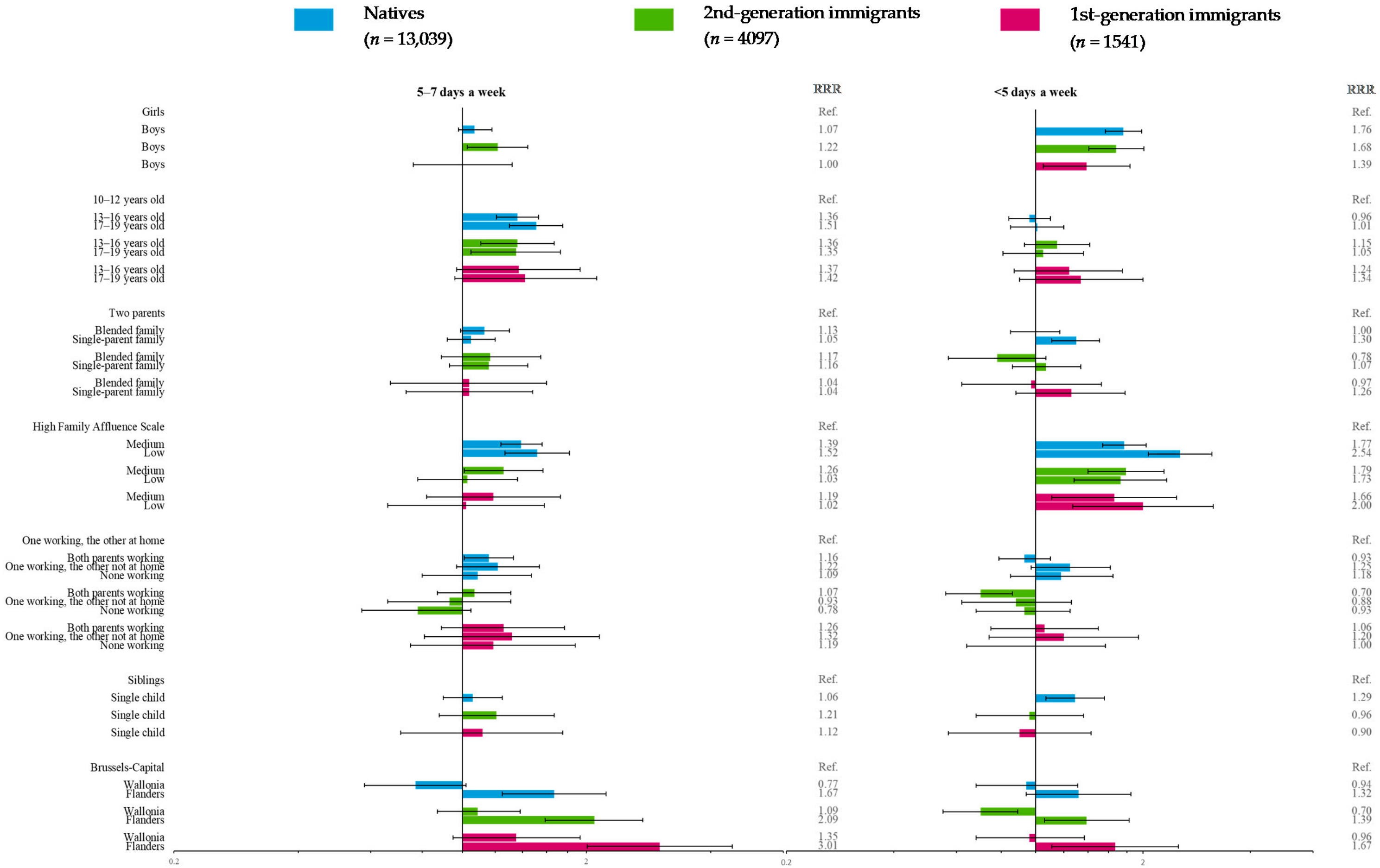
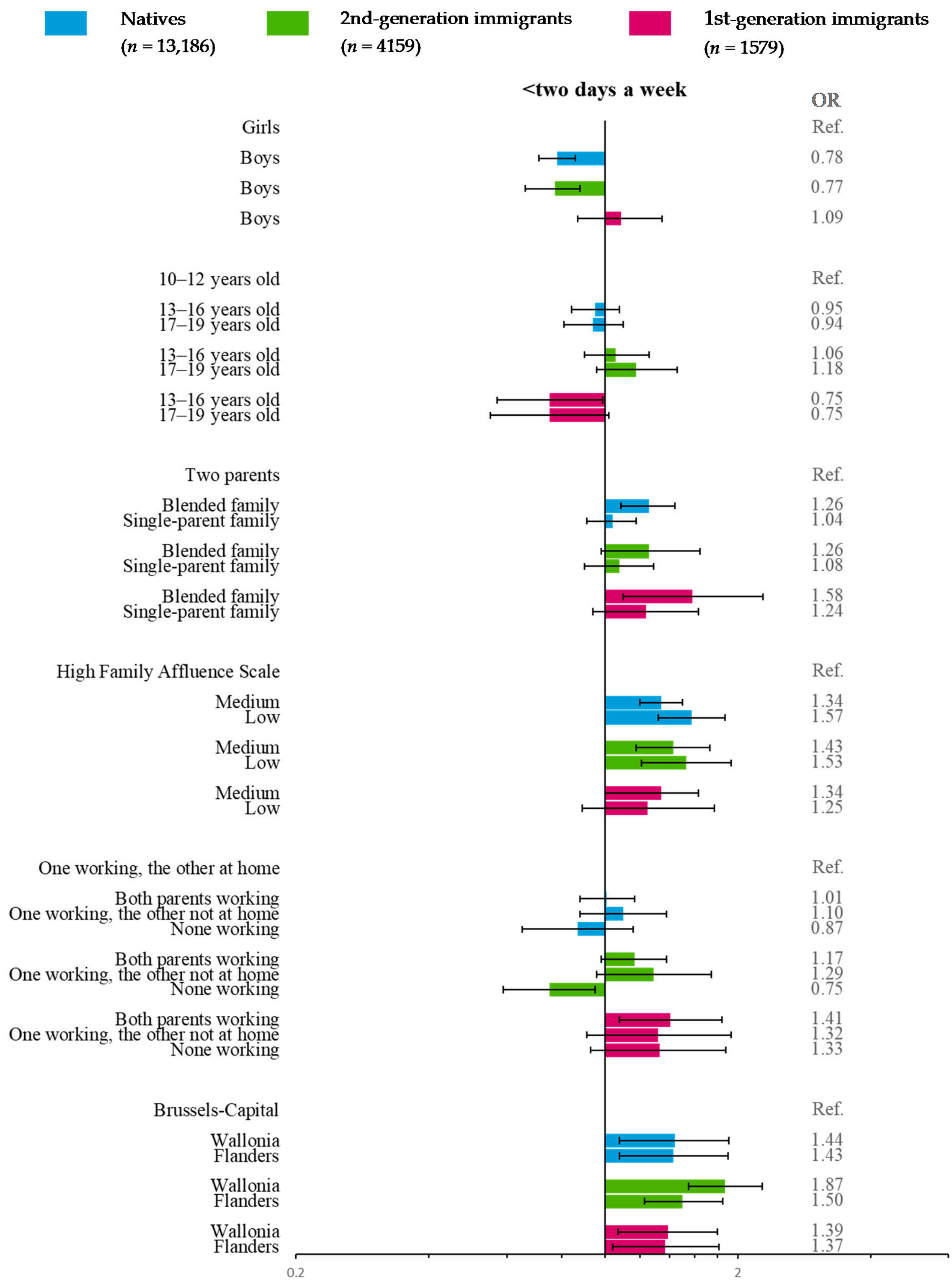


Figure 3. Multiple multilevel multinomial regression* for fruit consumption (reference category: >once a day) stratified by migration status—HBSC, Belgium, 2014 (*n* = 19,172). * RRR < 1: More favorable for health; RRR > 1: Less favorable for health.



RRR of school ***5–7 days a week*: *1.55 (1.12–2.15)*; *1.10 (0.79–1.54)*; *0.74 (0.43–1.27)*** ***<5 days a week*: *0.48 (0.33–0.71)*; *1.04 (0.73–1.47)*; *0.64 (0.36–1.11)***

Figure 4. Multiple multilevel multinomial regression* for vegetable consumption (reference category: >once a day) stratified by migration status—HBSC, Belgium, 2014 (n = 18,974). * RRR < 1: More favorable for health; RRR > 1: Less favorable for health.



OR of school *3.16 (2.28–4.36)*; *1.38 (1.05–1.81)*; *1.15 (0.75–1.76)*

Figure 5. Multiple multilevel logistic regression* for fish consumption (reference category: ≥two days a week) stratified by migration status—HBSC, Belgium, 2014 (*n* = 18,924). * OR < 1: More favorable for health; OR > 1: Less favorable for health.

3.4. Dairy Product Consumption (Reference Category: >Once a Day)

For all migration situations, neither FAS nor family structure nor parental working status was significantly associated with dairy consumption (Figure 6). Compared with Brussels-Capital, natives and 2nd-generation immigrants in Flanders were at significantly lower odds of consuming dairy foods ≤once a day (Figure 6).

In addition, dairy consumption frequency was significantly associated with gender in all migration strata and with age in natives and 2nd-generation immigrants, whereas the presence of siblings was significant only in natives. The school effect was significant in all migration strata (Figure 6).

3.5. Chips and Fries Consumption (Reference Category: <Once a Day)

Compared with those having a high FAS, natives with a low FAS were significantly more likely to declare frequent eating of chips and fries (≥once a day) (Figure 7). High frequency was also more likely in natives from blended or single-parent families than in those with two parents. Compared with adolescents having one working parent and the other who stayed at home, adolescents with two working parents were less likely to consume chips and fries ≥once a day whatever their migration status. In natives and 2nd-generation immigrants with no working parents, high frequency was more likely. In Flanders, compared to Brussels-Capital, adolescents among all migration groups were significantly less likely to declare high consumption of chips and fries; in Wallonia, this was also the case for 2nd- and 1st-generation immigrants (Figure 7).

In addition, frequent eating of chips and fries was significantly associated with gender in all migration strata, and with age in natives and 2nd-generation immigrants. Sibling presence was significantly associated only in 1st-generation immigrants. The school effect was significant in all migration strata (Figure 7).

3.6. Sugar-Sweetened Beverages (Reference Category: ≤Once a Week)

In natives and 2nd-generation immigrants, the odds of declaring very high SSB consumption (≥once a day) decreased with FAS (Figure 8). For all migration strata, adolescents from blended families were significantly more likely to declare very high frequency. In addition, natives from blended families were more likely to consume SSB at high frequency (2–6 days a week). In natives and 2nd-generation immigrants, very high SSB frequency was more often seen in adolescents from single-parent families (vs. two-parent families) and in adolescents with nonworking parents (vs. one working parent and the other at home) and was less likely in adolescents with both parents working. In 2nd-generation immigrants only, very high SSB frequency was also less likely in adolescents with one parent working and the other absent from the home. In Flanders, compared with Brussels-Capital, natives and 2nd-generation immigrants were more likely to consume SSB 2–6 days a week.

In addition, "gender and age" was significantly associated with SSB frequency in all migration strata, whereas "siblings" was significant only in natives. The school effect was significant only in natives (Figure 8).

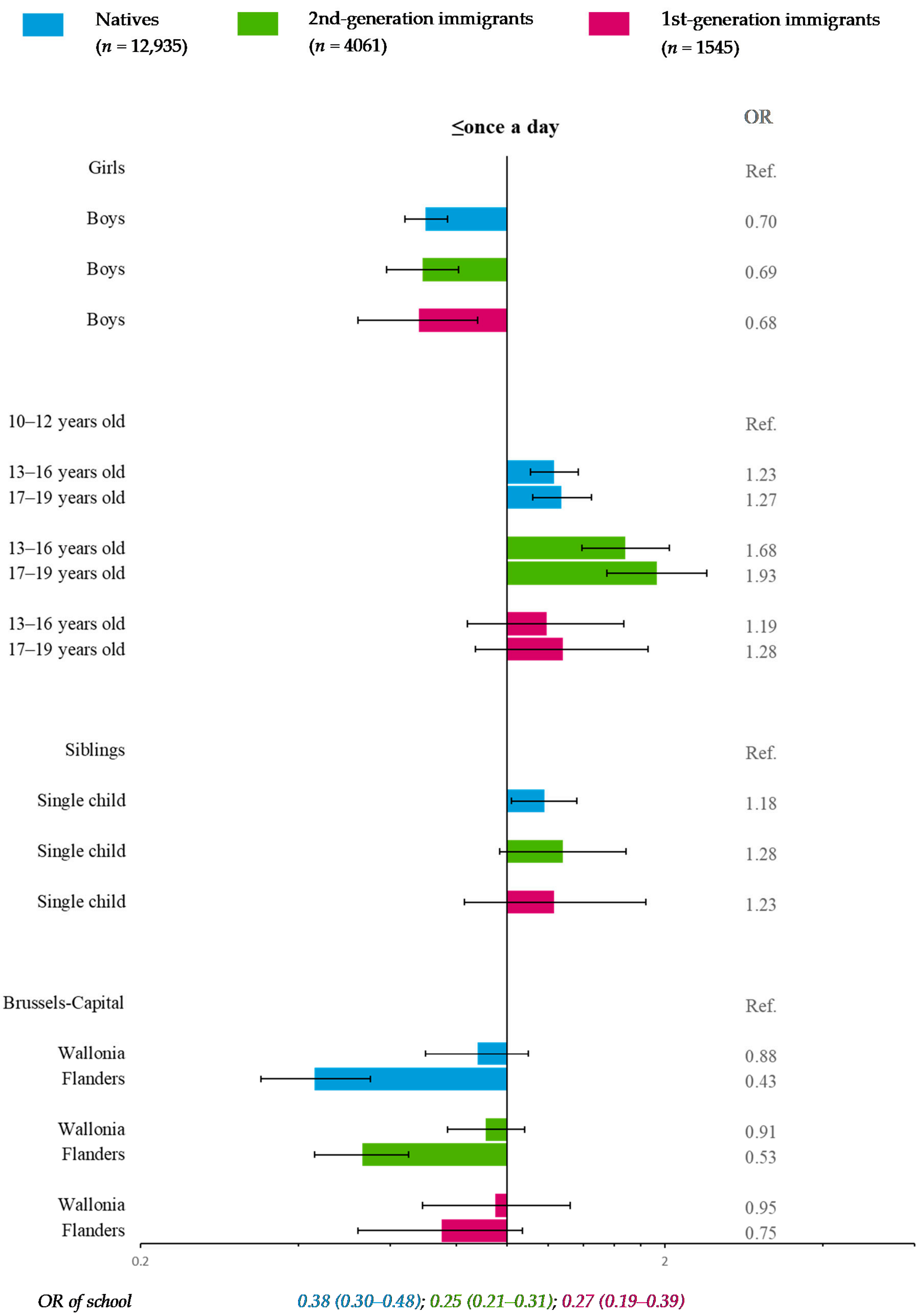


Figure 6. Multiple multilevel logistic regression* for dairy product consumption (reference category: >once a day) stratified by migration status—HBSC, Belgium, 2014 (n = 18,541). * OR < 1: More favorable for health; OR > 1: Less favorable for health.

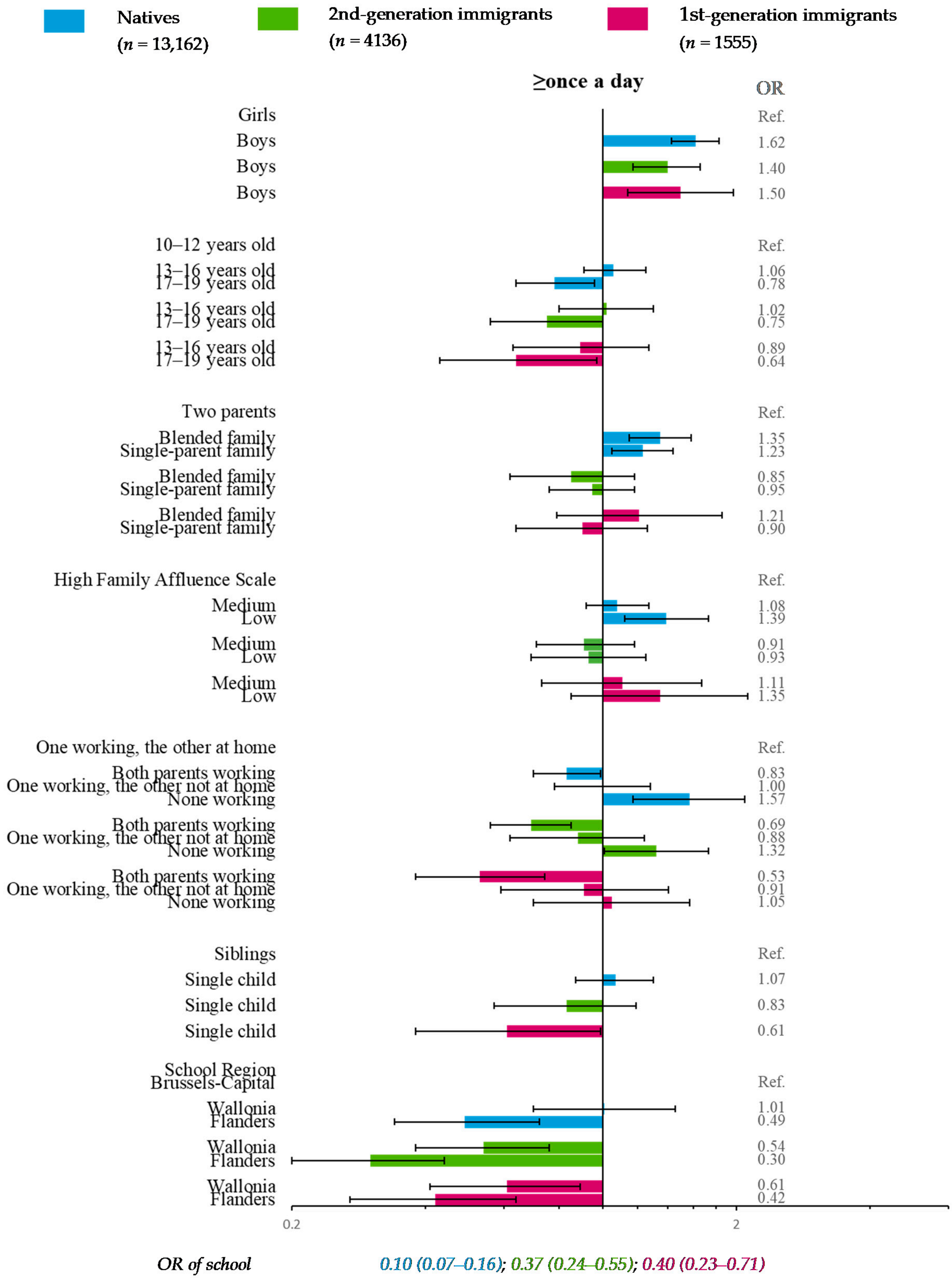


Figure 7. Multiple multilevel logistic regression* for chips and fries consumption (reference category: <once a day) stratified by migration status—HBSC, Belgium, 2014 (*n* = 18,853). * OR < 1: More favorable for health; OR > 1: Less favorable for health.

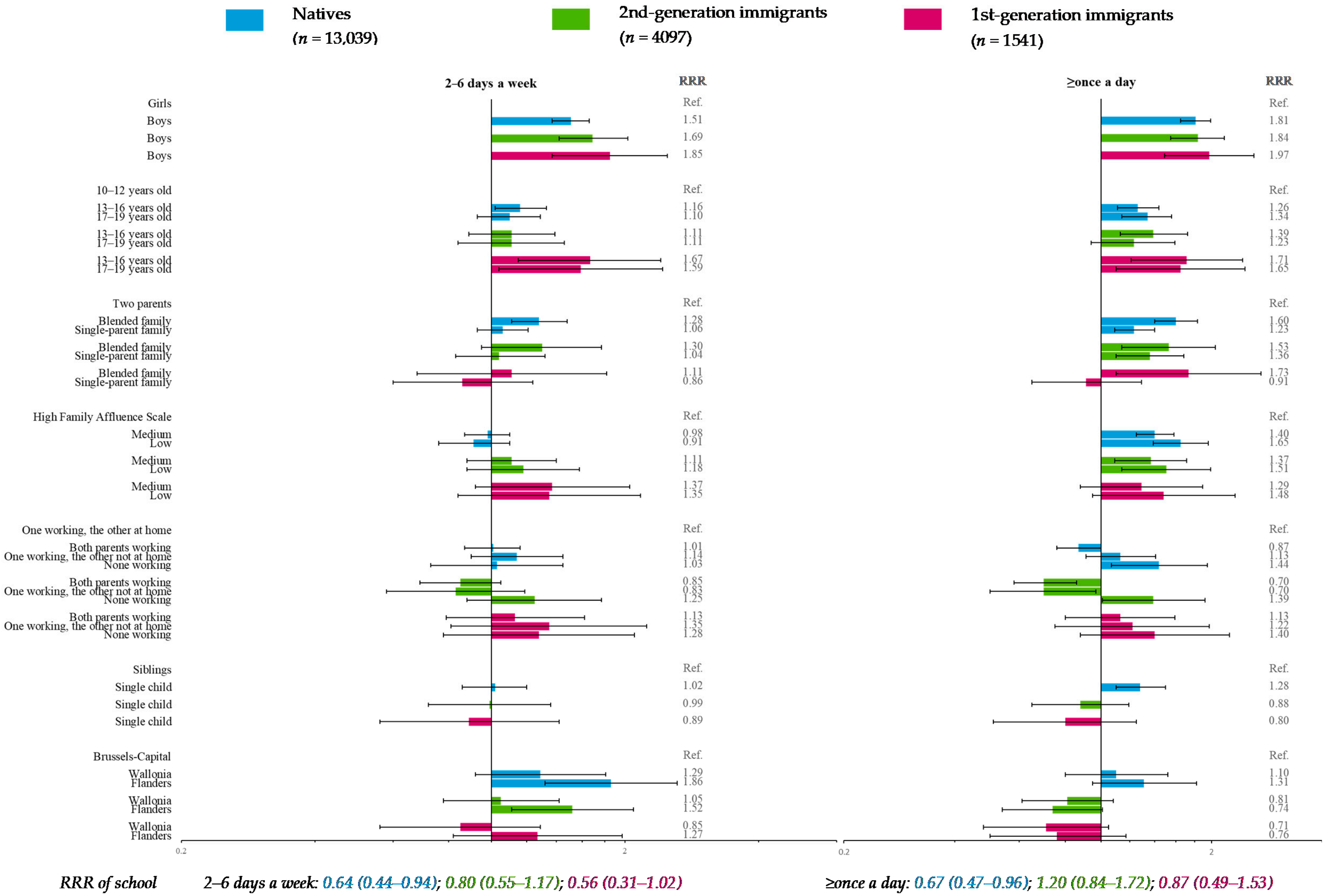


Figure 8. Multiple multilevel multinomial regression* for sugar-sweetened beverages consumption (reference category: ≤once a week) stratified by migration status—HBSC, Belgium, 2014 (*n* = 18,642). * RRR < 1: More favorable for health; RRR > 1: Less favorable for health.

4. Discussion

The aim of the present study was to estimate socioeconomic disparities in dietary habits of school adolescents in Belgium from different migration backgrounds. Our results emphasize that the migration component that was rarely considered in previous studies is fundamental regarding dietary behavior at these ages. Indeed, dietary habits differed according to migration strata. Furthermore, socioeconomic disparities varied amongst the migration groups: For all food groups, disparities were particularly wide in natives and more limited in 1st-generation immigrants. Overall, the sociodemographic and socioeconomic disparities observed in immigrants did not change after adjusting for their geographical area of origin. By food group, the widest socioeconomic and cultural disparities were observed for SSB and vegetables, and the least for dairy foods. Such findings provide interesting and original hypotheses that could further support the development of health promotion interventions in the future.

4.1. Dietary Acculturation

In descriptive analyses, immigrant adolescents, whether of the 1st or 2nd generation, were more likely to frequently consume both healthy (fruits, vegetables, and fish, but not dairy products) and unhealthy foods (chips and fries, SSB). In addition, a migration gradient in food frequencies was underlined for vegetables, fish, and chips and fries: Consumption gradually increased (for healthy food) or decreased (for unhealthy food) from natives to 2nd-generation immigrants, and from 2nd-generation immigrants to 1st-generation immigrants. However, no significant differences were found between 1st- and 2nd-generation immigrants regarding consumption of fruits, dairy products, and SSB.

The situation of 2nd-generation immigrants in terms of food consumption, intermediate between natives and 1st-generation immigrants, suggests ongoing acculturation. The interplay of host behavior and culture with that of immigrants may lead to a mixture of healthy and unhealthy dietary habits. Indeed, at a given age, 2nd-generation immigrants have probably been in Belgium much longer than 1st-generation immigrants and are therefore more likely to be further engaged in the process of integration of culinary habits of the host country and partial substitution of family roots, as reported for adults in different countries [18]. In addition to the migration generation, the region of origin may play differently in the acquisition of European dietary habits for immigrants. Indeed, differences in dietary habits were of lower size between European, American, and Asian, than between European and African and Middle-East immigrants. Nevertheless, the results could not be precisely interpreted due to the cultural heterogeneity remaining in this categorization by the geographical area of origin.

The acculturation process may depend on factors such as accessibility and affordability, acting as an "external push", and on individual factors such as curiosity, acting as an "internal pull" [28], which might encourage the adding of novel foods to the traditional diet, thus offering wider diversity. Such diversity could result in greater intake via gradual adaptation to new food products [29]. This may also explain why immigrants more frequently ate almost each food group studied. Maintaining traditional food habits implies the availability and accessibility of such food; when this is not the case, then people of foreign culture might progressively abandon their diet in favor of the host diet [30]. The acculturation process should also be further studied by considering the age of arrival in Belgium of the 1st-generation immigrants, unavailable in this survey.

4.2. Socioeconomic Disparities in Dietary Habits

Our results emphasize several socioeconomic disparities in dietary habits in adolescents, mainly in natives and 2nd-generation immigrants. Indeed, adolescents with lower FAS less frequently ate healthy foods like fruits and more frequently consumed unhealthy foods like SSB, consistent with previous studies [10,11]. These disparities may be explained by a lower level of familiarity or adoption of dietary recommendations by parents [31], and by the affordability of healthy foods [32].

Some disparities related to family structure were also revealed, mainly in natives and 2nd-generation immigrants. In line with previous studies [33,34], adolescents from blended or single-parent families more frequently ate chips and fries and SSB and less frequently ate fruits, vegetables and fish. Single-parent families often have fewer financial resources, thereby impairing their access to healthy foods [32]. Indeed, in our sample, 30.8% of adolescents belonging to a single-parent family were in a low FAS compared to 14.0% of adolescents from two-parent families and 15.7% of adolescents from blended families (data not shown). In addition, single parents may also have less time for monitoring meals compared to dual-parent families [33,35]. Adolescents from blended families also tended to have less healthy food habits than adolescents from two-parent families. Indeed, stepparents may have fewer opportunities for active involvement in their stepchildren's education and health [33].

Moreover, parental work status disparities were observed, mainly in natives and 2nd-generation immigrants. In our study, parental working status was mainly related to the socioeconomic condition: 10.2% of adolescents with both parents working had a low FAS, while 51.8% of adolescents with no parents working fell into this category ($p < 0.001$; 24.1% in those with one parent working and one at home, 31.5% for one parent working and the other "absent" from home). After adjustment for FAS and other covariates, our results related to parental working status were mixed. Indeed, compared to adolescents with both parents working, those with no working parents were more likely to frequently eat vegetables and fish, but they also more frequently ate chips and fries and SSB (data not shown). These results might appear surprising if we assume that parental working status is related only to socioeconomic conditions. However, they suggest an interplay between free time and work. Indeed, parental working status might also indicate that fully employed parents have less time to cook [36].

For all migration strata, eating habits varied according to the school region. Numerous differences were found in consumption frequencies between adolescents attending schools in Flanders, mainly Dutch-speaking, and those in Brussels and Wallonia, both primarily French-speaking. Another study indicating similar regional linguistic specificities in consumption of vegetables, dairy products, fish, and SSB in Switzerland hypothesized a possible influence of culture and eating habits of neighboring countries [37], which might also apply to Belgium: Culinary customs in Flanders may be strongly influenced by the Netherlands, while those in Brussels, although they do not border, and in Wallonia, may be influenced by France, which shares the same language, i.e., French. Further, several differences were pointed out between Brussels and Wallonia, mainly concerning 1st- and 2nd-generation immigrants. In 2011, nearly half of the inhabitants of the Brussels-Capital Region (42.4%) were born outside of Belgium, compared to 10.2% in Flanders and 14.1% in Wallonia [38]. Since the Brussels-Capital region is multicultural, this vast proportion of immigrants might contribute to slowing down the acculturation process; indeed, immigrants are usually surrounded by other immigrants [17]. By contrast, in Wallonia, such a process may have been accelerated, meaning that food habits in immigrants would differ from those of immigrants in Brussels.

Socioeconomic disparities were measurable in all food groups, except for dairy products, for which disparities were statistically significant only for the school region. The absence of socioeconomic disparities in consumption of dairy foods (milk, cheese, and other) could be explained by the diversity of these products and their overall affordability.

4.3. Sociodemographic Disparities in Dietary Habits

Our results underlined gender disparities in food consumption in almost all migration strata. Compared to boys, girls were more likely to more frequently eat fruits and vegetables, which could be explained by taste preferences [39,40], health beliefs, and greater concern about weight [41].

After adjustment for other covariates, sibling disparities continued to be unfavorable to the single child (except for chips and fries in 1st-generation immigrants). The sibling role in food consumption might be explained by two opposite phenomena: "Modeling" leads to imitation of the model (i.e., of the sibling), whereas "de-identification" leads to differentiation from the sibling [42]. The absence of sibling disparities in immigrants could be explained by the manner in which society views sibling relationships and their respective roles [43]. Thus, immigrants in our study might come from countries that do not promote sibling relationships. However, the sibling role has rarely been examined in dietary studies irrespective of migration status [44], thus preventing interpretation. Certain psychologists have suggested that older siblings may influence health behavior [45]; thus, birth order should be considered when evaluating the association between diet and siblings.

4.4. Strengths and Limitations

Due to the cross-sectional design of the HBSC survey and use of self-administrated questionnaires, a substantial sample size was obtained in each region of Belgium, along with a wide range of topics addressed. Although both Dutch- and French-speaking surveys were conducted separately and in different languages, standardization of the questionnaires according to the international HBSC protocol made it possible to combine data sets [23]. However, the two surveys were not identical. For instance, they were differently stratified in order to reach the representativeness of the linguistic regions. Therefore, the generalization of the results to the school population in Belgium should be interpreted cautiously. A second point related to the independence of studies is the use of reverse order categorization for food frequencies ("never" to ">once a day" for the Dutch-speaking survey versus ">once a day" to "never" for the French-speaking survey) may have contributed to lower frequencies of fruit and vegetable consumption in Flanders compared to Wallonia, since initial responses may have been chosen more frequently. This discrepancy could explain why we obtained results differing from the final national food consumption survey (based on 24-h recall) [46]. The short HBSC FFQ might also lead to inaccuracies due to use of large food group names rather than exact food names, and to the overestimation of consumption frequencies [25]. However, it has been validated in Belgium through a comparison with a seven-day record [24,25]. The conclusion was that it can be considered reliable for "ranking subjects according to consumption of the individual food items" [25]. In addition, we can only conclude about frequencies and the results must be interpreted as such given that a more frequent consumption does not necessarily imply—nor rules out—a higher food amount or a higher energy intake.

A significant strength of the current study was the use of multilevel analyses controlling for the school effect and, therefore, cluster bias. Nevertheless, further interpreting the school effect is difficult given that food-related school characteristics were unavailable in this study. To better understand such effects, further studies should simultaneously consider contextual characteristics of the schools, such as implementation of nutritional actions and canteen use. For some food groups (fruits, vegetables, and SSB), categorization was in three instead of two, as is the case in numerous studies using categorization and FFQ. Although disparities were narrower for the intermediate category and, therefore, little difference from the reference category was observed, intermediate categories provided new information in certain cases. Indeed, in natives and 2nd-generation immigrants, age-related disparities existed for vegetables 5–7 days a week but not for vegetables <5 days a week; in addition, school-region-related disparities existed for SSB consumption 2–6 days a week but not for SSB $\geq$once a day. Although difficult to interpret, the school effect for natives might be a protective factor for fruits 5–7 days a week and a risk factor for fruits <5 days a week.

Another limitation was the rather small sample size of 1st-generation immigrants (n_{max} = 1605), leading to fewer participants in some categories (n_{min} = 159) and resulting in loss of statistical power. However, confidence intervals of OR and RRR (Figures 3–8) suggested that nonsignificant results in 1st-generation immigrants were mainly due to fewer disparities rather than a lack of precision. This rather small sample size was also restrictive for in-depth analysis stratified by countries or continental regions of origin. To get around the small sample, results were subsequently adjusted for geographical areas of origin. Nevertheless, some cultural heterogeneity remained in this categorization and did not help to precisely interpret the findings.

Several biases could also be highlighted. First, adolescents may have overreported consumption of healthy foods and underreported consumption of unhealthy products due to social pressure [47]. Second, we observed differential distribution of fish and SSB consumption and of several covariates (migration status, gender, family structure, FAS, parental working status, and school region) between included participants and eligible participants not included in analyses due to missing data (Supplementary Table S8), leading to selection bias. Interpretation of results should thus be approached with caution, although some differences in percentages were slight, and statistical significance was mainly due to the large sample size. The generalization of the results is limited to the school adolescents, especially for the eldest beyond the legal school age (18 years of age in Belgium). It should also be interpreted cautiously due to the relatively low participation rate of schools.

5. Conclusions

Overall, rather poor adolescent dietary habits indicate that efforts should be made to improve knowledge and further prevent NCD in adulthood. The process of acculturation of dietary habits pointed out here warrants confirmation, taking into consideration the number of years in the host country and the age of arrival in that country. Narrower socioeconomic disparities in dietary habits among 2nd- and 1st-generation immigrants compared to natives suggest the prevailing role of culture in immigrant dietary habits with respect to socioeconomic conditions. Finally, our study reveals that interventions aimed at improving dietary habits in adolescents must take into account the cultural component of dietary habits, especially in immigrant adolescents. However, further research is needed to better understand the role of culture and its interaction with socioeconomic components in dietary habits.

Supplementary Materials: The following are available online at http://www.mdpi.com/2072-6643/11/4/812/s1, Table S1: Multilevel multinomial regressions for fruit consumption (reference category: >once a day) stratified by migration status—HBSC, Belgium, 2014 (n = 19,172), Table S2: Multilevel multinomial regressions for vegetable consumption (reference category: >once a day) stratified by migration status—HBSC, Belgium, 2014 (n = 18,974), Table S3: Multilevel logistic regressions for fish consumption (reference category: ≥two days a week) stratified by migration status—HBSC, Belgium, 2014 (n = 18,924), Table S4: Multilevel logistic regressions for dairy product consumption (reference category: >once a day) stratified by migration status—HBSC, Belgium, 2014 (n = 18,541), Table S5: Multilevel logistic regressions for chips and fries consumption (reference category: <once a day) stratified by migration status—HBSC, Belgium, 2014 (n = 18,853), Table S6: Multilevel multinomial regressions for sugar-sweetened beverages consumption (reference category: ≤once a week) stratified by migration status—HBSC, Belgium, 2014 (n = 18,642), Table S7: Multilevel logistic regressions* for food consumption stratified by migration status—HBSC, Belgium, 2014, Table S8: Comparisons of food consumptions, cultural, and sociodemographic characteristics between participants included in the analyses and those excluded due to missing data.

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3. Additional analyses

3.1. Socioeconomic characteristics of adolescents of different migration status

To help interpret the main findings of this chapter, the socioeconomic characteristics of adolescents were described according to their migration status for the French- and Dutch-speaking HBSC surveys of 2014 (**Table 9**). In addition, the description has been made through the years with the surveys of 1986 and from 2010 onwards (**Table 9**). The surveys from 1988 to 2006 were not described since adolescents were asked about nationality and not country of birth. In view of the large sample sizes, changes in characteristics have been commented on the basis of difference magnitude ("effect") and not of a statistical test. Finally, for a consistent comparison between surveys and since the Dutch-speaking 2014 survey did not include adolescents attending a Brussels school, the regional distribution only covers French-speaking data (Brussels-Capital and Wallonia).

In 2014, almost half of immigrants attended a school in Brussels-Capital region compared to less than a tenth of the natives. Regarding the family structure, immigrants were proportionally more likely than natives to live in a single-parent family, but less likely to live in a blended-family. Overall, for all other socioeconomic indicators, a migration gradient was observed. Indeed, the proportion of adolescents with a high or medium FAS decreased from natives to 2nd-generation immigrants and from 2nd-generation immigrants to 1st-generation immigrants. The proportion of adolescents with a low FAS increased from natives to 1st-generation immigrants, 2nd-generation immigrants also being in an intermediate position. Furthermore, one or no working parent families were more frequent in immigrants. However, a higher proportion of immigrants than that of natives reported for perceived family wealth to be well off or in the average. Finally, the parental education level was not available for this survey, but the results of the 2018 survey also highlighted a gradient, with a higher level in native adolescents.

Socioeconomic characteristics of adolescents with different migration status are relatively stable over the surveys. However, family structure has changed a lot, including a drastic decrease in two-parent families between 1986 and 2010, and a plateau afterwards. Nevertheless, these changes are of the same magnitude between the different categories of migration status. Moreover, among natives, the proportion attending schools in Brussels-Capital was stable between 1986 and 2018 surveys. However, among immigrants, the share enrolled in Brussels-Capital schools increased over the years.

In summary, even if the countries of origin of immigrants and the reasons why they emigrated may have changed,[75] the socioeconomic profile of adolescent immigrants remained similar over the years. The absence of major changes indicates that the 2014 survey did not stand out from the others. Furthermore, the analysis of the characteristics revealed a diversity of socioeconomic status among both natives and immigrants. Although immigrants have a generally lower socioeconomic status, differences in socioeconomic indicators between them and natives were of limited magnitude, with the exception of parental education and working status. Moreover, the hierarchical distribution of the different indicators was similar across the migration status groups.

These results complement the main findings on dietary disparities highlighted in the paper. As a reminder, narrower socioeconomic disparities were observed among immigrants compared to natives. These differences in disparities cannot therefore be explained only by socioeconomic differences between immigrants and natives, as even if their socioeconomic status differed, it was not to a great extent. On the contrary, dietary habits appears to not be driven by the same factors. Among natives, socioeconomic conditions appear to be a determining factor. In contrast, we assume that culture prevails over socioeconomic conditions in dietary habits of immigrants, especially those of the 1st-generation.

Table 9. Characteristics of adolescents (%) according to their migration status in the French-speaking 1986, 2010, 2014, 2018 and Dutch-speaking 2014 surveys.

