Childhood Obesity

Data informed policies for targeted interventions in the Netherlands

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by

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Relevant files for the analysis are available at https://github.com/violettii

TU Delft

Preface

This thesis topic was inspired from my passion for health, fitness and in general psychical activity of all sorts. When I joined the Engineering and Policy Analysis program, two years ago, I have never thought of the crucial societal issues such as climate change, health, quality education as societal challenges, which can be tackled upon. This course showed me there is not a single actor to be held responsible and that by collaboration, a solution which is greater than the one a single actor can achieve, is possible. With this research, I fulfill the last part of the this program, with a research topic which is close to my heart.

I am grateful that I had the chance to meet and collaborate with another university, Leiden Medical Center, since without their contribution my thesis would not have been the same. Also, I would like to thank my Committee, who helped me when I was confused and unsure of the new directions the topic was developing towards. Lastly, I am proud that I figured a way to understand, during the past 5 months, how CBS works, despite all the Dutch and all the restricting rules. Lastly, I would to thank professor Alexander Verbraeck, who so generously provided me with a fully working laptop when mine lost total connectivity with CBS.

This thesis would not have been finished within the nominal time-frame if it wasn't for some dear friends being on my side the whole time. I am grateful I had my *EPA Support Group* during fun, stressful and unmotivated times. Also, a huge shout-out to my best Dutch girlfriends. Lise and Maartje for making my days better, funnier and cozier and for helping me overcome mental blocks throughout this process. Lastly, I want to thank my Greek girlfriends, Angelika and Maria, who from the other side of Europe received my Skype calls and listen to me talking about all sorts of stuff, while managing to make me focus on the important things. Lastly, I dedicate this thesis to my family and all the loved ones who are not with me anymore. Their opinions, guidance and perceptions have shaped me to the person I am today.

Violetta Matzorou
Den Haag, August 2019

Commonly Used Terms

- Obesity: The existence of excess body weight for a given height. This simple definition contradicts an etiologically complex phenotype primarily associated with excess, or body fatness, that can manifest metabolically and not just in terms of body size (Hruby & Hu, 2015).
- Obesogenic environment: is the collective physical, economic, policy, and sociocultural surrounding, opportunities, and conditions that promote obesity (Swinburn et al., 2019)
- Overweight: The state of a human being above the 85th centile of the body mass index for age and sex specific data (Cole, Bellizzi, Flegal, & Dietz, 2000).
- Obese: The state of a human being above the 95th centile of the body mass index for age and sex specific data (Cole et al., 2000).
- Body mass index (BMI): The index is a person's weight in kilograms divided by the square of height in meters (kg/m^2). A high BMI can be an indicator of high body fatness. It is the current most widely used criterion for classifying obesity (Hruby & Hu, 2015).
- z-score: z-score or standard deviation classification system is the system which enables a standardised value for body weight which is reflected upon specific reference of a population segment.
- Socio-economic status (SES): Is a composite measure of the social class of an individual or a group. Usually it refers to income, education and occupation (American Psychological Association, 2019).
- Youth and Family Centers (YFC): These are centers initiated by the Dutch government to facilitate new families in their beginning (Centrum Jeugd & Gezin Den Haag, 2019).
- Sustainable Development Goals (SDGs): These goals are set by the United Nations as guidelines for improving societies. Specificlly UN defines the SDGs as ”blueprint to achieve a better and more sustainable future for all”. They are related to the global challenges societies are confronted with, including poverty, inequality, global health, climate change, environmental degradation, prosperity, peace and justice and many more (United Nations, 2018).
- Social determinant of Health (SDH): Conditions in the environments in which people are born, live, learn, work, play, worship, and age that affect a wide range of health, functioning, and quality-of-life outcomes and risks (HealthyPeople2020, 2010).
- Health Inequity: Is a broad concept and involves societal inequalities. The inequalities cause in the long run inequities in health.
- Syndemic: It refers to a synergy of epidemics, because they co-occur in time and place, interact with each other to produce a complex sequelae, and share common underlying societal drivers. A syndemic is largely applied to diseases at the individual level—two or more diseases clustering in time and place, interacting with each other and having common, societal determinants (Swinburn et al., 2019).
- Epidemic: The occurrence of more cases of a disease than expected in a given community or region or among a specific group of people over a particular period of time

- Health Care System: "The combination of resources, organization, financing and management that culminate in the delivery of health services to the population." It includes "all activities whose primary purpose is to promote, restore, and maintain health." Lately, the definition of "purpose" has been further extended to include the prevention of household poverty due to illness (World Bank, 2007).
- Public Health Service (PHS): For the current thesis with PHS is meant the Dutch Public Health Service and not in general the public health service of other countries or Europe.
- Leptogenic environment: healthy-weight-promoting urban environment (Hendriks et al., 2012).