	Natives					Second-generation immigrants					First-generation immigrants				
	1986	2010	2014		2018	1986	2010	2014		2018	1986	2010	2014		2018
			Dutch	French				Dutch	French				Dutch	French	
Family structure															
Two-parent family	86.9	64.4	**67.2**	**64.3**	61.1	86.1	64.4	**69.5**	**65.9**	65.1	88.0	58.2	**66.9**	**62.5**	62.6
Blended family	4.2	17.0	**14.8**	**16.8**	17.3	3.3	14.3	**9.5**	**10.1**	10.0	3.7	16.9	**13.6**	**11.3**	12.6
Single-parent family	8.9	18.6	**18.0**	**18.9**	21.6	10.6	21.3	**21.0**	**24.0**	24.9	8.3	24.9	**19.5**	**26.2**	24.8
Family Affluence Scale															
High	N/A	23.9	**21.2**	**19.8**	22.7	N/A	20.2	**18.6**	**16.0**	17.5	N/A	20.7	**18.5**	**14.8**	16.0
Medium	N/A	57.5	**66.8**	**64.5**	64.9	N/A	53.5	**60.8**	**58.9**	60.3	N/A	47.3	**58.3**	**50.4**	54.9
Low	N/A	18.5	**12.0**	**15.8**	15.4	N/A	26.3	**20.6**	**25.1**	22.2	N/A	32.0	**23.2**	**34.8**	29.1
Perceived family wealth															
Well off	N/A	9.3	**2.5**	**7.5**	13.8	N/A	10.4	**3.2**	**8.4**	15.8	N/A	11.2	**6.1**	**8.2**	16.2
Quite well off	N/A	43.3	**20.5**	**43.9**	52.1	N/A	40.6	**15.9**	**41.0**	47.9	N/A	35.1	**12.0**	**35.7**	45.0
Average	N/A	35.2	**65.7**	**35.2**	25.8	N/A	35.6	**65.0**	**37.2**	27.2	N/A	37.6	**62.0**	**40.9**	30.3
Not so/at all well off	N/A	12.2	**11.3**	**13.4**	8.3	N/A	13.4	**15.9**	**13.4**	9.1	N/A	16.1	**19.9**	**15.2**	8.5
Parental working status															
Both parents working	N/A	70.9	**79.4**	**70.8**	72.2	N/A	54.7	**55.3**	**48.2**	53.4	N/A	49.5	**52.2**	**41.1**	51.7
One working parent	N/A	24.6	**17.9**	**23.5**	22.6	N/A	34.9	**33.8**	**37.3**	36.5	N/A	35.9	**30.7**	**35.9**	36.4
No working parent	N/A	4.5	**2.7**	**5.7**	5.2	N/A	10.4	**10.9**	**14.5**	10.1	N/A	14.6	**17.0**	**20.0**	11.9
Parental level of education															
Post-secondary	N/A	N/A	**N/A**	**N/A**	43.0	N/A	N/A	**N/A**	**N/A**	35.1	N/A	N/A	**N/A**	**N/A**	32.2
Secondary or lower	N/A	N/A	**N/A**	**N/A**	22.0	N/A	N/A	**N/A**	**N/A**	26.2	N/A	N/A	**N/A**	**N/A**	24.3
Undetermined	N/A	N/A	**N/A**	**N/A**	35.0	N/A	N/A	**N/A**	**N/A**	38.7	N/A	N/A	**N/A**	**N/A**	43.5
School Region															
Brussels-Capital	8.9	7.5	**-**	**6.5**	10.9	20.5	30.6	**-**	**41.2**	40.4	29.2	30.7	**-**	**45.4**	46.9
Wallonia	91.1	92.5	**-**	**93.5**	89.1	79.5	69.4	**-**	**58.8**	59.6	70.8	69.3	**-**	**54.6**	53.1

3.2. Dietary habits and proportion of time spent in Belgium

The proportion of time spent in the host country is an indicator of food acculturation, which may reflect, among other influences, exposure to the host culture.[85] Therefore, the analyses of this section further explored the issue of acculturation highlighted by the migration gradient. The aim was to estimate the association between daily food consumption (fruit, SSB) and proportion of time spent in Belgium among adolescents attending French-speaking schools, while taking into account a set of socioeconomic indicators. Data came from the 2018 French-speaking HBSC survey, the age at arrival in Belgium being available since that survey only. The proportion of time immigrant adolescents had spent in Belgium was calculated by taking their age and age at arrival of 1st-generation immigrants and was categorised based on terciles: <46%, 46-81%, >81%. A proportion of 100% was attributed by default to 2nd-generation immigrants and natives.

No gradient in the proportion of time spent in Belgium was observed in the non-daily fruit consumption. Nevertheless, adolescents who had not spent their whole life in Belgium were less likely to consume fruit on a non-daily basis than those who had spent all their life in Belgium (percentage of life spent in Belgium <41%: OR= 0.76 (95%CI: 0.61-0.96); 46-81%: OR= 0.65 (0.51-0.81); >81%: OR= 0.66 (0.54-0.82)).

Similarly, no gradient was observed in the daily consumption of SSB. However, 1st-generation immigrants who had spent a small part of their life in Belgium were less likely to report daily SSB consumption than adolescents who had spent their whole life in Belgium (OR= 0.73 (0.58-0.91)). No statistical difference was found with 1st-generation immigrants who had spent a larger part of their life in Belgium (46-81%: OR= 0.87 (0.65-1.17); >81%: OR= 1.26 (0.98-1.63)).

To sum up, the process of acculturation among 1st-generation immigrants cannot be confirmed in both fruit and SSB consumption. Nevertheless, 1st-generation immigrants, regardless of their proportion of life spent in Belgium, more frequently consumed healthy food than 2nd-generation immigrants and natives. Adolescents who had spent a small part of their life in Belgium less frequently consumed unhealthy food than those who had spent their whole life in Belgium. Particularly in view of our sample size, these results must be confirmed with other food groups, especially those for which a clearer migration gradient had previously been highlighted, such as vegetables and crisps and fries.

4. Conclusion

This chapter aimed to assess dietary habits and related-socioeconomic disparities in adolescents of different migration status, through sub-objectives helping to fill the literature gap in. First, our results highlighted relatively poor dietary habits among adolescents, regardless of their migration status, and that are far from the Belgian dietary guidelines. Interestingly, compared to adolescents in other HBSC countries, Belgian adolescents are among the best ranked for fruit[176] and vegetables[177] but among the worst ranked for SSB consumption.[176]

Furthermore, our findings pointed out mixed dietary behaviours among immigrants living in Belgium, which may arise from the interplay of the host country behaviours and culture with those of immigrants.[178] Immigrants were more likely to consume unhealthy foods, such as crisps and fries or SSB, but they were also more likely to consume healthy foods like fruit, vegetables or fish.

A migration gradient was observed, with consumption gradually increasing for both healthy and unhealthy foods from natives to 2nd-generation immigrants, and from 2nd-generation immigrants to 1st-generation immigrants. This gradient suggested a process of acculturation among immigrants. During this process, it appears that immigrants changed their dietary habits to make them both more and less healthy, in contrast with the "best of both worlds" hypothesis.[75] However, we could not confirm that the proportion of time spent in the host country had a role in this acculturation process, as no gradient was observed among 1st-generation immigrants. The hypothesis regarding diet acculturation therefore deserves to be further investigated by additional analyses on other food groups, such as vegetables, whole grains or crisps and fries. Further analyses should also be carried out with other acculturation indicators such as acculturation scales or specific food-based assessment,[85] as long as they are adapted to the adolescent population.

Our analyses confirmed that migration status does modify the association between socioeconomic indicators and adolescents' dietary habits, as suggested by the literature on health status.[130] The results of the stratified analyses revealed significant differences in socioeconomic disparities between adolescents of different migration status. Indeed, compared to natives, narrower disparities were observed in 1st-generation immigrants, and to a lesser extent in 2nd-generation immigrants. Additional analyses have shown that immigrants and natives had equally varied socioeconomic profiles, with a generally lower status among immigrants although differences of limited magnitude with the natives were observed.

Altogether, these results suggest that the dietary habits of immigrants are more determined by the culture than by the socioeconomic conditions.

Thus, several socioeconomic disparities were underlined in dietary habits of natives, and to a lesser extent of 2nd-generation immigrants. In line with previous studies, adolescents with lower FAS[116,179] and living in single-parent families[180] tend to have less healthy dietary habits. Parental working status disparities were observed, also mainly among natives and 2nd-generation immigrants. The results related to this indicator were less consistent, suggesting that our four-categories indicator was probably related not only to socioeconomic conditions, but also to other concepts, such as meal preparation time. Finally, dietary habits varied according to the school region for all adolescents, regardless of their migration status. Regional differences in diet have already been highlighted among adults in Switzerland,[181] a country also characterised by several linguistic regions.

To conclude, a process of diet acculturation was highlighted in the dietary habits of adolescents. Immigrants' dietary habits are less subject to socioeconomic disparities than natives, suggesting the prevailing role of culture over the socioeconomic conditions among immigrants. As an application, interventions aimed at improving dietary habits of adolescents must take into account the cultural component of dietary habits.

CHAPTER IV. LONG-TERM TRENDS IN DIETARY DISPARITIES AMONG ADOLESCENTS

⁂

1. Introduction

The results of the 2014 HBSC survey globally highlighted poor dietary habits among adolescents, regardless of their migration status and socioeconomic status (**Chapter III**, **section 2**). Yet a set of actions has been developed in recent decades,[26–29,31,32] although not specifically targeted at adolescents. These actions have been implemented at local, regional, and national levels together, resulting in variable exposures within the population living in Belgium. Consequently, their evaluation is complex. One way to address their potential effect is to study long-term changes in dietary habits. Therefore, the first objective of this chapter was **to describe trends in the prevalence of three food groups that have been particularly subject to public health actions, i.e. fruit, vegetables and SSB, among adolescents in Belgium between 1990 and 2014**.

In addition, our previous findings confirmed that adolescents' dietary habits are determined by a set of factors. The public health actions can contribute to these disparities in a positive or negative way, in particular when regarding regional disparities. Indeed, the responsibility for health promotion has not always been under the authority of the same stakeholders (see **Chapter I**, **section 1.2.3.2, footnote d**). Health promotion was firstly under the language communities, with a Flemish decree in 1991[182] and a French decree in 1997.[183] With the Sixth State Reform for which an agreement was signed in 2011, health promotion has been decentralised from these language communities to the Regions.[184] As a result, actions' content may differ according to the place, leading to regional disparities that may have evolved differently over time.

These interventions may also have various impact on adolescents depending on their social position. Indeed, the societal context has changed. In Belgium, a major change in family structure has been observed in recent decades, with an increase in single-parent and blended families (see definition **Chapter II**, **section 2.2.2** and **Table 9**). Under these circumstances, we assumed that such societal context could have influenced dietary disparities. Therefore, the second objective of this chapter was **to determine how the dietary disparities related to the family structure and to the school region have evolved between 1990 and 2014**.

These two objectives have been addressed in the published paper presented in **section 2**. The supplemental materials of the paper are presented in **appendices I-K** of this doctoral thesis: (i) inclusion diagram of adolescents (**Appendix I**); (ii) food consumption and characteristics of participants by survey year (**Appendix J**); (iii) graphic representation of the prevalence of food consumption by survey year (**Appendix K**). Apart from this paper, the PAF was determined in order to be related to the RII and the SII (**Appendix L**).

In addition to changes in the family structure, the number of immigrants has increased in Belgium,[185] with varying countries of origin and reasons for migration.[75] As before, it is assumed that these changes may have an impact on dietary disparities related to the migration status. Thus, additional analyses were carried out for the Brussels-Capital Region, which comprises a high proportion of immigrants. The aim of these complementary analyses was **to determine how the dietary disparities related to the migration status have evolved between 1986 and 2014 in Brussels-Capital**. Results are presented in the text hereafter (**section 3**) and have not been published elsewhere.

2. Published paper: "Twenty-Four-Year Trends in Family and Regional Disparities in Fruit, Vegetable and Sugar-Sweetened Beverage Consumption among Adolescents in Belgium"

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Twenty-Four-Year Trends in Family and Regional Disparities in Fruit, Vegetable and Sugar-Sweetened Beverage Consumption among Adolescents in Belgium

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Abstract: Dietary habits are influenced by various determinants that may evolve over time. This study aimed to examine, among adolescents in Belgium, trends in the dietary habits between 1990 and 2014 and to determine changes in family and regional disparities related to diet during this time period. In the 1990, 2002 and 2014 cross-sectional "Health Behaviour in School-aged Children" (HBSC) surveys, food consumption was estimated using a short Food Frequency Questionnaire. The Relative Index of Inequality (RII) enabled quantification of the gradients of inequality related to the family structure and to the region for non-daily fruit and vegetable and daily sugar-sweetened beverage (SSB) consumption. Between 1990 and 2014, the prevalence of non-daily fruit consumption increased from 27.7% to 60.6%, whereas the daily SSB consumption decreased from 58.9% to 34.8%. Over time, a downward trend in family disparities ($p = 0.007$) was observed for daily fruit consumption (RII: 1.58 (1.33–1.88) to 1.18 (1.13–1.23)). An upward trend in region-related disparities ($p < 0.001$) for SSB was found (RII: 1.15 (1.07–1.23) to 1.37 (1.28–1.47)). The overall trend of increasing disparities when dietary habits improved and decreasing disparities when dietary habits worsened highlights the need to implement actions that improve overall dietary habits while ensuring that disparities do not increase.

Keywords: dietary habits; social disparities; trends; adolescents

1. Introduction

The dietary habits of adolescents may be determined by a set of individual factors [1], such as the family structure [2], and contextual factors [1], such as the region of a country [3]. Reducing such disparities may be translated into different policy actions, with the combination of these leading to more effective strategies [1].

However, family structure-related disparities in adolescents' dietary habits have been scarcely documented [4]. Adolescents from single-parent and blended families, i.e., composed of a biological/adoptive parent and a non-biological/adoptive parent, are more likely to have less favorable dietary habits compared to those from two-parent families [2,5]. This may be related to there being fewer financial resources for single parents, reducing their access to healthy food [6]. In addition, in blended families, step-parents may be less involved in the health education of their stepchildren [5].

Moreover, country region-related disparities in dietary habits have been highlighted in several studies [3,7,8]. For instance, in Switzerland, dietary habits in adults differed according to the linguistic region. One hypothesis was the cultural influence of the neighboring countries [8]. Similarly, in Belgium, adolescents in Flanders are more likely to have healthier dietary habits than those of the two other Belgian regions, i.e., Wallonia and Brussels-Capital [3,7]. Among other determinants, such disparities can be explained by the influence of the neighboring countries, especially for Flanders and Wallonia, and by different cultural [9] and economic [10] backgrounds and food supplies.

Furthermore, the societal context has changed and may have impacted the extent of disparities over time. The few studies on trends in dietary disparities mainly focused on beverages and ethnicity in the U.S. and highlighted persistent disparities [11,12]. Between 1989–1991 and 2007–2008, the consumption of fruit-based and soft drinks per capita intake increased along with disparities related to ethnicity among children [11]. However, between 2003–2004 and 2013–2014, ethnic disparities among children and adolescents regarding the typical intake of fruit drinks declined [12]. This example highlights the need to understand the evolution of such disparities. Indeed, public health initiatives should not only aim at improving the diet of the whole population (population-based approach) [13] or of those at the bottom of a social gradient (targeted approach) [14], but they should also aim to reduce disparities (proportionate universalism approach) [15].

For example, the changing societal context has resulted in a shift of the household structure in recent years. A change in marriage and divorce rates has resulted in an increase in single-parent and blended families [16]. This shift may have been accompanied by changes in the role of the step-parent in blended family structures. Additionally, the three administrative Belgian regions, which are federated entities, are Flanders (mainly Dutch-speaking), Wallonia (mainly French-speaking) and Brussels-Capital (both Dutch- and French-speaking). In recent years, health promotion has been decentralized under the responsibility of the regions. This may have resulted in variable exposure to public health messages regarding diet according to the region.

Under these circumstances, we assume that such societal context changes may have influenced dietary habits and related disparities. The aims of this study were twofold: (i) to describe trends in the prevalence of non-daily fruit and vegetable and daily sugar-sweetened beverage (SSB) consumption among adolescents in Belgium between 1990 and 2014 and (ii) to determine how the dietary disparities related to family structure or to school region have evolved during this time period.

This research is one of the first to investigate, in adolescents, trends over a long period of time regarding different social disparities in several food groups with appropriate methods for analyzing disparities over time. Through our two objectives, our findings might help identify key areas to improve current public health actions on both overall food consumption and related disparities.

2. Materials and Methods

2.1. Study

Since 1983–1984, the World Health Organization collaborative cross-national "Health Behaviour in School-Aged Children" (HBSC) survey has taken place every four years (in almost 50 countries at present) [17]. The survey aims to produce comprehensive indicators supporting the implementation of health promotion policies and interventions. The standardized research protocol has mostly been constant over the years, enabling the analysis of trends.

In Belgium, which is a regionalized country, the HBSC survey has been conducted independently in French-speaking schools since 1986 and in Dutch-speaking schools since 1990. Altogether, these surveys cover the three regions, namely Wallonia, Flanders and Brussels-Capital, with the latter including both French- and Dutch-speaking schools. The present research was based on the surveys conducted in 1990, 2002 and 2014 in French- and Dutch-speaking schools of the three regions.

Following advice from school authorities, no written consent was requested for French-speaking schools; for the Dutch-speaking schools, an opt-out consent process was implemented. For each survey, questionnaires were self-administrated in a classroom. Adolescents were clearly informed on the survey content and on their right to refuse the completion of the entire questionnaire or specific questions. All procedures used during data collection enabled confidentiality and anonymity.

2.2. Sampling

The sampling plans, developed in order to achieve representativeness of the estimators for each linguistic region, were based on a random sample stratified proportionally to the school networks and included public and private schools. In addition, depending on the survey, samples were stratified proportionally to the province and/or the type of education (general, technical, vocational, etc.). For each survey, schools from the mainstream school system were first randomly selected in each stratum based on an official list of all schools in Belgium. The sampling was repeated for each survey, regardless of whether or not some schools had participated in the previous survey(s). Then, one class from the fifth grade of elementary school (corresponding to adolescents aged ±10 years) to the final grade of secondary school (corresponding to adolescents aged ±18 years) was randomly selected in each grade among the schools participating in the study. In Flanders, several classes may have been selected when different types of education were available in the school. All adolescents in the selected classes were invited to participate over a period of approximately two months, regardless of their health status or social characteristics when they attended one of the participating schools.

In 1990, 2002 and 2014, data from 8866, 32,048 and 23,688 questionnaires were collected, respectively (Figure S1). Adolescents aged 20 or over (included only in French-speaking schools) were excluded. Participants with no missing data for all covariates and fruit consumption (i.e., the most frequently filled-in dietary variable) were included in the analyses. The rate of missing data ranged from 1.0% to 3.0%. Thus, the maximum number of adolescents included in the analyses was 8001 in 1990, 29,825 in 2002 and 21,939 in 2014 (Figure S1).

2.3. Measures

The HBSC questionnaire is available in two to three versions adapted to the adolescents' age. With regard to these analyses, the questions were exactly the same for all adolescents, regardless of their age.

A validated short Food Frequency Questionnaire (sFFQ) was used [18]—the most reliable tool that could be used given the conditions of data collection. Adolescents were asked how often they usually consumed 16 food groups in 1990 and 23 in 2002 and 2014. Fruits, vegetables ("cooked" and "raw" separately in 1990) and sugar-sweetened beverages (SSBs) were selected for the analyses. Five-answer categories were proposed in 1990 in the Dutch-speaking questionnaire—"every day"; "every week"; "every month"; "less than once a month"; and "never"—and in the French-speaking questionnaire—"more than once a day"; "once a day"; "at least once a week"; "rarely"; and "never". In 2002 and 2014, seven-answer categories were proposed in French- and Dutch-speaking schools: "more than once a day"; "once a day"; "5–6 days a week"; "2–4 days a week"; "once a week"; "less than once a week"; and "never".

The family structure variable was based on the people declared by the adolescents as living in their main house and, if applicable, in another house. Three categories were determined: "two-parent family" (adolescents living with both parents in the same house); "blended family" (those living with one parent and one step-parent); and "single-parent family" (those living with a single parent). Based on the address of the school, the school regions were (also referred to as) "Flanders" (Flemish), "Wallonia" (Walloon) and "Brussels-Capital" (Brussels).

2.4. Statistical Analyses

2.4.1. Reprocessing Data

All food group answers were categorized as "daily" and "non-daily" consumption in order to correspond, as closely as possible, to the Belgian nutritional recommendations [19], while also being determined by the original answer modalities. In all surveys (except for the 1990 Dutch-speaking assessment), daily consumption corresponded to a consumption of "more than once a day" and "once a day". In the 1990 Dutch-speaking survey, daily consumption corresponded to consumption "every day". All of the other answer categories corresponded to non-daily consumption. In order to focus on unfavorable consumption, dietary outcome was "non-daily" consumption of fruit and vegetables and "daily" consumption of SSB.

Presumed inequalities related to the family structure and to the school region were ranked based on prior hypotheses about the overall dietary pattern of adolescents [3,7]. It was found that two-parent families may be considered as more likely to have favorable dietary habits than single-parent families, with blended families in an intermediate position [7]. In fact, single-parent families may have unhealthier dietary habits, partly due to their limited money and time resources [6] impairing their financial access to healthy food and limiting their availability for preparing healthy meals. In addition, step-parents may be less involved in the nutritional education of children in blended families [5]. Accordingly, the ranking considered here was as follows: two-parent family, blended family and single-parent family. Regional disparities are less homogenous and can differ greatly according to the food group [3,7]. Overall, Walloon adolescents tend to have an intermediate position between Flemish and Brussels adolescents [3,7]. Regional differences may be due to a more or less healthy influence of neighboring countries on the regions [7,8] and different food and socioeconomic environments. In addition, Belgian and regional public health actions might have a different effect [3]. Thus, the retained ranking for the school region was Flanders, Wallonia and Brussels-Capital.

Following such a ranking, a modified ridit transformation [20,21] was distinctly applied to the family structure (model A) and to the school region (model B), and for each survey year, in order to obtain a ranking score x_i between 0 and 1. The family and regional ranks x_i were determined as follows for each family and regional category and for each survey year:

$$\frac{c_i + c_{i-1}}{2} \tag{1}$$

where c_i is the fraction of the population in the class i or lower (c_0 = 0 and c_i = 1) [21].

Hypothetical best-placed adolescents had a score equal to 0, while hypothetical worst-placed adolescents had a score equal to 1.

2.4.2. Modeling

Following Mackenbach and Kunst [22], the Relative Index of Inequality (RII) and the Slope Index of Inequality (SII) were used to quantify the gradient of inequality related to the family structure (model A) and to the school region (model B) in relative and absolute terms, respectively. The RII and SII are "the expected relative and excess risks comparing the hypothetical extremes of the scale under the log-linear and linear models, respectively, that best approximate the relation" [23] between the family structure or the school region and dietary habits. These measures are complementary, as relative inequalities and absolute inequalities can evolve in opposite ways, especially with high frequency of unfavorable consumption. Together, therefore, they provide a reliable overview of the situation and prevent wrongly concluding that inequalities have been reduced, for instance. Another advantage of these summary measures of inequality is that they take into account "both the population size and the relative [. . .] position of groups" [22].

(Non-)daily food consumption, expressed as prevalence, was assumed to depend on the notional regional and family ranks x and was denoted as $f(x)$ [21]. To estimate $f(x)$, a generalized linear model was used with a log link function to calculate the RII

$$[\frac{f(1)}{f(0)}] \quad (2)$$

and an identity link function to calculate the SII

$$[f(1) - f(0)] \quad (3)$$

where 0 is the "position of the hypothetical best-placed" adolescents and 1 is the "position of the hypothetical worst-placed" adolescents [23]. Given that the odds ratio estimated by logistic regressions could overestimate the prevalence ratios in cross-sectional studies, a Poisson regression with robust variance was used as a generalized linear model [24].

Following their definitions, the RII and SII can be interpreted as a rate ratio and a rate difference, respectively. An RII equal to 1 means no difference in relative inequalities and an SII equal to zero means no difference in absolute inequalities. A 95% confidence interval (95% CI), i.e., $\alpha = 0.05$, including 1 for the RII and 0 for the SII means that there is no difference in relative and absolute inequalities, respectively. An RII equal to x means that worst-placed adolescents are x-fold more likely to have a given food frequency consumption than best-placed adolescents. An SII equal to x means that worst-placed adolescents are x times more likely to have a given food frequency consumption than best-placed adolescents.

For each food group, crude RII and SII values were estimated for models A and B first. Secondly, RII and SII were adjusted for sex, age and school region (model A) or family structure (model B). Trends over time in RII and SII were estimated by including a two-way interaction term modified ridit score (based on family structure for model A and on school region for model B) by survey in the related model equation [25]. In the case where the evolution of RII and SII was quadratic, i.e., an extremum observed in 2002, a test for quadratic trend was performed (including survey year squared in the two-way interaction term).

Due to the substantial sample sizes, the significance of the differences in adolescents' characteristics was determined by the magnitude of the differences rather than the p-value. The significance of the RII and SII was based on the 95% CI, while for trends, the p-value of the two-way interaction term was used [25]. All analyses were performed using Stata/IC 14.2® (StataCorp, College Station, TX, USA).

3. Results

Characteristics of adolescents were considered to be stable over the years, except for the family structure (Table S1). "Single-parent" and "blended" families became more common over time. In addition, in 2014, compared to previous survey years, more adolescents from schools in Wallonia and less adolescents from schools in Flanders were included. Between 1990 and 2014, the prevalence of daily SSB consumption decreased, while the overall prevalence of non-daily fruit and vegetable consumption increased, with a slight decrease since 2002 (Figure S2).

3.1. Disparities Related to the Family Structure

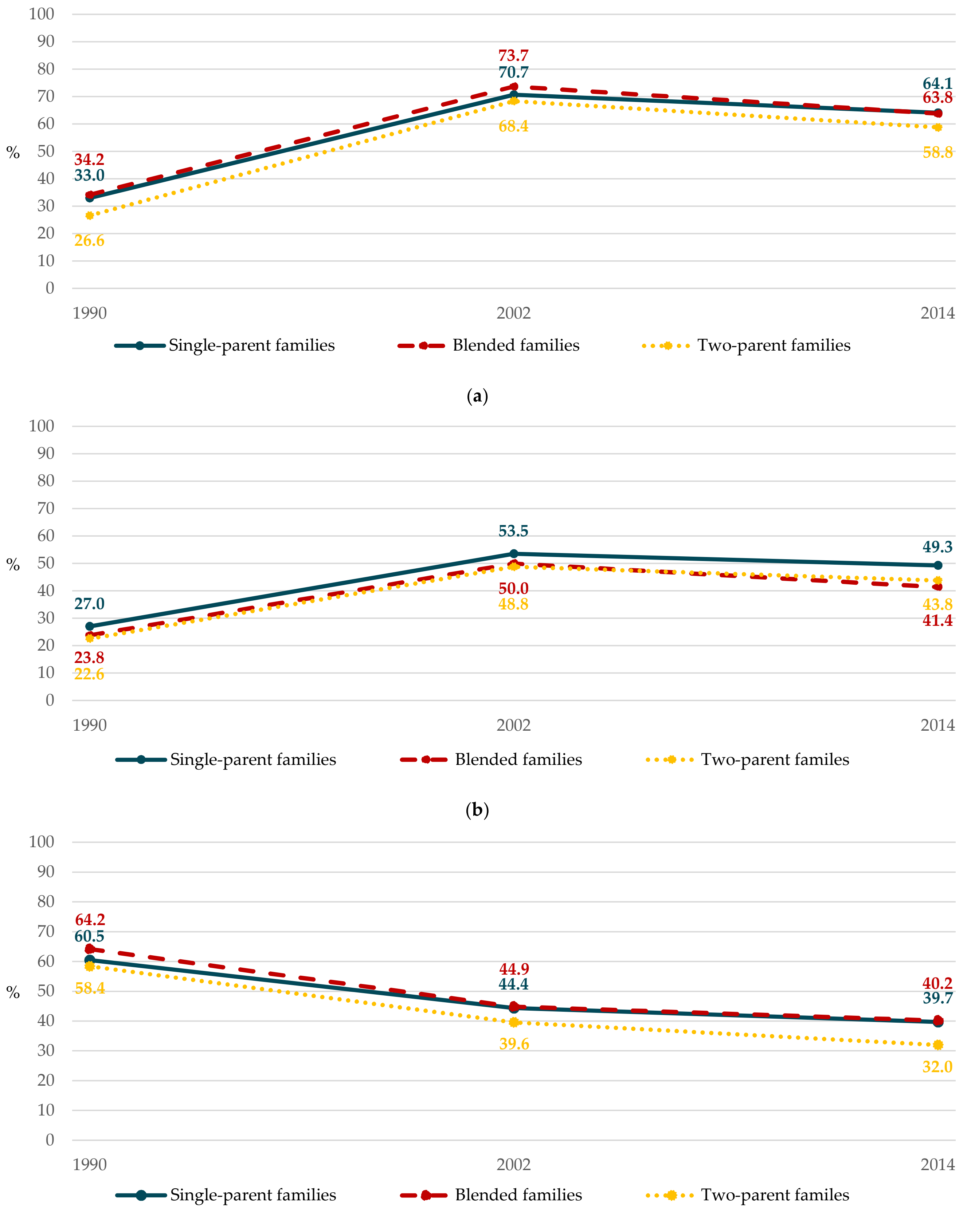
Over the years, disparities related to the family structure were observed for the three food groups, except for SSB consumption in 1990 (Table 1). For instance, in 1990, hypothetical worst-placed adolescents (i.e., from single-parent families) were 1.58-fold (95 %CI: 1.33–1.88) more prone to non-daily fruit consumption than the hypothetical best-placed (i.e., from two-parent families).

Table 1. Prevalence and Relative Index and Slope Index of Family Inequalities (RII-F and SII-F) of fruit, vegetable and sugar-sweetened beverage consumption among adolescents between 1990 and 2014 (HBSC, Belgium, 1990–2002–2014).

Family Structure	1990	2002	2014	*P* for Trend
Non-daily fruit consumption				
Single-parent family (%)	33.0	70.7	64.1	
Blended family (%)	34.2	73.7	63.8	
Two parents (%)	26.6	68.4	58.8	
cRII-F (95% CI) [1]	1.56 (1.32–1.86)	1.10 (1.06–1.14)	1.17 (1.13–1.23)	0.43 [a]
aRII-F (95% CI) [2]	1.58 (1.33–1.88)	1.15 (1.11–1.19)	1.18 (1.13–1.23)	0.007 [a]
cSII-F (95% CI) [1]	13.37 (7.82–18.92)	6.56 (4.10–9.02)	9.91 (7.26–12.55)	<0.001 [b]
aSII-F (95% CI) [2]	13.14 (7.59–18.70)	9.53 (7.04–12.03)	10.40 (7.72–13.08)	<0.001 [b]
Non-daily vegetable consumption				
Single-parent family (%)	27.0	53.5	49.3	
Blended family (%)	23.8	50.0	41.4	
Two parents (%)	22.6	48.8	43.8	
cRII-F (95% CI) [1]	1.35 (1.10–1.66)	1.14 (1.09–1.21)	1.15 (1.08–1.22)	0.26 [a]
aRII-F (95% CI) [2]	1.30 (1.06–1.60)	1.11 (1.06–1.17)	1.16 (1.09–1.23)	0.32 [a]
cSII-F (95% CI) [1]	7.30 (2.08–12.51)	6.80 (4.11–9.50)	6.10 (3.42–8.78)	0.68 [a]
aSII-F (95% CI) [2]	6.74 (1.54–11.94)	5.56 (2.84–8.28)	6.81 (4.11–9.50)	0.76 [a]
Daily sugar-sweetened beverage consumption				
Single-parent family (%)	60.5	44.4	39.7	
Blended family (%)	64.2	44.9	40.2	
Two parents (%)	58.4	39.6	32.0	
cRII-F (95% CI) [1]	1.10 (1.00–1.21)	1.26 (1.18–1.34)	1.51 (1.41–1.62)	<0.001 [a]
aRII-F (95% CI) [2]	1.08 (0.98–1.19)	1.27 (1.19–1.35)	1.47 (1.37–1.58)	<0.001 [a]
cSII-F (95% CI) [1]	5.87 (0.00–11.74)	9.70 (7.00–12.40)	15.05 (12.39–17.72)	0.001 [a]
aSII-F (95% CI) [2]	4.80 (−1.11–10.70)	10.10 (7.41–12.80)	14.34 (11.68–17.00)	0.002 [a]

[1] Crude Relative Index of family Inequality and Slope Index of family Inequality and their 95% confidence intervals; [2] Adjusted Relative Index of family Inequality and Slope Index of family Inequality for sex, age and school region, and their 95% confidence intervals; [a] *P* for linear trends; [b] *P* for quadratic trends.

Over time, a downward trend in family structure-related relative disparities ($p = 0.007$) was observed for non-daily fruit consumption. This was related to a differential increase in non-daily consumption according to the family structure between 1990 and 2014 (Figure 1a). Indeed, initially the biggest non-daily consumer group, adolescents from a blended family had the lowest increase in non-daily fruit consumption between 1990 and 2014. Conversely, adolescents from a two-parent family, i.e., the smallest non-daily consumer group in 1990, showed the highest increase in non-daily consumption. Considerable disparities for non-daily vegetable consumption were observed every survey year (Figure 1b); however, no trend ($p = 0.32$) was found. Conversely, a trend towards increasing disparities ($p < 0.001$) was observed for daily SSB consumption due to an increase in consumption differences between adolescents from different family structures (Figure 1c). Indeed, while they already had the lowest daily consumption, adolescents from a two-parent family experienced the largest decrease in daily SSB consumption. The smallest decrease in daily SSB consumption was observed among adolescents from a single-parent family.



(c)

Figure 1. Changes in prevalence of food consumption according to the family structure between 1990 and 2014 (HBSC, Belgium, 1990–2002–2014): (**a**) non-daily fruit; (**b**) non-daily vegetable; (**c**) daily sugar-sweetened beverage.

3.2. Disparities Related to the School Region

Regional disparities were observed for all food groups over the years, except for SSB consumption in 2002 and for vegetable consumption in 2014 (Table 2). In 2014, hypothetically worst-placed adolescents (i.e., in a school in Brussels) were 0.55-fold (95% CI: 0.52–0.57) more likely to have non-daily fruit consumption than hypothetically best-placed adolescents (i.e., in a Flemish school).

Table 2. Prevalence and Relative Index and Slope Index of regional Inequalities (RII-R and SII-R) of fruit, vegetable and sugar-sweetened beverage consumption among adolescents between 1990 and 2014 (HBSC, Belgium, 1990–2002–2014).

School Region	1990	2002	2014	*P* for Trend
Non-daily fruit consumption				
Brussels-Capital (%)	25.5	61.8	50.8	
Wallonia (%)	27.3	64.0	52.8	
Flanders (%)	28.6	74.4	72.7	
cRII-F (95% CI) [1]	0.87 (0.76–0.99)	0.74 (0.71–0.76)	0.54 (0.52–0.57)	<0.001 [a]
aRII-F (95% CI) [2]	0.83 (0.73–0.96)	0.73 (0.71–0.76)	0.55 (0.52–0.57)	<0.001 [a]
cSII-F (95% CI) [1]	−3.92 (−7.67–−0.17)	−20.75 (−22.76–−18.73)	−34.84 (−37.15–−32.53)	<0.001 [a]
aSII-F (95% CI) [2]	−4.19 (−7.94–−0.45)	−20.71 (−22.76–−18.67)	−34.68 (−37.03–−32.33)	<0.001 [a]
Non-daily vegetable consumption				
Brussels-Capital (%)	24.3	56.8	53.3	
Wallonia (%)	27.1	51.8	40.4	
Flanders (%)	20.0	46.4	46.9	
cRII-F (95% CI) [1]	1.57 (1.35–1.82)	1.31 (1.25–1.37)	0.97 (0.91–1.02)	<0.001 [a]
aRII-F (95% CI) [2]	1.55 (1.33–1.80)	1.29 (1.23–1.34)	0.99 (0.93–1.05)	<0.001 [a]
cSII-F (95% CI) [1]	11.07 (7.39–14.76)	13.43 (11.24–15.62)	−1.44 (−3.79–0.91)	<0.001 [a]
aSII-F (95% CI) [2]	11.38 (7.65–15.10)	12.65 (10.44–14.87)	−0.38 (−2.75–1.98)	<0.001 [a]
Daily sugar-sweetened beverage consumption				
Brussels-Capital (%)	64.0	41.1	41.2	
Wallonia (%)	59.2	40.4	35.5	
Flanders (%)	57.3	41.0	32.0	
cRII-F (95% CI) [1]	1.13 (1.06–1.22)	0.99 (0.94–1.04)	1.35 (1.26–1.45)	<0.001 [b]
aRII-F (95% CI) [2]	1.15 (1.07–1.23)	0.99 (0.94–1.04)	1.37 (1.28–1.47)	<0.001 [b]
cSII-F (95% CI) [1]	7.41 (3.32–11.49)	−0.55 (−2.72–1.62)	10.27 (7.89–12.66)	<0.001 [b]
aSII-F (95% CI) [2]	8.13 (4.00–12.26)	1.13 (−1.05–3.31)	11.03 (8.65–13.40)	<0.001 [b]

[1] Crude Relative Index of regional Inequality and Slope Index of regional Inequality and their 95% confidence intervals; [2] Adjusted Relative Index of regional Inequality and Slope Index of regional Inequality for sex, age and family structure and their 95% confidence intervals; [a] *P* for linear trends; [b] *P* for quadratic trends.

Throughout the years, a trend towards increasing disparities with time ($p < 0.001$) was observed for non-daily fruit consumption. This was related to a differential change in non-daily consumers according to the school region (Figure 2a). The lowest increase in non-daily fruit consumption was observed among adolescents from Walloon schools. Those from Flemish schools had the highest increase in consumption, although they were the largest consumer group in 1990. Interestingly, adolescents considered as better-placed, i.e., adolescents in a Flemish school, were more likely to have non-daily fruit consumption (RII < 1).

In addition, a trend towards decreasing regional disparities ($p < 0.001$) for non-daily vegetable consumption was found: the lowest increase in non-daily vegetable consumption was observed among adolescents in a Walloon school, while the highest increase was among those in a Flemish school (Figure 2b). Conversely, an upward trend ($p < 0.001$) was observed for daily SSB consumption. This increase was mainly due to the highest decrease among the initially smallest daily SSB consumer group, i.e., adolescents in a Flemish school, and the lowest decrease among the initially largest daily consumer group, i.e., adolescents in a Brussels-Capital school (Figure 2c).

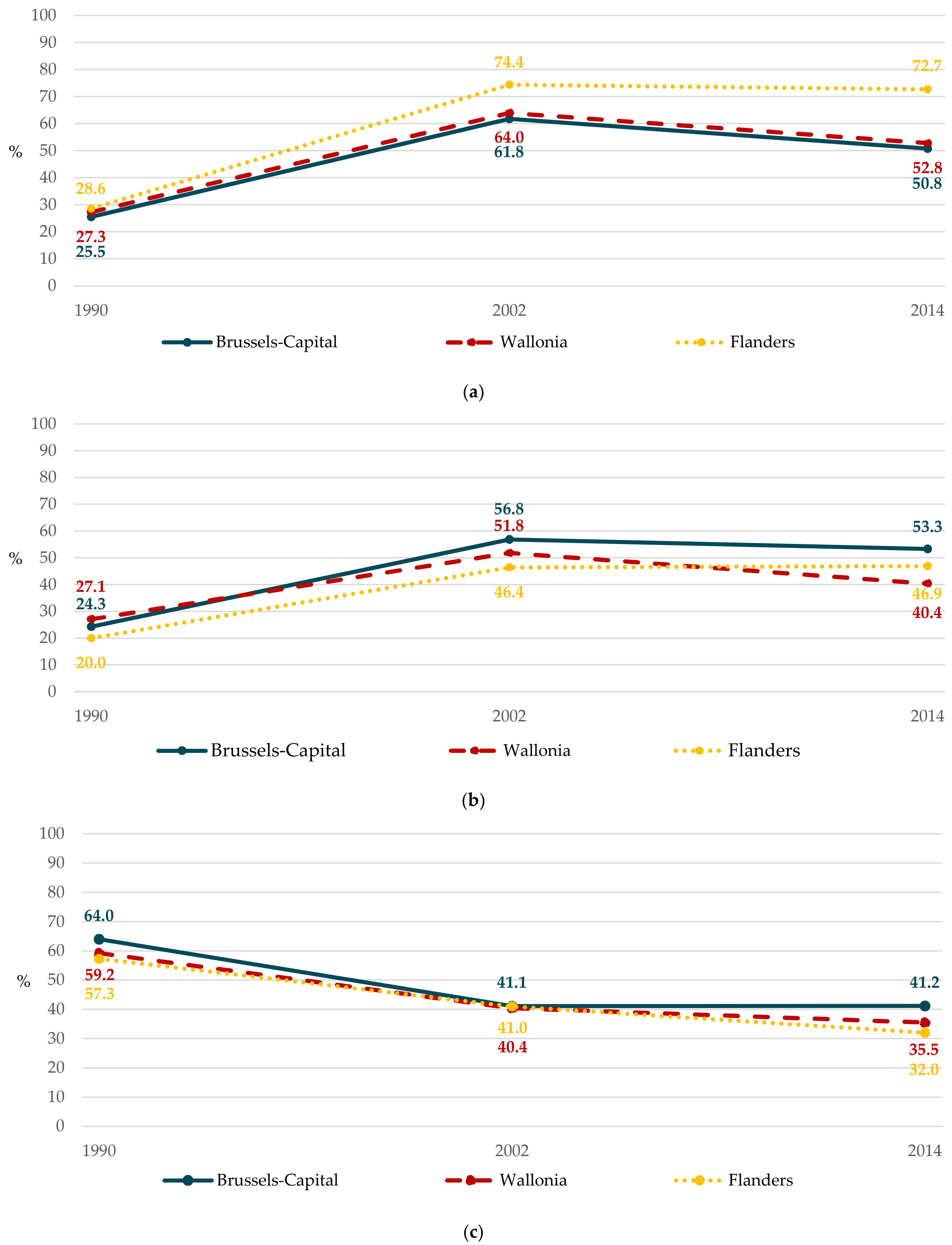


Figure 2. Changes in prevalence of food consumption according to the school region between 1990 and 2014 (HBSC, Belgium, 1990–2002–2014): (**a**) non-daily fruit; (**b**) non-daily vegetable; (**c**) daily sugar-sweetened beverage.