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Executive Summary

The dietary habits changed drastically since 1980 and the chemical composition of a lot of processed foods was altered to meet new requirements. This nutrition shift along with the industrialisation and the rise of the sedentary lifestyle, led to the spread of the obesity epidemic, which still manifests in many countries, including European. Children are affected from this epidemic, with childhood overweight and obesity trends growing strong across the world. More specifically, the OECD children average in 2017, reached a 15.5% level, aggregated for overweight and obesity. This matter, came this year to the spotlight from the *Lancet* report, which exposed the multi-faceted nature of the epidemic. Growing percentages, lack of urgency, policy inertia and lack of inter-sectoral approaches are reasons why the disease has taken such dimensions and it got appointed with the term of *syndemic*.

However, the disease is mostly idiopathic. This implies that people have the power to eliminate the factors contributing to the manifestation of the phenomenon. The connection between the environment where people grow and live in, "nourishes" tendencies for obesity and is called as "obesogenic environment". From biology, the time-frame when an individual develops fat cells and sets his nutrition patterns is during early childhood and approximately up to adolescence. For these reasons, in the current thesis, children are the focus, since tackling the disease from an early age would ensure the health of future population. By understanding the factors which contribute to weight gain or loss during childhood, prevention can be facilitated to tackle the disease with the design of new policies. The main research question is:

> *How can Dutch government data inform policies for targeted interventions addressing childhood obesity?*

The literature review showed a fragmentation in the theory and frameworks used for health studies. Since contemporary societies experience social inequalities, these lead to inequities in terms of how citizens with different background experience health and health care. For this reason, the general framework which is used in the Netherlands for health studies, is expanded to fit factors which capture health inequities. To continue, the methodology of the current thesis is actor analysis and explanatory modeling. Actor analysis sets the foundation of the problem, identifies the involved actors in the policy arena and sets their perceptions.

For the quantitative part, governmental data obtained from a national survey and from medical databases Statistics of The Netherlands (CBS), is used to identify factors explaining the weight in preschool children and specifically from 0 – 6 years of age. By formulating and testing iteratively hypotheses about the weight of children and how it is influenced, an idea about the factors affecting it and to what extent, is formed. The modeling is conducted with the use of linear regression. This is due to the continuous nature of the variable of interest, namely the weight of children. These factors will later on be used to propose policies. Additionally, the used definition of obesity and overweight for children in the data is compared with a relatively new standard for children. After the comparison, conclusions are drawn upon the differences about the health state of children.

The results of the analysis show that there is a clear connection of the weight of children with non-biological factors from their environment. The most prominent influences are observed from the family structure, the psychological state of the child, the ethnicity and education of the mother. In terms of the urban environment, a relationship is observed with the urbanity index of the neighborhoods. The lower the urbanity level, the less is the absolute contribution to the weight of children. A significant but small influence is observed from the use of the preventive measure of consultation visits to the Youth and Family Centers. In terms of the definition for overweight and obesity, the need to adjust the thresholds for children is crucial. The comparison showed that overweight children are mislabeled in the dataset, posing risks for research and for understanding the extent of the epidemic.

To answer the main research question, the identified factors and insights are used to propose data-informed policies. The policy proposal is segmented to address the different pillars of the analysis framework. Namely, policies referring to the *Economics*, *Environment* and *Community* of the Netherlands. Suggestions for the *Medical Professionals* are made, to communicate the need for a new approach when it comes to identifying risk-prone children. Medical professionals are identified as the actor who can initiate discussions on a national level to raise awareness for organised action for childhood obesity prevention and cure, by reaching to governmental bodies. In general, all proposed policies are aligned with the policy goals of the European framework, *Health 2020*.

The current thesis managed to set the foundation of the non-biological factors affecting the weight of preschool children for the country of the Netherlands. Future research can focus on the design of prediction models for obesity based on the significant factors identified in this study. Lastly, the expansion of the current models with more variables from the urban environment is needed, to shed light on more specific associations with urban features.