4. Discussion

Throughout the years, the overall prevalence of non-daily fruit and vegetable consumption increased (with a slight decrease since 2002), while family and regional disparities decreased, except for regional disparities for non-daily fruit consumption. In contrast, the overall prevalence of daily SSB consumption decreased, whereas family and regional disparities increased. The major changes in food consumption were mainly observed between 1990 and 2002. This is most likely due to the characteristics of the adolescents and their environment rather than to methodological issues (as discussed below).

To the best of our knowledge, few studies have investigated trends in dietary habits, especially in adolescent populations [12,26–28] and covering such a long period (>20 years) [28], thus limiting their comparability. The prevalence of non-daily fruit and vegetable consumption doubled between 1990 and 2002 and slightly decreased thereafter, in line with the literature, which highlighted a similar trend for fruit consumption [27]. In addition, the HBSC reports (starting in 1993–1994) confirmed an increase in non-daily fruit and vegetable consumers between the 1990s and early 2000s [29–31]. Not eating fruit and vegetables regularly may be due to the unpleasant taste perceived by some adolescents compared with more palatable foods and to practical constraints such as washing, peeling or cooking before consumption compared with ready-to-eat snacks [32]. Fruit, frequently eaten as a snack/dessert, could be replaced by more attractive foods [32], such as biscuits or milky desserts. Furthermore, adolescents may have progressively replaced fruit and vegetables with various industrial processed ready-to-eat fruit-based or vegetable-based foods, such as applesauce or composite dishes. Adolescents may not identify such foods as a consumption of fruit or vegetables and may consequently underreport their consumption when filling out a short FFQ, such as in the HBSC survey. Between 2002 and 2014, the observed small decrease in non-daily fruit and vegetable consumers could partly be explained by public health efforts regarding such foods resulting in a possible increased awareness of the general population on their benefits [33].

The proportion of daily SSB consumers decreased by almost half between 1990 and 2014, with most of the decrease being observed between 1990 and 2002. The observed decrease in daily SSB consumers is in line with most of the HBSC countries since 1998 [30,31,34] (information was not available in the 1993–1994 international HBSC report). Previous studies in the US [12,26] have also highlighted a decline in SSB intake since 1990. For years, policy stakeholders and health professionals have advised the public to limit intake of sugary drinks due to their association with various negative health outcomes [35]. In addition, this warning has potentially pushed industries to progressively market artificially sweetened beverages (ASBs). Although the potential adverse effects of these drinks on health have recently been underlined [36], ASBs were suggested as substitutes for sugary drinks due to their low calorie content. As a result of both the awareness on SSBs and the development of ASBs, adolescents could have substituted SSBs for ASBs [37], which would explain the decrease in SSB consumption between the 1990s and the early 2000s. However, this hypothesis cannot be verified with our data, as the question regarding ASBs was not included until 2002 in the Dutch-speaking schools and 2006 in the French-speaking schools.

To our knowledge, no study has analyzed trends in family and regional disparities regarding dietary habits, thus limiting comparison. Nonetheless, to understand the reasons behind the changes and to provide tools to implement public health initiatives, potential causes of disparities are discussed.

Single-parent families, often with fewer financial resources (one-third had a low family affluence scale (FAS) [38] in 2002 and 2014 compared to one in six for other family structures), may have adopted the new dietary recommendations more slowly than other family structures did, including the limitation of SSB consumption. Indeed, income is associated with adherence to nutritional recommendations [39]. In addition, these families may have been less likely to substitute SSBs for ASBs due to the slightly higher average price of the latter [40]. Moreover, in recent years, blended families have become increasingly frequent at the expense of two-parent families. In Belgium, the share of blended families was less than 5% in 1990, while it was almost 10% in 2002 and 15% in 2014. Since step-parents are usually less active and involved in the education and the health of the children [5], we assumed that the increase in the blended family structure could have led to a shift in the role of step-parents, resulting, in turn, in a change in the families' dietary habits. In addition, adolescents from blended families reported a higher FAS in 2014 compared to 2002 (84.3% had a medium or a high FAS in 2014 vs. 79.3% in 2002). Therefore, healthy foods, such as fruits and vegetables, may have become more affordable [6] over the years for a greater proportion of blended families.

In recent years, in Belgium, the change in federated entities responsible for health promotion led to different campaigns and interventions being implemented in the regions, in terms of messages, target population, dissemination or intensity. In addition, the effectiveness of these actions may be different given that the responsiveness could be culturally influenced [11]. Our results suggest that public health initiatives focusing on fruit and vegetable consumption were less effective in the Flemish population than they were in other regions, while those for SSB consumption were more effective in Flanders. In addition, we assumed that the food supply and the culture-related behaviors, which are complex to evaluate, may have changed differently over the years depending on the region, but this requires further examination. Furthermore, the regional changes in food consumption were also similar to the changes observed in neighboring countries, i.e., in France between 1993–1994 and 2013–2014 [29–31] and in the Netherlands between 2001–2002 and 2013–2014 [30,31]. Indeed, a higher increase in non-daily fruit consumption and a higher decrease in daily SSB consumption were observed in the Netherlands compared to France, confirming the influence of neighboring countries. However, no similarity for vegetable consumption was observed with neighboring countries [30,31]. The imbalanced increase in non-daily vegetable consumers resulted in a homogenization of behaviors in Belgium.

A major strength of our study was the long retrospective period (24 years), with repeated and similar assessments of dietary habits. This enabled to highlight trends that would have been different compared to a shorter timer period that would have only started in the 2000s. However, some characteristics could not be used because they were not comparable across the surveys or were not yet developed, such as the Family Affluence Scale [38]. In addition, the food groups available for analyses since 1990 were rather limited, but the selected groups are amongst the most important in terms of health [35] and have particularly been subject to public health actions. The long-term assessment led to a potential bias related to the small differences between the questionnaires. Indeed, the number of response categories increased from five to seven, and some foods were grouped together ("raw" and "cooked" vegetables into one category) or specified (sugar- and non-sugar-sweetened beverages were more clearly differentiated). These changes should not cause a major methodological issue [27] and, therefore, are unlikely to be responsible for the major changes occurring since the 1990s. Nevertheless, they may be responsible for a slight overestimation of the consumption of vegetables in 1990, for instance. The initial response categories also prevented a more accurate categorization of food consumption in relation to the dietary recommendations. Furthermore, the large sample size led to a gain in statistical power but did not hinder the confidence in tests for trends based on interaction terms. The methodology used to evaluate the disparities has the advantage of considering whole regional/family distribution and not only the extreme groups as is the case in classic comparisons. Indeed, social inequalities cannot be reduced on the extremes of the social hierarchy. Actions, especially those directed at high-risk populations, could shift the risk to intermediate groups. Therefore, meaningful information on the changes in disparities would have been missed with classic measures. Furthermore, thanks to the x-rankings of the family and the regional distributions, these indices allow valid cross-population comparisons [23]. However, although the changing structure of the population is taken into account, their disadvantage is that they do not actually capture a possible change in the structure of the population. These measures must, therefore, be complemented by the population attributable factor. Indeed, the change in disparities was a genuine change and was not due to changes in the population structure (data not shown). Finally, in order to facilitate the interpretation of the findings, the same category order based on prior assumption of the overall dietary pattern [3,7] was kept throughout the analyses. However, depending on the year and the food group studied, the ranking of family structure and school region categories may be somewhat different. Given the small differences observed, keeping the original order only led to a slightly lower accuracy of these estimates.

5. Conclusions

In summary, increasing disparities were observed when dietary habits improved, whereas decreasing disparities were observed when dietary habits worsened. This trend is to be confirmed with other food groups, e.g., whole grains or animal protein foods such as dairy or meat, although the consistency of our results for the three food groups suggests that the same trend will be observed. Furthermore, changes in other significant determinants of dietary habits, such as socioeconomic or migration status, must be studied when available.

While it was suspected and hypothesized, this is the first time that such a figure has been demonstrated for several indicators and food groups and over a long period of time. Our results underline that public health actions in Belgium have, thus far, failed to both improve dietary habits and tackle social inequalities, possibly due to a counterproductive environment such as intensive marketing of unhealthy foods. Furthermore, our study confirms that interventions regarding dietary habits must better mobilize the concept of proportionate universalism, i.e., improving dietary habits proportionally to the degree of needs. More practically, actions should take into account the specificities, needs and access barriers to a healthy diet of different sub-populations in order to be universal, but with an intensity that depends on the level of disadvantage. Thus, improved affordability of healthy foods and including a cultural component in actions could help improve the dietary habits of adolescents while reducing family- and regional-related inequalities, respectively.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/ijerph18094408/s1, Figure S1: Inclusion diagram of adolescents in Belgium (HBSC, 1990–2002–2014); Figure S2: Prevalence of food consumption by year of survey (HBSC, Belgium, 1990–2002–2014); Table S1: Food consumption and characteristics of participants in percentages by year of survey (HBSC, Belgium, 1990–2002–2014).

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Institutional Review Board Statement: This survey was carried out according to guidelines articulated in the Declaration of Helsinki. For Dutch-speaking schools, the study was approved by the ethics review committee of the University Hospital of Ghent (for the 2013/2014 survey: project EC/2013/1145). For French-speaking schools, the survey was approved by school authorities. This protocol was not submitted to a medical ethics committee in view of the topics and methods used for data collection (Belgian law of 7 May 2004 and Advisory Committee on Bioethics of Belgium, opinion n°40, 12 February 2007).

Informed Consent Statement: Following advice from school authorities, no written consent was requested for French-speaking schools; for the Dutch-speaking schools, consent was passive. For all surveys, adolescents were clearly informed about the survey content and about their full right to refuse to fill out the questionnaire or answer specific questions. All procedures used during data collection enabled confidentiality and anonymity.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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3. Additional analyses on the Brussels-Capital Region

These additional analyses aimed to determine how the dietary disparities related to migration status have evolved between 1986 and 2014 in the Brussels-Capital Region, which includes a high proportion of immigrants from very various backgrounds. The data came from three waves of French-speaking surveys: 1986, 2010 and 2014. The gap in years between the first two selected surveys is due to the fact that migration status was not available between these two surveys, when adolescents were questioned about their nationality rather than their country of birth. The Dutch-speaking surveys were not taken into account here as adolescents from Dutch-speaking schools in the Brussels-Capital Region were not included in the sampling.

In total, 3,458 adolescents were included in analyses, 417 in 1986, 1,096 in 2010 and 1,945 in 2014. The same methodology as the main analyses of this chapter was followed (see **section 2**). Three food groups categorised in daily and non-daily consumption were considered: fruit, vegetables and SSB. The RII and SII were used to quantify the gradient of inequality related to the migration status. In this respect, the migration status was ranked according to prior hypotheses on dietary behaviours, mainly drawn from our previous results (**Chapter III**, **section 2**). Thus, the ranking was as follows: natives, 2nd-generation immigrants, and 1st-generation immigrants. Note that the ranking was disordered for certain food groups and survey years. Nevertheless, with the exception of fruit in 1986 and SSB in 2010, the proportion of 2nd-generation immigrants with unfavourable consumption was close either to that of natives or to that of 1st-generation immigrants, which should not affect the RII and SII interpretation in a consequent way. For further interpretation of these measures of inequalities, the PAF was determined and is presented together with the RII and SII and their evolution over time in **Table M-1**.

Overall, prevalence of non-daily consumption of healthy foods (fruit and vegetables) increased between 1986 and 2010, and then stabilised, regardless the migration status of adolescents attending schools in Brussels-Capital (**Table 10**). The proportion of adolescents of all migration status who daily consumed unhealthy foods (SSB) decreased between 1986 and 2010, then increased in 2014 (without, however, reaching the 1986 proportion again).

No significant relative or absolute disparities related to migration status were observed for fruit. By contrast, disparities were observed for vegetable consumption throughout the survey years. For instance, in 2014, hypothetical worst-placed adolescents (i.e. close to 1st-generation immigrants) were 1.40-fold (95%CI: 1.18-1.65) more likely to consume vegetables on a daily basis than hypothetical best-placed (i.e. close to natives). Finally, while no significant relative or absolute migration-related disparities were observed for SSB in 1986 and 2010, significant disparities appeared in 2014.

No trend was observed for fruit and SSB consumption. However, a trend toward decreasing absolute inequalities was sizeable for vegetable consumption ($p = 0.02$). The PAF suggests that between 2010 and 2014 the decrease in inequality may be partly due to a change in the structure of the population. However, it confirms that, overall, the observed fall in inequality is a genuine reduction and thus, cannot be completely due to the increasing number of immigrants in Brussels-Capital Region. Further analyses should be carried out on larger samples, in particular to confirm the lack of disparities and trends, as well as the impact of changing population structure, and to investigate migration-related disparities in other food groups.

In summary, while the number of immigrants has increased, and their origins as well as reasons for coming in the Brussels-capital Region have changed, the consumption of fruit has overall evolved in a similar way between natives and immigrants. In addition, no migration-related disparities were observed for this food group. Conversely, different trends according to migration status were noted for vegetables, resulting in changes in disparities. Indeed, a decrease in disparities was observed in vegetable consumption since 1986, whereas the proportion of non-daily vegetable consumption increased. Therefore, actions directed at vegetables must ensure that they improve the overall frequency of vegetable consumption and continue not to increase inequalities. Regarding unhealthy foods, while an overall decrease in non-daily SSB consumers was observed between 1986 and 2014, an increase was observed between 2010 and 2014, and disparities related to migration status appeared in 2014. These findings suggest that public health actions implemented in recent years seem to have been ineffective, probably partly as a result of intensive private marketing of SSB. Finally, the trend of increasing inequalities when dietary habits improved and decreasing inequalities when dietary habits worsened that have been observed in Belgium with regard to family structure and school region, was partially retrieved when addressing the migration status in Brussels.

Table 10. Prevalence and Relative Index (RII) and Slope Index of Inequalities (SII) related to migration status in fruit, vegetables, and sugar-sweetened beverages consumption among adolescents between 1986 and 2014. HBSC, French-speaking Belgium, 1986-2010-2014.

	1986	2010	2014	*P* for trend
Non-daily fruit consumption				
1st-gen. imm. (%)	26.8	48.3	47.9	
2nd-gen. imm. (%)	19.9	49.8	47.7	
Natives (%)	28.8	45.2	50.6	
cRII (95% CI)[1]	0.66 (0.34-1.28)	1.13 (0.90-1.43)	0.93 (0.78-1.11)	0.99
aRII (95% CI)[2]	0.68 (0.35-1.35)	1.15 (0.91-1.45)	0.90 (0.75-1.07)	1
cSII (95% CI)[1]	−9.46 (−24.23-5.31)	6.15 (−5.35-17.66)	−3.44 (−11.89-5.01)	0.84
aSII (95% CI)[2]	−10.43 (−25.38-4.53)	7.63 (−4.19-19.45)	−4.84 (−13.41-3.74)	0.81
Non-daily vegetable consumption				
1st-gen. imm. (%)	37.5	56.6	54.9	
2nd-gen. imm. (%)	19.9	55.5	54.9	
Natives (%)	10.3	44.2	40.8	
cRII (95% CI)[1]	6.23 (2.74-14.17)	1.46 (1.17-1.82)	1.43 (1.21-1.69)	0.02
aRII (95% CI)[2]	6.46 (2.81-14.87)	1.46 (1.17-1.82)	1.40 (1.18-1.65)	0.02
cSII (95% CI)[1]	29.91 (16.41-43.42)	20.33 (8.54-32.11)	19.83 (10.47-29.19)	0.14
aSII (95% CI)[2]	29.74 (15.92-43.56)	20.80 (8.65-32.95)	19.03 (9.54-28.51)	0.15
Daily sugar-sweetened beverage consumption				
1st-gen. imm. (%)	60.7	24.4	40.4	
2nd-gen. imm. (%)	57.8	32.6	41.8	
Natives (%)	59.5	26.4	32.1	
cRII (95% CI)[1]	0.99 (0.73-1.34)	1.08 (0.76-1.52)	1.32 (1.06-1.63)	0.12
aRII (95% CI)[2]	0.92 (0.68-1.25)	1.07 (0.76-1.49)	1.25 (1.01-1.54)	0.10
cSII (95% CI)[1]	−0.63 (−18.42-17.15)	2.45 (−8.81-13.72)	11.70 (2.62-20.77)	0.15
aSII (95% CI)[2]	−5.49 (−23.84-12.86)	2.97 (−8.79-14.72)	10.92 (1.62-20.21)	0.12

[1] Crude Relative Index of Inequality and Slope Index of Inequality and their 95% confidence interval
[2] Adjusted Relative Index of Inequality and Slope Index of Inequality for sex, age and family structure, and their 95% confidence interval

4. Conclusion

The aim of this chapter was to assess long-term trends in dietary habits and in dietary disparities related to the family structure and school region in Belgium, and to the migration status in the Brussels-Capital Region. This research is one of the first to investigate, in adolescents, trends over many years regarding different social disparities in some iconic food groups and using appropriate methods for comparison of disparities over time. Our findings might help identify ways to improve current public health actions on both overall food consumption and related disparities.

First of all, a worsening of fruit and vegetable consumption was highlighted in the 1990s, followed by an improvement since the 2000s in Belgium. By contrast, the proportion of daily SSB consumers decreased sharply in the 1990s and then slightly in the 2000s. Note that in Brussels-Capital, the proportion of daily SSB consumers increased in the 2010s after a decrease between 1990 and 2010. Our results are in line with the literature,[116,176,186–191] which mainly comprises international descriptive reports[176,186,188] and studies conducted in the U.S.[189,190] However, these studies were conducted over shorter periods of time, focusing either before the years 2000s or since then. As a result, the overall picture of the trend in healthy food consumption, which may be divided into worsening followed by improvement, could not be highlighted throughout standardized information. The recent improvements that were highlighted in dietary habits may be the result of the awareness of the general population on the disadvantages of unhealthy foods, such as SSB, and on the benefits of healthy foods like fruit and vegetable. This awareness can partly arise from the various public health actions implemented, including the fruit and vegetable “five-a-day” campaign for instance.[192]

Disparities related to family structure and school region were highlighted for each food groups and almost each survey years. By contrast, few disparities related to migration status were found in the Brussels-Capital Region: they were observed for vegetable consumption and more recently, for SSB. Regarding the family structure, a trend towards increasing disparities was observed in fruit consumption, while a downward trend in disparities was revealed in SSB consumption. This may be explained by a slower adoption of the new dietary recommendation, including limiting SSB, by single-parent families due to their fewer financial resources, as income is associated with adherence to dietary recommendations.[193] In addition, given their increasing financial resources over years, blended families may have a better financial access to healthy foods,[63] such as fruit and vegetables. Furthermore, while decreasing region-related disparities were highlighted for vegetable consumption, an upward trend in disparities was observed for both fruit and SSB consumption. The most likely reasons for this would be that federal actions have culturally different impacts on the population[194] and actions implemented at a regional level would be more or less active and effective. Finally, a downward trend in disparities related to the migration status in Brussels-Capital was observed in vegetable consumption. The increase in immigrants may have led to an increase in the cultural diversification of the food supply, particularly regarding vegetables, which would therefore be more suitable for these populations and would induce their greater consumption. This will deserve complementary investigation through other methods.

Very few studies have investigated trends in dietary disparities among adolescents, and none over the long term or with appropriate measures to compare populations at different points in time.[116] Among the few on trends, none have examined these indicators (family structure, school region and migration status), preventing a specific comparison. In Nordic countries, increasing and decreasing inequalities related to FAS were both observed for fruit and vegetable consumption among adolescents, depending on the country, while overall decreasing inequalities were highlighted in soft drink consumption.[116] In the U.S., ethnicity-related disparities in typical fruit drink intake tend to decrease over time among adolescents.[195] Thus, unlike the evolution of food consumption which seems to be similar across the world, the change of inequalities related to social position seems to be both indicator- and context-specific. This suggests that public health actions must take into account the specifics of the social position in the context along with the context itself.

To conclude, overall, increasing disparities were emphasised when dietary habits improved, whereas decreasing disparities were observed when dietary habits worsened (**Table 11**). While it was suspected and hypothesised, this is the first time that such a figure has been demonstrated for several social position indicators and food groups, and also over a long period of time. In fact, our results underline that public health actions in Belgium have failed to improve dietary habits and tackle social inequalities at the same time. This also suggests that strategies to improve food consumption and reduce inequalities are different even if they can be combined in one action. Interestingly, some countries, such as Norway and Finland, managed to achieve this double objective of improving dietary behaviour of adolescents while addressing inequalities over the years.[116,195] To do so, public health actions must incorporate the concept of proportionate universalism, i.e. improving dietary habits proportionally to the degree of needs, which will be addressed in the discussion section (see **Chapter VI**, **section 4**).

Table 11. Summary of trends in dietary habits and related inequalities.

	Changes in Belgium between 1990 and 2014			Changes in Brussels-Capital between 1986 and 2014	
	% Non-daily consumers	**RII-Family Structure**	**RII-School Region**	**% Non-daily consumers**	**RII-Migration Status**
Fruit	**Increase**	**Reduction**	*Increase*	**Increase**	**Reduction**
Vegetables	**Increase**	**Reduction**	**Reduction**	**Increase**	**Reduction**
	% Daily consumers	**RII-Family Structure**	**RII-School Region**	**% Daily consumers**	**RII-Migration Status**
Sugar-sweetened beverages	**Decrease**	**Increase**	**Increase**	**Decrease**	**Increase**

CHAPTER V. DIETARY DISPARITIES AMONG ADOLESCENTS: RESPECTIVE EFFECTS OF INDIVDUAL AND SCHOOL CHARACTERISTICS

⁂

1. Introduction

So far, the literature as well as this doctoral thesis have mainly focused on the individual determinants of adolescents' dietary habits, especially those related to the socioeconomic and sociocultural positions. However, dietary habits of adolescents could also be influenced by more contextual determinants, especially the environment of their school (e.g. socioeconomic, nutrition-related components…). These contextual characteristics should be viewed independently of individual characteristics when investigating social disparities in dietary habits. Although these indicators may be interrelated, they are complementary and thus not interchangeable (see **Chapter I**, **section 1.2.3.1**). Therefore, distinguishing and understanding individual and contextual socioeconomic respective influences on dietary habits is useful to develop effective public health actions.

The school socioeconomic environment of adolescents in relation to their dietary habits has been addressed in a few studies.[65,111,196] Findings highlighted that adolescents in lower socioeconomic environment tended to have less favourable dietary behaviours.[65,111,196] Athough rarely studied together, individual and contextual socioeconomic status are likely to be independently related to adolescents' dietary habits.[65,111] As a result, the underlying mechanisms of disparities differ;[58,64] however, those of contextual socioeconomic disparities remain unclear due to the lack of process studies. For instance, dietary habits of adolescents may positively be influenced by their peers, through a greater exposure to healthier habits from more affluent peers when the individual socioeconomic status within the school are diverse.

Along with the contextual socioeconomic status, the nutrition-related environment could play an important role in dietary habits of adolescents. This issue has mainly been addressed in intervention studies.[197] In this respect, more favourable behaviours have been reported among adolescents in schools with a favourable food offer, such as free provision of fruit,[197] or in which food-related actions like educational program on beverages[198,199] have been implemented. Although the literature on this subject is quite extensive,[197,200] particularly in the U.S.,[197] the results need to be confirmed in "real life" settings and in diverse samples in Europe, including by considering the whole environment rather than a specific component of it only. Indeed, very often, such interventions have been evaluated after a short-term endpoint and were not easily integrated in the schools' routine.

Under these considerations, the main aim of this chapter was **to estimate individual and contextual socioeconomic disparities in dietary habits of adolescents in French-speaking schools, while taking into account school nutrition-related characteristics.** This objective has been addressed in the submitted paper presented in **section 2**. The supplemental materials of this paper are presented in **appendices N-Q**: (i) inclusion diagram of schools and adolescents (**Appendix N**); (ii) factor map of the Multiple Correspondence Analysis (**Appendix O**); (iii) food consumption and characteristics of participants (**Appendix P**); (iv) multilevel logistic regressions for dairy products consumption (**Appendix Q**).

In the same way as for the socioeconomic level,[65,111] it is expected that the sociocultural position of the adolescent and its sociocultural environment may be independently involved in dietary habits. However, to the best of our knowledge, this issue has never been addressed in adolescents' dietary habits. As part of this work, we therefore assumed that individual migration status and its counterpart at the contextual level, namely the proportion of immigrants in schools, would be independently related to adolescent dietary habits. Nonetheless, in Belgium, the proportion of immigrants in schools is strongly associated with the school socioeconomic status, with very high proportions of immigrants in schools with lower socioeconomic levels. In order to be as complete as possible, the two components were kept and combined (see **Chapter II**, **section 2.2.3**). Indeed, studying dietary habits by taking into account both socioeconomic status and migration status, and both at individual and contextual levels, could provide interesting insights for understanding the disparities related to each of these determinants.

In that regard, additional analyses have been carried out on the Brussels-Capital Region, which includes a high proportion of immigrants from very various backgrounds. The objective of these complementary analyses was to **estimate the dietary disparities related to individual and contextual socioeconomic and sociocultural status, among adolescents in the Brussels-Capital Region**. The findings regarding fruit, and crisps and fries consumption are presented in the text below (**section 3**), while results relating to the other food groups are displayed in **Appendix R**. None of these latter results have been published elsewhere.

2. Draft paper: “Dietary disparities among adolescents according to individual and school socioeconomic status: a multilevel analysis”

Dietary disparities among adolescents according to individual and school socioeconomic status: a multilevel analysis

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Disclosure statements

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Conflict of Interest

None.

Authorship

Conceptualization, MR and KC; methodology, MR and KC; formal analysis, MR; investigation, MR; resources, KC; data curation, KC; writing—original draft preparation, MR and KC; writing—review

and editing, TL, CP, EH, AB and LD; visualization, MR; supervision, KC; project administration, KC; funding acquisition, KC.

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 the Ethical Committee of the Faculty of Psychology at the *Université libre de Bruxelles* in Belgium (opinion n°032/2017). The invited adolescents and their parents received an information letter prior the survey. Both were free to refuse participation, by letter for the parents and on the day of the survey for the adolescents.

Abstract

Objective

Along with individual socioeconomic characteristics, school socioeconomic context may influence dietary habits in adolescents. Based on a multilevel approach, this study aimed to estimate disparities in dietary habits according to the individual and contextual socioeconomic status, while taking into account school nutrition-related characteristics.

Design and setting

Data were collected from secondary schools in French-speaking Belgium that were part of the 2017/2018 cross-sectional "Health Behaviour in School-aged Children" (HBSC) survey.

Participants

The final sample include 6,017 adolescents from 120 secondary schools in French-speaking Belgium.

Results

Over two-thirds of the observed variance was explained by individual and school characteristics, with SES and SEI being the main contributors. For example, 76.9% of the initial variance observed for daily sugar-sweetened beverage (SSB) intake was explained by individual and school characteristics. Indeed, adolescents of a secondary or lower parental education level were more likely to consume SSB daily than those of a post-secondary level (aOR= 1.46 (1.29-1.66)). Compared to those in a high SEI school, the odds to consume SSB daily was higher for adolescents attending a low SEI school (aOR= 2.37 (1.90-2.96)).

Conclusions

Individual and school socioeconomic background are independently related to the dietary habits of adolescents. Since the association with nutrition-related projects and health promotion is not conclusive, schools should pursue a consistent nutrition policy, with an increased support in low socioeconomic populations.

Keywords

Dietary habits; socioeconomic disparities; contextual disparities; multilevel analyses; adolescents

Introduction

Growing evidence is available on disparities in adolescent dietary habits related to individual socioeconomic status (SES)[1–3]. Among others, these disparities may be driven by health literacy[4] and food affordability[5]. Furthermore, adolescent dietary habits may be influenced by the contextual SES, such as the SES of their school, where they spend a large time of their day and they connect with their peers. Indeed, among adolescents, unhealthier dietary habits tend to be more frequent in lower SES schools[6–8]. Since the literature on this topic is limited, the underlying determinants are still not well established. Adolescent dietary habits may be influenced by peers[9] through, for instance, a greater exposure to healthier habits from more affluent peers when the individual SES within the school are diverse. In addition, based on the literature on contextual SES, such as the area[10], the nutrition-related environment within and around schools may be unhealthier in the lowest SES schools.

Furthermore, many strategies have been implemented in schools worldwide to improve adolescent dietary habits, however, findings from interventional studies are mixed[11,12]. For example, direct provision of fruit and/or vegetables, either free of charge, at a reduced or full price, tends to increase their daily consumption[11]. Conversely, contradictory results have been noted concerning the raise in access to water[11]. Studies suggest that water intake would improve only when the provision of water is combined with promotion of water consumption[13,14]. Reducing availability and sales of sugar-sweetened beverages may reduce habitual intake but not in-school intake[11]. Furthermore, restricting unhealthy snacks may decrease their consumption[11].

Some school-based interventions aimed at improving beverage consumption have implemented a curriculum, including an educational program[15,16]. For instance, reducing intakes of sugar-sweetened beverages can be reached by emphasising the quantity of added sugar in such beverages[16] or by promoting water consumption[15]. Although interventional study design allows causality to be established, there is a need to assess such associations in real-life settings and in large and diverse samples. In addition, most studies took into account specific rather than overall school food availability or health promotion. However, the availability of one given food could influence the consumption of another[17]. Similarly, the consumption of one specific food, for instance sugar-sweetened beverages, may be improved through health-promotion actions targeting another one, for instance water[15].

The literature on the school environment is quite extensive[11,12]. However, previous studies have mainly been conducted in the U.S.[11], where food and structural context differs greatly from European countries. In addition, individual and contextual disparities have been rarely addressed simultaneously when describing adolescent dietary habits and have been often limited to a few indicators[6]. To date, only a few studies have considered both individual and contextual SES in adolescent dietary disparities[6,8]. There is some evidence that contextual SES may influence dietary habits independently of individual SES[8,18] and, as a matter of fact, the underlying determinants of the two levels of disparities may differ[4,9]. Therefore, distinguishing individual and contextual influences on adolescent dietary habits remains useful, especially to implement effective nutrition-related interventions.

The aim of this study was to estimate the individual and contextual socioeconomic disparities in dietary habits of adolescents in secondary schools in Belgium. Based on multilevel analyses, we assessed the extent to which these disparities together with the main nutrition-related school characteristics could explain the school effect observed.

Methods

The "Health Behaviour in School-aged Children" (HBSC) is a cross-national school-based survey focusing on adolescent health behaviours, health status and well-being. It is conducted every four years in Europe and North America (about 50 countries in 2018) under the aegis of the World Health Organization (WHO) Regional Office for Europe[19]. This research is based on the 2017/2018 HBSC survey conducted in the French-speaking schools of Belgium. The study protocol was approved by the Ethical Committee of the Faculty of Psychology at the *Université libre de Bruxelles* in Belgium (opinion n°032/2017).

Sampling

The sampling was based on a two-stage plan. Schools were drawn from a random sample, stratified proportionally to the distribution of the school population by province (n= 6) and education system (n= 3)[20]. In each stratum, the number of schools selected was proportional to the distribution of the school population in these strata. Within the selected schools, one class from each level, from the 5th grade of primary school (corresponding to adolescents aged ± 10 years) to the final grade of secondary school (corresponding to adolescents aged ± 18 years), was randomly selected. All adolescents of the selected classes were invited to take part in the survey. The invited adolescents and their parents received an information letter prior the survey. Both were free to refuse participation, by letter for the parents and on the day of the survey for the adolescents. The pupils who agreed to participate were invited to complete the HBSC questionnaire in the classroom[20]. In addition, a school member of the participating schools was invited to fill out a school-level questionnaire on school characteristics, including nutrition-related questions.

Due to the disparity in the nutrition-related environement and projects in primary schools (data not shown), this study included adolescents in secondary schools only. Among the 401 secondary schools invited to take part to the survey, 134 schools actually participated, leading to the inclusion of 10.289 adolescents. The final sample included all participants, whose schools fully answered the school-level questionnaire (n= 120 schools and 9,098 adolescents), who filled out a short Food Frequency Questionnaire (FFQ) (n= 6,797) and responded to all covariates. Thus, a total of 6,017 adolescents from 120 secondary schools were included in the analyses (**Supplementary Figure 1**).

Measures

Food groups

Food data were collected using a validated short FFQ[21,22], including 20 food groups and 7-answer categories: "more than once a day"; "once a day"; "5–6 days a week"; "2–4 days a week"; "once a week"; "less than once a week"; and "never". Fruit, vegetables, dairy products and water were selected as food groups for which consumption was to be favoured whereas crisps and fries, and sugar-sweetened beverages (SSB) were selected as those to be limited. In order to focus on unhealthy consumption, dietary outputs were "non-daily consumption" for the former four and "daily consumption" for the latter two.

For composite variables such as dairy products (composed of "skimmed or semi-skimmed milk", "whole milk"; "cheese" and "yoghurt, white cheese" separately in the questionnaire), crisps and fries ("crisps" and "fries") and sugar-sweetened beverages ("coke and other sugary drinks" and "light/zero coke and other light drinks"), initial frequency consumption for each indicator was transformed into monthly consumption by multiplying the initial consumption by the mean number of weeks per month (i.e., 4.35). Then, frequency consumption per month of the group items were added up to obtain the frequency consumption of the composite variable. A "daily consumption" therefore corresponded to a consumption of at least 26.5 days.

Individual characteristics

Adolescents' socioeconomic and demographic characteristics included in analyses were as follows: gender; age; family structure; siblings; Family Affluence Scale (FAS); perceived financial wealth; parental working status; and parental education level.

The FAS is a validated "brief assets-based measure of family wealth" composed of six items[(23)]. The corresponding score ranged from 0 to 13 and was divided into three categories based on quintiles. The first quintile corresponded to adolescents with a "low" FAS, the second to the fourth quintiles to adolescents with a "medium" FAS and the fifth quintile to those with a "high" FAS.

Parental education level was based on the highest level of education of the household in which the adolescent was living and was categorised into two groups: "secondary or lower" and "post-secondary school". For adolescents living in single-parent and blended families, if the level of education of the parent with whom the adolescent was living was not available, the level of education of the parent with whom the adolescent was not living was considered (n= 444). A significant amount of missing data remained and was, therefore, kept in a third category named "undetermined" (n= 506).

School characteristics

School-level data included in analyses were the following: health promotion addressed in school missions; purpose of food projects (3 items) and food sold in the school (10 items). In addition, school region and school socioeconomic index (SEI) were taken into consideration.

The school SEI is used to determine the allocation and use of school resources[(24)]. It is based on individual characteristics of each school population: per capita income, parental education level, unemployment rates, labour force activity and social assistance allowance rates, and occupational activities[(24)]. Schools were divided into 20 classes, with each class comprising 5% of the total secondary school population. Based on the quartiles, three categories were defined[(24)] and were used in our analyses. The first quartile corresponded to low SEI, the second quartile to medium SEI, and the last two quartiles to high SEI.

Statistical analyses

In order to consider together, rather than separately, all the listed foods sold in the school, a Multiple Correspondence Analysis (MCA) was conducted (**Supplementary Figure 2**). The first three dimensions, accounting for 68.3% of the variance, were retained to perform a Hierarchical Clustering on Principal Components (HCPC) with Ward's methods and Euclidean distance[(25)]. This HCPC identified three clusters of schools: (1) schools with "few foods" available for sale; (2) schools with "mainly unhealthy foods" for sale; and (3) schools with "many foods" were available.

The database had a two-level hierarchical structure (adolescents nested in schools). As a result, multilevel logistic regressions with random intercepts were performed for each food group consumption. The first model incorporated only school-specific random effects without adolescent or school characteristics (model 1). The second model included all the individual characteristics in addition to the school-specific random effects (model 2). The third model included both individual characteristics and school characteristics in addition to the school-specific random effect (model 3). In the models 2 and 3, the slope of each individual characteristic was deemed to vary randomly across groups (i.e. schools). A likelihood-ratio test was performed to compare the random-slope model and the fixed-slope model[26]. The random-slope model was retained when the *P*-value was significant, indicating that this model fits better than the fixed one. Odds ratio and 95% confidence intervals (95% CI) are presented as measures of association along with the Proportion of Opposed Odds Ratio (POOR) as measures of the effects of cluster-variables[27]. Noteworthy, the POOR is used as a complement to OR of contextual variables and helps to address the problematic interpretation of these OR. It can take values ranging from 0% (homogenous association) to 50% (heterogeneous association)[27]. Proportional Change of Variance (PCV), Variance Partition Coefficient (VPC) and Median Odds Ratio (MOR) are displayed as measures of components of variance and of heterogeneity respectively[27]. Since the individual-level variance is fixed when using latent variable formulation in binary logistic regression, a scale correction factor was applied to the variance of models 2 and 3, resulting in a corrected VPC[27].

Statistical significance of tests was set at 0.05. Analyses on MCA and HCPC were performed using R® and multilevel regression modelling was performed using Stata/IC 14® (StataCorp, College Station, TX, USA).

Results

Characteristics of adolescents and their schools are displayed in **Supplementary Table 1**. Around half of the adolescents did not eat fruit or vegetables daily, and one adolescent out of eight did not drink water daily (**Fig. 1**). One-third of adolescents consumed SSB daily and one out of seven ate crisps and fries daily.

All results on associations between variables at the individual or contextual level and the food groups presented here relate to Models 3. Since we focused on adolescent SES and school SEI, results on sociodemographic associations are summarised at the end of the section. The analyses performed for dairy products revealed an association with gender and age only (**Supplementary Table 2**).

Fruit consumption (Reference Category: daily)

The likelihood of not consuming fruit daily was reduced as FAS category, perceived financial wealth and parental education level increased (**Table 1**). In addition, adolescents with no working parent were less likely to report non-daily consumption than adolescents with both parents working. Besides, the overall odds ratio for the school SEI denoted higher non-daily consumption of fruit in adolescents attending a low or medium SEI school. The POORs indicated that in around 10% of pair-wise comparisons, the odds would be higher for adolescents attending a high SEI school, meaning that the associations related to the SEI were homogenous across schools (**Table 1**). In addition, adolescents in Walloon schools are homogeneously (POOR= 3.7%) more likely to not consume fruit daily than those in Brussels-Capital.

Three-quarter (75.7%) of the total between-school variance, which decreased from 0.07 (model 1) to 0.02 (model 3), was explained by individual- and school-level factors considered here (**Table 1**). The school effect became non-significant in model 3.

Vegetable consumption (Reference Category: daily)

The likelihood of eating vegetables non-daily increased as the level of FAS and the parental education level decreased (**Table 2**). Furthermore, the odds of not consuming vegetables daily increased as school SEI decreased. The POORs of SEI supported a homogenous association. In contrast, perceived financial wealth and parental working status were not associated with vegetable consumption (**Table 2**). Individual- and school-level factors explained 73.9% of the total between-school variance, which decreased from 0.18 (model 1) to 0.05 (model 3) (**Table 2**).

Water consumption (Reference Category: daily)

Adolescents attending a school selling mainly unhealthy foods were more likely to not drink water daily than those attending a school where few foods were available for sale (**Table 3**). In addition, adolescents from a school that did not aim to include fruit or vegetables at school events were more likely to drink water non-daily than those attending a school that did. The odds of non-daily water consumption were lower for adolescents attending school in Brussels compared to those attending school in Wallonia. The POORs of each of these variables supported homogeneous associations.

Disparities related to the school SEI were homogeneously unfavourable to adolescents from a low and medium SEI school (**Table 3**). In addition, the odds of non-daily water consumption decreased with FAS and parental education level. Perceived financial wealth and parental working status were not associated with water consumption. The between-school variance, which was equal to 0.17 in model 1, was entirely explained by the individual- and school-level factors studied in our analyses (model 3, **Table 3**).

Crisps and fries consumption (Reference Category: non-daily)

Adolescents who reported perceived financial wealth as "quite well off", "average" or "not so/at all well off" were less likely to consume crisps and fries daily than those who reported "very well off" (**Table 4**). Compared with adolescents with both parents working, those with one or none of their parents working were more prone to consume crisps and fries daily. The odds of consuming crisps and fries daily was reduced as parental education level increased. FAS was not associated with crisps and fries consumption. In addition, the likelihood of eating crisps and fries daily increased as school SEI decreased. The POORs indicated homogenous associations (**Table 4**).