Keywords: childhood obesity, policies, interventions, health inequity, social determinants of health, health distribution

1

Introduction

1.1. The obesity epidemic

Over the last 30 years, industrialization, urbanization, a highly sedentary lifestyle and a nutritional transition to processed foods have resulted in quadruple rise in obesity levels (Hruby & Hu, 2015). The statistics for childhood obesity and overweight incidents are also rising in OECD country members (World Health Organization, 2017), (OECD, 2017b). In early 2000s, the aggregated average rate for overweight and obesity was at around 12%, whereas in the 2013-2014, it increased to 15.5%. Researchers predict that this epidemic is worsening in the future given the current practices, showing the need to adjust the policies and measures. Figure 1.1, shows the projections for some of the major OECD country members for adulthood obesity as presented from the latest obesity report (OECD, 2017b). From a systems perspective, obesity has been characterised as a ”wicked policy problem” since it has a variety of interconnected determinants where its solution lies in collaborative intersectoral actions (Baker, Gill, Friel, Carey, & Kay, 2017), Hendriks et al. (2012). The term ”syndemic” has been identified as an umbrella concept from the Lancet, which includes obesity, highlighting the need to address it in a bottom-up way in order to minimise its prevalence (Swinburn et al., 2019).

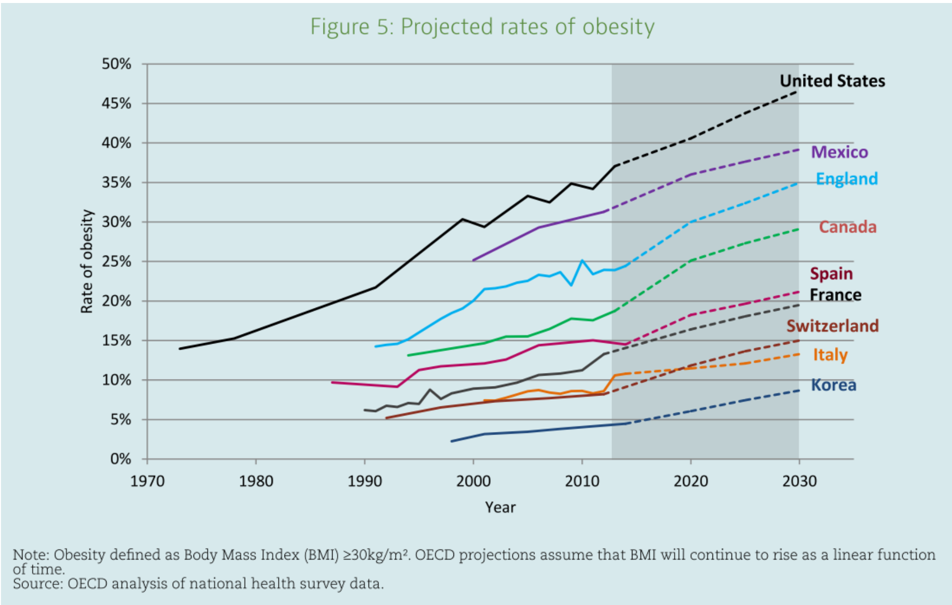


Figure 1.1: Projections for adulthood obesity (OECD, 2017b)

1.2. Childhood obesity

Apart from adulthood obesity, the epidemic is spreading to the youngest of the population groups. Childhood obesity trends have increased the past years, marking a disadvantaged health start for a significant amount of the population (OECD, 2017b). The health consequences associated with childhood obesity are diverse and are correlated with both physical and psychological disorders (see Appendix A) (Pandita et al., 2016), (Robertson, Murphy, & Johnson, 2016), (Bryant, Hess, & Bowen, 2015). At the same time, as a direct consequence, the health systems across the countries become financially burdened by the respective drug prescriptions, hospitalizations and surgical procedures (Hruby & Hu, 2015). The current state of the health systems around the world, seems to be unsustainable since World Health Organization Europe (2013), as stated in the OECD report, the yearly spending on health is at a 9.9% of GDP in Europe in 2016 and increasing, whereas in 2005, was at 8.7% (OECD, 2017a).

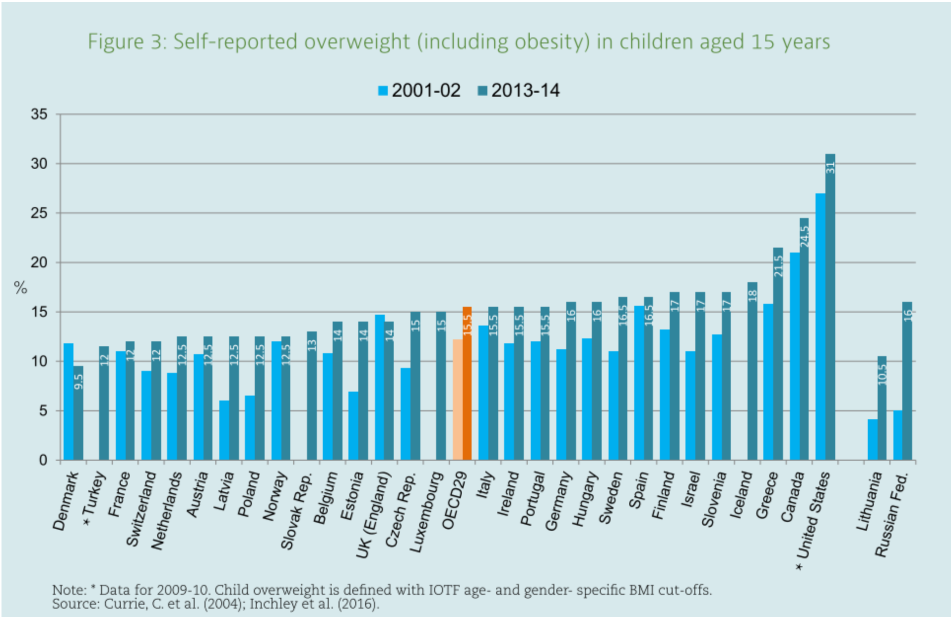


Figure 1.2: Comparison of overweight and obese adolescents percentages for each OECD country member, in early 2000 and in 2014 (OECD, 2017b)

1.3. Impact of non-biological factors on childhood obesity

Obesity is a disease which manifests from a very early age in life, while children constitute a major group affected from this epidemic (Pandita et al., 2016). The epidemic is defined as an excessive amount of adipose tissue during childhood. Multiple studies have shown that in order to minimise its prevalence and treat the existing people who are affected, early interventions and preventive care are easier, most cost effective and lead to better long-term health outcomes (Baker et al., 2017),(Soskolne, Cohen-Dar, Obeid, Cohen, & Rudolf, 2018), Sassi et al. (2010), (Martínez Vizcaíno, Cañete García-Prieto, Notario-Pacheco, & Sánchez-López, 2013). Therefore, promotion of health and disease prevention are considered approaches to achieve a healthier future population avoiding costly mitigation measures (OECD, 2015). To increase the need for such measures, from a medical perspective, treatment is still in elementary stage, hence, early prevention holds better than cure at future acute stages (Pandita et al., 2016), (Robertson et al., 2016), (Horne et al., 2011).

1.4. Research objectives

Which are then the root causes of this disease? It is established that some of the causes are genetic (Xu & Xue, 2016), (Martínez Vizcaíno et al., 2013), however, a lot of them stem from non-biological factors (Xu & Xue, 2016), mainly existing in the environment of the children. Consequently, it is obvious that for these causes, different actors have the power to influence them, unveiling levers to tackle the epidemic. Health is one of the Sustainable Development Goals that is fundamental for the prosperity and advancement of societies (United Nations, 2018). Research globally has taken place to identify biological or not factors which lead to childhood obesity. However, since the disease is idiopathic, geographic characteristics play a major role. Each country or province has different systemic causes contributing to the disease. Consequently, there is room for more thorough exploration to map spatial heterogeneity, specifically for the Netherlands.

The objective of this research is to reduce the prevalence of childhood overweight and obesity rates in the Netherlands. This is achieved by providing data-informed policies to municipal decision-makers for interventions. The *client* of the current thesis is the decision maker of a hypothetical Dutch Municipality, who is interested in investigating and exploring the issue of childhood obesity in the area of his sovereignty. *A Dutch municipality*, can use the advice to facilitate early diagnosis of vulnerable children and to implement general prevention measures. This choice is made since the Dutch health system is increasingly decentralised and the government follows a shared governance approach in terms of decision-making (van de Berg et al., 2016). A population based approach is implemented with focus on spatial characteristics and metrics measuring the health of the child. The scope is to identify relationships between different non-biological factors of the immediate environment of a child and its weight, for pre-school children.