Individual- and school-level factors explained 71.6% of the total between-school variance which decreased from 0.39 (model 1) to 0.11 (model 3) (**Table 4**). The VPC in model 1 indicated that 10.8% of the individual variation in the underlying propensity to eat crisps and fries daily is due to systematic differences between schools, i.e. unmeasured differences, while the remaining 89.2% is due to systematic differences between individuals.

Sugar-sweetened beverage consumption (Reference Category: non-daily)

Adolescents attending a school that did not address promotion or did not aim to include fruit or vegetables at school events were more likely to drink daily SSB than those in a school that did (**Table 5**).

However, the respective POORs indicate a heterogeneous association. Indeed, in around 30% of the cases, an adolescent attending a school that did not address promotion or did not aim to include fruit or vegetables at school events will be less likely to drink daily SSB than those in a school that did. In addition, disparities related to the school region were homogeneously unfavourable to adolescents attending a school in Wallonia compared with Brussels-Capital.

The odds of drinking SSB daily was reduced as the school SEI increased (**Table 5**). The POORs indicated homogenous association. In addition, the likelihood to consume SSB daily was reduced as FAS category and parental education level increased. In contrast, compared with adolescents who reported perceived financial wealth as "very well off", those who reported "quite well off", "average" or "not so/at all well off" were less likely to drink SSB daily. Parental working status was not associated with SSB consumption (**Table 5**).

Three-quarters (76.9%) of the total between-school variance, which decreased from 0.34 (model 1) to 0.08 (model 3), was explained by individual- and school-level factors. The VPC in model 1 indicated that 9.4% of the individual variation in the underlying propensity to drink SSB daily was due to systematic differences between schools (**Table 5**).

Association between sociodemographic variables and food groups

Overall, boys were more likely to have unhealthy dietary behaviour than girls (**Tables 1-5**). Older adolescents (15-16y, 17-20y) were more likely to have non-daily fruit consumption whereas younger (<14y) adolescents were more likely to consume crisps and fries, and SSB daily. Compared with adolescents living with both parents, those living in a blended family were more likely to report an unhealthy consumption of fruit and SSB, while those living in a single-parent family were more likely to report non-daily water consumption. The presence of siblings was not associated with any of these five food groups (**Tables 1-5**).

Discussion

Our study aimed to determine the variation in dietary habits of adolescents in Belgium that may be driven by individual and contextual socioeconomic characteristics. A significant school effect was highlighted for all food groups explored, except dairy products; however, it became non significant for fruit and water consumption. Three-quarters of the observed variance for all food groups was explained by variables at the individual and school level. Adolescents' SES, school SEI, and to a lesser extent, school region explained the main variability. Overall, adolescents with a lower SES, based on FAS, perceived family wealth, parental education level or parental working status, were more likely to have unhealthy dietary behaviours. Similarly, adolescents attending a school with a low SEI were more prone to have unhealthy dietary behaviours. The other contextual variables were rarely associated with food groups except for beverages; water and SSB (health promotion, project to include fruits and vegetables and foods available for sale). Moreover, the inclusion of contextual variables in the multilevel analysis model did not fundamentally change the association between individual variables and food groups, indicating independent effects.

Individual socioeconomic disparities were measured using four indicators which are interrelated but independently involved in dietary habits. Parental working status was used here as an indication of income, since two working parents are more likely to have a higher income than no working parents.

The FAS is a complementary indicator of socioeconomic status[28] that overcomes the difficulties of measuring adolescents' socioeconomic status with conventional measures[29]. In contrast to these two indicators and the parental education level, the perceived family wealth is a subjective indicator. This subjective indicator may be a more accurate measure of the socioeconomic position[30] and may also reflect the relative position in the socioeconomic structure of the population. From a health perspective, a relative position may indeed play a more important role in SES disparities than absolute position [31]. Furthermore, objective and subjective measures may be independently associated to health outcomes[32]. Although subjective measures are less discussed in dietary studies, relative position may also be associated with diet[33].

Our findings regarding FAS and parental educational disparities are in line with the literature[2,19,34]. Higher educated and SES families tend to have a better grasp of the health promotion messages[4,35] and a prone interest towards healthy foods[36]. The "undetermined" category for the parental education level was too heterogeneous and lead to mixed results, nevertheless, it helped reduce the number of lost observations. Moreover, adolescents whose parents did not work were more likely to eat fruit but also crisps and fries daily. Considering that healthier patterns tend to be more expensive[5,36], it was expected that parental working status would systematically be negatively associated with unhealthy dietary behaviours. Thus, our results suggest that the working indicator used here also measures concepts complementary to income. Noteworthy, literature on parental income and dietary habits are inconsistent[2,37]. Similarly, our results regarding the perceived family wealth were not consistent. Furthermore, for unhealthy foods, perceived family wealth disparities contrasted with disparities related to the other socioeconomic indicators, especially for SSB and crisps/fries. Given that perceived family wealth partly reflects ability to purchase resources[38], we assume that adolescents cannot financially purchase accessory foods like SSB or crisps. However, literature regarding perceived family wealth is scarce, thus limiting interpretation.

In line with other studies[6–8], school SEI was associated with adolescent food consumption. Nonetheless, to date, more specific studies are needed to understand the mechanisms behind these disparities. Given that school SEI was based on individual characteristics of the school population, adolescents in a low SEI school are more likely to be socioeconomically disadvantaged, and therefore, to have less favourable dietary habits[2]. This is further supported by the changes, albeit small (<10%), in the association between socioeconomic variables and food groups caused by the school SEI variable introduction in the models. However, it is worth noting that school SEI was associated with dietary behaviours independently of adolescent SES, in accordance with the literature[8], suggesting that independent mechanisms may be involved. In addition, a school classified as having a low SEI is likely to be located in a disadvantaged neighbourhood. No study on the food environment of neighbourhoods is available in Belgium, but it is expected to be different between disadvantaged and advantaged neighbourhoods[39], whether in availability or in accessibility. In contrast to other countries[40–42], disadvantaged schools in Belgium only receive support for teaching and not for nutrition-related programs. Implementing such programs, especially in disadvantaged schools, could have positive effects on dietary habits of adolescents[43,44].

Healthier beverage consumption was observed among adolescents in schools including fruit and vegetables at school events, addressing health promotion in school missions, and selling limited foods. Of the schools that sold limited foods, none sold bottled water (data not shown), and therefore were supposed to make water available free of charge. In interventional settings, combining water provision and the promotion of its consumption may result in healthier water consumption[13,14]. It is worth noting that in our setting, almost half of the schools that did not sell bottled water addressed health promotion in their missions. However, the exact purpose of health promotion was not identified in our setting, preventing interpretation and comparison of results in this regard. Besides, a reverse causality cannot be ruled out with regard to the cross-sectional study design, with promotion and food projects implemented in schools where adolescents had already healthier dietary habits.

Moreover, a lack of association was observed between promotion and projects, and fruit, vegetables and crisps and fries consumption. This may be due to promotion and projects being recent, although it cannot be verified with our questionnaire. Furthermore, the discrepancy between food availability and projects and promotion may reduce the effectiveness of the latter. Indeed, of the schools addressing promotion or having a food project, three-quarters sold unhealthy foods, a quarter of which sold mainly unhealthy foods (data not shown). Beyond these assumptions, our results emphasise that addressing health promotion in schools to improve dietary habits is not conclusive especially when they are not consistent with the food availability.

In line with the literature[6,11], there was also a lack of association, for the groups mentioned above, between available types of food and consumption. Preliminary results with food items considered separately or as a score led to the same conclusion. However, the number of sale points is not known, while the number of vending machines may influence consumption[17,45]. Furthermore, we assumed that, given the increasing independence of adolescents in secondary school, the food environment surrounding the school[46] may also partly explain the lack of association.

Regional disparities revealed by our study may be due to population cultural differences, leading to variation in dietary habits[47,48]. Indeed, 73.6% of adolescents attending schools in Brussels were immigrants compared to 31.8% of adolescents attending Walloon schools (data not shown). Cultural differences could also have an impact on the food environment of the two Belgian regions but has yet to be confirmed. Regional school authorities are free to use the allocated resources, resulting in different school contexts such as health-promotion projects.

A major strength of this study was the province-based random sample along with the diversity of individual and contextual indicators available. The SES of adolescents was assessed using different but complementary[4,28] objective indicators adapted to adolescents, together with a subjective indicator that should be included more systematically in future studies[30]. In addition, the socioeconomic external environment of adolescents was evaluated through the standardized school SEI. Although the cross-sectional design of our study precludes causality conclusion, our results highlighted possible factors explaining a large part of the observed differences in food consumption between adolescents, and even all of them for water consumption. The main limitation of our study was the accuracy of the school-level questionnaire, which was based on general statements from the schools' staff and was not based on independent observations. The broad scope of questions related to health-promotion might be prone to interpretation and a reason of the lack of association with some food consumption. Nevertheless, the school environment and the adolescent dietary habits were assessed at the same time. In addition, a short FFQ was used to assess food consumption instead of repeated 24-hour dietary recalls as recommended. It cannot be excluded that some contextual indicators may cause variations not only on frequencies but also in quantities[11] which is not sizeable with a FFQ.

Conclusion

The variability in food consumption among adolescents being in different school socioeconomic backgrounds indicates that efforts must be made to improve their overall nutrition-related environment. Our findings suggest that the effectiveness of nutrition and health promotion projects may be considered inconclusive at first glance. Indeed, food availability within school was not always consistent with the nutrition-related projects and health promotion addressed in schools, which could help understand such a counterintuitive finding. Further research should also consider the school environment as a whole, including the food environment within and around the school, along with all the different specific projects and activities related to nutrition and health promotion. Finally, it would be beneficial for schools to have a two-pronged plan to both support the consumption of health-promoting foods and discourage unhealthy foods. Last, support to schools, with a greater intensity for those defined as disadvantaged, is needed to develop a more consistent and effective nutrition policy in those settings.

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Table 1. Multilevel logistic regressions* for **fruit** consumption (ref: daily consumption) (n= 6,017).
2018 HBSC in French-speaking Belgium

	Model 1	Model 2		Model 3	
		ORa (95% CI)	*P* value	ORa (95% CI)	*P* value
Individual-level variables					
Gender (*vs.* Girls)			<0.001		<0.001
Boys		1.36 (1.22-1.52)		1.35 (1.21-1.50)	
Age group (*vs.* <14 years old)			0.01		0.01
15-16 years old		1.19 (1.04-1.36)		1.20 (1.05-1.37)	
17-20 years old		1.20 (1.05-1.37)		1.20 (1.05-1.37)	
Family structure (*vs.* Two-parent family)			0.02		0.04
Blended family		1.23 (1.06-1.43)		1.20 (1.03-1.40)	
Single-parent family		1.11 (0.97-1.27)		1.11 (0.97-1.27)	
Siblings (*vs.*: Siblings)			0.22		0.24
Single child		1.14 (0.93-1.39)		1.13 (0.92-1.38)	
Family Affluence Scale (*vs.* High)			0.004		0.01
Middle		1.24 (1.08-1.43)		1.21 (1.05-1.39)	
Low		1.35 (1.11-1.64)		1.33 (1.09-1.62)	
Perceived family wealth (*vs.* Very well off)			<0.001		<0.001
Quite well off		1.24 (1.05-1.48)		1.26 (1.06-1.50)	
Average		1.51 (1.25-1.83)		1.53 (1.26-1.85)	
Not so/at all well off		1.47 (1.15-1.87)		1.46 (1.14-1.86)	
Parental working status (*vs.* Both working)			0.07		0.04
One working parent		0.92 (0.82-1.05)		0.91 (0.81-1.04)	
No working parent		0.78 (0.63-0.97)		0.77 (0.62-0.95)	
Parental education level (*vs.* Post-secondary)			0.004		0.02
Secondary or lower		1.23 (0.63-0.97)		1.20 (1.06-1.36)	
Undetermined		1.16 (0.95-1.42)		1.12 (0.91-1.37)	
School-level variables					
School Region (*vs.* Wallonia)					<0.001
Brussels-Capital				0.71 (0.61-0.83)	
POOR (%)				3.7%	
School socioeconomic status (*vs.* High)					0.005
Middle				1.23 (1.07-1.42)	
POOR (%)				13.7%	
Low				1.27 (1.07-1.52)	
POOR (%)				10.1%	
Intercept	1.60 (1.48-1.72)	0.78 (0.59-1.03)		0.70 (0.49-0.99)	
Variance of random effects	0.07[a]	0.04[a]		0.02	
Corrected variance of random effects †	-	0.04[a]		0.02	
Measures of components of variance and heterogeneity					
PCV	Reference	39.6%		75.7%	
VPC	0.022	0.014		0.005	
MOR	1.30	1.23		1.14	

POOR, proportion of odds ratios in the opposite direction; PCV, proportional change of the corrected variance; VPC, variance partition coefficient; MOR, median odds ratio
[a] Significant school effect
* Model 1: school-specific random effects; model 2: model 1 adjusted on all individual-level variables; model 3: model 2 adjusted on school-level variables including the non-significant ones: health promotion addressed in school; purpose of food project: to increase consumption of health-promoting foods, to limit consumption of unhealthy foods, to include fruits or vegetables at school events; foods available for sale at school
† Scale correction factor= 0.987

Table 2. Multilevel logistic regressions* for **vegetable** consumption (ref: daily consumption) (n= 6,017).
2018 HBSC in French-speaking Belgium

	Model 1	Model 2		Model 3	
		ORa (95% CI)	*P* value	ORa (95% CI)	*P* value
Individual-level variables					
Gender (*vs*. Girls)			<0.001		<0.001
Boys		1.34 (1.20-1.49)		1.35 (1.22-1.51)	
Age group (*vs*. <14 years old)			0.81		0.57
15-16 years old		0.96 (0.84-1.10)		0.95 (0.83-1.51)	
17-20 years old		0.97 (0.84-1.11)		0.93 (0.82-1.07)	
Family structure (*vs*. Two-parent family)			0.13		0.11
Blended family		0.90 (0.78-1.05)		0.90 (0.82-1.07)	
Single-parent family		1.08 (0.95-1.23)		1.09 (0.95-1.24)	
Siblings (*vs*.: Siblings)			0.50		0.46
Single child		1.07 (0.88-1.31)		1.08 (0.88-1.32)	
Family Affluence Scale (*vs*. High)			<0.001		<0.001
Middle		1.40 (1.21-1.62)		1.36 (1.18-1.58)	
Low		1.55 (1.27-1.88)		1.47 (1.20-1.78)	
Perceived family wealth (*vs*. Very well off)			0.37		0.25
Quite well off		1.14 (0.95-1.37)		1.17 (0.97-1.40)	
Average		1.19 (0.98-1.45)		1.22 (1.00-1.48)	
Not so/at all well off		1.11 (0.87-1.42)		1.14 (0.89-1.45)	
Parental working status (*vs*. Both working)			0.52		0.48
One working parent		1.06 (0.94-1.20)		1.03 (0.91-1.16)	
No working parent		0.96 (0.78-1.18)		0.90 (0.73-1.11)	
Parental education level (*vs*. Post-secondary)			<0.001		<0.001
Secondary or lower		1.47 (1.30-1.67)		1.42 (1.25-1.60)	
Undetermined		1.64 (1.34-2.00)		1.59 (1.30-1.94)	
School-level variables					
School socioeconomic status (*vs*. High)					<0.001
Middle				1.36 (1.16-1.60)	
POOR (%)				15.9%	
Low				1.77 (1.46-2.16)	
POOR (%)				3.2%	
Intercept	0.84 (0.77-0.93)	0.42 (0.32-0.56)		0.30 (0.93-1.29)	
Variance of random effects	0.18[a]	0.10[a]		0.05[a]	
Corrected variance of random effects †	-	0.10[a]		0.05[a]	
Measures of components of variance and heterogeneity					
PCV	Reference	42.4%		73.9%	
VPC	0.051	0.031		0.014	
MOR	1.49	1.36		1.23	

POOR, proportion of odds ratios in the opposite direction; PCV, proportional change of the corrected variance; VPC, variance partition coefficient; MOR, median odds ratio

[a] Significant school effect

* Model 1: school-specific random effects; model 2: model 1 adjusted on all individual-level variables; model 3: model 2 adjusted on school-level variables including the non-significant ones: school region, health promotion addressed in school; purpose of food project: to increase consumption of health-promoting foods, to limit consumption of unhealthy foods, to include fruits or vegetables at school events; foods available for sale at school

† Scale correction factor= 0.983

Table 3. Multilevel logistic regressions* for **water** consumption (ref: daily consumption) (n= 6,017).
2018 HBSC in French-speaking Belgium

	Model 1	Model 2		Model 3	
		ORa (95% CI)	*P* value	ORa (95% CI)	*P* value
Individual-level variables					
Gender (*vs*. Girls)			0.001		0.002
Boys		1.29 (1.10-1.52)		1.29 (1.10-1.51)	
Age group (*vs*. <14 years old)			0.68		0.58
15-16 years old		0.95 (0.78-1.16)		0.95 (0.78-1.16)	
17-20 years old		0.92 (0.75-1.11)		0.90 (0.74-1.10)	
Family structure (*vs*. Two-parent family)			0.03		0.03
Blended family		1.12 (0.90-1.40)		1.08 (0.87-1.35)	
Single-parent family		1.28 (1.06-1.54)		1.28 (1.06-1.54)	
Siblings (*vs*.: Siblings)			0.82		0.78
Single child		0.96 (0.71-1.30)		0.96 (0.71-1.29)	
Family Affluence Scale (*vs*. High)			<0.001		0.001
Middle		1.47 (1.14-1.88)		1.44 (1.13-1.85)	
Low		1.79 (1.33-2.41)		1.75 (1.30-2.37)	
Perceived family wealth (*vs*. Very well off)			0.39		0.40
Quite well off		0.79 (0.61-1.03)		0.80 (0.61-1.04)	
Average		0.83 (0.63-1.10)		0.83 (0.63-1.10)	
Not so/at all well off		0.80 (0.57-1.13)		0.79 (0.56-1.12)	
Parental working status (*vs*. Both working)			0.10		0.11
One working parent		1.18 (0.99-1.41)		1.17 (0.98-1.39)	
No working parent		0.94 (0.70-1.26)		0.91 (0.68-1.23)	
Parental education level (*vs*. Post-secondary)			<0.001		<0.001
Secondary or lower		1.81 (1.52-2.16)		1.74 (1.46-2.08)	
Undetermined		1.52 (1.15-2.02)		1.45 (1.09-1.92)	
School-level variables					
School Region (*vs*. Wallonia)					<0.001
Brussels-Capital				0.65 (0.52-0.81)	
POOR (%)				0.00%	
School socioeconomic status (*vs*. High)					0.005
Middle				1.36 (1.13-1.64)	
POOR (%)				0.00%	
Low				1.30 (1.03-1.64)	
POOR (%)				0.00%	
Project to include fruits or vegetables at school events (*vs*. Yes)					0.009
No				1.33 (1.08-1.65)	
POOR (%)				0.00%	
Foods available for sale at school (*vs*. Few foods)					0.01
Mainly unhealthy foods				1.24 (1.01-1.53)	
POOR (%)				0.00%	
Many foods				0.93 (0.77-1.13)	
POOR (%)				0.00%	
Intercept	0.14 (0.13-0.16)	0.07 (0.05-0.10)		0.06 (0.04-0.10)	
Variance of random effects	0.17[a]	0.06[a]		0.00	
Corrected variance of random effects †	-	0.06[a]		0.00	
Measures of components of variance and heterogeneity					
PCV	Reference	65.9%		100%	
VPC	0.050	0.019		0.000	
MOR	1.49	1.27		1.00	

POOR, proportion of odds ratios in the opposite direction; PCV, proportional change of the corrected variance; VPC, variance partition coefficient; MOR, median odds ratio

[a] Significant school effect

* Model 1: school-specific random effects; model 2: model 1 adjusted on all individual-level variables; model 3: model 2 adjusted on school-level variables including the non-significant ones: health promotion addressed in school; purpose of food project: to increase consumption of health-promoting foods, to limit consumption of unhealthy foods

† Scale correction factor= 0.976

Table 4. Multilevel logistic regressions for **crisps and fries** consumption (ref: non-daily consumption) (n= 6,017). *2018 HBSC in French-speaking Belgium*

	Model 1	Model 2		Model 3	
		ORa (95% CI)	*P* value	ORa (95% CI)	*P* value
Individual-level variables					
Gender (*vs*. Girls)			0.003		0.002
Boys		1.27 (1.09-1.48)		1.27 (1.09-1.47)	
Age group (*vs*. <14 years old)			<0.001		<0.001
15-16 years old		0.66 (0.55-0.79)		0.65 (0.54-0.78)	
17-20 years old		0.47 (0.39-0.57)		0.45 (0.37-0.55)	
Family structure (*vs*. Two-parent family)			0.27		0.33
Blended family		1.08 (0.88-1.32)		1.08 (0.88-1.33)	
Single-parent family		0.89 (0.74-1.08)		0.91 (0.75-1.09)	
Siblings (*vs*.: Siblings)			0.36		0.34
Single child		1.14 (0.86-1.50)		1.14 (0.87-1.51)	
Family Affluence Scale (*vs*. High)			0.09		0.26
Middle		1.07 (0.86-1.33)		1.02 (0.82-1.26)	
Low		1.31 (0.99-1.71)		1.19 (0.91-1.56)	
Perceived family wealth (*vs*. Very well off)			0.004		0.01
Quite well off		0.71 (0.52-0.97)		0.73 (0.58-0.92)	
Average		0.62 (0.48-0.81)		0.65 (0.50-0.83)	
Not so/at all well off		0.71 (0.52-0.97)		0.73 (0.54-1.01)	
Parental working status (*vs*. Both working)			<0.001		<0.001
One working parent		1.56 (1.32-1.85)		1.50 (1.27-1.78)	
No working parent		1.49 (1.14-1.95)		1.39 (1.06-1.81)	
Parental education level (*vs*. Post-secondary)			<0.001		<0.001
Secondary or lower		1.43 (1.20-1.70)		1.35 (1.14-1.60)	
Undetermined		1.79 (1.40-2.29)		1.73 (1.35-2.21)	
School-level variables					
School socioeconomic status (*vs*. High)					<0.001
Middle				2.03 (1.58-2.59)	
POOR (%)				7.7%	
Low				2.97 (2.23-3.94)	
POOR (%)				1.4%	
Intercept	0.19 (0.16-0.21)	0.29 (0.19-0.46)		0.14 (0.08-0.24)	
Variance of random effects	0.39[a]	0.29[a]		0.12[a]	
Corrected variance of random effects †	-	0.27[a]		0.11[a]	
Measures of components of variance and heterogeneity					
PCV	Reference	32.3%		71.6%	
VPC	0.108	0.082		0.036	
MOR	1.82	1.68		1.40	

POOR, proportion of odds ratios in the opposite direction; PCV, proportional change of the corrected variance; VPC, variance partition coefficient; MOR, median odds ratio

[a] Significant school effect

* Model 1: school-specific random effects; model 2: model 1 adjusted on all individual-level variables; model 3: model 2 adjusted on school-level variables including the non-significant ones: school region, health promotion addressed in school; purpose of food project: to increase consumption of health-promoting foods, to limit consumption of unhealthy foods, to include fruits or vegetables at school events; foods available for sale at school.

† Scale correction factor= 0.956

Table 5. Multilevel logistic regressions* for **sugar-sweetened beverages** consumption (ref: non-daily consumption) (n= 6,017).
2018 HBSC in French-speaking Belgium

	Model 1	Model 2		Model 3	
		ORa (95% CI)	*P* value	ORa (95% CI)	*P* value
Individual-level variables					
Gender (*vs*. Girls)			<0.001		<0.001
Boys		1.30 (1.16-1.46)		1.29 (1.15-1.45)	
Age group (*vs*. <14 years old)			0.005		0.003
15-16 years old		1.02 (0.88-1.17)		1.01 (0.88-1.16)	
17-20 years old		0.83 (0.72-0.95)		0.82 (0.71-0.94)	
Family structure (*vs*. Two-parent family)			0.02		0.03
Blended family		1.23 (1.06-1.44)		1.22 (1.05-1.42)	
Single-parent family		1.10 (0.96-1.26)		1.11 (0.97-1.27)	
Siblings (*vs*.: Siblings)			0.19		0.19
Single child		1.15 (0.93-1.41)		1.15 (0.93-1.41)	
Family Affluence Scale (*vs*. High)			<0.001		0.002
Middle		1.29 (1.10-1.50)		1.26 (1.08-1.47)	
Low		1.48 (1.20-1.82)		1.44 (1.17-1.77)	
Perceived family wealth (*vs*. Very well off)			0.02		0.03
Quite well off		0.79 (0.68-0.95)		0.79 (0.66-0.96)	
Average		0.73 (0.60-0.89)		0.74 (0.60-0.90)	
Not so/at all well off		0.78 (0.61-1.00)		0.79 (0.61-1.01)	
Parental working status (*vs*. Both working)			0.13		0.28
One working parent		1.12 (0.99-1.28)		1.10 (0.97-1.25)	
No working parent		1.17 (0.95-1.46)		1.12 (0.90-1.39)	
Parental education level (*vs*. Post-secondary)			<0.001		<0.001
Secondary or lower		1.51 (1.33-1.72)		1.46 (1.29-1.66)	
Undetermined		1.50 (1.22-1.84)		1.45 (1.18-1.78)	
School-level variables					
School Region (*vs*. Wallonia)					<0.001
Brussels-Capital				0.53 (0.43-0.66)	
POOR (%)				5.8%	
School socioeconomic status (*vs*. High)					<0.001
Middle				1.81 (1.50-2.18)	
POOR (%)				7.2%	
Low				2.37 (1.90-2.96)	
POOR (%)				1.6%	
Health promotion addressed in school (*vs*. Yes)					0.02
No				1.22 (1.03-1.44)	
POOR (%)				31.4%	
Project to include fruits or vegetables at school events (*vs*. Yes)					0.04
No				1.24 (1.01-1.54)	
POOR (%)				29.5%	
Intercept	0.70 (0.62-0.79)	0.47 (0.37-0.59)		0.27 (0.17-0.42)	
Variance of random effects	0.34[a]	0.24[a]		0.08[a]	
Corrected variance of random effects †	-	0.24[a]		0.08[a]	
Measures of components of variance and heterogeneity					
PCV	Reference	30.9%		76.9%	
VPC	0.094	0.069		0.024	
MOR	1.75	1.60		1.31	

POOR, proportion of odds ratios in the opposite direction; PCV, proportional change of the corrected variance; VPC, variance partition coefficient; MOR, median odds ratio
[a] Significant school effect
* Model 1: school-specific random effects; model 2: model 1 adjusted on all individual-level variables; model 3: model 2 adjusted on school-level variables including the non-significant ones: purpose of food project: to increase consumption of health-promoting foods, to limit consumption of unhealthy foods; foods available for sale at school
† Scale correction factor= 0.984

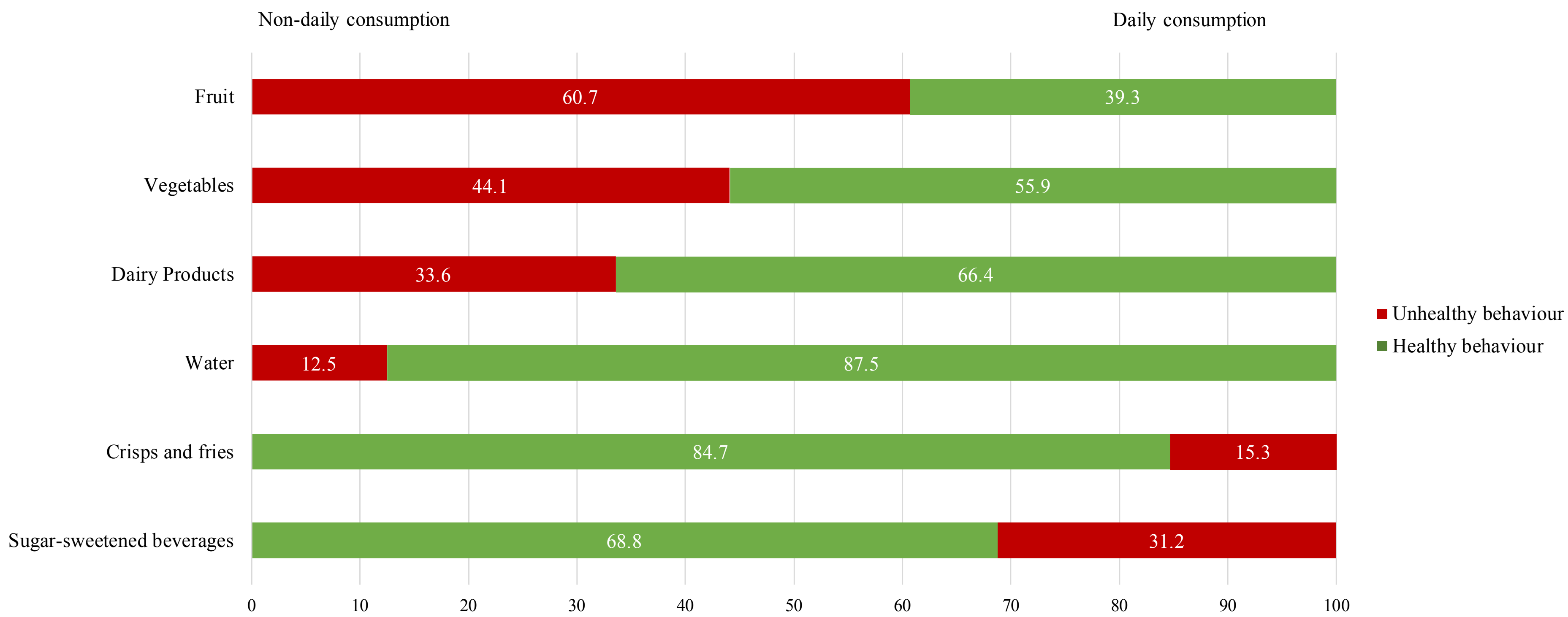

Fig. 1 Food frequency consumption of adolescents in secondary schools (n = 6,017).
2018 HBSC in French-speaking Belgian schools

3. Additional analyses on the Brussels-Capital Region

These additional analyses aimed to estimate the dietary disparities related to individual migration status and socioeconomic status, and related to the school socioeconomic context combined with the sociocultural context among adolescents in the Brussels-Capital Region. The data came from the 2018 French-speaking HBSC survey.

In total, 1,603 adolescents from 29 Brussels schools were included in our analyses. The same methodology as the main analyses of this chapter, i.e. a succession of multilevel models for each food group, was followed (see **section 2**). Thus, six food groups categorised in daily and non-daily consumption were considered: fruit, vegetables, dairy products, water, crisps and fries, and SSB. The presentation of the results will be based mainly on the consumption of fruit (**Table 12**) and crisps and fries (**Table 13**); the results of the other food groups did not require to be further commented and are displayed in **Appendix R**. After estimating the effect of school for a given food group in a model 1, individual disparities related to the adolescent socioeconomic and migration status were assessed in a second model. The third model consisted of including contextual variables, i.e. the socioeconomic status of the school combined with the proportion of immigrants in the given school. By contrast with the previous paper, variables related to the food environment like the availability of food in the school were not included due to the small number of schools that responded fully to the school-level questionnaire (n= 24) and above all, to the lack of variability in the food environment of schools in Brussels-Capital.

Consumption of fruit and crisps and fries significantly differed by school (**Table 12** and **Table 13)**. In fact, individual- and contextual-level factors explained almost all of the between-school variance (89.7% for fruit (**Table 12)**; 90.7% for crisps and fries (**Table 13**)). The main variability was explained by individual-level factors for crisps and fries consumption (51.6%), and by the contextual-level factor for fruit consumption (52.2%). Furthermore, the VPC indicated that of the residual variation in fruit and crisps and fries consumption that persisted after adjusting for individual and school characteristics, 0.3% and 2.0%, respectively, were due to systematic differences between schools, while the remaining 99.7% and 98.0% were due to unmeasured differences between adolescents.

Only socioeconomic disparities related to the parental education level were observed in fruit consumption (**Table 12**), and to the parental working status for crisps and fries consumption (**Table 13**). The consumption of crisps and fries did not differ according to the migration status of the adolescent in the Brussels-Capital Region ($p = 0.86$). Nevertheless, 1st-generation immigrants were less likely than natives to consume fruit on a non-daily basis (ORa= 0.64 (0.47-0.87)). Compared to adolescents from schools with a high socioeconomic level and a low proportion of immigrants, and independently of their individual characteristics, adolescents from schools with a medium socioeconomic level and proportion of immigrants ($ORa_{non\text{-}daily\ fruit}$= 1.67 (1.19-2.35); $ORa_{daily\ crisps\&fries}$= 2.49 (1.37-4.52)), as well as those in schools with a low socioeconomic level regardless of the immigrants' proportion (low or middle proportion: $ORa_{non\text{-}daily\ fruit}$= 1.47 (1.00-2.15) and $ORa_{daily\ crisps\&fries}$ = 4.26 (2.34-7.76); high proportion: $ORa_{non\text{-}daily\ fruit}$= 1.76 (1.24-2.50) and $ORa_{daily\ crisps\&fries}$= 3.42 (1.94-6.03)), were more likely to non-daily consume fruit but also more likely to daily eat crisps and fries. The respective POOR (<1.0%) supported homogenous associations. Furthermore, the MOR indicated that the magnitude of the effect of clustering was mainly smaller than that of the individual and school characteristics.

With regards to the other food groups, both individual and contextual migration status were associated with daily SSB consumption (**Table R-4** (**Appendix R**)) in a similar way to non-daily fruit consumption. Vegetable consumption differed only by socioeconomic and sociocultural context (**Table R-1**), while water consumption differed only by individual socioeconomic status (**Table R-3**). Finally, no disparities related to individual and contextual socioeconomic and sociocultural position were found for dairy product consumption (**Table R-2**).

Like for socioeconomic status, our results underline an independence between individual and contextual sociocultural variables in relation to dietary habits. Two main different situations of individual-contextual disparities were pointed out. On the one hand, individual and contextual migration components were inversely associated with daily fruit consumption. At equal socioeconomic levels (medium or low), the likelihood of not consuming fruit daily was higher for adolescents in schools with a medium or a high proportion of immigrants than for those in a low or low-medium proportion school, respectively. On the other hand, for crisps and fries consumption, while there was little difference by adolescent socioeconomic status and no association was observed for migration status, a strong association for their contextual counterparts was found.

Table 12. Multilevel logistic regressions for fruit consumption (ref: daily consumption) (n=1,603). *2018 HBSC in French-speaking Belgium*.

	Model 1	Model 2		Model 3	
		ORa (95% CI)	*P* value	ORa (95% CI)	*P* value
Individual-level variables					
Gender (*vs*. Girls)			0.01		0.01
Boys		1.31 (1.06-1.61)		1.31 (1.06-1.61)	
Age group (*vs*. <14 years old)			0.40		0.72
15-16 years old		1.08 (0.83-1.40)		1.04 (0.81-1.35)	
17-20 years old		1.19 (0.92-1.54)		1.11 (0.86-1.44)	
Family structure (*vs*. Two-parent family)			0.10		0.07
Blended family		1.19 (0.85-1.67)		1.24 (0.88-1.75)	
Single-parent family		1.30 (1.01-1.66)		1.32 (1.03-1.68)	
Family Affluence Scale (*vs*. High)			0.26		0.43
Middle		1.13 (0.85-1.49)		1.08 (0.82-1.42)	
Low		1.43 (0.93-2.19)		1.32 (0.86-2.01)	
Perceived family wealth (*vs*. Very well off)			0.18		0.12
Quite well off		1.34 (0.97-1.85)		1.39 (1.00-1.92)	
Average		1.51 (1.05-2.18)		1.57 (1.09-2.26)	
Not so/at all well off		1.37 (0.84-2.23)		1.40 (0.87-2.28)	
Parental working status (*vs*. Both working)			0.33		0.33
One working parent		1.16 (0.91-1.47)		1.13 (0.89-1.43)	
No working parent		0.91 (0.61-1.35)		0.86 (0.58-1.28)	
Parental level of education (*vs*. Post-secondary)			0.03		0.05
Secondary or lower		1.15 (0.89-1.48)		1.08 (0.84-1.40)	
Undetermined		1.90 (1.18-3.06)		1.82 (1.13-2.95)	
Migration Status (*vs*. Natives)			0.06		0.02
Second-generation immigrants		0.87 (0.67-1.13)		0.82 (0.63-1.07)	
First-generation immigrants		0.69 (0.51-0.94)		0.64 (0.47-0.87)	
School-level variables					
School socioeconomic index and proportion of immigrants (*vs*. high SEI, low MIG)					0.01
Medium SEI, low MIG				1.22 (0.83-1.81)	
POOR (%)				8.4%	
Medium SEI, middle MIG				1.67 (1.19-2.35)	
POOR (%)				0.0%	
Low SEI, low or middle MIG				1.47 (1.00-2.15)	
POOR (%)				0.0%	
Low SEI, high MIG				1.76 (1.24-2.50)	
POOR (%)				0.0%	
Intercept	1.26 (1.07-1.48)	0.63 (0.42-0.96)		0.53 (0.36-0.78)	
Variance of random effects	**0.10**	**0.06**		0.01	
Corrected variance of random effects†	**-**	**0.06**		0.01	
Measures of components of variance and heterogeneity					
PCV	Reference	37.5%		89.7%	
VPC	0.029	0.019		0.003	
MOR	1.35	1.27		1.10	

POOR: proportion of odds ratios in the opposite direction; PCV: proportional change of the variance; VPC: variance partition coefficient; MOR: median odds ratio. Significant school effect in **bold**. Model 1: school-specific random effects; model 2: model 1 adjusted on individual-level variables; model 3: model 2 adjusted on school-level variables

† Scale correction factor= 0.979982

Table 13. Multilevel logistic regressions for crisps and fries consumption (ref: non-daily consumption) (n= 1,603). *2018 HBSC in French-speaking Belgium*.

	Model 1	Model 2		Model 3	
		ORa (95% CI)	*P* value	ORa (95% CI)	*P* value
Individual-level variables					
Gender (*vs*. Girls)			0.37		0.34
Boys		1.15 (0.84-1.57)		1.16 (0.85-1.58)	
Age group (*vs*. <14 years old)			0.01		0.02
15-16 years old		0.74 (0.50-1.09)		0.70 (0.47-1.03)	
17-20 years old		0.56 (0.37-1.09)		0.49 (0.33-0.73)	
Family structure (*vs*. Two-parent family)			0.28		0.30
Blended family		1.03 (0.61-1.74)		1.06 (0.63-1.78)	
Single-parent family		0.74 (0.51-1.09)		0.76 (0.52-1.10)	
Family Affluence Scale (*vs*. High)			0.29		0.61
Middle		1.48 (0.90-2.44)		1.28 (0.78-2.11)	
Low		1.57 (0.82-2.99)		1.32 (0.70-2.49)	
Perceived family wealth (*vs*. Very well off)			0.12		0.23
Quite well off		0.57 (0.36-0.92)		0.62 (0.38-0.99)	
Average		0.57 (0.34-0.96)		0.62 (0.37-1.05)	
Not so/at all well off		0.66 (0.34-1.27)		0.71 (0.37-1.36)	
Parental working status (*vs*. Both working)			<0.001		<0.001
One working parent		1.93 (1.36-2.76)		1.87 (1.32-2.67)	
No working parent		2.47 (1.49-4.10)		2.37 (1.44-3.91)	
Parental level of education (*vs*. Post-secondary)			0.04		0.17
Secondary or lower		1.60 (1.11-2.29)		1.41 (0.99-2.02)	
Undetermined		1.27 (0.68-2.35)		1.20 (0.65-2.23)	
Migration Status (*vs*. Natives)			0.84		0.86
Second-generation immigrants		0.96 (0.62-1.49)		0.90 (0.58-1.40)	
First-generation immigrants		1.08 (0.66-1.76)		0.97 (0.60-1.60)	
School-level variables					
School socioeconomic index and proportion of immigrants (*vs*. high SEI, low MIG)					<0.001
Medium SEI, low MIG				1.37 (0.64-2.96)	
POOR (%)				19.2%	
Medium SEI, middle MIG				2.49 (1.37-4.52)	
POOR (%)				0.6%	
Low SEI, low or middle MIG				4.26 (2.34-7.76)	
POOR (%)				0.0%	
Low SEI, high MIG				3.42 (1.94-6.03)	
POOR (%)				0.0%	
Intercept	0.17 (0.12-0.24)	0.15 (0.07-0.30)		0.09 (0.04-0.16)	
Variance of random effects	**0.66**	**0.35**		0.07	
Corrected variance of random effects†	**-**	**0.32**		0.06	
Measures of components of variance and heterogeneity					
PCV	Reference	51.6%		90.7%	
VPC	0.168	0.095		0.020	
MOR	2.17	1.75		1.28	

POOR: proportion of odds ratios in the opposite direction; PCV: proportional change of the variance; VPC: variance partition coefficient; MOR: median odds ratio. Significant school effect in **bold**. Model 1: school-specific random effects; model 2: model 1 adjusted on individual-level variables; model 3: model 2 adjusted on school-level variables

† Scale correction factor= 0.961681

4. Conclusion

This chapter aimed to estimate individual and contextual disparities in the dietary habits of adolescents. Two sub-objectives have been addressed and filled the gap on this issue albeit further studies are still needed to strengthen our conclusions.