Early diagnosis of vulnerable children can be facilitated and tailor-made interventions can be designed when the decision makers of a municipality are aware of the unique attributes and characteristics the environment has and their consecutive effect on citizens' health. The vision is to improve childhood health in the near future for the Netherlands. To conclude, by identifying the non-biological factors which drive the weight of children, a new possible solution space to tackle childhood obesity could be unveiled. As such, this research contributes to achieving the Sustainable Development Goal for prosperity and health of societies. The main research question of the thesis is:

> *How can Dutch governmental data inform policies for targeted interventions addressing childhood obesity?*

The main research question is formed in a way that it utilises the available resources the Dutch government has to design policies which can address childhood obesity. The role of the government in Health is increasingly being decentralised and the municipalities are the actors who can initiate change in the Health arena of the country (van de Berg et al., 2016). However, the government is the actor who is responsible for documenting and keeping databases with different data about the municipalities and the population state. Thus, in this thesis such data, provided by the Centraal Bureau voor de Statistiek (CBS) are employed to identify factors which drive the weight gain in pre-school children. The result of the research is policies and advice which can be used by municipal decision makers to initiate change and start a conversation with other bodies of the government, such as the Informatieberaad, for the general epidemic of obesity and ways to tackle it.

1.5. Thesis outline

The current thesis proposal is structured in eleven chapters. A schematic representation is shown in Figure 1.3. In Chapter 2, elaboration on definitions and state of the art concerning influential factors to childhood obesity is conducted. Also, at the end of this chapter, the scientific gap is identified and the proposed research question is demarcated. Chapter 3, explains how the framework for public health is expanded based on theories. In Chapter 4, an explanation of the nature of the used dataset is provided. Also, the proxies of measurement are defended. Chapter 5, explains in detail the proposed methodologies for each of the sub-research questions. Chapter 6 discusses the context of actors, legislation and resources that needs to be taken into account when making policy proposals to municipalities. In Chapter 7 the implementation and results of the analysis are provided and explained. In Chapter 8, the comparison of two scientific methods is provided to unveil potential differences and derive conclusions for risk-prone children. Lastly, the main research question is answered in Chapter 9. There, all the results of the thesis are combined to propose data-informed policies for municipal decision-makers. Chapter 10, restates the limitations of the analysis and future work is suggested. Finally, Chapter 11, presents the final conclusions and states the contribution to the literature.