First of all, our results in French-speaking schools highlighted that dietary habits differed between adolescents from different schools, except for dairy products. Greater variability was observed for unhealthy foods like crisps and fries than for healthy foods, such as fruit. For all food groups, a very large part of the observed variability was explained by individual and contextual factors, especially socioeconomic in FWB, and sociocultural and socioeconomic in Brussels-Capital. As a result, the differences in food consumption between the schools in FWB were hardly or not at all explained by the nutrition-related environment based on the indicators we collected through the school questionnaire.

In fact, while the intervention studies drew robust conclusions about the effectiveness of supportive food environments or food-related actions,[197] the results in "real life" settings are less conclusive.[111] Our results also pointed to an effectiveness of food-related projects that may be considered inconclusive at first glance. Our counterintuitive findings could be explained by an inconsistency between such announced projects and the availability of food in schools. In addition, a measurement bias related to the school questionnaire may also be a factor in our conclusion (see **Chapter VI**, **section 2.1.2**). More importantly, the ineffectiveness can result from a reverse causality due to the cross-sectional nature of the survey. This apparent ineffectiveness should therefore be confirmed by also taking into account all the different projects actually implemented in the schools, but also the environment as a whole, i.e. within and around the school.

In line with the literature,[99,111,196] our findings underlined that adolescents with a low socioeconomic status or from a low socioeconomic status school were more likely to have unhealthier dietary habits than those with a high socioeconomic status or in a high socioeconomic school. The socioeconomic status of the school was associated with dietary habits independently of the adolescent socioeconomic status, suggesting that different mechanisms are involved. These results, based on four individual indicators that are interrelated but independently involved in dietary habits, reinforce the conclusion of independence that was already highlighted in the literature but to a limited extent. Indeed, the few studies that have addressed both individual and contextual socioeconomic status were limited to one or two indicators at the individual level, such as material wealth,[111] and therefore to a limited aspect of the socioeconomic status. Since our contextual socioeconomic indicator was based on individual population characteristics, further analysis deserves to be carried out with an indicator based on contextual characteristics (see **Chapter I**, **section 1.2.3.1**). In this respect, it will be easier to determine whether the association between the socioeconomic context and the dietary habits of adolescents is related to the socioeconomic characteristics of the school or to the socioeconomic characteristics of the people attending that school,[64] and thus to better understand the mechanisms involved.

As with socioeconomic status, our results highlighted that in Brussels-Capital, migration status was associated with adolescent dietary habits independently of the similar contextual component, i.e. the proportion of immigrants in the school. Two main different relationships were highlighted for the individual-contextual pair. On the one hand, individual and contextual migration status were observed to be inversely associated with dietary habits. On the other hand, still in the Brussels-Capital Region, a lack of individual socioeconomic and sociocultural disparities was observed, while a strong association of the socioeconomic and cultural context with dietary habits was highlighted. As far as we know, this is the first time that the sociocultural individual position and context have been studied simultaneously in relation to dietary habits of adolescents. Therefore, it is complex to put forward hypotheses to explain such contrasting results. Nevertheless, our findings pointed out the need to study the sociocultural environment more systematically when investigating dietary disparities.

Finally, nutrition-related projects seem ineffective, but they might be inconsistent with the real food environment. Thus, support to schools, with a greater intensity for those defined as disadvantaged, is needed to develop a more consistent and effective nutrition policy. Moreover, socioeconomic and sociocultural factors are associated with adolescents' dietary habits independently of the corresponding indicators at the contextual level. In addition, the context may have, in some situations, a more important role on diet than individual factors. Therefore, public health actions should consider including a component related to the socioeconomic and sociocultural environment in order to tackle social disparities in dietary habits more effectively.

CHAPTER VI. GENERAL DISCUSSION

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1. Summary of results

This doctoral thesis aimed at investigating the socioeconomic and sociocultural disparities in adolescents' dietary habits through diverse but complementary approaches. **In the first part**, we have shown that food consumption frequencies among adolescents gradually increased, for both healthy and unhealthy foods, from natives to 1st-generation immigrants, with 2nd-generation immigrants in between.[157] This migration gradient suggests a process of acculturation across generations of immigrants, in line with the literature.[114,174] In the course of acculturation, immigrants are likely to gradually change their dietary habits to make them both more and less healthy, thus contradicting the "best of both worlds" hypothesis.[75] However, based on analyses focusing on Brussels-Capital, we could not demonstrate that dietary habits of 1st-generation immigrants greatly differed by their proportion of time spent in the host country.[85]

Furthermore, we observed that migration status did modify the association between socioeconomic characteristics and dietary habits. In this respect, compared with natives, narrower socioeconomic disparities were observed in 2nd-generation and even more so in 1st-generation immigrants. In addition, the socioeconomic profiles of immigrants were as diverse as those of natives. Although the profile of immigrants was generally less favourable, the difference with that of natives was limited in magnitude. Altogether, such findings led us to hypothesize that dietary habits of immigrants were more determined by their culture than by their socioeconomic conditions.

The socioeconomic disparities observed mainly among natives, and to a lesser extent among 2nd-generation immigrants, were in line with the literature. Adolescents with higher FAS and living in two-parent families had more favourable dietary habits than their counterparts.[99,116,179,180,201] Regarding parental working status-related disparities, results were mixed, suggesting that our indicator, unfrequently used in the literature, could reflect both income and time available for everyday life. Finally, compared to Flanders, the dietary habits were sometimes more favourable for the Brussels-Capital Region and sometimes more unfavourable there, which could be due among others, to the different exposures to public health action within the Belgian population.

In the second part of this work, in Belgium[202] as well as in Brussels-Capital, overall, a trend towards increasing disparities was observed when dietary habits improved, and towards decreasing disparities when dietary habits deteriorated. The evolution of disparities related to family structure can be attributed to the more or less rapid adoption of dietary recommendations and to the evolution of the financial means of certain families. The most likely reasons for the changes in regional disparities would be that federal actions have culturally different impacts on the population[194] and actions implemented at a regional level would be more or less active and effective. Finally, the trend in disparities related to migration status in Brussels-Capital may be explained by the increase in the cultural diversifcation of food supply.

For the first time documented in such a long period of time, this trend of increasing disparities when dietary habits improved and decreasing disparities when dietary habits worsened highlights that Belgian public health actions may have, thus far, failed to both improve dietary habits and tackle social disparities, maybe due in part to a counterproductive environment. Such findings underline the increased need for public actions to incorporate the concept of proportionate universalism, which will be deepened below.

The third section of this thesis revealed that a significant part of the observed differences between schools were explained by the socioeconomic or sociocultural components but not by the nutrition-related school environment. The documented inconsistency between the nutrition-related projects and the availability of food in schools might be a reason why the nutritional environment appeared as "ineffective". Although interaction with the environment outside the school cannot be excluded, it is crucial that schools develop a fully consistent nutrition policy. Moreover, since a cross-sectional scheme was used, reverse causality cannot be excluded either.

The socioeconomic and sociocultural environments were found to be associated with adolescents' dietary habits, independently of the corresponding individual characteristics. As with the individual level, adolescents in low socioeconomic schools were more likely to have unhealthy dietary habits than those attending a more favourable setting. In contrast, individual migration status, and the corresponding school characteristic, were strongly or differently associated with adolescents' dietary habits in Brussels-Capital Region. For some food groups, there was no or only a weak association with the individual level, while a strong association was observed with the contextual level. For others, individual and contextual migration status were observed to be associated with dietary habits with opposite directions. While these findings remain to be better understood, they highlight the importance of the environment in which adolescents evolve in addition to their individual characteristics in their dietary behaviours.

Our results largely inform the theoretical concept that health and dietary habits are determined by a set of different level factors that influence each other between and within levels (**Figure 10**).[203] Key information was identified to support the implementation of public health actions that would lead to reduce social disparities. In this respect, such actions should be anchored in the concept of proportionate universalism and be comprehensive by integrating both individual and contextual sociocultural and socioeconomic components.

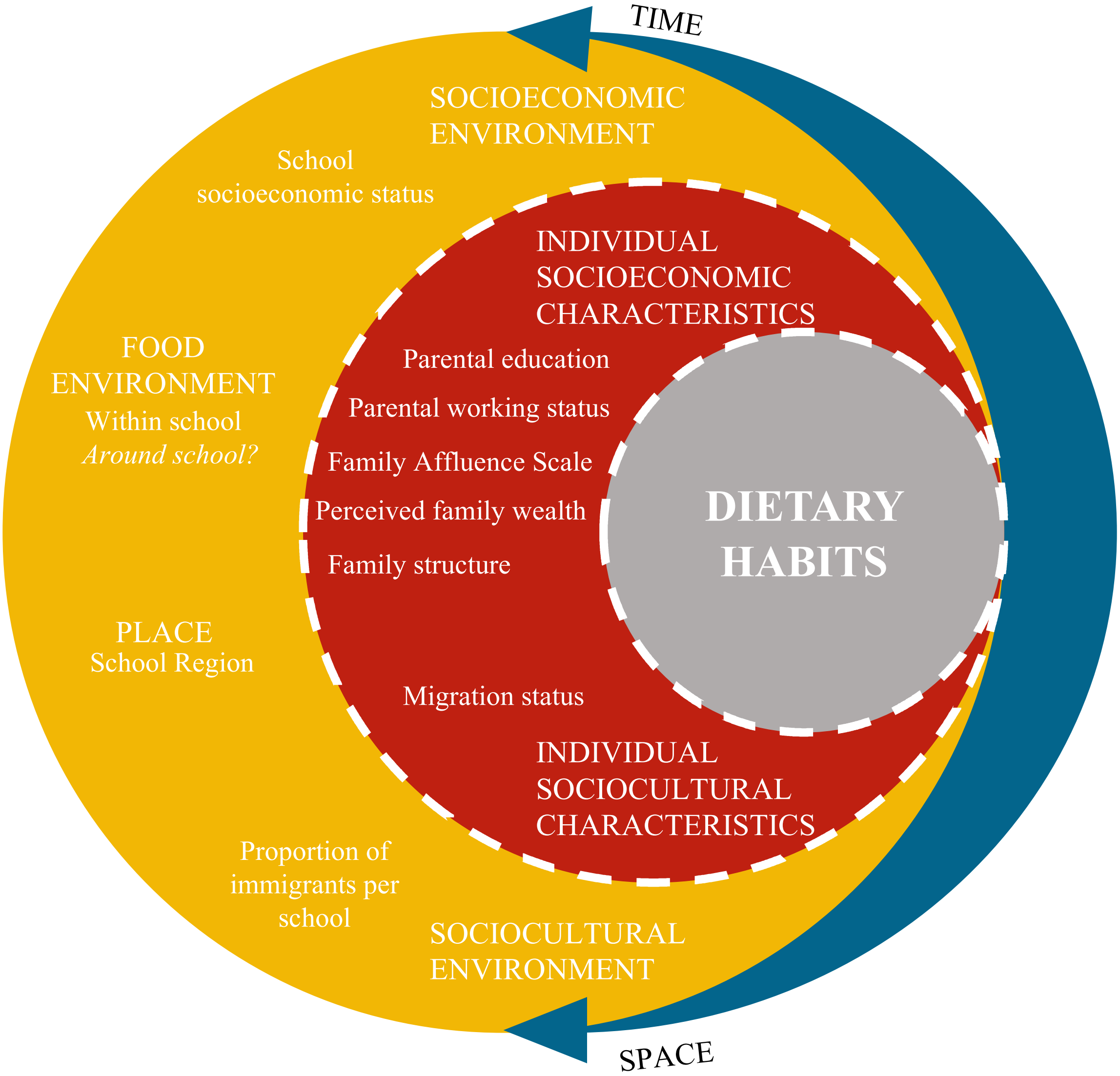

Figure 10. Map of dietary habits and their determinants based on the analysis of the Health Behaviour in School-aged Children surveys in Belgium. *Source: adapted from "Carte de la santé et de ses déterminants" of the National Institute of Public Health of Québec, 2012).*

2. Methodological considerations

Altogether, our results have to be interpreted critically, bearing in mind the methodological issues specific to the survey and the statistical analyses. Some of these aspects have already been discussed in the three respective chapters of results. In this section, we are focusing on those that are most relevant to the survey as a whole. Schematically, we are addressing the biases that can be induced by the sampling, data collection relating to indicators and the diet description, and statistical analyses. These methodological considerations also help estimate the extent to which our results can be extended to our national context but also to the international context.

2.1. Internal validity

2.1.1. Selection bias

As the HBSC survey is not an exhaustive assessment, the study population may differ from the source population. In such a case, the sampling scheme, the participation rates and the exclusion of participants due to missing values for instance may have introduced a selection bias.

To limit the bias from the outset, a stratified random sampling was applied, i.e. adolescents from randomly selected schools and classes in the strata were invited to participate in the survey. These strata were defined in such a way that the intra-stratum variability in individual characteristics and health behaviours was as low as possible, and the inter-stratum variability as high as possible, in order to improve the representativeness and the precision of the estimates. However, creating these strata is challenging, as individual characteristics of adolescents attending schools are not available for sampling; therefore, the definition is based on one[140] or several[144] contextual characteristics, such as school networks and provinces. Thanks to the sustainability of the HBSC survey repeated at regular intervals, the strata could be readjusted over the rounds to improve the representativeness of the target population, by examining the sources of variability in previous surveys. Consequently, the definition of strata has changed over the survey years and regions (see **Chapter II**, **section 1.2**). In view of the similar variability in the socioeconomic characteristics across the samples, but especially in the change in family structure and migration status that follows the evolution of Belgian society (**Table 9** and **Table J-1**), we assume that the selection bias induced by the sampling procedure was weak.

The varying participation rates of schools and adolescents depending on their characteristics may also contribute to the selection bias. Indeed, in the HBSC surveys conducted in Belgium, the school participation rate is relatively low (at the highest 55%, see **Chapter II**, **section 1.2**). At-random refusal of schools has minimal effect on the baseline sampling bias, but systematic refusal is problematic and might undermine validity. Several techniques were used to limit the consequences of such refusals. These included: oversampling certain strata based on the participation rate of previous survey years; conducting a second wave as in 2018; or inviting substitute schools from the same stratum like in 2014.

In contrast to schools, the participation rate of adolescents has been very high so far (around 95%), thanks in particular to the fact that the data collection was conducted during school hours. The passive consent favoured for HBSC surveys allows for a higher participation rate[204] (which would require a written response from parents about their adolescent's participation). Therefore, no additional bias should have been introduced at this level. Nevertheless, some immigrants may have been systematically excluded because they did not speak the survey language well enough, either because they recently arrived or because they were far away in the process of acculturation. However, the inclusion of these immigrants would certainly have reinforced rather than weakened our conclusions about the migration gradient.

Finally, the partial non-response of adolescents may be another source of selection bias. Nevertheless, the partial non-response was generally relatively limited. In addition, unlike adults,[58,205] the partial non-response of adolescents for their socioeconomic position would be non-differential. Therefore, the selection bias generated by the partial non-response rate should be minimal. This was indeed confirmed by comparisons of included *vs.* non-included adolescents due to missing data in analyses (**Table H-1**). Overall, partial non-response is more responsible for weaker associations than for spurious associations. Exploratory analyses showed that adolescents with partial non-response for the food frequency questionnaire differed from adolescents with no missing data for the 2018 survey. In fact, they were more often young, living in a particular family configuration, such as a foster, or also had missing data for socioeconomic variables like the FAS. This is why specific weighting was computed for the use of the sFFQ.

Partial non-response and all of the above issues were taken into account in weighting factors since the 2018 survey. These factors ensure that the estimates are likely to be representative of the source population despite the refusal of schools and adolescents to participate and the partial non-response of adolescents. However, they cannot be reliably included in more advanced statistical analyses, such as multilevel analyses. The objective of our analyses led us to favour statistical analyses over sampling issues. Interestingly, one-level preliminary analyses considering weighting factors showed that the results differed only very slightly from more extensive analyses without weighting factors (data not shown).

In conclusion, all of these points suggest good internal validity with respect to sampling issues; therefore, we can extrapolate our results from the sampled population to the source population, with a good degree of confidence. However, caution should be taken when extending our results beyond the source population, for example to adolescents in Belgium. Adolescents from the German-speaking community, as well as out-of-school adolescents and those who are in special education, were not included in the surveys. Though in a limited number, these adolescents may greatly differ in terms of cultural-related behaviours for the German adolescents but also in terms of dietary habits. Hence, our overall estimates are unbiased regarding the adolescents schooled in the mainstream networks.

2.1.2. Information bias

Questions related to the adolescent's social position or school environment and the methods used to describe the diet might have induced information biases. Such biases are likely to be even greater when questions are not adapted to the study population.

Most of the HBSC indicators of social position are adequate to the adolescent population and therefore of great value for the study of dietary disparities among adolescents. These include the FAS, the perceived family wealth or the parental working status (see **Chapter I**, **section 1.2.3.1**).[3,66] However, finding suitable indicators for this population is still sometimes complex. For instance, the parental education indicator may have induced a measurement bias but that should be non-differential (see **section 2.1.1**). Besides, the high consistency with literature of our results regarding individual social disparities, including parental education level, suggest that the indicators used here did not constitute a source of measurement bias that would have resulted in a false estimate of associations for instance.

Furthermore, some of the questions in the school-level questionnaire seem to have been unclear and may have induced a significant and differential measurement bias. For example, almost 20% of the schools reported that adolescents did not have free access (*"accès librement"*) to a place to buy food in the school, but reported that they could buy at least one product in the school. If the term 'free access' has induced a different understanding between schools while they did sell food, a differential measurement bias might be expected. In fact, the baseline idea was that schools that did not provide free access could not declare selling food. In addition, almost 15% of the schools declared that they had a specific food project after reporting that there was no food project developed this school year. Another measurement bias may have been induced, since the question on the type of food project did not specify that it was the project developed this year. Therefore, the differential misunderstanding of the questions for schools on the food environment may have led to an over- or underestimation of associations.

Finally, the sFFQ used in the HBSC surveys can also be a source of an information bias. First, according to the validation studies,[149,150] this tool is likely to induce a measurement bias, with an overestimation of certain foods like diet drinks[149] and an underestimation of some others, such as crisps.[150] However, the sFFQ used in HBSC surveys has a sufficient reliability and validity to rank *« subjects according to consumption of the individual food items »*.[149] Thus, although the raw results on dietary habits should be interpreted with caution, we assumed that the impact on dietary disparities' findings is minimal. Indeed, the conclusions regarding dietary habits using the FCS database (based on two 24-hour recalls)[110] are similar to ours.

While the investigator bias is avoided, the sFFQ is considered as a source of a significant cognitive bias. Adolescents are not only asked to convert their consumption over a long period of time into a usual consumption per week, but also to think in terms of rough food groups and not specific foods for most of the proposed list. This effort may lead to a higher non-response rate or to an over- or underestimation of certain food groups.[120] Moreover, a social desirability bias is probable when using a sFFQ as previously mentioned. Unlike with other methods such as the FFQ and 24HR, it is very complex to detect. Thus, adolescents may tend to report their consumption to be closer to the dietary recommendations they know. This bias is likely to be differential, with a greater likelihood of social desirability among adolescents of higher socioeconomic status.[206] Therefore, differences between social groups may have been overestimated in our study with this regard.

2.1.3. Confounding

The objective of our analyses was to investigate socioeconomic and sociocultural disparities in adolescents' dietary habits. The purpose of constructing multivariate models of social determinants was to consider that each of the social characteristics could intervene in the relationship between the other characteristics and dietary habits. Thus, a weaker association between one indicator and dietary habits due to another indicator introduction, primarily reflected the interrelationship between these two indicators. The observed variation cannot be attributed to confounding by this third indicator, because of the distal relationship between social indicators and dietary habits (see **Chapter I**, **section 2.3.2**).

Other factors involved in the relationship between social determinants and dietary habits could have been taken into consideration, such as beliefs, representations, food preference, emotions or even physical activity and body mass index when they are relevant to dietary behaviours. Nevertheless, considering them would have entailed a risk of over-adjusting[135] and a difficulty in interpretation, as they often are intermediate in the relationship between social position and dietary habits. Hence, the association estimated will not be more accurate. Nevertheless, such factors could be considered in further types of analysis in order to better understand related mechanisms, but this would be outside the current scope of this doctoral thesis.

2.2. External validity

In addition to a good internal validity, good external validity of our results is expected. The use of social position indicators that are not specific to the Belgian context allows us to extend our conclusions to other European countries whose social context does not differ excessively. For instance, results regarding migration status, based on whether or not one was born abroad, can be more easily transposed to the international level than those based on ethnicity, the ethnic group being very country- or region- specific. Since our results suggest a process of acculturation, we assume that even if the origin of immigrants is very different between countries, the conclusions related to the migration status should be mostly similar. Furthermore, the relative nature of some indicators, such as the FAS purposely developed for different social contexts[66] and perceived family wealth, should not be a source of limitation to extrapolate our results. By contrast, the regional indicator, which is by definition specific to the Belgian context, cannot be used to extend our results as such. However, the overall regional disparities can be extrapolated to countries with health promotion entities or linguistic divisions, like Switzerland.[181]

3. Research perspectives

Our results, which partially fill the gap in the literature on social disparities regarding the dietary habits of adolescents, lead to several reflections. First, the differences in food consumption and socioeconomic disparities between immigrants and natives raise the question of the mechanisms behind these differences. In this respect, non- or semi-structured qualitative interviews should be conducted among natives and immigrants, the latter possibly divided into several groups according to generation and country of birth. These interviews, addressing among others, the barriers to access to a healthy diet and the place of cultural norms, would allow a better understanding of the observed differences between natives and immigrants.

In addition to social disparities, the dietary habits of adolescents were subject to significant environmental disparities. Although the dietary habits are acquired during adolescence[93] and are likely to track into adulthood,[92,95] these behaviours may change with early adulthood.[110] In fact, this period brings with it major changes in social conditions (first jobs, budget, etc.) and in the social and food environment (by leaving the family home), which may have consequences for diet. Cohorts such as the Dutch Lifelines cohort[207] make it possible to study diet and social conditions at several points in time, from childhood to old age. Combined with other databases like GECCO,[208] the social and dietary environment and its evolution over time can be estimated. Such data would make it possible to determine whether changes in dietary behaviours between adolescence and early adulthood are driven primarily by changes in social conditions or by changes in the environment.

Moreover, we mentioned that the apparent ineffectiveness of promotion projects in school could be explained by reverse causality. In order to confirm this hypothesis, a longitudinal design study in which diet, disparities and the exact set of projects are evaluated at several points has to be carried out. The hypothesis of the contradiction between school-based promotion projects and the school food environment was also raised to explain the apparent ineffectiveness. In this respect, interventions evaluated over the long term and at several points in time might be carried out. For example, limiting the sale of SSB, providing free fresh and drinking water points and containers like glasses or water bottles, combined with water promotion that considers access barriers is an example of an intervention. The multi-point evaluation should address changes in dietary habits and social disparities through a questionnaire for adolescents, but also implementation difficulties, sustainability, and barriers to effectiveness through qualitative interviews with school' staffs. All these findings will guide schools in their health promotion projects.

Finally, both the promotional environment and the food environment in the school raised the issue of the food environment around the school as an important contributor to disparities between adolescents in different schools. This last reflection, being more directly operational through the HBSC survey, is developed here. As mentioned several times before, the food environment could contribute both to the dietary habits of adolescents and to social disparities in their dietary habits. The aim of this research perspective would therefore be **to estimate individual and contextual social disparities in the dietary habits of adolescents, while taking into account the nutritional environment around and within the school.** The objective of this study would require the use of two databases: (i) the 2022 HBSC survey database; (ii) the "Crossroad Banks for Enterprise" (CBE) database.[209]

First, the next HBSC will undergo significant changes that will improve the validity of these future analyses, including the way the questionnaire is administered and the school-level questionnaire. The sampling process could be improved by including the Flemish schools in the Brussels-Capital Region, which is still under discussion at this stage of the survey preparation. This inclusion would provide an overview of that region and of the population in mainstream education in Brussels-Capital.

The mode of the next HBSC survey administration will change from paper to computer. One of the main advantages of computer-based questionnaire is the use of filters and consistency controls. As a result, the number of inconsistent responses and the length of the questionnaire completion will greatly be reduced, and a lower rate of partial non-response is expected.[210]

The school-level questionnaire will significantly be revised and improved. In addition to improved question wording, new and more informed questions are under consideration. These include the set of questions that help to assess Health Promoting Schools (HPS), which are described as "*holistic, whole-school approach in which a broad health education curriculum is supported by the environment and ethos of the school*".[211] Compared to a specific measure, a holistic intervention approach to school health promotion[212] would be more promising to improve health behaviours such as dietary habits,[213] as it goes beyond individual behaviour by including the social and physical environment. Therefore, being an HPS could have a more important effect on dietary habits and related disparities than school having only implemented a limited action like including fruit and vegetable during school events. Lastly, although not proposed by the network, a question on free access to water and other healthy foods will be added, since free access could improve their consumption.[197]

The food environment around school can be determined using the CBE database,[209] developed by the Belgian Federal Public Service Economy. This database contains all enterprises in Belgium as well as information on the type of enterprise, its activities and its address. Through the NACEBEL code ("*Statistical Classification of Economic Activities in the European Community*" for Belgium), places providing foods (e.g. "restricted restaurants", supermarkets)[209] can be identified and linked to schools through geocoding.

Since the purpose of these analyses partly would be to estimate the role of the food environment around the school, no change would be made to the selection of the variables used to determine the dietary habits (fruit, vegetables, water, crisps and fries, SSB), the social position (migration status, FAS, perceived family wealth, parental education level and working status) and the social environment (school socioeconomic status and proportion of immigrants in school).

The food environment within school will be determined with the foods available for free and for sale at school whereas the food environment around school with the distribution of supermarkets, restaurants (including fast-food) and other similar places within 400m of the school, a standard for walkability.[214] Finally, the HPS tool will help determine the health promotion environment at school.

The same analysis strategy would be chosen as for **Chapter V**. Thus, a succession of multilevel models would be carried out, each including a supplementary aspect of the adolescent's life that may be relevant to their dietary habits. Each model would meet several specific objectives (**Table 14**).

These analyses will therefore make it possible to estimate more precisely and more validly the effect of a set of *a priori* determining characteristics on the dietary habits of adolescents. Multilevel models will help determine the intensity with which actions, addressing one or more of the elements behind the disparities, should be taken. For example, if the effect of health promotion actions "disappears" as a result of an unfavourable food environment, actions should not focus primarily on the promoting environment but on the food environment, for example by regulating vending machines. Our results should thus point to ways of understanding the disparities. These avenues can be used to define and guide future surveys, such as qualitative surveys. In this respect, a better understanding of the mechanisms behind disparities is expected.

Regarding the HBSC survey itself, although the sFFQ has several limitations (see **Chapter I**, **section 2.2.2**), it remains the most appropriate tool for the HBSC survey and will not be replaced in the near future. In addition, by keeping mandatory items and the same answer modalities, it is possible to study the evolution of dietary behaviours of adolescents in the HBSC countries. It should also be noted that a data management centre (DMC, University of Bergen) has been implemented within the HBSC network. Along with guidelines for data management (missing, inconsistencies…), the DMC provides support to the network teams and has developed e-learning on statistical methods adapted to the HBSC data, such as multilevel modelling or trend analysis. Since sampling plan may differ across countries (while sharing the same objective, sampling units may differ), a standard statistical plan has not been developed. However, workshops are regularly organised to discuss problematic but not uncommon situations with HBSC data, such as how to reliably account for the study design in complex multilevel models.

Table 14. Description of the successive models and their specific objectives

	Model 1	Model 2	Model 3	Model 4	Model 5
Variables	-	**Social position**	Model 2 + **social environment**	Model 3 + **HPS**	Model 4 + **Food environment within and around school**
Aim	To estimate the differences between schools	To estimate the disparities related to the social position	To estimate the social environment-related disparities	To determine the effects to being an HPS on dietary habits	To estimate the food environment-related disparities
		To estimate the differences between schools that are attributable to the social position	To estimate the effect of the social environment on the individual disparities	To estimate the effect of being an HPS on social position and environment	To estimate the effect of the food environment on HPS and social position and environment-related disparities
			To estimate the differences between schools that are attributable to the social environment	To estimate the differences between schools that are attributable to HPS	To estimate the differences between schools that are attributable to the food environment

4. Public health implications

The dietary habits of adolescents are subject to social inequalities, both at the individual and contextual levels, and which, in addition, evolve in a direction that may be inverse to more or less healthy food consumption. One way to improve dietary habits and reduce inequalities would be to implement public health actions having this double objective, such as those anchored in the concept of proportionate universalism.[42] Actions from a proportionate universalism perspective are "*universal but with a scale and intensity that is proportionate to the level of disadvantage*".[42] Such an approach is to be distinguished from population-based actions, which tend to aggravate inequalities, and from targeted actions, which leave aside those at a marginal risk thus addressing only a small part of the problem.[215]

A universalism proportionate action is thus characterised by its aim to put in place policies that benefit the whole population structure along with measures so that the actions can benefit each individual to the extent of the needs he/she faces.[3] Thus, a nutrition tax, such as the one implemented in Belgium on sugary drinks,[29] is a good example of this type of intervention, although the evaluation of such an action relies on modelling approaches.[3] Indeed, a nutrition tax is universal in nature and the whole population is affected. Its effects will naturally be tailored to the social gradient in consumption. Thus, if the most disadvantaged populations "react" more strongly than others, a reduction in social inequalities is expected.[3] However, such a tax would lead to economic inequalities and should therefore be accompanied by measures to compensate the disadvantaged, like subsidies in the form of vouchers redeemable for fruit and vegetables, for example.[3]

More generally, the social and physical environment must be supportive and conducive to behaviour change.[216] In fact, public health initiatives must promote an environment that is favourable to dietary recommendations. In this respect, the environment should meet the specific cultural needs of the whole population, with a culturally varied food offer for instance. In addition, an environment that encourages a change in behaviour should be promoted.[216] Although not yet sufficiently studied, certain levers have been identified to encourage change through the environment, such as moving the dessert bar and the fruit bar in the canteen or introducing additional difficulties such as payment by bank card for unhealthy foods.[216]

Despite the lack of evidence, it appears that multi-component actions are the most effective.[3] Thus, communication actions should accompany the environment initiatives. Such actions can also achieve the objective of proportionate universalism. For example, the communication of recommendations through different channels and forms, as was recently done in Belgium,[21] may reach the universal target. Disseminating information in schools with low socioeconomic status or with a high rate of immigrants, i.e. high risk groups of having unfavourable dietary behaviours, while adapting the messages to these populations and accompanying them with a varied food offer in line with the recommendations, would help to reduce inequalities.

Overall, nutritional messages should encourage a shift to favourable dietary behaviour.[216] In addition to being simple, clear and unambiguous, nutritional messages must be non-coercive. Indeed, coercion could lead to a psychological reactance[216] from adolescents in search of freedom.[96] These messages can also include symbols or colours to induce change, provided that these are interpreted in the same way across different cultures. In addition, messages for adolescents must be adapted and relevant to their specific interests,[96] thus referring to their risk behaviours seem inadequate in view of their low perception of risk.[93] Particularly in Belgium where cultural disparities have been highlighted, messages need to be adapted to the different sociocultural meanings associated with food, without explicitly contradicting individual identities. In addition, the healthy behaviours of sociocultural groups should be more positively highlighted in the messages. Finally, the communication should be done through different channels,[96] including mass media heavily used by adolescents.[95] Several levers, specific or not to the adolescent population, have been identified to generate behavioural change and can be used for messages aimed at the population, sub-population or individual.[216] These include the use of positive emotions such as humour, the mobilisation of values shared by personalities or peers, and the valuing of favourable rather than unfavourable behaviour,[216] all provided that it is culturally appropriate.

However, nutritional information can be undermined by other factors such as immediate pleasure and taste,[216] which seem very important for adolescents.[96] Although it is mainly determined by dietary variety in the first six years of life, actions can trigger taste and pleasure through claims using words like "special ingredient".[216] Other claims have been identified among adults like those mentioning words such as "healthy",[216] but the expected effect among adolescents may be the opposite. Moreover, according to the "Law of Free Food", the taste barrier could be bypassed by the price of the food, so the cheaper the food, the better the taste.[216]

Health messages must take into account that individuals resist attempts at awareness and persuasion.[216] Several theoretical models of behaviour change have been developed, such as the "trans-theoretical model of behaviour change". Following this model, the individual goes through a total of five phases, from pre-contemplation through preparation to maintenance.[217] They will therefore first be in denial before considering and then carrying out the recommended behaviour, for instance drinking enough water every day. To accompany this change, messages must be adapted to each stage of the process and thus to the readiness for change.[216] According to the "Social Cognitive Theory", behaviour change is also influenced by self-efficacy, fixed goals or outcome expectations.[216] With regards to these models, many factors have been identified to counter resistance to change in dietary habits, such as self-affirmation. Nevertheless, these models of behaviour change place the responsibility for change exclusively on the individual. However, as mentioned above, the environment plays a key role in dietary behaviours. Thus, it seems complex to adopt a dietary behaviour change, such as a limited SSB consumption, if the environment encourages the initial food choice, a heavy SSB consumption. Therefore, addressing poor health behaviours is not only a matter of individual responsibility but also a public health priority, and the environment supplemented with nutrition messages should be a priority for action.

In Belgium, several initiatives have already been put in place to improve dietary habits, such as the taxation of sugary drinks,[29] the officialization of the Nutri-score[28] or the food guides.[31,32] The diversity of actions should ensure a good population coverage, but the effect on disparities still needs to be addressed more specifically. Other actions, mobilising the levers mentioned above, could be targeted to adolescents in Belgium. These include the regulation of food marketing, the regulation of food supply in and around schools, the mandatory use of the Nutri-score, or a higher taxation of sugary drinks with a subsidy for healthy food. In view of the cultural diversity in Belgium and the significant disparities between natives and immigrants, actions should better take into account the cultural specificities of the population, by valuing cultural identity and improving the cultural food offer for example.

CHAPTER VII. CONCLUSION

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Adolescence represents an opportunity to develop healthy and long-lasting dietary behaviours. Also, dietary habits are particularly subject to social variations. Specific actions should improve diet and reduce related inequalities, but a comprehensive approach to the social determinants at this life stage remains necessary. In recent decades, methods in social and nutritional epidemiology have been considerably developed and awareness of the social determinants of nutrition-related health inequalities has actually increased. Despite such developments, the disparities and associated mechanisms are still insufficiently documented.

In the framework of this doctoral thesis, differences in adolescent dietary habits according to their socioeconomic and sociocultural position were documented in Belgium. Interestingly, the observed socioeconomic differences were also specific to the migration status. Moreover, dietary habits and social disparities evolved in opposite directions. Lastly, disparities according to socioeconomic, sociocultural and to a lesser extent nutritional environment have also been documented. The mechanisms involved are still not well known and deserve to be explored further, with qualitative studies for instance, in order to further implement effective actions.

It is worth noting that all these conclusions are valid for the period prior to Covid-19. In fact, the Covid-19 pandemic may have had effects on social inequalities in dietary habits, particularly with changes in work (loss of employment, teleworking, etc.) or with the increase in food insecurity. Our findings will therefore need to be updated with post-Covid data.

In any case, future nutritional actions have to already integrate the concept of proportionate universalism in order to improve dietary habits and reduce – or at least do not increase – related social inequalities among adolescents. To avoid increasing inequalities between adolescents, especially when they are of different sociocultural backgrounds, the meaning that adolescents give to food but also the cultural aspect of diet, while respecting identities, beliefs, values and tradition, is to be integrated in actions. Finally, it is crucial that public health actions do not shift responsibility exclusively to the individual and that they focus on their environment.

To conclude, reducing inequalities in the dietary habits of adolescents in Belgium is a complex objective to achieve, given the diversity and interrelation of these inequalities and the particular nature of the Belgian and adolescent population. However, this complexity should not constitute a waiver, because acting on adolescents will promote positive health trajectories throughout life and is a considerable investment for the future.

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APPENDICES

⁂

Appendix A. Research syntax used in Medline for updating knowledge on dietary disparities

("Diet"[Mesh] OR "Diet" [TIAB] OR "Food"[Mesh:noExp] OR "Fruit"[Mesh] OR "Vegetables"[Mesh] OR "Dairy Products"[Mesh] OR "Nutrition Surveys"[Mesh] OR "Nutrition*" [TIAB])

AND

("Socioeconomic Factors"[Mesh] OR "Socioeconomic Factors"[TIAB] OR "Risk Factors"[Mesh] OR "Ethnic groups"[Mesh] OR "family characteristics"[Mesh] OR "health status"[Mesh] OR "human migration"[Mesh] OR "residence characteristics"[Mesh] OR "Family"[Mesh])

AND

("Europe"[Mesh] OR "Canada"[Mesh] OR "United States"[Mesh] OR "Australia"[Mesh] OR "New Zealand"[Mesh])

AND

("2018/01/01"[PDAT] : "2020/12/31"[PDAT])

AND

("humans"[MeSH Terms])

AND

("adolescent"[MeSH Terms])

Appendix B. Inclusion and exclusion criteria for studies in the literature review

Table B-1. PICOS (Population, Intervention, Comparison, Outcomes and Study design) criteria for inclusion and exclusion of the studies in the literature review

PICOS	Inclusion and exclusion criteria
Population	General population, 10 to 17 years old, living in Europe, the United States, Canada, Australia or New Zealand. Results specifically presented in adolescent (i.e. 10-17-year-old) subgroup. *Excluded: patients, elderly, infant or pre-school children, pregnant or lactating women, overweight or obese persons, those participating in a diet program, persons with eating disorders, specific ethnic groups (e.g. Inuits), refugees, low-income countries or geographic areas such as Asia.*
Intervention	Not applicable.
Comparison	Of subjects, their parents, their household: - Individual socioeconomic status: education level, income, occupation, employment status. - Contextual socioeconomic status: school status, geographic area status. - Family structure: parenthood, sibling(s), household size. - Sociocultural position: ethnicity, country of origin, migration background.
Outcome	Diet assessed by usual intake or food frequency, in terms of food groups, food patterns and diet scores. *Excluded outcomes: energy, macro- and micronutrient intake, eating behaviour (meal frequency, breakfast skipping, take-away or fast food consumption), and diet assessed through biomarkers.*
Study design	Cross-sectional Longitudinal: description of cohort at baseline or at follow-up point.

Appendix C. Example of the short Food Frequency Questionnaire in HBSC

Figure C-1. The sFFQ of the 2018 French-speaking HBSC survey.

40. Habituellement, combien de fois par semaine bois-tu ou manges-tu les aliments suivants :

coche une réponse par ligne, stp	Plus d'1 fois par jour, chaque jour	Une fois par jour, chaque jour	5 à 6 jours par semaine	2 à 4 jours par semaine	1 fois par semaine	Moins d'1 fois par semaine	Jamais
Fruits	☐	☐	☐	☐	☐	☐	☐
Légumes	☐	☐	☐	☐	☐	☐	☐
Sucreries (bonbons, chiques, chocolat…)	☐	☐	☐	☐	☐	☐	☐
Coca® et autres boissons sucrées (Fanta®, Caprisun®, Ice Tea®…)	☐	☐	☐	☐	☐	☐	☐
Coca® light/zéro et autres boissons light	☐	☐	☐	☐	☐	☐	☐
Boissons énergétiques (Red Bull®…)	☐	☐	☐	☐	☐	☐	☐
Lait aromatisé (Cécémel®, Fristi®…)	☐	☐	☐	☐	☐	☐	☐
Lait écrémé ou demi-écrémé	☐	☐	☐	☐	☐	☐	☐
Lait entier	☐	☐	☐	☐	☐	☐	☐
Fromages	☐	☐	☐	☐	☐	☐	☐
Yaourt, fromage blanc	☐	☐	☐	☐	☐	☐	☐
Crèmes desserts, riz au lait, flans, mousses au chocolat…	☐	☐	☐	☐	☐	☐	☐
Poisson pané (fishstick…)	☐	☐	☐	☐	☐	☐	☐
Poisson non pané	☐	☐	☐	☐	☐	☐	☐
Céréales pour petit-déjeuner (cornflakes, muesli, Choco pops®…)	☐	☐	☐	☐	☐	☐	☐
Pain blanc	☐	☐	☐	☐	☐	☐	☐
Pain gris, multicéréales, complet	☐	☐	☐	☐	☐	☐	☐
Chips	☐	☐	☐	☐	☐	☐	☐
Frites	☐	☐	☐	☐	☐	☐	☐
Eau	☐	☐	☐	☐	☐	☐	☐

Appendix D. Outlines of multilevel modelling – Methods related to chapters III and V

Multilevel modelling is designed to handle the data structure. In the HBSC surveys, data is organised in a hierarchical structure[152] following the sampling design, with participating adolescents [level 1] nested within classes [level 2], in turn nested in schools [level 3]. Such a structure can result in correlated or non-independent data. Indeed, we might expect that two randomly selected adolescents from the same school should be more alike regarding food frequency consumption than two adolescents from different schools.[153] In other words, characteristics of the school, particularly in terms of nutrition, might influence adolescent dietary habits. In the analyses of this thesis (chapters III and V), class level is not considered, as dietary habits were not influenced by class characteristics in addition to those of schools.

Single-level modelling

In the absence of such a data structure, single-level modelling is performed. Under these circumstances, are assumed the independence of the observations and the uncorrelation with each other of the residuals denoted e_i.[218] The equation of the single-level logistic regression model is written as follows:[219]

$$y_i = \beta_0 + \Sigma_{i=1}^{k} \beta_i X_i + e_i$$

with $e_i \sim N(0, \sigma_e^2)$.

Two-level modelling

As mentioned throughout this work, adolescents participating in HBSC surveys are nested within schools. Let's consider that the adolescent i belongs to a school j and his/her binary response is written y_{ij}. Compared to a one-level model (**Figure D-1**), the residuals in two-level modelling are split into two components: individual residuals denoted e_{ij} and school residuals denoted u_j.[218]

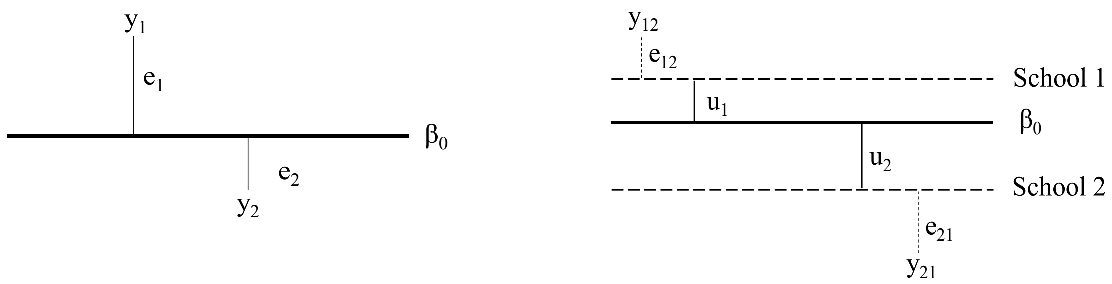


Figure D-1. Graphical representation of a one-level (left) and a two-level (right) binary logistic regressions.

When school residuals u_j are not fixed and are assumed to vary across schools, the model is said to be "**random intercept model**" [154]. Let X_{ij} the individual-level independent variables, Z_j the school-level independent variables, the equation of this model is the following [154]:

$$y_i = \beta_0 + \Sigma_{i=1}^{k} \beta_i X_{ij} + \Sigma_{l=1}^{m} \beta_l Z_j + u_j + e_{ij}$$

with $u_j \sim N(0, \sigma_u^2)$ and $e_{ij} \sim N(0, \sigma_e^2)$.

The first step in multilevel analyses is to determine whether dietary habits do differ between schools or not. Hence, a likelihood ratio test comparing the one-level model to the two-level random intercept model is performed.[154] When the null hypothesis of no group difference is rejected (*P* value significant), the two-level model is retained. Indeed, a significant test implies that the more complete (i.e. two-level) model fits better than the less complete (i.e. one-level) model.

In the random intercept model, only the intercept β_0 is allowed to vary while the slope β_i is assumed to be fixed across schools, meaning that the relationship between *y* and *x* does not vary across schools. The equation of the **random slope model** is the following:[154]

$$y_i = \beta_0 + \beta_1 x_{ij} + \Sigma_{i=2}^{k} \beta_i X_{ij} + \Sigma_{l=1}^{m} \beta_l Z_j + u_{0j} + u_{1j} x_{ij} + e_{ij}$$

with $u_{0j} \sim N(0, \sigma_{u0}^2)$, $u_{1j} \sim N(0, \sigma_{u1}^2)$, covariance σ_{u01} and $e_{ij} \sim N(0, \sigma_e^2)$.

The slopes of all the independent individual-level variables can be allowed to vary across schools, leading to a very complex and difficult to estimate model. Hence, if the effect of a variable is not different from one group to another, it is not necessary to use a random slope model. To determine whether the slope should be fixed or random, a likelihood ratio test is performed,[168] comparing a first model with a fixed slope nested in a second with a random slope. The random slope model will be retained when the *P* value is significant, meaning that this model fits better than the fixed slope model. Note that contextual variables, which are specific to schools, may also vary and could be considered at a higher level, i.e. level 3. However, we did not consider such a level in our analyses.

Appendix E. Outlines of Multiple Correspondence Analysis – Methods related to chapter V

Multiple Correspondence Analysis (MCA) is one of the descriptive and multidimensional method of Geometric Data Analysis.[220] MCA is analogous to Principal Component Analysis (PCA), with the difference that MCA is performed on categorical data while PCA on quantitative data. MCA can also be viewed as an extension of Correspondence Analysis (CA), in that it applies to more than two categorical variables.

The main objectives of MCA are:

i. "*To study similarities between individuals from a multidimensional perspective;*

ii. *To assess the relationships between the variables and study the associations between the categories;*

iii. *To link together the study of individuals and that of variables in order to characterise the individuals using the variables*".[162]

As part of this work, the MCA was performed on *foods available at schools* and is intended to be the preliminary step to hierarchical clustering.[162] Indeed, one solution to avoid stability problems[163] is to first transform categorical variables into quantitative variables before performing a hierarchical clustering.

Reprocessing data

The first step before performing an MCA is to transform the raw database in an indicator[a] matrix (**Figure E-1**).[162] The matrix is of size I x K, with I the set of individuals and K the set of categories. As part of this work, the individuals are the schools and the variables are the foods available for sale at school (10 items, each with two modalities). A value of 1 is assigned when the individual has the category and 0 when he does not. Therefore, y_{ik} equals 1 if the individual i has the category k of the variable j, otherwise 0. Noteworthy in MCA, all the individuals have the same weight: $\frac{1}{I}$. Given that a rare category is much more characteristic of an individual than a frequent category, the proportion of individuals with the category k (p_k)

[a] An indicator variable (or dummy variable) is a variable that can only takes a value of 0 or 1, corresponding to the absence or presence of a qualitative attribute.[221].

is taken into consideration as follows: $\frac{y_{ik}}{p_k}$. MCA is based on the matrix Z, the centred version, with $x_{ik} = \frac{y_{ik}}{p_k} - 1$.[167]

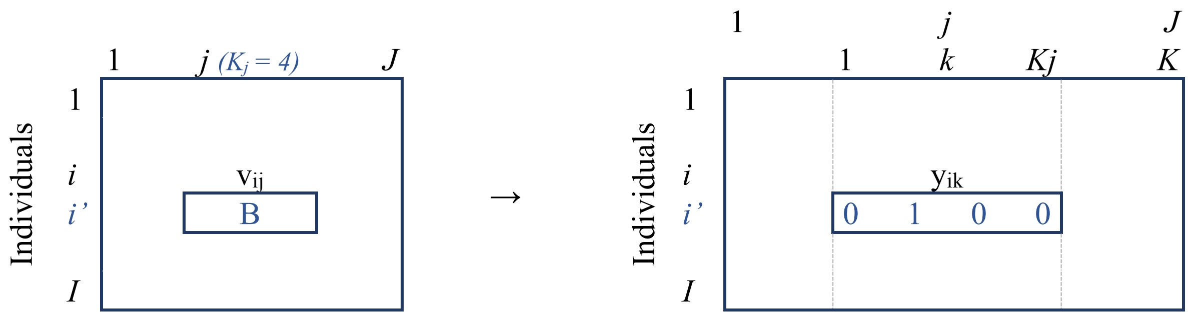


Figure E-1. Conversion of a raw database into an indicator matrix. I: individuals; J: variables; K: categories.

Studying individuals

The study of individuals provides information of the similarity between them, i.e. the variability of individuals.[162] For instance, two individuals are similar if they have many categories in common. Conversely, two individuals are different if they have few categories in common. MCA aims to explore this variability from a multidimensional perspective.

Initially, individuals are represented in a vector space $\mathbb{R}^K$, each dimension representing a category *k*.[162] As a result, the set of individuals forms a cloud N_I with a centre of gravity G_I. The profile M_i has the *principal coordinates* x_{ik} with respect of *principal axes* and a weight of $\frac{1}{I}$. The total inertia of the cloud, "*a multidimensional extension of the concept of variance*", is:[162]

$$Inertia(N_I) = \frac{1}{I}\sum_{i=1}^{I} d^2(i, G_I) \ = \frac{K}{J} - 1$$

The distance between individuals, a method of studying similarity, is calculated as follows:[162]

$$d_{i,i'}^2 = \frac{1}{J}\sum_{k=1}^{K} \frac{1}{p_k}(y_{ik} - y_{i'k})^2$$

Therefore, the distance between two individuals equals zero if they have the same categories. Conversely, the distance is high if one individual has a rare category. Furthermore, the more rare categories an individual has, the further away he will be from the origin (centre of gravity due to data centring):[220]

$$d(i, G_I)^2 = \frac{1}{J}\sum_{k=1}^{K}\frac{y_{ij}}{p_k} - 1$$

Given that the high dimensionality of the space prevents visualisation of the cloud of individuals, the cloud N_I in $\mathbb{R}^K$ can be represented in a lower dimensional space.[167] Among others, one of the challenges is to distort distances between individuals as little as possible and thus, to obtain the more accurate image of the cloud. Therefore, a sequence of orthogonal axes of maximum inertia is searched, with the origin of the axes at the centre of gravity G_I. Afterwards, the cloud N_I is projected on these axes denoted μ_s. The first two orthogonal axes correspond to the plane P, that is the best plane representation.[167] As a result of the projection, the profile M_i has new coordinates, that is the mean of the coordinates of the categories taken by the individual i. Let $F_s(i)$ the coordinates of individual i and $G_s(i)$ the coordinates of category k on the rank axis s:[167]

$$F_s(k) = \sum_{j=1}^{J}\sum_{k=1}^{K_j}\frac{x_{ik}}{J}G_s$$

Therefore, the set of projections of all the points of the cloud N_I on the factorial axis μ_s forms a new synthetic variable F_s.[165] This quantitative synthetic variable is also called *principal component* and summarise all the original categorical variables.[165]

Axes are characterised by two mains properties: the eigenvalue and the percentage of inertia. The eigenvalue of the axe s (λ_s) is the inertia of the cloud N_I projected on the axis s, i.e. the variance explained by this axis.[167] The percentage of inertia relates the projected inertia of the cloud N_I to total inertia:[167]

$$\frac{\lambda_s}{\sum_{s=1}^{K}\lambda_s}$$

Noteworthy, the maximum percentage of inertia related to an axis is equal to: $\frac{J}{K-J} x\ 100$.[167] Therefore, this percentage tend to be weak in MCA.[162] The eigenvalues can be used to determine the number of axes to be retain. The challenge is to find the number of axes that allow both to interpret the data and to preserve as much variability as possible. The scree plot, a line plot of the eigenvalues, can be used to determine the number of dimensions to be kept.[222] The dimensions to be retained are those before the eigenvalues levelling-off. However, only the first plane can also be retained[222] to facilitate data visualisation and interpretation.

From the cloud of individuals, categories can be projected.[162] A category is similar to a group of individuals. Therefore, a category k is at the barycentre[a] of the individuals who have chosen this category k. In addition, the origin of the cloud is at the barycentre of the variable's categories. Therefore, the more frequent a category is, the closer it will be to the origin.[162] By visualising the categories in the cloud of individuals, we will be able to observe the structure of the data.

Studying categories

Another way of representing the categories through the barycentre of individuals is to project the cloud of categories in a lower dimensionality space, similarly to the cloud of individuals. The categories are represented in a vector space $\mathbb{R}^I$, each dimension representing an individual i.[162] Therefore, the set of categories forms a cloud N_K with a center of gravity G_K.

The variance of the category k is equal to:[162]

$$var(k) = d^2(k, O) = \sum_{i=1}^{I} \frac{1}{I} x_{ik}^2 = \frac{1}{p_k} - 1$$

The inertia of the category k and the inertia of the cloud N_K are equal to:[162]

$$Inertia(k) = \frac{1 - p_k}{J}$$

$$Inertia(N_K) = \frac{1}{J} \sum_{k=1}^{K_j} (1 - p_k) = \frac{K}{J} - 1$$

Therefore, the rarer the category, the further away it is from the origin and the greater the inertia. The distance between two categories is calculated as follows:[167]

$$d_{k,k'}^2 = \sum_{i=1}^{I} \left(\frac{y_{ik}}{p_k} - \frac{y_{ik'}}{p_{k'}} \right)^2$$

As before, in order to represent the cloud N_K in $\mathbb{R}^I$ in a lower dimensional space, a sequence of orthogonal axes of maximum inertia is searched, with the origin of the axes at the centre of gravity G_J. The profile M_k has the coordinates x_{ik} and a weight of $\frac{p_k}{J}$. Afterwards, the cloud N_K is projected on these axes, with the first two orthogonal axes corresponding to a plane P.

[a] Centroid, average. The coordinates of the barycentre are the arithmetic mean of the coordinates of all the points

Therefore, the profile M_k has new coordinates, that is the mean of the coordinates of the individuals with the category k:[167]

$$G_s(k) = \sum_{i=1}^{I} \frac{x_{ik}}{I_k} F_s(i)$$

From the cloud of categories, individuals can be projected. An individual can be considered as a set of categories he has chosen. Therefore, an individual is at the barycenter of the categories he has.

Duality relation – graphical representation of MCA

The cloud of individuals and the cloud of categories are linked by relations of duality[a]. Among others, the clouds N_I and N_J have the same total inertia, that is: $\frac{K}{J} - 1$.[167] In addition, the graph of individuals with the categories at the barycentre and the graph of categories with the individuals at the barycentre are identical to within one multiplier $\left(\frac{1}{\sqrt{\lambda_s}}\right)$:[167]

$$F_s = \frac{1}{\sqrt{\lambda_s}} \sum_{j=1}^{J} \sum_{k=1}^{K_j} \frac{x_{ik}}{J} G_s$$

$$G_s(k) = \frac{1}{\sqrt{\lambda_s}} \sum_{i=1}^{I} \frac{x_{ik}}{I_k} F_s(i)$$

The latter duality relation makes it possible to obtain the graph of individuals and categories simultaneously. On the graph of individuals (resp. categories), the coordinates of the categories (resp. individuals) are multiplied by λ_s.[167] As a result, the categories (resp. individuals) are now considered to be at the pseudo-barycentre of individuals (resp. categories).[167]

[a] If the dual of *A* is *B*, the dual of *B* is *A*

Appendix F. Supplementary material to the article "*Socioeconomic disparities in diet vary according to migration status among adolescents in Belgium*" – Multilevel logistic regression models related to the results in figure form

Table F-1. Multilevel multinomial regressions for fruit consumption (reference category: >once a day) stratified by migration status (n = 19,172). *2014 HBSC in Belgium.*

				Simple multilevel multinomial regression							Multiple multilevel multinomial regression				
		Fruit consumption >once a day		Fruit consumption 5-7 days a week			Fruit consumption <5 days				Fruit consumption 5-7 days a week		Fruit consumption <5 days		
	Variables	n	%	%	cRRR (IC 95%) [b]	*P* value	%	cRRR (IC 95%) [b]	*P* value	Overall *P* value	aRRR (IC 95%) [c]	*P* value	aRRR (IC 95%) [c]	*P* value	Overall *P* value
Natives (n=13,353)	**Gender**					0.08			<0.001	<0.001		0.03		<0.001	<0.001
	Boys	6 872	12.9	29.4	1.10 (0.99-1.23)		57.7	1.68 (1.51-1.87)			1.13 (1.01-1.26)		1.69 (1.53-1.88)		
	Girls	6 481	18.1	35.8	1		46.1	1			1		1		
	Age					0.48			<0.001	<0.001		0.55		<0.001	<0.001
	10-12 y	3 956	18.7	38.3	1		43.0	1			1		1		
	13-16 y	6 662	14.4	30.7	1.09 (0.93-1.27)		54.9	1.74 (1.50-2.02)			1.07 (0.94-1.21)		1.71 (1.51-1.94)		
	17-19 y	2 735	13.2	28.5	1.11 (0.92-1.34)		58.3	2.02 (1.68-2.43)			1.08 (0.91-1.27)		1.88 (1.61-2.21)		
	Family structure [a]					0.12			<0.001	<0.001		0.05		<0.001	<0.001
	Two parents	8 826	16.5	33.7	1		49.8	1			1		1		
	Blended family	2 104	13.2	31.3	1.18 (1.01-1.38)		55.5	1.42 (1.22-1.64)			1.21 (1.03-1.41)		1.46 (1.26-1.69)		
	Single-parent family	2 423	13.5	29.3	1.05 (0.91-1.22)		57.2	1.39 (1.21-1.60)			1.07 (0.92-1.24)		1.29 (1.12-1.49)		
	Family Affluence Scale [a]					0.29			<0.001	<0.001		0.14		<0.001	<0.001
	High	2 746	19.3	37.5	1		43.2	1			1		1		
	Medium	8 826	14.6	32.1	1.10 (0.97-1.26)		53.3	1.59 (1.40-1.80)			1.14 (1.00-1.29)		1.65 (1.46-1.87)		
	Low	1 781	13.4	26.8	1.03 (0.84-1.25)		59.8	1.99 (1.65-2.39)			1.08 (0.89-1.31)		2.13 (1.77-2.56)		
	Parental working status [a]					0.3			0.05	0.001					
	Both parents working	10 162	15.5	33.4	1.15 (0.98-1.35)		51.1	1.00 (0.86-1.16)							
	One working, the other at home	1 786	16.1	30.3	1		53.6	1							
	One working, the other not at home	969	14.7	29.4	1.07 (0.83-1.38)		55.9	1.16 (0.92-1.46)							
	None working	436	13.1	28.7	1.27 (0.89-1.81)		58.2	1.46 (1.06-2.02)							
	Siblings					0.31			<0.001	<0.001		0.22		<0.001	<0.001
	Single child	1 303	11.7	28.6	1.11 (0.91-1.35)		59.7	1.49 (1.23-1.79)			1.13 (0.93-1.38)		1.40 (1.16-1.69)		
	Siblings	12 050	15.8	32.9	1		51.3	1			1		1		
	School Region					<0.001			<0.001	<0.001		<0.001		<0.001	<0.001
	Brussels-Capital	452	20.8	38.1	1		41.1	1			1		1		
	Wallonia	6 507	21.2	34.4	0.84 (0.61-1.15)		44.4	1.00 (0.73-1.37)			0.86 (0.64-1.16)		0.99 (0.74-1.33)		
	Flanders	6 394	9.2	30.2	1.75 (1.26-2.42)		60.6	3.25 (2.35-4.49)			1.76 (1.30-2.38)		3.21 (2.38-4.33)		
	Intercept				*2.12 (1.92-2.35)*	*<0.001*		*3.40 (3.09-3.75)*	*<0.001*		*1.50 (1.10-2.05)*	*0.01*	*0.62 (0.46-0.85)*	*0.003*	

		Fruit consumption >once a day	Simple multilevel multinomial regression							Multiple multilevel multinomial regression				
			Fruit consumption 5-7 days a week			Fruit consumption <5 days				Fruit consumption 5-7 days a week		Fruit consumption <5 days		
Variables	n	%	%	cRRR (IC 95%) [b]	*P* value	%	cRRR (IC 95%) [b]	*P* value	Overall *P* value	aRRR (IC 95%) [c]	*P* value	aRRR (IC 95%) [c]	*P* value	Overall *P* value
Second-generation immigrants (n=4,214)														
Gender					0.29			0.002	0.002		0.28		0.003	0.006
Boys	2 002	18.8	32.5	1.10 (0.92-1.31)		48.7	1.31 (1.11-1.55)			1.10 (0.92-1.31)		1.29 (1.09-1.53)		
Girls	2 212	22.3	34.4	1		43.3	1			1		1		
Age					0.38			<0.001	<0.001		0.23		<0.001	<0.001
10-12 y	1 209	26.0	37.7	1		36.3	1			1		1		
13-16 y	2 130	18.7	32.8	1.17 (0.94-1.45)		48.5	1.79 (1.44-2.22)			1.20 (0.97-1.47)		1.82 (1.48-2.23)		
17-19 y	875	17.9	29.4	1.09 (0.83-1.43)		52.7	2.03 (1.56-2.64)			1.14 (0.88-1.48)		2.17 (1.68-2.79)		
Family structure [a]					0.38			0.07	0.001		0.44		0.19	0.03
Two parents	2 861	21.2	35.1	1		43.7	1			1		1		
Blended family	416	18.7	33.2	1.06 (0.78-1.43)		48.1	1.23 (0.92-1.64)			1.07 (0.79-1.45)		1.22 (0.92-1.64)		
Single-parent family	937	19.6	28.9	0.87 (0.70-1.08)		51.5	1.24 (1.01-1.52)			0.88 (0.71-1.10)		1.16 (0.95-1.43)		
Family Affluence Scale [a]					0.39			<0.001	<0.001		0.29		<0.001	<0.001
High	716	26.5	38.1	1		35.4	1			1		1		
Medium	2 519	19.5	33.7	1.14 (0.91-1.43)		46.8	1.71 (1.37-2.15)			1.19 (0.95-1.48)		1.74 (1.39-2.19)		
Low	979	19.1	29.7	1.02 (0.77-1.34)		51.2	1.89 (1.45-2.47)			1.10 (0.83-1.44)		1.94 (1.48-2.54)		
Parental working status [a]					0.87			0.39	0.41					
Both parents working	2 187	21.3	34.6	1.08 (0.88-1.33)		44.1	0.95 (0.78-1.15)							
One working, the other at home	1 172	20.6	32.4	1		47.0	1							
One working, the other not at home	358	19.0	32.4	1.13 (0.80-1.60)		48.6	1.17 (0.84-1.62)							
None working	497	18.7	32.2	1.09 (0.80-1.48)		49.1	1.14 (0.85-1.53)							
Siblings					0.88			0.29	0.27		0.90		0.53	0.63
Single child	315	19.4	30.5	0.97 (0.69-1.37)		50.1	1.19 (0.87-1.63)			0.98 (0.70-1.37)		1.11 (0.80-1.53)		
Siblings	3 899	20.7	33.8	1		45.5	1			1		1		
School Region					<0.001			<0.001	<0.001		<0.001		<0.001	<0.001
Brussels-Capital	1 229	23.3	35.2	1		41.5	1			1		1		
Wallonia	1 811	23.8	34.1	1.00 (0.76-1.32)		42.1	1.05 (0.80-1.38)			0.96 (0.76-1.22)		1.05 (0.83-1.33)		
Flanders	1 174	12.9	30.8	1.69 (1.22-2.33)		56.3	2.61 (1.91-3.57)			1.60 (1.21-2.12)		2.72 (2.07-3.57)		
Intercept				*1.73 (1.53-1.96)*	*<0.001*		*2.37 (2.10-2.67)*	*<0.001*		*1.19 (0.88-1.60)*	*0.25*	*0.56 (0.51-0.76)*	*<0.001*	
First-generation immigrants (n=1,605)														
Gender					0.60			0.14	0.28		0.49		0.18	0.40
Boys	829	21.2	32.5	1.08 (0.82-1.42)		46.3	1.22 (0.94-1.59)			1.10 (0.84-1.45)		1.20 (0.92-1.57)		
Girls	776	24.6	33.4	1		42.0	1			1		1		
Age					0.02			<0.001	<0.001		0.01		<0.001	<0.001
10-12 y	361	31.3	34.1	1		34.6	1			1		1		
13-16 y	825	21.5	32.1	1.41 (1.00-2.00)		46.4	2.01 (1.43-2.82)			1.41 (1.02-1.95)		1.95 (1.41-2.70)		
17-19 y	419	18.4	33.4	1.78 (1.18-2.68)		48.2	2.52 (1.69-3.76)			1.81 (1.23-2.67)		2.55 (1.74-3.75)		
Family structure [a]					0.48			0.08	0.007		0.55		0.12	0.02
Two parents	1 044	23.7	35.3	1		41.0	1			1		1		
Blended family	192	18.2	28.7	0.99 (0.62-1.59)		53.1	1.59 (1.04-2.44)			0.98 (0.62-1.56)		1.53 (0.99-2.37)		
Single-parent family	369	23.0	28.2	0.81 (0.58-1.14)		48.8	1.21 (0.89-1.66)			0.83 (0.59-1.16)		1.20 (0.87-1.65)		
Family Affluence Scale [a]					0.79			0.008	<0.001		0.86		0.002	<0.001
High	264	26.1	39.8	1		34.1	1			1		1		
Medium	860	23.1	32.9	0.88 (0.61-1.29)		44.0	1.38 (0.94-2.01)			0.91 (0.63-1.31)		1.42 (0.97-2.08)		
Low	481	20.6	29.1	0.95 (0.62-1.45)		50.3	1.91 (1.26-2.91)			0.95 (0.62-1.44)		2.10 (1.38-3.21)		
Parental working status [a]					0.71			0.83	0.89					
Both parents working	755	22.9	32.1	0.88 (0.63-1.25)		45.0	1.03 (0.74-1.44)							
One working, the other at home	381	23.1	34.9	1		42.0	1							
One working, the other not at home	224	24.1	31.7	0.82 (0.52-1.29)		44.2	0.95 (0.61-1.47)							
None working	245	21.2	33.5	1.05 (0.67-1.66)		45.3	1.18 (0.76-1.83)							
Siblings					0.69			0.39	0.68		0.71		0.83	0.93
Single child	168	20.8	32.2	1.10 (0.69-1.74)		47.0	1.21 (0.78-1.86)			1.09 (0.69-1.72)		1.05 (0.68-1.63)		
Siblings	1 437	23.1	33.0	1		43.9	1			1		1		
School Region					0.01			<0.001	<0.001		0.009		<0.001	<0.001
Brussels-Capital	509	27.7	35.8	1		36.5	1			1		1		
Wallonia	613	26.4	33.9	1.02 (0.72-1.44)		39.7	1.16 (0.82-1.64)			1.02 (0.74-1.41)		1.26 (0.91-1.73)		
Flanders	483	13.2	28.6	1.72 (1.14-2.61)		58.2	3.44 (2.31-5.11)			1.74 (1.17-2.57)		3.95 (2.71-5.75)		
Intercept				*1.48 (1.25-1.75)*	*<0.001*		*1.99 (1.69-2.34)*	*<0.001*		*0.98 (0.62-1.56)*	*0.94*	*0.37 (0.23-0.60)*	*<0.001*	

[a] For details, see *Methods* section
[b] Crude relative risk ratio and 95% confidence interval
[c] Adjusted relative risk ratio and 95% confidence interval

Table F-2. Multilevel multinomial regressions for vegetable consumption (reference category: >once a day) stratified by migration status (n = 18,974). *2014 HBSC in Belgium*.

				Simple multilevel multinomial regression							Multiple multilevel multinomial regression				
			Vegetable consumption >once a day	Vegetable consumption 5-7 days a week			Vegetable consumption <5 days a week				Vegetable consumption 5-7 days a week		Vegetable consumption <5 days a week		
	Variables	n	%	%	cRRR (IC 95%) [b]	*P* value	%	cRRR (IC 95%) [b]	*P* value	Overall *P* value	aRRR (IC 95%) [c]	*P* value	aRRR (IC 95%) [c]	*P* value	Overall *P* value
Natives (n=13,236)	**Gender**					0.06			<0.001	<0.001		0.15		<0.001	<0.001
	Boys	6 817	16.5	58.5	1.10 (1.00-1.21)		25.0	1.68 (1.50-1.88)			1.07 (0.98-1.18)		1.76 (1.57-1.98)		
	Girls	6 419	20.0	62.5	1		17.5				1		1		
	Age					<0.001			0.33	<0.001		<0.001		0.77	<0.001
	10-12 y	3 912	20.7	55.3	1		24.0	1			1		1		
	13-16 y	6 613	17.7	62.2	1.37 (1.20-1.56)		20.1	1.02 (0.88-1.19)			1.36 (1.21-1.53)		0.96 (0.84-1.10)		
	17-19 y	2 711	15.8	63.7	1.53 (1.30-1.80)		20.5	1.14 (0.95-1.37)			1.51 (1.30-1.75)		1.01 (0.85-1.20)		
	Family structure [a]					0.09			<0.001	<0.001		0.17		0.002	<0.001
	Two parents	8 754	18.9	60.7	1		20.4	1			1		1		
	Blended family	2 084	17.5	63.1	1.14 (1.00-1.30)		19.4	1.04 (0.89-1.22)			1.13 (0.99-1.30)		1.00 (0.85-1.17)		
	Single-parent family	2 398	16.1	57.3	1.10 (0.97-1.25)		26.6	1.52 (1.31-1.76)			1.05 (0.92-1.20)		1.30 (1.11-1.51)		
	Family Affluence Scale [a]					<0.001			<0.001	<0.001		<0.001		<0.001	<0.001
	High	2 728	23.5	60.2	1		16.3	1			1		1		
	Medium	8 743	17.2	61.3	1.37 (1.23-1.54)		21.5	1.78 (1.54-2.05)			1.39 (1.24-1.56)		1.77 (1.54-2.04)		
	Low	1 765	15.0	56.3	1.45 (1.22-1.72)		28.7	2.74 (2.25-3.34)			1.52 (1.27-1.82)		2.54 (2.07-3.12)		
	Parental working status [a]					0.17			<0.001	<0.001		0.16		0.05	<0.001
	Both parents working	10 074	18.4	61.6	1.14 (0.99-1.30)		20.0	0.86 (0.73-1.01)			1.16 (1.01-1.33)		0.93 (0.79-1.10)		
	One working, the other at home	1 773	19.0	56.7	1		24.3	1			1		1		
	One working, the other not at home	957	15.4	57.9	1.26 (1.01-1.58)		26.7	1.36 (1.06-1.75)			1.22 (0.97-1.54)		1.25 (0.97-1.62)		
	None working	432	16.9	53.5	1.10 (0.82-1.48)		29.6	1.42 (1.02-1.97)			1.09 (0.80-1.47)		1.18 (0.85-1.65)		
	Siblings					0.21			0.002	0.002		0.51		0.008	0.007
	Single child	1 295	15.4	59.5	1.11 (0.94-1.31)		25.1	1.36 (1.12-1.64)			1.06 (0.90-1.25)		1.29 (1.07-1.56)		
	Siblings	11 941	18.5	60.6	1		20.9	1			1		1		
	School Region					<0.001			<0.001	<0.001		<0.001		<0.001	<0.001
	Brussels-Capital	451	20.4	58.5	1		21.1	1			1		1		
	Wallonia	6 432	22.9	53.7	0.78 (0.58-1.05)		23.4	0.94 (0.67-1.33)			0.77 (0.58-1.02)		0.94 (0.68-1.31)		
	Flanders	6 353	13.3	67.4	1.68 (1.24-2.28)		19.3	1.34 (0.94-1.90)			1.67 (1.25-2.23)		1.32 (0.94-1.85)		
	Intercept				*3.39 (3.13-3.67)*	*<0.001*		*1.20 (1.10-1.30)*	*<0.001*		*1.55 (1.12-2.15)*	*0.009*	*0.48 (0.33-0.71)*	*<0.001*	

Variables	n	Vegetable consumption >once a day %	Vegetable consumption 5-7 days a week %	cRRR (IC 95%) [b]	*P* value	Vegetable consumption <5 days a week %	cRRR (IC 95%) [b]	*P* value	Overall *P* value	Vegetable consumption 5-7 days a week aRRR (IC 95%) [c]	*P* value	Vegetable consumption <5 days a week aRRR (IC 95%) [c]	*P* value	Overall *P* value
			Simple multilevel multinomial regression							Multiple multilevel multinomial regression				
Second-generation immigrants (n=4,156)														
Gender					0.006			<0.001	<0.001		0.02		<0.001	<0.001
Boys	1 968	17.1	44.4	1.27 (1.07-1.51)		38.5	1.66 (1.39-1.98)			1.22 (1.03-1.44)		1.68 (1.41-2.01)		
Girls	2 188	22.7	46.5	1		30.8	1			1		1		
Age					0.05			0.24	0.19		0.008		0.40	0.01
10-12 y	1 190	22.9	42.8	1		34.3	1			1		1		
13-16 y	2 101	18.5	46.8	1.31 (1.05-1.62)		34.7	1.21 (0.97-1.51)			1.36 (1.11-1.67)		1.15 (0.93-1.42)		
17-19 y	865	19.8	46.2	1.22 (0.94-1.62)		34.0	1.12 (0.86-1.47)			1.35 (1.05-1.73)		1.05 (0.81-1.36)		
Family structure [a]					0.35			0.06	0.002		0.29		0.19	0.02
Two parents	2 814	20.4	44.5	1		35.1	1			1		1		
Blended family	411	20.7	53.5	1.20 (0.91-1.58)		25.8	0.73 (0.53-0.99)			1.17 (0.89-1.55)		0.78 (0.57-1.07)		
Single-parent family	931	18.7	45.2	1.10 (0.90-1.36)		36.1	1.11 (0.90-1.38)			1.16 (0.93-1.44)		1.07 (0.86-1.34)		
Family Affluence Scale [a]					0.02			<0.001	<0.001		0.04		<0.001	<0.001
High	708	25.7	49.9	1		24.4	1			1		1		
Medium	2 483	18.4	46.5	1.19 (0.96-1.49)		35.1	1.84 (1.44-2.35)			1.26 (1.01-1.57)		1.79 (1.40-2.29)		
Low	965	20.0	39.9	0.91 (0.70-1.18)		40.1	1.86 (1.40-2.47)			1.03 (0.78-1.36)		1.73 (1.28-2.33)		
Parental working status [a]					0.05			0.001	<0.001		0.19		0.008	<0.001
Both parents working	2 153	21.0	50.1	1.13 (0.92-1.38)		28.9	0.67 (0.54-0.83)			1.07 (0.87-1.31)		0.70 (0.56-0.86)		
One working, the other at home	1 159	18.1	41.7	1		40.2	1			1		1		
One working, the other not at home	354	19.8	43.2	1.00 (0.72-1.39)		37.0	0.89 (0.63-1.25)			0.93 (0.66-1.31)		0.88 (0.62-1.26)		
None working	490	20.6	36.1	0.76 (0.56-1.02)		43.3	0.94 (0.70-1.26)			0.78 (0.57-1.05)		0.93 (0.68-1.25)		
Siblings					0.15			1	0.14		0.25		0.81	0.19
Single child	311	18.3	50.8	1.27 (0.92-1.75)		30.9	1.00 (0.71-1.41)			1.21 (0.88-1.67)		0.96 (0.68-1.36)		
Siblings	3 845	20.2	45.1	1		34.7	1			1		1		
School Region					0.001			0.001	0.001		<0.001		<0.001	<0.001
Brussels-Capital	1 209	21.3	37.4	1		41.3	1			1		1		
Wallonia	1 785	23.5	46.9	1.16 (0.90-1.50)		29.6	0.66 (0.51-0.86)			1.09 (0.87-1.38)		0.70 (0.55-0.89)		
Flanders	1 162	13.3	51.9	2.20 (1.64-2.93)		34.8	1.33 (0.99-1.79)			2.09 (1.59-2.74)		1.39 (1.06-1.83)		
Intercept				*2.34 (2.10-2.62)*	*<0.001*		*1.77 (1.58-1.98)*	*<0.001*		*1.10 (0.79-1.54)*	*0.56*	*1.04 (0.73-1.47)*	*0.84*	
First-generation immigrants (n=1,582)														
Gender					0.53			0.02	0.03		1		0.02	0.009
Boys	819	19.4	39.7	1.09 (0.83-1.43)		40.9	1.39 (1.06-1.84)			1.00 (0.76-1.32)		1.39 (1.05-1.84)		
Girls	763	23.1	42.6	1		34.3	1			1		1		
Age					0.20			0.19	0.37		0.14		0.33	0.38
10-12 y	357	24.9	39.2	1		35.9	1			1		1		
13-16 y	811	20.2	42.2	1.36 (0.96-1.94)		37.6	1.33 (0.93-1.90)			1.37 (0.97-1.93)		1.24 (0.87-1.75)		
17-19 y	414	19.8	40.6	1.34 (0.89-2.01)		39.6	1.43 (0.95-2.15)			1.42 (0.96-2.12)		1.34 (0.90-2.00)		
Family structure [a]					0.69			0.27	0.18		0.97		0.41	0.59
Two parents	1 029	22.1	41.1	1		36.8	1			1		1		
Blended family	189	20.1	46.6	1.20 (0.79-1.84)		33.3	0.96 (0.62-1.50)			1.04 (0.67-1.60)		0.97 (0.62-1.53)		
Single-parent family	364	19.2	38.2	1.05 (0.75-1.46)		42.6	1.30 (0.93-1.82)			1.04 (0.73-1.48)		1.26 (0.88-1.78)		
Family Affluence Scale [a]					0.31			0.005	<0.001		0.50		0.01	0.003
High	262	26.3	46.6	1		27.1	1			1		1		
Medium	849	19.9	43.1	1.15 (0.80-1.66)		37.0	1.70 (1.14-2.52)			1.19 (0.82-1.73)		1.66 (1.11-2.48)		
Low	471	20.6	34.4	0.90 (0.60-1.36)		45.0	2.02 (1.32-3.11)			1.02 (0.66-1.58)		2.00 (1.27-3.15)		
Parental working status [a]					0.33			0.62	0.25		0.56		0.88	0.83
Both parents working	749	20.7	44.2	1.34 (0.96-1.88)		35.1	1.01 (0.72-1.42)			1.26 (0.89-1.77)		1.06 (0.75-1.50)		
One working, the other at home	372	23.7	37.1	1		39.2	1			1		1		
One working, the other not at home	221	18.6	39.8	1.34 (0.84-2.13)		41.6	1.32 (0.83-2.10)			1.32 (0.81-2.15)		1.20 (0.74-1.94)		
None working	240	21.3	38.7	1.12 (0.72-1.75)		40.0	1.09 (0.70-1.70)			1.19 (0.75-1.88)		1.00 (0.64-1.57)		
Siblings					0.47			0.95	0.59		0.63		0.65	0.52
Single child	165	20.0	44.8	1.18 (0.75-1.83)		35.2	0.98 (0.62-1.56)			1.12 (0.71-1.75)		0.90 (0.57-1.43)		
Siblings	1 417	21.3	40.7	1		38.0	1			1		1		
School Region					<0.001			0.01	<0.001		<0.001		0.01	<0.001
Brussels-Capital	496	25.0	32.5	1		42.5	1			1		1		
Wallonia	609	24.0	40.2	1.38 (0.96-1.99)		35.8	0.94 (0.65-1.35)			1.35 (0.95-1.93)		0.96 (0.68-1.37)		
Flanders	477	13.6	51.2	3.12 (2.06-4.72)		35.2	1.64 (1.08-2.48)			3.01 (2.01-4.51)		1.67 (1.11-2.51)		
Intercept				*2.04 (1.73-2.41)*	*<0.001*		*1.87 (1.58-2.21)*	*<0.001*		*0.74 (0.43-1.27)*	*0.27*	*0.64 (0.36-1.11)*	*0.11*	

[a] For details, see *Methods* section
[b] Crude relative risk ratio and 95% confidence interval
[c] Adjusted relative risk ratio and 95% confidence interval

Table F-3. Multilevel logistic regressions for fish consumption (reference category: ≥two days a week) stratified by migration status (n = 18,924). *2014 HBSC in Belgium.*