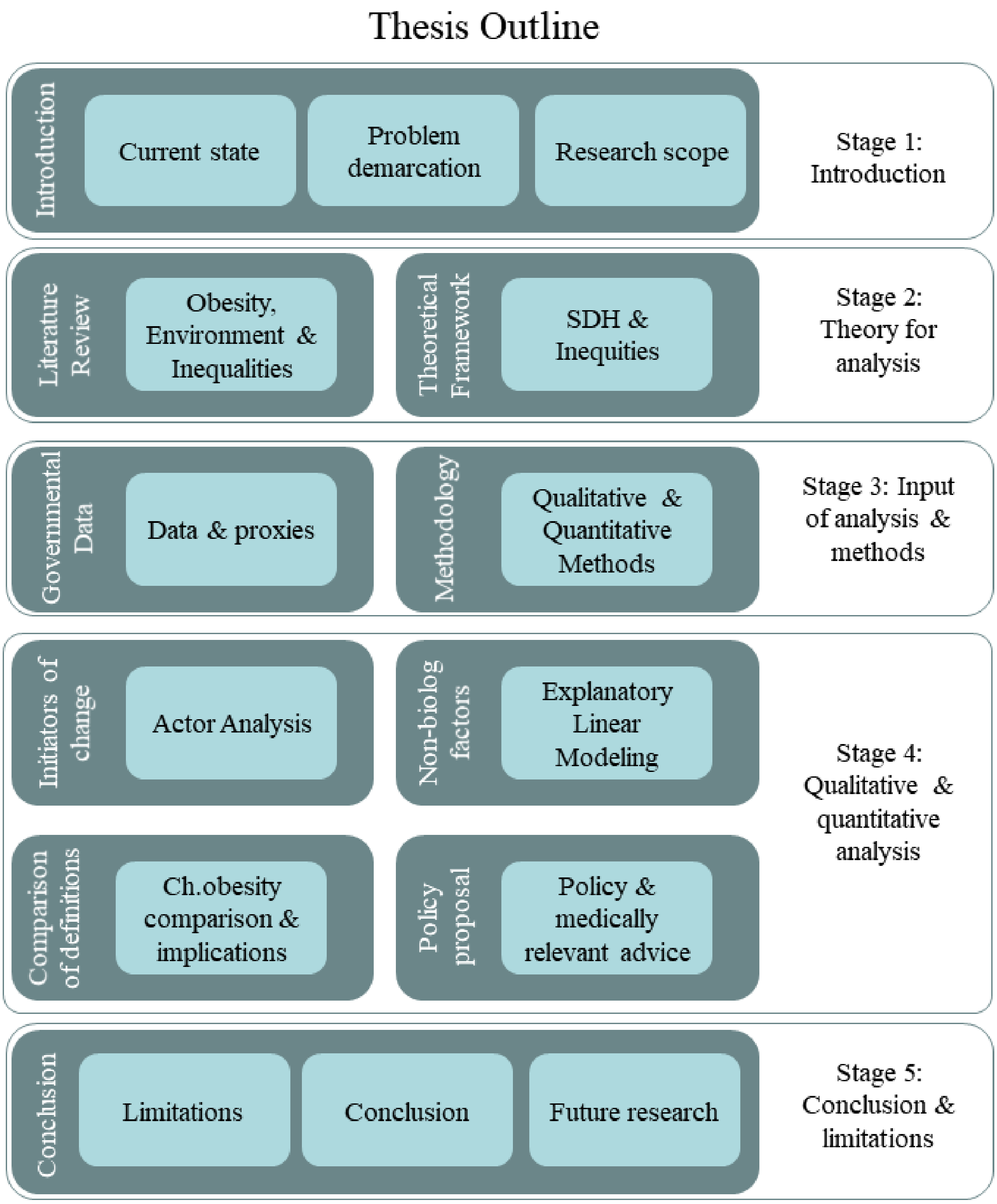


Figure 1.3: Thesis outline.

2

Literature Review

This chapter reviews the literature around childhood obesity. The issue of complexity and the inter-dependencies are main characteristics of this epidemic. This nature is reflected upon dividing this Chapter into different sections to aid the reader get acquainted with the topic.

Search Terms

The research is conducted by mainly searching on ScienceDirect, PubMed and Google. The most used search terms are:

1. “child obesity”
2. “child* obesity”
3. “child* obesity” AND “polic*”
4. “obesogenic environment” AND “child* obesity”
5. “obesity” AND “Netherlands”
6. “child* obesity” AND “Netherlands”
7. ”determinant* of health” AND ”obesity”
8. ”Jaap Seidell” AND ”obesity” [1]
9. ”Tessa Roseboom” AND ”obesity” [2]

2.1. Introduction and Definitions

Obesity has been the object of research since ancient times. Evidence about its historical context can be found in various forms of art, like sculptures, literature or paintings (Greydanus et al., 2018). However, since the 20th century industrialization, the shift which occurred in food production increased the percentage of calorie-dense, high-refined sugar, salt and saturated fat products. This was preferred by the industry since it reduces costs and improves the structure and appearance of food. There is a threshold around the 1980s, from which onward the incidents of both childhood and adult obesity have increased around the globe (Hruby & Hu, 2015). Such an alteration resulted in an increase in the global prevalence of obesity, diabetes and heart disease (Greydanus et al., 2018).

In order to define childhood obesity, firstly, the definition of which population segment is characterized as child, is needed. As can be found in the WHO report (World Health Organization, 2013), children are individuals between the ages of 0-9 years old and adolescents

[1] this search is suggested from LUMC since the author is a researcher of obesity
[2] this search is suggested from LUMC since the author is a researcher of public health

range from the age of 10-19 years old. However, depending on the study, different working definitions are presented and used. Some studies aggregate the data and present results for children using the definition of people aged up to 15 (Frongillo et al., 2017), up to 16 (Isasi et al., 2017) or even from 6-18 years old (Grow et al., 2010). In general, studies collect and process data from individuals ranging from 0-19 years old, since at 19 is the strict adult threshold, unless is somehow else defined by national laws (World Health Organization, 2018). In the current study, the selected child definition is the one from World Health Organization (2013), since our sample refers to preschool children and solely for the ages of 0-6 years old.