		Simple multilevel logistic regression					Multiple multilevel logistic regression	
		Fish consumption ≥two days a week		Fish consumption <two days a week			Fish consumption <two days a week	
	Variables	**n**	**%**	**%**	**cOR (IC 95%) [b]**	***P* value**	**aOR (IC 95%) [c]**	***P* value**
Natives (n=13,186)	**Gender**					<0.001		<0.001
	Boys	6 679	18.5	81.5	0.77 (0.70-0.85)		0.78 (0.71-0.86)	
	Girls	6 407	14.8	85.2	1		1	
	Age					0.77		0.69
	10-12 y	3 897	16.0	84.0	1		1	
	13-16 y	6 585	17.1	82.9	0.96 (0.84-1.08)		0.95 (0.84-1.08)	
	17-19 y	2 704	16.8	83.2	0.96 (0.83-1.12)		0.94 (0.81-1.10)	
	Family structure [a]					0.002		0.006
	Two parents	8 722	17.4	82.6	1		1	
	Blended family	2 082	14.2	85.8	1.28 (1.11-1.46)		1.26 (1.09-1.44)	
	Single-parent family	2 382	16.5	83.5	1.08 (0.95-1.22)		1.04 (0.91-1.18)	
	Family Affluence Scale [a]					<0.001		<0.001
	High	2 728	20.7	79.3	1		1	
	Medium	8 698	16.0	84.0	1.36 (1.21-1.52)		1.34 (1.20-1.50)	
	Low	1 760	14.0	86.0	1.59 (1.34-1.88)		1.57 (1.32-1.87)	
	Parental working status [a]					0.19		0.55
	Both parents working	10 034	17.0	83.0	0.97 (0.84-1.11)		1.01 (0.88-1.17)	
	One working, the other at home	1 767	16.5	83.5	1		1	
	One working, the other not at home	958	14.2	85.8	1.20 (0.96-1.49)		1.10 (0.88-1.38)	
	None working	427	16.9	83.1	0.96 (0.72-1.28)		0.87 (0.65-1.16)	
	Siblings					0.43		
	Single child	1 291	17.7	82.3	0.94 (0.81-1.10)			
	Siblings	11 895	16.6	83.4	1			
	School Region					0.03		0.04
	Brussels-Capital	445	21.3	78.7	1		1	
	Wallonia	6 421	16.0	84.0	1.46 (1.10-1.94)		1.44 (1.08-1.91)	
	Flanders	6 320	17.1	82.9	1.42 (1.06-1.89)		1.43 (1.08-1.90)	
	Intercept				*5.12 (4.80-5.45)*	*<0.001*	*3.16 (2.28-4.36)*	*<0.001*
Second-generation immigrants (n=4,159)	**Gender**					<0.001		<0.001
	Boys	1 975	29.1	70.9	0.77 (0.67-0.89)		0.77 (0.66-0.88)	
	Girls	2 184	24.2	75.8	1		1	
	Age					0.54		0.30
	10-12 y	1 188	27.3	72.7	1		1	
	13-16 y	2 104	26.7	73.3	1.05 (0.88-1.26)		1.06 (0.90-1.26)	
	17-19 y	867	25.1	74.9	1.13 (0.91-1.41)		1.18 (0.96-1.46)	
	Family structure [a]					0.04		0.19
	Two parents	2 823	27.7	72.3	1		1	
	Blended family	412	21.1	78.9	1.36 (1.05-1.76)		1.26 (0.98-1.64)	
	Single-parent family	924	25.4	74.6	1.12 (0.94-1.33)		1.08 (0.90-1.29)	
	Family Affluence Scale [a]					0.001		<0.001
	High	708	31.2	68.8	1		1	
	Medium	2 486	25.3	74.7	1.41 (1.16-1.71)		1.43 (1.18-1.73)	
	Low	965	26.2	73.8	1.43 (1.14-1.80)		1.53 (1.21-1.93)	
	Parental working status [a]					0.001		<0.001
	Both parents working	2 156	24.9	75.1	1.13 (0.96-1.34)		1.17 (0.98-1.38)	
	One working, the other at home	1 153	28.1	71.9	1		1	
	One working, the other not at home	356	21.3	78.7	1.42 (1.07-1.90)		1.29 (0.96-1.74)	
	None working	494	33.4	66.6	0.79 (0.63-1.00)		0.75 (0.59-0.95)	
	Siblings					0.18		
	Single child	311	22.8	77.2	1.21 (0.91-1.60)			
	Siblings	3 848	26.8	73.2	1			
	School Region					<0.001		<0.001
	Brussels-Capital	1 210	34.1	65.9	1		1	
	Wallonia	1 790	21.6	78.4	1.92 (1.59-2.33)		1.87 (1.55-2.27)	
	Flanders	1 159	26.1	73.9	1.51 (1.23-1.86)		1.50 (1.23-1.85)	
	Intercept				*2.98 (2.71-3.29)*	*<0.001*	*1.38 (1.05-1.81)*	*0.02*
First-generation immigrants (n=1,579)	**Gender**					0.44		0.46
	Boys	808	31.6	68.4	1.09 (0.88-1.35)		1.09 (0.87-1.35)	
	Girls	771	33.3	66.7	1		1	
	Age					0.16		0.10
	10-12 y	357	28.0	72.0	1		1	
	13-16 y	808	33.7	66.3	0.77 (0.58-1.02)		0.75 (0.57-0.99)	
	17-19 y	414	33.8	66.2	0.77 (0.56-1.06)		0.75 (0.55-1.02)	
	Family structure [a]					0.009		0.03
	Two parents	1 025	34.9	65.1	1		1	
	Blended family	191	24.6	75.4	1.64 (1.15-2.34)		1.58 (1.10-2.28)	
	Single-parent family	363	29.5	70.5	1.29 (0.99-1.67)		1.24 (0.94-1.63)	
	Family Affluence Scale [a]					0.22		0.16
	High	261	35.6	64.4	1		1	
	Medium	846	30.5	69.5	1.27 (0.94-1.72)		1.34 (1.00-1.63)	
	Low	472	34.1	65.9	1.10 (0.79-1.54)		1.25 (0.89-1.77)	
	Parental working status [a]					0.03		0.08
	Both parents working	745	30.2	69.8	1.44 (1.11-1.88)		1.41 (1.08-1.84)	
	One working, the other at home	375	38.7	61.3	1		1	
	One working, the other not at home	219	29.2	70.8	1.53 (1.07-2.19)		1.32 (0.91-1.93)	
	None working	240	32.5	67.5	1.33 (0.94-1.88)		1.33 (0.93-1.88)	
	Siblings					0.10		
	Single child	165	26.7	73.3	1.35 (0.94-1.95)			
	Siblings	1 414	33.1	66.9	1			
	School Region					0.007		0.02
	Brussels-Capital	504	37.9	62.1	1		1	
	Wallonia	600	30.0	70.0	1.42 (1.11-1.83)		1.39 (1.07-1.80)	
	Flanders	475	29.7	70.3	1.45 (1.11-1.89)		1.37 (1.04-1.81)	
	Intercept				*2.12 (1.88-2.40)*	*<0.001*	*1.15 (0.75-1.76)*	*0.53*

[a] For details, see *Methods* section
[b] Crude odds ratio and 95% confidence interval
[c] Adjusted odds ratio and 95% confidence interval

Table F-4. Multilevel logistic regressions for dairy product consumption (reference category: >once a day) stratified by migration status (n = 18,541). *2014 HBSC in Belgium*.

		Simple multilevel logistic regression					Multiple multilevel logistic regression	
		Dairy product consumption >once a day		Dairy product consumption ≤once a day			Dairy product consumption ≤once a day	
	Variables	n	%	%	cOR (IC 95%) [b]	*P* value	aOR (IC 95%) [c]	*P* value
Natives (n=12,935)	**Gender**					<0.001		<0.001
	Boys	6 645	83.0	17.0	0.70 (0.64-0.77)		0.70 (0.64-0.77)	
	Girls	6 290	76.7	23.3	1		1	
	Age					0.03		<0.001
	10-12 y	3 804	82.3	17.7	1		1	
	13-16 y	6 472	79.1	20.9	1.19 (1.04-1.35)		1.23 (1.11-1.37)	
	17-19 y	2 659	78.6	21.4	1.20 (1.03-1.40)		1.27 (1.12-1.45)	
	Family structure [a]					0.79		
	Two parents	8 560	80.1	19.9	1			
	Blended family	2 032	80.0	20.0	0.99 (0.88-1.12)			
	Single-parent family	2 343	79.2	20.8	1.04 (0.92-1.17)			
	Family Affluence Scale [a]					0.11		
	High	2 659	81.0	19.0	1			
	Medium	8 552	80.1	19.9	1.07 (0.95-1.20)			
	Low	1 724	77.7	22.3	1.18 (1.01-1.39)			
	Parental working status [a]					0.90		
	Both parents working	9 844	80.4	19.6	0.97 (0.85-1.10)			
	One working, the other at home	1 740	79.0	21.0	1			
	One working, the other not at home	932	78.4	21.6	1.02 (0.84-1.24)			
	None working	419	77.6	22.4	0.99 (0.76-1.29)			
	Siblings					0.03		0.03
	Single child	1 269	78.2	21.8	1.17 (1.02-1.35)		1.18 (1.02-1.36)	
	Siblings	11 666	80.1	19.9	1		1	
	School Region					<0.001		<0.001
	Brussels-Capital	445	72.6	27.4	1		1	
	Wallonia	6 355	74.7	25.3	0.88 (0.69-1.11)		0.88 (0.70-1.10)	
	Flanders	6 135	85.9	14.1	0.43 (0.33-0.54)		0.43 (0.34-0.55)	
	Intercept				*0.24 (0.22-0.26)*	*<0.001*	*0.38 (0.30-0.48)*	*<0.001*
Second-generation immigrants (n=4,061)	**Gender**					<0.001		<0.001
	Boys	1 931	81.7	18.3	0.68 (0.58-0.80)		0.69 (0.59-0.81)	
	Girls	2 130	75.3	24.7	1		1	
	Age					<0.001		<0.001
	10-12 y	1 152	84.7	15.3	1		1	
	13-16 y	2 056	76.9	23.1	1.64 (1.35-2.01)		1.68 (1.39-2.04)	
	17-19 y	853	73.3	26.7	1.97 (1.56-2.48)		1.93 (1.55-2.41)	
	Family structure [a]					0.64		
	Two parents	2 752	78.7	21.3	1			
	Blended family	404	79.2	20.8	0.99 (0.76-1.29)			
	Single-parent family	905	77.1	22.9	1.09 (0.91-1.31)			
	Family Affluence Scale [a]					0.74		
	High	689	79.7	20.3	1			
	Medium	2 432	78.2	21.8	1.09 (0.88-1.35)			
	Low	940	78.0	22.0	1.07 (0.83-1.38)			
	Parental working status [a]					0.50		
	Both parents working	2 105	79.3	20.7	0.95 (0.80-1.14)			
	One working, the other at home	1 130	78.1	21.9	1			
	One working, the other not at home	345	75.4	24.6	1.18 (0.88-1.57)			
	None working	481	77.1	22.9	1.02 (0.79-1.33)			
	Siblings					0.16		0.08
	Single child	310	75.8	24.2	1.22 (0.92-1.61)		1.28 (0.97-1.69)	
	Siblings	3 751	78.6	21.4	1		1	
	School Region					<0.001		<0.001
	Brussels-Capital	1 189	74.5	25.5	1		1	
	Wallonia	1 762	76.6	23.4	0.90 (0.75-1.08)		0.91 (0.77-1.08)	
	Flanders	1 110	85.4	14.6	0.50 (0.40-0.63)		0.53 (0.43-0.65)	
	Intercept				*0.25 (0.23-0.28)*	*<0.001*	*0.25 (0.21-0.31)*	*<0.001*
First-generation immigrants (n=1,545)	**Gender**					0.002		0.004
	Boys	795	83.4	16.6	0.66 (0.51-0.86)		0.68 (0.52-0.88)	
	Girls	750	77.2	22.8	1		1	
	Age					0.32		0.44
	10-12 y	343	82.8	17.2	1		1	
	13-16 y	792	80.4	19.6	1.17 (0.83-1.63)		1.19 (0.84-1.67)	
	17-19 y	410	78.3	21.7	1.33 (0.92-1.93)		1.28 (0.87-1.86)	
	Family structure [a]					0.06		
	Two parents	1 006	82.1	17.9	1			
	Blended family	188	77.1	22.9	1.38 (0.94-2.01)			
	Single-parent family	351	77.2	22.8	1.37 (1.01-1.85)			
	Family Affluence Scale [a]					0.20		
	High	257	84.1	15.9	1			
	Medium	826	80.4	19.6	1.28 (0.87-1.86)			
	Low	462	78.4	21.6	1.45 (0.96-2.17)			
	Parental working status [a]					0.34		
	Both parents working	730	81.6	18.4	0.89 (0.65-1.23)			
	One working, the other at home	367	79.8	20.2	1			
	One working, the other not at home	213	76.1	23.9	1.25 (0.83-1.87)			
	None working	235	81.3	18.7	0.90 (0.59-1.37)			
	Siblings					0.34		0.30
	Single child	160	77.5	22.5	1.21 (0.82-1.80)		1.23 (0.83-1.84)	
	Siblings	1 385	80.7	19.3	1		1	
	School Region					0.12		0.24
	Brussels-Capital	485	78.1	21.9	1		1	
	Wallonia	600	79.8	20.2	0.91 (0.67-1.25)		0.95 (0.69-1.32)	
	Flanders	460	83.5	16.5	0.70 (0.50-0.99)		0.75 (0.52-1.07)	
	Intercept				*0.24 (0.21-0.28)*	*<0.001*	*0.27 (0.19-0.39)*	*<0.001*

[a] For details, see *Methods* section
[b] Crude odds ratio and 95% confidence interval
[c] Adjusted odds ratio and 95% confidence interval

Table F-5. Multilevel logistic regressions for crips and fries consumption (reference category: <once a day) stratified by migration status (n = 18,853). *2014 HBSC in Belgium*.

		Simple multilevel logistic regression					Multiple multilevel logistic regression	
		Chips and fries consumption <once a day		Chips and fries consumption ≥once a day			Chips and fries consumption ≥once a day	
	Variables	n	%	%	cOR (IC 95%) [b]	*P* value	aOR (IC 95%) [c]	*P* value
Natives (n=13,162)	**Gender**					<0.001		<0.001
	Boys	6 769	88.6	11.4	1.55 (1.37-1.76)		1.62 (1.43-1.83)	
	Girls	6 393	92.0	8.0	1		1	
	Age					0.004		0.002
	10-12 y	3 881	90.1	9.9	1		1	
	13-16 y	6 566	89.8	10.2	1.13 (0.94-1.35)		1.06 (0.91-1.25)	
	17-19 y	2 715	91.7	8.3	0.84 (0.67-1.05)		0.78 (0.64-0.96)	
	Family structure [a]					<0.001		<0.001
	Two parents	8 709	91.5	8.5	1		1	
	Blended family	2 072	87.9	12.1	1.40 (1.20-1.64)		1.35 (1.15-1.58)	
	Single-parent family	2 381	88.1	11.9	1.36 (1.17-1.57)		1.23 (1.05-1.44)	
	Family Affluence Scale [a]					<0.001		0.004
	High	2 698	92.0	8.0	1		1	
	Medium	8 710	90.7	9.3	1.06 (0.90-1.25)		1.08 (0.92-1.27)	
	Low	1 754	85.6	14.4	1.51 (1.22-1.85)		1.39 (1.12-1.73)	
	Parental working status [a]					<0.001		<0.001
	Both parents working	10 026	91.4	8.6	0.80 (0.68-0.95)		0.83 (0.70-0.99)	
	One working, the other at home	1 752	88.6	11.4	1		1	
	One working, the other not at home	960	87.2	12.8	1.10 (0.86-1.41)		1.00 (0.78-1.28)	
	None working	424	78.5	21.5	1.82 (1.37-2.42)		1.57 (1.17-2.09)	
	Siblings					0.56		0.53
	Single child	1 292	90.0	10.0	1.06 (0.87-1.29)		1.07 (0.87-1.30)	
	Siblings	11 870	90.3	9.7	1		1	
	School Region					<0.001		<0.001
	Brussels-Capital	438	87.7	12.3	1		1	
	Wallonia	6 398	87.7	12.3	0.97 (0.66-1.44)		1.01 (0.70-1.46)	
	Flanders	6 326	93.1	6.9	0.45 (0.30-0.68)		0.49 (0.34-0.72)	
	Intercept				*0.11 (0.10-0.12)*	*<0.001*	*0.10 (0.07-0.16)*	*<0.001*
Second-generation immigrants (n=4,136)	**Gender**					0.001		<0.001
	Boys	1 965	80.7	19.3	1.34 (1.12-1.60)		1.40 (1.17-1.66)	
	Girls	2 171	84.7	15.3	1		1	
	Age					0.04		0.03
	10-12 y	1 178	83.4	16.6	1		1	
	13-16 y	2 090	82.4	17.6	1.07 (0.83-1.39)		1.02 (0.80-1.30)	
	17-19 y	868	83.1	16.9	0.79 (0.58-1.08)		0.75 (0.56-1.00)	
	Family structure [a]					0.54		0.60
	Two parents	2 805	82.4	17.6	1		1	
	Blended family	409	86.5	13.5	0.84 (0.61-1.15)		0.85 (0.62-1.18)	
	Single-parent family	922	82.4	17.6	0.98 (0.80-1.21)		0.95 (0.76-1.18)	
	Family Affluence Scale [a]					0.82		0.78
	High	703	85.3	14.7	1		1	
	Medium	2 477	83.5	16.5	0.95 (0.74-1.22)		0.91 (0.71-1.18)	
	Low	956	79.2	20.8	1.01 (0.75-1.35)		0.93 (0.69-1.25)	
	Parental working status [a]					<0.001		<0.001
	Both parents working	2 140	87.1	12.9	0.69 (0.56-0.85)		0.69 (0.56-0.85)	
	One working, the other at home	1 152	79.0	21.0	1		1	
	One working, the other not at home	353	83.0	17.0	0.85 (0.61-1.18)		0.88 (0.62-1.24)	
	None working	491	72.7	27.3	1.29 (0.99-1.67)		1.32 (1.01-1.73)	
	Siblings					0.26		0.31
	Single child	310	87.4	12.6	0.81 (0.56-1.17)		0.83 (0.57-1.19)	
	Siblings	3 826	82.4	17.6	1		1	
	School Region					<0.001		<0.001
	Brussels-Capital	1 203	73.9	26.1	1		1	
	Wallonia	1 776	84.3	15.7	0.50 (0.35-0.71)		0.54 (0.38-0.76)	
	Flanders	1 157	89.7	10.3	0.28 (0.18-0.41)		0.30 (0.20-0.44)	
	Intercept				*0.15 (0.13-0.18)*	*<0.001*	*0.37 (0.24-0.55)*	*<0.001*
First-generation immigrants (n=1,555)	**Gender**					0.008		0.004
	Boys	804	78.6	21.4	1.45 (1.10-1.90)		1.50 (1.14-1.97)	
	Girls	751	82.4	17.6	1		1	
	Age					0.10		0.07
	10-12 y	351	79.2	20.8	1		1	
	13-16 y	795	79.7	20.3	0.98 (0.69-1.40)		0.89 (0.63-1.27)	
	17-19 y	409	82.9	17.1	0.70 (0.46-1.06)		0.64 (0.43-0.97)	
	Family structure [a]					0.92		0.48
	Two parents	1 013	80.2	19.8	1		1	
	Blended family	189	80.9	19.1	0.99 (0.66-1.50)		1.21 (0.79-1.86)	
	Single-parent family	353	81.0	19.0	0.94 (0.68-1.29)		0.90 (0.64-1.26)	
	Family Affluence Scale [a]					0.03		0.32
	High	256	85.2	14.8	1		1	
	Medium	837	82.2	17.8	1.16 (0.77-1.74)		1.11 (0.73-1.67)	
	Low	462	74.7	25.3	1.64 (1.06-2.54)		1.35 (0.85-2.12)	
	Parental working status [a]					<0.001		<0.001
	Both parents working	738	86.2	13.8	0.50 (0.36-0.70)		0.53 (0.38-0.74)	
	One working, the other at home	366	75.7	24.3	1		1	
	One working, the other not at home	218	77.5	22.5	0.90 (0.60-1.36)		0.91 (0.59-1.41)	
	None working	233	72.5	27.5	1.04 (0.70-1.54)		1.05 (0.70-1.57)	
	Siblings					0.06		0.05
	Single child	163	85.9	14.1	0.63 (0.39-1.01)		0.61 (0.38-0.99)	
	Siblings	1 392	79.8	20.2	1		1	
	School Region					<0.001		<0.001
	Brussels-Capital	487	72.9	27.1	1		1	
	Wallonia	594	81.8	18.2	0.61 (0.41-0.89)		0.61 (0.41-0.89)	
	Flanders	474	86.5	13.5	0.40 (0.26-0.61)		0.42 (0.27-0.64)	
	Intercept				*0.21 (0.18-0.26)*	*<0.001*	*0.40 (0.23-0.71)*	*0.002*

[a] For details, see *Methods* section
[b] Crude odds ratio and 95% confidence interval
[c] Adjusted odds ratio and 95% confidence interval

Table F-6. Multilevel multinomial regressions for sugar-sweetened beverages consumption (reference category: ≤once a week) stratified by migration status (n = 18,642). *2014 HBSC in Belgium.*

			Simple multilevel multinomial regression								Multiple multilevel multinomial regression				
			Sugar-sweetened beverages consumption ≤once a week	Sugar-sweetened beverages consumption 2-6 days a week			Sugar-sweetened beverages consumption ≥once a day				Sugar-sweetened beverages consumption 2-6 days a week		Sugar-sweetened beverages consumption ≥once a day		
	Variables	n	%	%	cRRR (IC 95%) [b]	*P* value	%	cRRR (IC 95%) [b]	*P* value	Overall *P* value	aRRR (IC 95%) [c]	*P* value	aRRR (IC 95%) [c]	*P* value	Overall *P* value
Natives (n=13,015)	**Gender**					<0.001			<0.001	<0.001		<0.001		<0.001	<0.001
	Boys	6 680	20.4	32.9	1.52 (1.38-1.68)		46.7	1.76 (1.60-1.93)			1.51 (1.37-1.66)		1.81 (1.65-1.99)		
	Girls	6 335	30.1	31.3	1		38.6	1			1		1		
	Age					0.08			<0.001	<0.001		0.07		<0.001	<0.001
	10-12 y	3 827	28.4	32.7	1		38.9	1			1		1		
	13-16 y	6 514	24.1	32.6	1.17 (1.02-1.34)		43.3	1.31 (1.14-1.50)			1.16 (1.02-1.33)		1.26 (1.11-1.44)		
	17-19 y	2 674	22.8	30.1	1.09 (0.92-1.29)		47.1	1.43 (1.22-1.69)			1.10 (0.93-1.29)		1.34 (1.14-1.56)		
	Family structure [a]					0.006			<0.001	<0.001		0.003		<0.001	<0.001
	Two parents	8 609	27.1	33.0	1		39.9	1			1		1		
	Blended family	2 057	19.7	31.1	1.26 (1.09-1.44)		49.2	1.64 (1.44-1.87)			1.28 (1.11-1.48)		1.60 (1.40-1.83)		
	Single-parent family	2 349	22.3	29.9	1.06 (0.93-1.20)		47.8	1.40 (1.24-1.57)			1.06 (0.93-1.21)		1.23 (1.09-1.40)		
	Family Affluence Scale [a]					0.20			<0.001	<0.001		0.62		<0.001	<0.001
	High	2 687	29.9	36.3	1		33.8	1			1		1		
	Medium	8 604	24.5	31.8	0.95 (0.85-1.06)		43.7	1.40 (1.25-1.57)			0.98 (0.87-1.10)		1.40 (1.25-1.58)		
	Low	1 724	20.9	26.9	0.85 (0.72-1.01)		52.2	1.78 (1.51-2.10)			0.91 (0.76-1.10)		1.65 (1.39-1.96)		
	Parental working status [a]					0.56			<0.001	<0.001		0.67		<0.001	<0.001
	Both parents working	9 919	26.2	33.1	1.05 (0.91-1.22)		40.7	0.83 (0.73-0.95)			1.01 (0.87-1.16)		0.87 (0.76-1.00)		
	One working, the other at home	1 734	23.5	30.0	1		46.5	1			1		1		
	One working, the other not at home	947	19.5	29.5	1.17 (0.93-1.48)		51.0	1.31 (1.06-1.62)			1.14 (0.90-1.45)		1.13 (0.91-1.41)		
	None working	415	17.6	22.6	0.97 (0.69-1.36)		59.8	1.65 (1.23-2.21)			1.03 (0.73-1.45)		1.44 (1.07-1.95)		
	Siblings					0.97			<0.001	<0.001		0.84		0.002	<0.001
	Single child	1 274	21.8	29.2	1.00 (0.85-1.18)		49.0	1.29 (1.11-1.51)			1.02 (0.86-1.20)		1.28 (1.10-1.50)		
	Siblings	11 741	25.5	32.4	1		42.1	1			1		1		
	School Region					<0.001			0.07	<0.001		<0.001		0.03	<0.001
	Brussels-Capital	431	31.8	25.5	1		42.7	1			1		1		
	Wallonia	6 305	27.6	29.2	1.23 (0.85-1.77)		43.2	1.09 (0.77-1.54)			1.29 (0.92-1.81)		1.10 (0.80-1.52)		
	Flanders	6 279	22.2	35.5	1.82 (1.26-2.63)		42.3	1.30 (0.92-1.84)			1.86 (1.32-2.62)		1.31 (0.95-1.82)		
	Intercept				*1.32 (1.22-1.44)*	*<0.001*		*1.77 (1.63-1.92)*	*<0.001*		*0.64 (0.44-0.94)*	*0.02*	*0.67 (0.47-0.96)*	*0.03*	

	Variables	n	Sugar-sweetened beverages consumption ≤once a week	Simple multilevel multinomial regression: Sugar-sweetened beverages consumption 2-6 days a week			Sugar-sweetened beverages consumption ≥once a day				Multiple multilevel multinomial regression: Sugar-sweetened beverages consumption 2-6 days a week		Sugar-sweetened beverages consumption ≥once a day		
			%	%	cRRR (IC 95%) [b]	*P* value	%	cRRR (IC 95%) [b]	*P* value	Overall *P* value	aRRR (IC 95%) [c]	*P* value	aRRR (IC 95%) [c]	*P* value	Overall *P* value
Second-generation immigrants (n=4,087)	**Gender**					<0.001			<0.001	<0.001		<0.001		<0.001	<0.001
	Boys	1 944	18.5	32.1	1.72 (1.44-2.06)		49.4	1.79 (1.51-2.12)			1.69 (1.42-2.03)		1.84 (1.55-2.17)		
	Girls	2 143	28.4	28.8	1		42.8	1			1		1		
	Age					0.56			0.001	<0.001		0.62		0.009	0.02
	10-12 y	1 179	28.8	31.8	1		39.4	1			1		1		
	13-16 y	2 062	21.7	29.6	1.13 (0.90-1.42)		48.7	1.50 (1.21-1.87)			1.11 (0.89-1.39)		1.39 (1.13-1.72)		
	17-19 y	846	21.6	30.3	1.08 (0.82-1.42)		48.1	1.38 (1.06-1.80)			1.11 (0.84-1.46)		1.23 (0.94-1.59)		
	Family structure [a]					0.15			<0.001	<0.001		0.26		0.001	0.002
	Two parents	2 779	25.1	31.2	1		43.7	1			1		1		
	Blended family	402	20.4	31.3	1.35 (1.00-1.83)		48.3	1.49 (1.12-1.98)			1.30 (0.95-1.77)		1.53 (1.14-2.05)		
	Single-parent family	906	20.7	27.4	1.07 (0.86-1.33)		51.9	1.45 (1.18-1.77)			1.04 (0.83-1.32)		1.36 (1.10-1.68)		
	Family Affluence Scale [a]					0.59			<0.001	<0.001		0.54		0.008	0.03
	High	700	30.6	32.3	1		37.1	1			1		1		
	Medium	2 437	23.4	30.4	1.11 (0.88-1.39)		46.2	1.46 (1.17-1.82)			1.11 (0.88-1.40)		1.37 (1.09-1.71)		
	Low	950	19.5	28.8	1.15 (0.87-1.52)		51.7	1.79 (1.37-2.34)			1.18 (0.88-1.58)		1.51 (1.14-1.99)		
	Parental working status [a]					0.23			<0.001	<0.001		0.09		<0.001	<0.001
	Both parents working	2 117	27.3	31.7	0.90 (0.73-1.10)		41.0	0.70 (0.57-0.84)			0.85 (0.69-1.05)		0.70 (0.58-0.86)		
	One working, the other at home	1 144	20.7	29.7	1		49.6	1			1		1		
	One working, the other not at home	345	24.6	29.0	0.89 (0.63-1.25)		46.4	0.85 (0.62-1.16)			0.83 (0.58-1.19)		0.70 (0.50-0.97)		
	None working	481	14.6	27.0	1.23 (0.87-1.73)		58.4	1.60 (1.17-2.18)			1.25 (0.88-1.77)		1.39 (1.01-1.92)		
	Siblings					0.79			0.53	0.58		0.95		0.41	0.61
	Single child	313	25.6	31.9	1.04 (0.76-1.43)		42.5	0.91 (0.67-1.23)			0.99 (0.72-1.36)		0.88 (0.65-1.19)		
	Siblings	3 774	23.6	30.2	1		46.2	1			1		1		
	School Region					0.009			0.16	<0.001		0.006		0.15	<0.001
	Brussels-Capital	1 178	22.2	24.7	1		53.1	1			1		1		
	Wallonia	1 752	25.5	28.7	1.06 (0.76-1.47)		45.8	0.79 (0.58-1.08)			1.05 (0.78-1.42)		0.81 (0.61-1.08)		
	Flanders	1 157	22.6	38.7	1.56 (1.10-2.20)		38.7	0.72 (0.52-1.01)			1.52 (1.11-2.09)		0.74 (0.54-1.01)		
	Intercept				*1.29 (1.14-1.46)*	*<0.001*		*1.95 (1.74-2.20)*	*<0.001*		*0.80 (0.55-1.17)*	*0.25*	*1.20 (0.84-1.72)*	*0.32*	
First-generation immigrants (n=1,540)	**Gender**					<0.001			<0.001	<0.001		<0.001		<0.001	<0.001
	Boys	796	17.3	34.8	1.93 (1.43-2.59)		47.9	1.88 (1.42-2.49)			1.85 (1.37-2.49)		1.97 (1.49-2.61)		
	Girls	744	27.2	30.2	1		42.6	1			1		1		
	Age					0.01			0.002	0.008		0.02		0.008	0.03
	10-12 y	343	30.0	30.6	1		39.4	1			1		1		
	13-16 y	796	19.5	33.7	1.74 (1.20-2.51)		46.8	1.88 (1.32-2.67)			1.67 (1.15-2.41)		1.71 (1.21-2.43)		
	17-19 y	401	20.4	32.2	1.54 (1.01-2.36)		47.4	1.77 (1.18-2.65)			1.59 (1.04-2.43)		1.65 (1.10-2.47)		
	Family structure [a]					0.67			0.07	0.12		0.60		0.04	0.05
	Two parents	1 003	22.5	33.5	1		44.0	1			1		1		
	Blended family	187	17.1	28.9	1.15 (0.71-1.87)		54.0	1.64 (1.06-2.56)			1.11 (0.68-1.82)		1.73 (1.10-2.73)		
	Single-parent family	350	23.4	32.0	0.91 (0.64-1.27)		44.6	0.96 (0.70-1.33)			0.86 (0.60-1.24)		0.91 (0.65-1.29)		
	Family Affluence Scale [a]					0.27			0.12	0.17		0.29		0.22	0.35
	High	256	29.3	30.1	1		40.6	1			1		1		
	Medium	832	21.3	34.2	1.38 (0.93-2.04)		44.5	1.33 (0.91-1.92)			1.37 (0.92-2.05)		1.29 (0.88-1.89)		
	Low	452	19.5	31.0	1.32 (0.84-2.06)		49.5	1.56 (1.02-2.38)			1.35 (0.84-2.17)		1.48 (0.95-2.32)		
	Parental working status [a]					0.73			0.44	0.72		0.65		0.55	0.82
	Both parents working	734	22.8	33.1	1.14 (0.80-1.63)		44.1	1.10 (0.79-1.54)			1.13 (0.79-1.62)		1.13 (0.80-1.59)		
	One working, the other at home	367	24.0	31.9	1		44.1	1			1		1		
	One working, the other not at home	212	19.8	34.0	1.30 (0.80-2.10)		46.2	1.28 (0.81-2.02)			1.35 (0.81-2.24)		1.22 (0.75-1.97)		
	None working	227	18.9	30.9	1.21 (0.74-1.96)		50.2	1.42 (0.90-2.23)			1.28 (0.78-2.10)		1.40 (0.88-2.24)		
	Siblings					0.83			0.48	0.74		0.63		0.33	0.61
	Single child	159	24.5	33.3	0.95 (0.60-1.50)		42.2	0.86 (0.55-1.32)			0.89 (0.56-1.42)		0.80 (0.51-1.25)		
	Siblings	1 381	21.8	32.5	1		45.7	1			1		1		
	School Region					0.10			0.32	0.006		0.12		0.23	0.007
	Brussels-Capital	476	19.5	29.4	1		51.1	1			1		1		
	Wallonia	593	25.6	30.2	0.86 (0.56-1.33)		44.2	0.73 (0.48-1.10)			0.85 (0.56-1.29)		0.71 (0.48-1.05)		
	Flanders	471	20.2	38.8	1.33 (0.84-2.09)		41.0	0.81 (0.52-1.25)			1.27 (0.82-1.97)		0.76 (0.50-1.17)		
	Intercept				*1.54 (1.29-1.83)*	*<0.001*		*2.14 (1.80-2.53)*	*<0.001*		*0.56 (0.31-1.02)*	*0.06*	*0.87 (0.49-1.53)*	*0.63*	

[a] For details, see *Methods* section
[b] Crude relative risk ratio and 95% confidence interval
[c] Adjusted relative risk ratio and 95% confidence interval

Appendix G. Supplementary material to the article "*Socioeconomic disparities in diet vary according to migration status among adolescents in Belgium*" – Multilevel logistic regression stratified by geographical origin of immigrants

Table G-1. Multilevel logistic regressions* for food consumption stratified by geographical origin of immigrants. *2014 HBSC Belgium.*

			Reference: Europe			America			Asia			Middle East and North Africa			Sub-Saharan Africa			
Fruit consumption (Reference: >once a day)			**n**	**5-7 days a week**	**<5 days a week**	**n**	**5-7 days a week**	**<5 days a week**	**n**	**5-7 days a week**	**<5 days a week**	**n**	**5-7 days a week**	**<5 days a week**	**n**	**5-7 days a week**	**<5 days a week**	**Overall *P* value**
	Second-generation immigrants		1830			124			307			1 510			419			0.86
		%		34.3	45.3		33.0	46.0		33.9	49.8		33.4	45.5		29.8	46.8	
		aRRR (IC 95%)[1]					0.99 (0.59-1.67)	1.09 (0.66-1.80)		1.06 (0.73-1.55)	1.02 (0.71-1.47)		0.90 (0.73-1.12)	0.94 (0.76-1.15)		0.78 (0.58-1.06)	0.92 (0.69-1.23)	
	First-generation immigrants		953			107			123			209			202			0.32
		%		34.6	42.8		29.9	48.6		24.4	47.1		31.1	47.4		32.7	43.5	
		aRRR (IC 95%)[1]					0.98 (0.55-1.75)	1.36 (0.78-2.35)		0.52 (0.31-0.89)	0.73 (0.45-1.18)		0.88 (0.57-1.36)	1.02 (0.67-1.55)		0.92 (0.59-1.43)	0.84 (0.55-1.28)	
Vegetable consumption (Reference: >once a day)			**n**	**5-7 days a week**	**<5 days a week**	**n**	**5-7 days a week**	**<5 days a week**	**n**	**5-7 days a week**	**<5 days a week**	**n**	**5-7 days a week**	**<5 days a week**	**n**	**5-7 days a week**	**<5 days a week**	**Overall *P* value**
	Second-generation immigrants		1 808			123			305			1 488			410			<0.001
		%		50.4	29.4		61.8	20.3		42.9	38.4		39.5	41.5		42.2	32.9	
		aRRR (IC 95%)[2]					1.51 (0.91-2.50)	0.81 (0.44-1.48)		0.75 (0.53-1.07)	1.02 (0.71-1.47)		0.89 (0.72-1.10)	1.18 (0.94-1.48)		0.71 (0.53-0.94)	0.89 (0.66-1.20)	
	First-generation immigrants		942			105			121			205			198			<0.001
		%		44.7	35.9		41.9	33.3		41.3	36.4		27.8	41.0		37.9	47	
		aRRR (IC 95%)[2]					0.85 (0.49-1.46)	0.79 (0.45-1.38)		0.70 (0.42-1.18)	0.76 (0.45-1.29)		0.35 (0.23-0.54)	0.59 (0.39-0.88)		1.15 (0.71-1.89)	1.44 (0.89-2.34)	
Fish consumption (Reference: ≥two days a week)			**n**	**<two days a week**		**n**	**<two days a week**		**n**	**<two days a week**		**n**	**<two days a week**		**n**	**<two days a week**		**Overall *P* value**
	Second-generation immigrants		1 804			123			303			1 492			413			<0.001
		%		78.4			77.2			74.3			66.4			76.0		
		aOR (IC 95%)[3]					1.02 (0.65-1.58)			0.85 (0.63-1.14)			0.63 (0.53-0.75)			0.90 (0.69-1.16)		
	First-generation immigrants		939			105			121			204			199			0.004
		%		68.9			76.2			71.1			64.7			57.3		
		aOR (IC 95%)[3]					1.43 (0.88-2.30)			1.14 (0.75-1.74)			0.92 (0.66-1.30)			0.56 (0.40-0.78)		
Dairy consumption (Reference: >once a day)			**n**	**≤once a day**		**n**	**≤once a day**		**n**	**≤once a day**		**n**	**≤once a day**		**n**	**≤once a day**		**Overall *P* value**
	Second-generation immigrants		1 776			120			291			1 442			409			0.13
		%		22.6			23.3			20.6			21.7			18.1		
		aOR (IC 95%)[4]					1.07 (0.69-1.67)			1.10 (0.80-1.51)			0.88 (0.73-1.05)			0.73 (0.55-0.97)		
	First-generation immigrants		919			102			119			202			192			0.03
		%		19.0			20.6			23.5			12.9			25.5		
		aOR (IC 95%)[4]					1.05 (0.63-1.78)			1.30 (0.82-2.08)			0.59 (0.37-0.93)			1.39 (0.95-2.02)		
Crisps and fries (Reference: <once a day)			**n**	**≥once a day**		**n**	**≥once a day**		**n**	**≥once a day**		**n**	**≥once a day**		**n**	**≥once a day**		**Overall *P* value**
	Second-generation immigrants		1 803			124			301			1 479			405			<0.001
		%		12.3			8.1			13.6			24.9			16.5		
		aOR (IC 95%)[2]					0.69 (0.35-1.37)			1.29 (0.88-1.91)			1.67 (1.33-2.09)			1.35 (0.98-1.86)		
	First-generation immigrants		930			104			122			197			191			<0.001
		%		18.0			5.8			10.7			33.5			26.2		
		aOR (IC 95%)[2]					0.25 (0.11-0.60)			0.52 (0.28-0.97)			1.90 (1.30-2.78)			1.43 (0.95-2.16)		
Sugar-sweetened beverages (Reference: ≤once a week)			**n**	**2-6 days a week**	**≥once a day**	**n**	**2-6 days a week**	**≥once a day**	**n**	**2-6 days a week**	**≥once a day**	**n**	**2-6 days a week**	**≥once a day**	**n**	**2-6 days a week**	**≥once a day**	**Overall *P* value**
	Second-generation immigrants		1 779			120			302			1 459			403			<0.001
		%		28.5	43.6		31.7	30.8		37.7	37.1		30.0	52.7		34.2	42.7	
		aRRR (IC 95%)[2]					0.94 (0.59-1.50)	0.57 (0.35-0.91)		1.32 (0.94-1.84)	0.92 (0.66-1.28)		1.73 (1.37-2.18)	1.65 (1.33-2.04)		1.53 (1.13-2.07)	1.13 (0.85-1.52)	
	First-generation immigrants		927			99			121			195			187			0.004
		%		33.3	43.5		38.4	35.3		31.4	37.2		29.7	55.4		30.0	54.5	
		aRRR (IC 95%)[2]					1.09 (0.62-1.91)	0.68 (0.39-1.21)		0.62 (0.37-1.04)	0.60 (0.37-0.98)		1.25 (0.75-2.10)	1.78 (1.10-2.87)		1.27 (0.76-2.15)	1.62 (1.00-2.64)	

* Multilevel binary logistic regression for food groups with consumption frequencies in two categories; multilevel multinomial logistic regression for food groups with consumption frequencies in three categories

[1] Adjusted for gender, age, family structure, family affluence scale, siblings and school region

[2] Adjusted for gender, age, family structure, family affluence scale, parental working status, siblings and school region

[3] Adjusted for gender, age, family structure, family affluence scale, parental working status and school region

[4] Adjusted for gender, age, siblings and school region

Appendix H. Supplementary material to the article "*Socioeconomic disparities in diet vary according to migration status among adolescents in Belgium*" – Comparisons between adolescents included in analyses and those eligible but not included

Table H-1. Comparisons of food consumptions, cultural, and sociodemographic characteristics between participants included in the analyses and those excluded due to missing data. *2014 HBSC Belgium.*

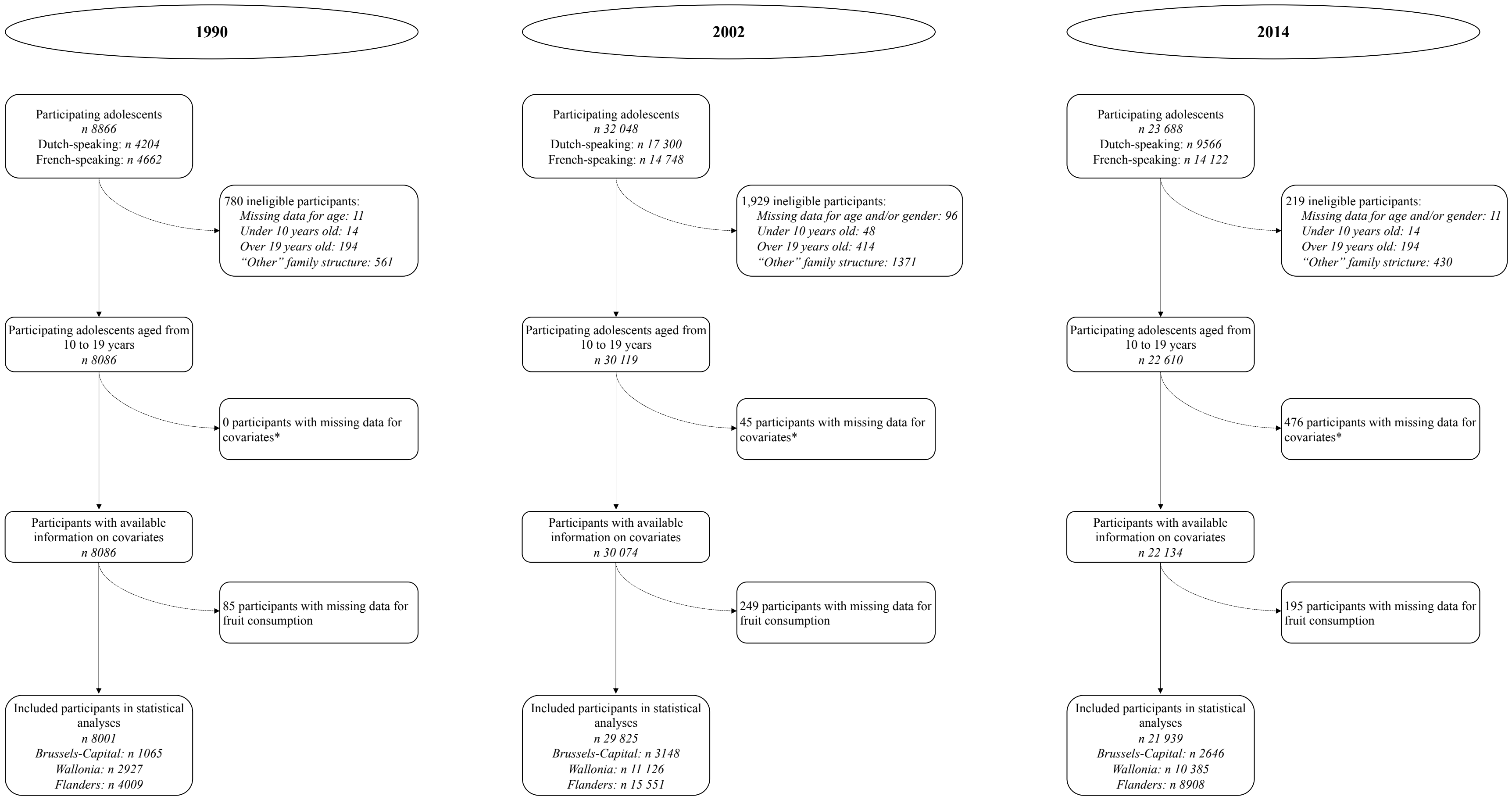
	Included participants (n = 19,172)		**Eligible participants not included (n_{max} = 3,859)**		
	n	**%**	***n***	**%**	***P* value**
Fruit			*3,634*		0.004
>once a day		17.2		19.4	
5-7 days a week		32.8		31.2	
<5 days a week		50.0		49.4	
Vegetable	*18,974*		*3,674*		<0,001
>once a day		18.8		19.9	
5-7 days a week		55.6		48.7	
<5 days a week		25.6		31.4	
Fish	*18,924*		*3,676*		<0,001
≥two days a week		20.2		24.3	
<two days a week		79.8		75.7	
Dairy products	*18,541*		*3,539*		0.20
>once a day		79.6		80.6	
≤once a day		20.4		19.4	
Crisps and fries	*18,853*		*3,615*		<0,001
<once a day		87.7		81.1	
≥once a day		12.2		18.9	
Sugar-sweetened beverages	*18,642*		*3,567*		<0,001
≤once a week		24.5		21.3	
2-6 days a week		31.8		29.9	
≥once a day		43.7		48.8	
Gender			*3,859*		<0,001
Boys		50.6		58.9	
Girls		49.4		41.1	
Age			*3,859*		<0,001
10-12		28.8		31.8	
13-16		50.2		47.1	
17-19		21.0		21.1	
Migration status [a]			*3,381*		<0,001
Natives		69.6		59.8	
2nd-generation immigrants		22.0		25.8	
1st-generation immigrants		8.4		14.4	
Family structure [a]			*2,955*		<0,001
Two parents		66.4		58.4	
Blended family		14.1		15.6	
Single-parent family		19.5		26.0	
Family Affluence Scale [a]			*2,089*		<0,001
High		19.4		15.4	
Medium		63.7		56.7	
Low		16.9		27.9	

(Continued)

	Included participants (n = 19,172)		Eligible participants not included (n_{max} = 3,859)		
	n	%	*n*	%	***P* value**
Parental working status [a]			*3,314*		<0,001
Both parents working		68.4		52.7	
One working, the other at home		17.4		16.6	
One working, the other not at home		8.1		12.2	
None working		6.1		18.5	
Siblings			*2,606*		0.52
Single child		9.3		9.7	
Siblings		90.7		90.3	
School Region			*3,859*		<0,001
Brussels-Capital Region		11.4		15.2	
Walloon Region		46.6		49.4	
Flemish Region		42.0		35.4	

[a] For details, see Methods section

Appendix I. Supplementary material to the article "*Twenty-four-year trends in family and regional disparities in fruit, vegetable and sugar-sweetened beverage consumption among adolescents*" – Inclusion diagram



* Family structure and school region

Figure I-1. Inclusion diagram of adolescents in Belgium, HBSC, 1990-2002-2014.

Appendix J. Supplementary material to the article "*Twenty-four-year trends in family and regional disparities in fruit, vegetable and sugar-sweetened beverage consumption among adolescents*" – Food consumption and characteristics of participants by survey year

Table J-1. Food consumption and characteristics of participants in percentages by year of survey. *1990-2002-2014 HBSC in Belgium.*

	1990 **n = 8,001**	**2002** **n = 29,825**	**2014** **n = 21,939**	***P* value**
Non-daily fruit	27.7	69.2	60.6	<0.001
Non-daily vegetables	23.1	49.5	44.6	<0.001
Daily Sugar-sweetened beverages	58.9	40.7	34.8	<0.001
Sex				<0.001
Boys	47.3	48.6	51.7	
Girls	52.7	51.4	48.3	
Age Group				<0.001
10-12 y	33.6	33.5	29.6	
13-16 y	45.5	47.4	49.8	
17-19 y	20.9	19.1	20.6	
Family Structure				<0.001
Two parents	83.9	77.4	65.4	
Blended family	4.4	9.4	14.4	
Single-parent family	11.7	13.2	20.2	
School Region				<0.001
Brussels-Capital	13.3	10.6	12.1	
Wallonia	36.6	37.3	47.3	
Flanders	50.1	52.1	40.6	

Appendix K. Supplementary material to the article "*Twenty-four-year trends in family and regional disparities in fruit, vegetable and sugar-sweetened beverage consumption among adolescents*" – Graphical representation of prevalence of food consumption by survey year

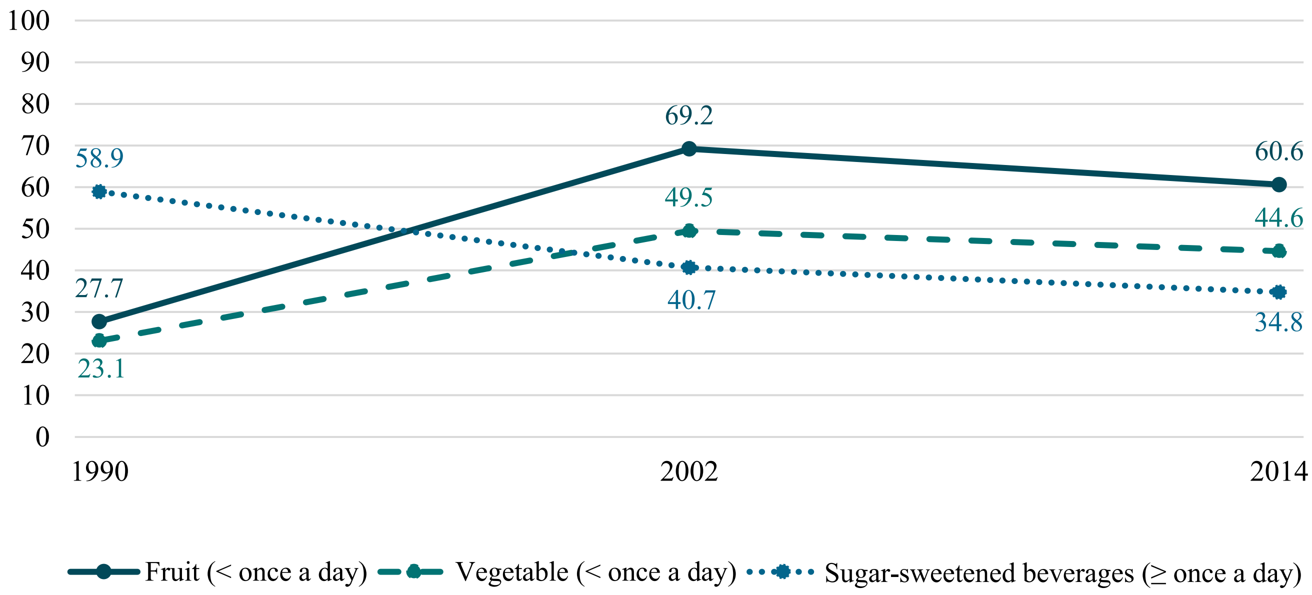


Figure K-1. Prevalence of food consumption by year of survey. *1990-2002-2014 HBSC in Belgium.*

Appendix L. Measures of inequalities related to family structure and school region in dietary habits of adolescents in Belgium (Chapter IV)

Table L-1. Measures of inequalities related to family structure for fruit, vegetables and sugar-sweetened beverages among adolescents between 1990 and 2014. *1990-2002-2014 HBSC in Belgium.*

	1990	2002	2014	Change between 1990 and 2002	Change between 2002 and 2014	Change between 1990 and 2014
Non-daily fruit consumption						
RII[1]	1.58	1.15	1.18	-27.2%	+2.6%	-25.3%
SII[2]	13.14	9.53	10.40	-27.5%	+9.1%	-20.9%
PAF[3]	0.04	0.01	0.03	-75.0%	+200%	-25.0%
Non-daily vegetable consumption						
RII[1]	1.30	1.11	1.16	-14.6%	+4.51%	-10.8%
SII[2]	6.74	5.56	6.81	-17.5%	+22.5%	+1.0%
PAF[3]	0.03	0.01	0.02	-66.7%	+100%	-33.3%
Daily sugar-sweetened beverage consumption						
RII[1]	1.08	1.27	1.47	+17.6%	+15.7%	+36.1%
SII[2]	4.80	10.10	14.34	+110.4%	+42.0%	+198.8%
PAF[3]	0.01	0.03	0.08	+200.0%	166.7%	+700.0%

[1]RII: Adjusted Relative Index of Inequality; [2]SII: Adjusted Slope Index of Inequality; [3]PAF: Population Attributable Risk

Table L-2. Measures of inequalities related to school region for fruit, vegetables and sugar-sweetened beverages among adolescents between 1990 and 2014. *1990-2002-2014 HBSC in Belgium.*

	1990	2002	2014	Change between 1990 and 2002	Change between 2002 and 2014	Change between 1990 and 2014
Non-daily fruit consumption						
RII[1]	0.83	0.73	0.55	-12.0%	-24.7%	-33.7%
SII[2]	-4.19	-20.71	-34.68	-394.3%	-67.5%	-727.7%
PAF[3]	-0.03	-0.08	-0.20	-166.7%	-150.0%	-566.7%
Non-daily vegetable consumption						
RII[1]	1.55	1.29	0.99	-16.8%	-23.3%	-36.1%
SII[2]	11.38	12.65	-0.38	+11.2%	-103.0%	-103.3%
PAF[3]	0.14	0.06	-0.05	-57.1%	-183.3%	-135.7%
Daily sugar-sweetened beverage consumption						
RII[1]	1.15	0.99	1.37	-13.9%	+38.4%	+19.1%
SII[2]	8.13	1.13	11.03	-86.1%	+876.1%	+35.7%
PAF[3]	0.03	0.00	0.08	-100.0%	+1500.0%	+166.7%

[1]RII: Adjusted Relative Index of Inequality; [2]SII: Adjusted Slope Index of Inequality; [3]PAF: Population Attributable Risk

Appendix M. Measures of inequalities related to migration status in dietary habits of adolescents in French-speaking Belgium (Chapter IV)

Table M-1. Measures of inequalities related to migration status for fruit, vegetables and sugar-sweetened beverages among adolescents between 1986 and 2014. *1986-2010-2014 HBSC in French-speaking Belgium.*

	1986	2010	2014	Change between 1986 and 2010	Change between 2010 and 2014	Change between 1986 and 2014
Non-daily fruit consumption						
RII[1]	0.68	1.15	0.90	+69.1%	-21.7%	+32.4%
SII[2]	-10.43	7.63	-4.84	+173.2%	-163.4%	+53.6%
PAF[3]	-0.14	0.06	-0.05	+142.9%	-183.3%	+64.3%
Non-daily vegetable consumption						
RII[1]	6.46	1.46	1.40	-77.4%	-4.1%	-78.3%
SII[2]	29.74	20.80	19.30	-30.1%	-7.2%	-35.1%
PAF[3]	0.41	0.15	0.21	-63.4%	+40.0%	-48.8%
Daily sugar-sweetened beverage consumption						
RII[1]	0.92	1.07	1.25	+16.3%	+16.8%	+35.9%
SII[2]	-5.49	2.97	10.92	+154.1%	+267.7%	+298.9%
PAF[3]	-0.01	0.09	0.18	+1000.0%	+100.0%	+1900.0%

[1]RII: Adjusted Relative Index of Inequality; [2]SII: Adjusted Slope Index of Inequality; [3]PAF: Population Attributable Risk

Appendix N. Supplementary material to the article "*Dietary disparities among adolescents according to individual and school socioeconomic status: a multilevel analysis*" – Inclusion diagram

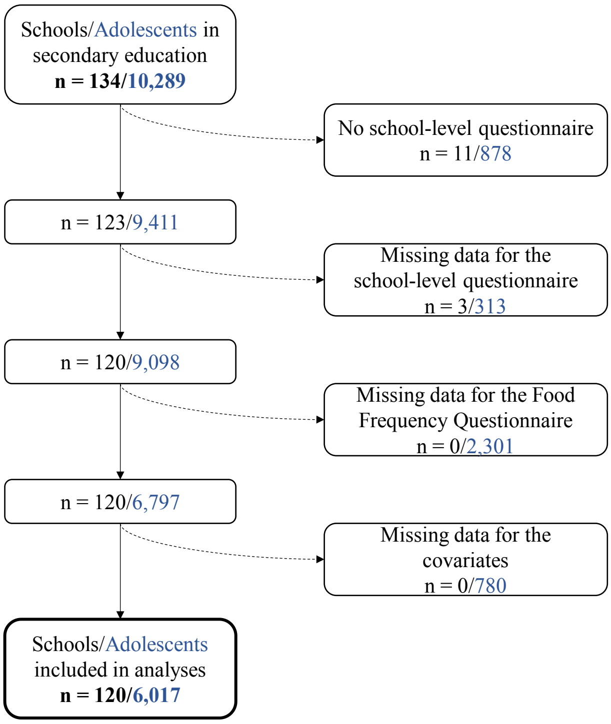


Figure N-1. Inclusion diagram of schools and adolescents in French-Speaking Belgium, HBSC, 2018.

Appendix O. Supplementary material to the article "*Dietary disparities among adolescents according to individual and school socioeconomic status: a multilevel analysis*" – Factor map of the Multiple Correspondence Analysis

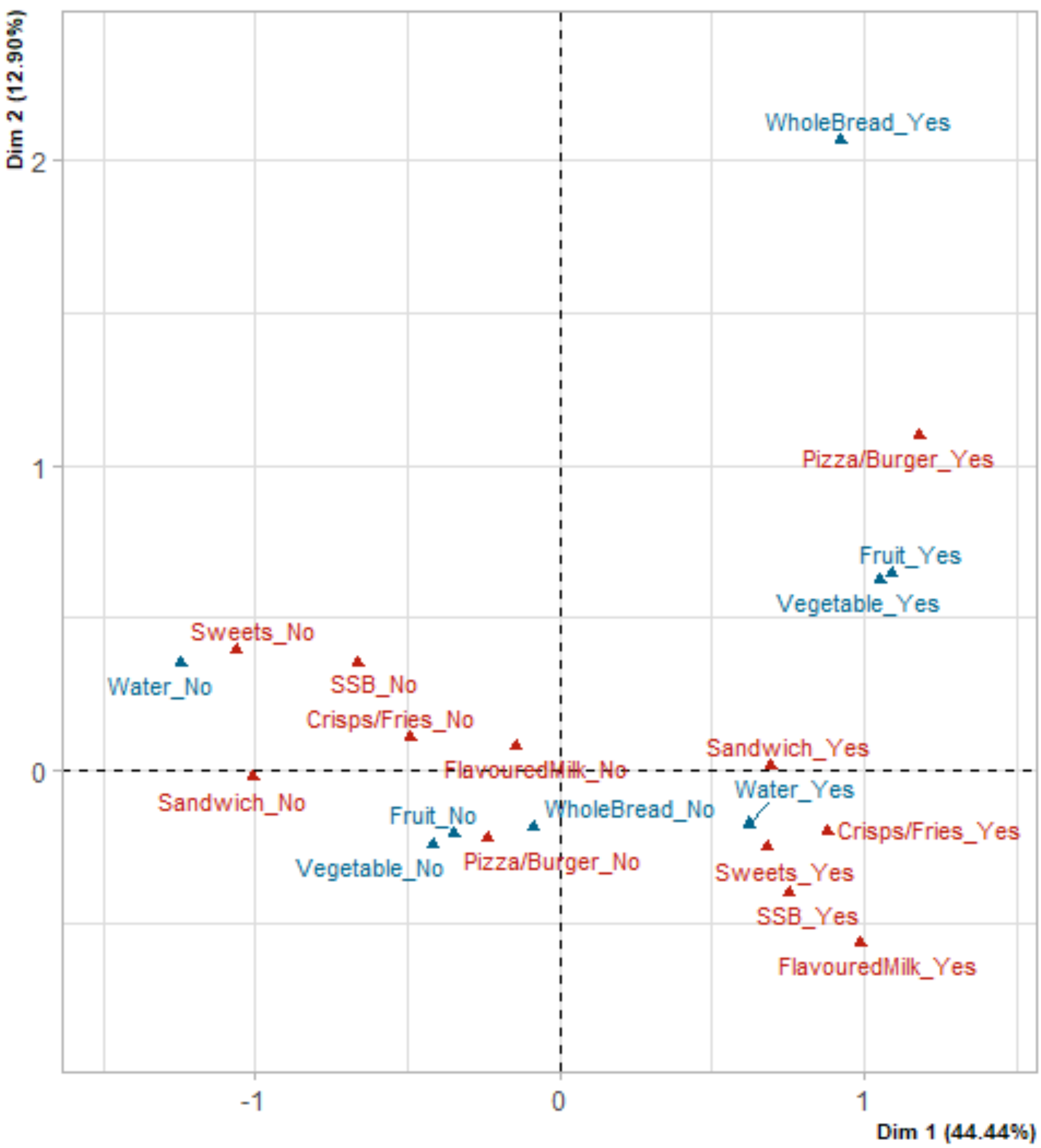


Figure O-1. Multiple Correspondence Analyses factor map of the 10 food items sold at schools. *2018 HBSC in French-speaking Belgium.*

Appendix P. Supplementary material to the article "*Dietary disparities among adolescents according to individual and school socioeconomic status: a multilevel analysis*" – Food consumption and characteristics of participants

Table P-1. Food consumption and characteristic of participants in percentages (n= 6,017). *2018 HBSC in French-speaking Belgium.*

Variables	**n**	**%**
Food groups		
Non-daily fruit	3,651	60.7
Non-daily vegetable	2,653	44.1
Non-daily dairy products	2,024	33.6
Non-daily water	750	12.5
Daily crisps and fries	920	15.3
Daily sugar-sweetened beverages	1,876	31.2
Individual-level characteristics		
Gender		
Boys	2,827	47.0
Girls	3,190	53.0
Age group		
< 14 years old	1,957	32.5
15-16 years old	1,931	32.1
17-20 years old	2,129	35.4
Family structure		
Two-parent family	3,630	60.3
Blended family	963	16.0
Single-parent family	1,424	23.7
Siblings		
Single child	454	7.6
Siblings	5,563	92.4
Family Affluence Scale		
High	1.240	20.6
Medium	3.661	60.8
Low	1.116	18.6
Perceived family wealth		
Well off	667	11.1
Quite well off	2,984	49.6
Average	1,796	29.9
Not so/at all well off	570	9.5
Parental working status		
Both parents working	3,782	62.8
One working parent	1,749	29.1
No working parent	486	8.1
Parental education level		
Post-secondary	3,447	57.3
Secondary or lower	2,064	34.3
Undetermined	506	8.4

(Continued)

Variables	**n**	**%**
School-level characteristics		
School region		
Brussels-Capital	1,275	21.2
Wallonia	4,742	78.8
School socioeconomic index		
High	2,801	46.6
Medium	1,970	32.7
Low	1,246	20,7
Health promotion addressed in school		
Yes	3,757	62.4
No	2,260	37.6
Project to increase consumption of health-promoting foods		
Yes	2,230	37.1
No	3,787	62.9
Project to limit the consumption of unhealthy foods		
Yes	2,900	48.2
No	3,117	51.8
Project to include fruit or vegetables at school events		
Yes	2,110	35.1
No	3,907	64.9
Foods available for sale at school		
Few foods	1,904	31.6
Mainly unhealthy foods	1,535	25.5
Many foods	2,578	42.9

Appendix Q. Supplementary material to the article "*Dietary disparities among adolescents according to individual and school socioeconomic status: a multilevel analysis*" – Multilevel logistic regressions for dairy products consumption

Table Q-1. Multilevel logistic regressions* for **dairy products** consumption (ref: daily consumption) (n= 6,017). *2018 HBSC in French-speaking Belgium.*

	Model 1	Model 2		Model 3*	
		ORa (95% CI)	*P* value	ORa (95% CI)	*P* value
Individual-level variables					
Gender (*vs*. Girls)			<0.001		<0.001
Boys		0.74 (0.66-0.82)		0.73 (0.66-0.82)	
Age group (*vs*. <14 years old)			<0.001		<0.001
15-16 years old		1.25 (1.09-1.43)		1.25 (1.09-1.43)	
17-20 years old		1.26 (1.10-1.44)		1.27 (1.11-1.45)	
Family structure (*vs*. Two-parent family)			0.54		0.59
Blended family		1.09 (0.94-1.27)		1.08 (0.93-1.26)	
Single-parent family		1.02 (0.89-1.17)		1.02 (0.89-1.17)	
Siblings (*vs*.: Siblings)			0.10		0.11
Single child		1.18 (0.97-1.45)		1.18 (0.96-1.44)	
Family Affluence Scale (*vs*. High)			0.43		0.41
Middle		1.08 (0.93-1.25)		1.08 (0.93-1.25)	
Low		1.14 (0.93-1.38)		1.15 (0.94-1.40)	
Perceived family wealth (*vs*. Very well off)			0.70		0.71
Quite well off		1.02 (0.84-1.22)		1.02 (0.85-1.23)	
Average		1.09 (0.89-1.33)		1.09 (0.89-1.33)	
Not so/at all well off		1.00 (0.78-1.29)		1.00 (0.78-1.28)	
Parental working status (*vs*. Both working)			0.09		0.11
One working parent		0.93 (0.82-1.06)		0.94 (0.82-1.06)	
No working parent		0.79 (0.64-0.98)		0.79 (0.64-0.99)	
Parental education level (*vs*. Post-secondary)			0.86		0.85
Secondary or lower		1.00 (0.88-1.13)		0.99 (0.88-1.13)	
Undetermined		1.06 (0.86-1.29)		1.05 (0.86-1.30)	
Intercept	0.51 (0.48-0.53)	0.37 (0.37-0.55)		0.35 (0.25-0.49)	
Variance of random effects	0.00	0.00		0.00	
Corrected variance of random effects†	0.00	0.00		0.00	
Measures of components of variance and heterogeneity					
PCV	Reference	-		-	
VPC	0.00	0.00		0.00	
MOR	1.00	1.00		1.00	

POOR, proportion of odds ratios in the opposite direction; PCV, proportional change of the corrected variance; VPC, variance partition coefficient; MOR, median odds ratio. Model 1: school-specific random effects; model 2: model 1 adjusted on all individual-level variables; model 3: model 2 adjusted on school-level variables including the non-significant ones: school region, school SEI, health promotion addressed in school; purpose of food project: to increase consumption of health-promoting foods, to limit consumption of unhealthy foods, to include fruit or vegetables at school events; foods available for sale at school.

†Scale correction factor= 0.994

Appendix R. Results of the additional analyses carried out on the Brussels-Capital Region (Chapter V)

Table R-1. Multilevel logistic regressions for **vegetable** consumption (ref: daily consumption) (n= 1,603). *2018 HBSC in French-speaking Belgium.*

	Model 1	Model 2		Model 3	
		ORa (95% CI)	*P* value	ORa (95% CI)	*P* value
Individual-level variables					
Gender (*vs*. Girls)			0.04		0.03
Boys		1.25 (1.01-1.54)		1.25 (1.02-1.55)	
Age group (*vs*. <14 years old)			0.55		0.64
15-16 years old		0.92 (0.70-1.20)		0.89 (0.68-1.15)	
17-20 years old		1.06 (0.81-1.38)		0.97 (0.75-1.26)	
Family structure (*vs*. Two-parent family)			0.21		0.17
Blended family		0.99 (0.69-1.40)		1.03 (0.73-1.47)	
Single-parent family		1.24 (0.97-1.60)		1.27 (0.99-1.63)	
Family Affluence Scale (*vs*. High)			0.06		0.15
Middle		1.25 (0.94-1.67)		1.18 (0.89-1.57)	
Low		1.69 (1.10-2.59)		1.52 (0.99-2.34)	
Perceived family wealth (*vs*. Very well off)			0.19		0.11
Quite well off		1.24 (0.88-1.75)		1.30 (0.93-1.82)	
Average		1.25 (0.85-1.82)		1.32 (0.91-1.93)	
Not so/at all well off		0.86 (0.52-1.41)		0.89 (0.54-1.45)	
Parental working status (*vs*. Both working)			0.44		0.33
One working parent		1.09 (0.86-1.39)		1.05 (0.83-1.34)	
No working parent		0.85 (0.57-1.27)		0.78 (0.53-1.16)	
Parental level of education (*vs*. Post-secondary)			0.003		0.009
Secondary or lower		1.33 (1.03-1.73)		1.25 (0.96-1.61)	
Undetermined		2.11 (1.31-3.39)		2.01 (1.25-3.22)	
Migration Status (*vs*. Natives)			0.02		0.10
Second-generation immigrants		1.43 (1.10-1.87)		1.33 (1.02-1.74)	
First-generation immigrants		1.41 (1.02-1.93)		1.26 (0.91-1.73)	
School-level variables					
School socioeconomic index and proportion of immigrants (*vs*. high SEI, low MIG)					<0.001
Medium SEI, low MIG				0.83 (0.56-1.25)	
POOR (%)				6.8%	
Medium SEI, middle MIG				1.77 (1.27-2.47)	
POOR (%)				0.0%	
Low SEI, low or middle MIG				1.94 (1.33-2.82)	
POOR (%)				0.0%	
Low SEI, high MIG				2.29 (1.62-3.23)	
POOR (%)				0.0%	
Intercept	0.94 (0.75-1.17)	0.35 (0.22-0.55)		0.27 (0.18-0.41)	
Variance of random effects	**0.27**	**0.13**		0.01	
Corrected variance of random effects†	**-**	**0.12**		0.01	
Measures of components of variance and heterogeneity					
PCV	Reference	53.7%		97.4%	
VPC	0.075	0.038		0.002	
MOR	1.64	1.41		1.09	

POOR: proportion of odds ratios in the opposite direction; PCV: proportional change of the variance; VPC: variance partition coefficient; MOR: median odds ratio. Significant school effect in **bold**. Model 1: school-specific random effects; model 2: model 1 adjusted on individual-level variables; model 3: model 2 adjusted on school-level variables

† Scale correction factor= 0.971786

Table R-2. Multilevel logistic regressions for **dairy products** consumption (ref: daily consumption) (n= 1,603). *2018 HBSC in French-speaking Belgium.*

	Model 1	Model 2		Model 3	
		ORa (95% CI)	*P* value	ORa (95% CI)	*P* value
Individual-level variables					
Gender (*vs*. Girls)			<0.001		<0.001
Boys		0.63 (0.51-0.79)		0.63 (0.51-0.78)	
Age group (*vs*. <14 years old)			0.04		0.03
15-16 years old		1.17 (0.89-1.53)		1.17 (0.89-1.54)	
17-20 years old		1.40 (1.08-1.82)		1.43 (1.09-1.88)	
Family structure (*vs*. Two-parent family)			0.007		0.006
Blended family		1.73 (1.23-2.43)		1.74 (1.23-2.44)	
Single-parent family		1.06 (0.82-1.37)		1.06 (0.82-1.37)	
Family Affluence Scale (*vs*. High)			0.36		0.34
Middle		0.97 (0.73-1.28)		0.98 (0.74-1.31)	
Low		1.24 (0.81-1.90)		1.27 (0.82-1.97)	
Perceived family wealth (*vs*. Very well off)			0.92		0.93
Quite well off		1.13 (0.80-1.59)		1.12 (0.79-1.58)	
Average		1.08 (0.73-1.59)		1.06 (0.72-1.57)	
Not so/at all well off		1.10 (0.66-1.83)		1.09 (0.65-1.81)	
Parental working status (*vs*. Both working)			0.27		0.30
One working parent		1.03 (0.80-1.32)		1.03 (0.80-1.33)	
No working parent		0.72 (0.47-1.11)		0.74 (0.48-1.14)	
Parental level of education (*vs*. Post-secondary)			0.41		0.51
Secondary or lower		0.86 (0.66-1.11)		0.88 (0.67-1.15)	
Undetermined		1.09 (0.67-1.76)		1.12 (0.69-1.81)	
Migration Status (*vs*. Natives)			0.38		0.45
Second-generation immigrants		0.89 (0.67-1.76)		0.90 (0.69-1.18)	
First-generation immigrants		0.80 (0.58-1.10)		0.81 (0.58-1.12)	
School-level variables					
School socioeconomic index and proportion of immigrants (*vs*. high SEI, low MIG)					0.87
Medium SEI, low MIG				1.04 (0.71-1.51)	
POOR (%)				0.0%	
Medium SEI, middle MIG				1.03 (0.74-1.44)	
POOR (%)				0.0%	
Low SEI, low or middle MIG				0.84 (0.57-1.24)	
POOR (%)				0.0%	
Low SEI, high MIG				0.93 (0.66-1.32)	
POOR (%)				0.0%	
Intercept	0.48 (0.43-0.53)	0.49 (0.33-0.72)		0.48 (0.32-0.71)	
Variance of random effects	0.00	0.00		0.00	
Corrected variance of random effects†	-	0.00		0.00	
Measures of components of variance and heterogeneity					
PCV	Reference	-		-	
VPC	0.000	0.000		0.000	
MOR	1.00	1.00		1.00	

POOR: proportion of odds ratios in the opposite direction; PCV: proportional change of the variance; VPC: variance partition coefficient; MOR: median odds ratio. Significant school effect in **bold**. Model 1: school-specific random effects; model 2: model 1 adjusted on individual-level variables; model 3: model 2 adjusted on school-level variables

† Scale correction factor= 0.981986

Table R-3. Multilevel logistic regressions for **water** consumption (ref: daily consumption) (n= 1,603). *2018 HBSC in French-speaking Belgium.*

	Model 1	Model 2		Model 3	
		ORa (95% CI)	*P* value	ORa (95% CI)	*P* value
Individual-level variables					
Gender (*vs*. Girls)			0.22		0.25
Boys		0.81 (0.57-1.14)		0.82 (0.58-1.16)	
Age group (*vs*. <14 years old)			0.98		0.88
15-16 years old		0.96 (0.62-1.50)		0.91 (0.59-1.42)	
17-20 years old		0.99 (0.64-1.53)		0.90 (0.58-1.39)	
Family structure (*vs*. Two-parent family)			0.007		0.004
Blended family		1.80 (1.11-3.21)		1.95 (1.15-3.32)	
Single-parent family		1.72 (1.17-2.53)		1.76 (1.20-2.60)	
Family Affluence Scale (*vs*. High)			0.18		0.37
Middle		1.60 (0.92-2.76)		1.45 (0.83-2.54)	
Low		1.87 (0.93-3.77)		1.63 (0.80-3.32)	
Perceived family wealth (*vs*. Very well off)			0.43		0.56
Quite well off		0.63 (0.37-1.10)		0.68 (0.39-1.18)	
Average		0.71 (0.39-1.27)		0.76 (0.42-1.37)	
Not so/at all well off		0.78 (0.39-1.27)		0.83 (0.40-1.72)	
Parental working status (*vs*. Both working)			0.75		0.85
One working parent		1.10 (0.74-1.63)		1.07 (0.72-1.59)	
No working parent		1.23 (0.70-2.19)		1.18 (0.66-2.09)	
Parental level of education (*vs*. Post-secondary)			0.006		0.03
Secondary or lower		1.83 (1.24-2.71)		1.66 (1.11-2.47)	
Undetermined		0.95 (0.43-2.14)		0.90 (0.40-2.03)	
Migration Status (*vs*. Natives)			0.85		0.96
Second-generation immigrants		1.07 (0.68-1.69)		0.99 (0.62-1.57)	
First-generation immigrants		1.16 (0.69-1.96)		1.05 (0.62-1.79)	
School-level variables					
School socioeconomic index and proportion of immigrants (*vs*. high SEI, low MIG)					0.21
Medium SEI, low MIG				0.85 (0.39-1.83)	
POOR (%)				23.5%	
Medium SEI, middle MIG				1.71 (0.98-3.00)	
POOR (%)				10.5%	
Low SEI, low or middle MIG				1.55 (0.84-2.87)	
POOR (%)				29.3%	
Low SEI, high MIG				1.67 (0.94-2.97)	
POOR (%)				1.4%	
Intercept	0.11 (0.09-0.14)	0.06 (0.03-0.13)		0.06 (0.03-0.11)	
Variance of random effects	**0.22**	0.07		0.03	
Corrected variance of random effects†	-	0.06		0.03	
Measures of components of variance and heterogeneity					
PCV	Reference	72.3%		88.7%	
VPC	0.063	0.020		0.008	
MOR	1.57	1.28		1.17	

POOR: proportion of odds ratios in the opposite direction; PCV: proportional change of the variance; VPC: variance partition coefficient; MOR: median odds ratio. Significant school effect in **bold**. Model 1: school-specific random effects; model 2: model 1 adjusted on individual-level variables; model 3: model 2 adjusted on school-level variables

† Scale correction factor= 0.963357

Table R-4. Multilevel logistic regressions for **sugar-sweetened beverages** consumption (ref: non-daily consumption) (n= 1,603). *2018 HBSC in French-speaking Belgium.*

	Model 1	Model 2		Model 3	
		ORa (95% CI)	*P* value	ORa (95% CI)	*P* value
Individual-level variables					
Gender (*vs*. Girls)			0.05		0.06
Boys		1.40 (1.11-1.77)		1.39 (1.10-1.75)	
Age group (*vs*. <14 years old)			0.10		0.04
15-16 years old		1.15 (0.86-1.55)		1.11 (0.83-1.49)	
17-20 years old		0.84 (0.62-1.14)		0.78 (0.58-1.05)	
Family structure (*vs*. Two-parent family)			0.56		0.69
Blended family		0.90 (0.61-1.34)		0.94 (0.64-1.40)	
Single-parent family		0.86 (0.65-1.14)		0.89 (0.67-1.17)	
Family Affluence Scale (*vs*. High)			0.05		0.11
Middle		1.54 (1.08-2.18)		1.45 (1.02-2.04)	
Low		1.58 (0.97-2.56)		1.38 (0.85-2.22)	
Perceived family wealth (*vs*. Very well off)			0.24		0.34
Quite well off		0.68 (0.47-0.99)		0.72 (0.50-1.04)	
Average		0.76 (0.51-1.15)		0.81 (0.54-1.22)	
Not so/at all well off		0.72 (0.42-1.22)		0.75 (0.44-1.28)	
Parental working status (*vs*. Both working)			0.03		0.08
One working parent		1.34 (1.02-1.76)		1.28 (0.98-1.67)	
No working parent		1.62 (1.07-2.46)		1.50 (0.99-2.26)	
Parental level of education (*vs*. Post-secondary)			0.04		0.16
Secondary or lower		1.44 (1.09-1.90)		1.30 (0.99-1.72)	
Undetermined		1.14 (0.69-1.88)		1.08 (0.66-1.79)	
Migration Status (*vs*. Natives)			0.08		0.02
Second-generation immigrants		0.84 (0.62-1.13)		0.80 (0.59-1.08)	
First-generation immigrants		0.66 (0.45-0.95)		0.60 (0.42-0.87)	
School-level variables					
School socioeconomic index and proportion of immigrants (*vs*. high SEI, low MIG)					<0.001
Medium SEI, low MIG				1.48 (0.93-2.35)	
POOR (%)				0.7%	
Medium SEI, middle MIG				2.52 (1.72-3.70)	
POOR (%)				0.0%	
Low SEI, low or middle MIG				3.86 (2.53-5.89)	
POOR (%)				0.0%	
Low SEI, high MIG				3.13 (2.13-4.61)	
POOR (%)				0.0%	
Intercept	0.46 (0.36-0.60)	0.35 (0.20-0.60)		0.19 (0.12-0.30)	
Variance of random effects	**0.38**	**0.26**		0.01	
Corrected variance of random effects†	**-**	**0.25**		0.01	
Measures of components of variance and heterogeneity					
PCV	Reference	32.6%		96.9%	
VPC	0.103	0.074		0.004	
MOR	1.80	1.63		1.11	

POOR: proportion of odds ratios in the opposite direction; PCV: proportional change of the variance; VPC: variance partition coefficient; MOR: median odds ratio. Significant school effect in **bold**. Model 1: school-specific random effects; model 2: model 1 adjusted on individual-level variables; model 3: model 2 adjusted on school-level variables

† Scale correction factor= 0.981762