The chosen definition of childhood obesity is the one coined by Paes et al. (2016). Namely,

> "childhood obesity is an excessive accumulation of body fat in adipose tissue during childhood, with negative implications for health; its occurrence is the most important risk factor for the development of cardiovascular diseases in adulthood" - (page 231).

Childhood obesity is a multifactorial disorder where both genetics and environment play a major role (Vanhala et al., 2009), (Robertson et al., 2016), (Paes et al., 2016). Medically, it is operationalised as being in the $\geq 85^{th}$ and $\geq 95^{th}$ percentile, respectively, for overweight and obese people, of age and sex specific Body Mass Index (BMI) values. These values are derived from each country's BMI reference data for its growth charts (Moghadam, Safarian, Vakili, & Ehteshamfar, 2015), (Grow et al., 2010), (Sandy, Tchernis, Wilson, Liu, & Zhou, 2013). Another measure of growth is the z-score or standard deviation classification system. This system is perceived as the most appropriate tool for analysis and presentation of anthropometric data because of its multiple advantages. Its calculation enables a standardised value which is reflected upon specific reference population segment (World Health Organization, 2010). Nevertheless, other researchers contest this system and they came up with another operationalisation of overweight and obesity especially for children and adolescents. This new definition was coined from Cole et al., where according to their research, using international data, they linked the 25^{th} and 30^{th} BMI values of adults to children-specific, new BMI thresholds. One of the benefits is that the comparison of children can happen without compensating the results accuracy. This is also the definition which is selected in selected and approved for the scope of the current thesis.

The causes of obesity are diverse (see Figure 2.1). Broadly they can be categorized in the following categories: genetic (Paes et al., 2016), psycho-social, behavioral, cultural (Soskolne et al., 2018) and environmental (Sandy et al., 2013). Regarding the biological growth of individuals, the fat cells along with the tissue and organ cells only increase during childhood and up to adolescence (Callahan, 2017). Previous studies showed that two specific timeframes during the life of a human are capable of generating fat cells (Lundahl, Kidwell, & Nelson, 2014). The first is during pregnancy and the second from the age of six up to adolescence. Factors such as dietary habits, physical activity and hormonal imbalances could alter the gene expression, trigger changes in the molecular biochemical behavior of hormonal imbalances. Consequently these can modify the gene expression and initiate changes in the molecular biochemical behavior of biological systems, thus associating the term of "re-programming disease" for obesity, showcasing that the behavioral patterns of pregnant women can affect the birth weight and metabolism of the offspring (Paes et al., 2016).

Lastly, some researchers believe that specifically for childhood overweight and obesity, another "critical period" may be the adiposity rebound around the age of five. This is defined as a period where the BMI of a child increases after reaching its minimum level during early childhood (Franchetti & Ide, 2014). Children who have an earlier obese period rebound tend to have higher fat tissue percentages later, however, this potentially could be associated with the timely establishment of dietary habits around the same age (Robertson et al., 2016). Hence, this biological "window" of treating weight abnormalities is known to be during the pre-school age. Apart from nutrition, physical activity plays an important role in the body structure and development of children. The British NHS argues that children who play or exercise actively reduce their risk of experiencing poor health later on (National Health Service, 2018).

To conclude, it is vital for children to have a healthy lifestyle (correct nutrition, levels of

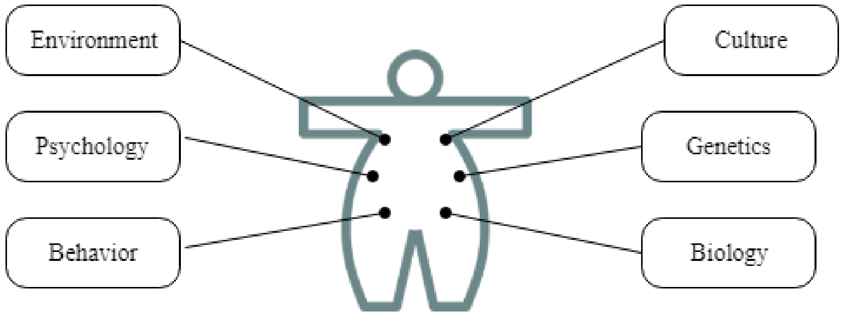


Figure 2.1: Causes of obesity, as identified from the literature (schema produced by the author)

physical activity and sedentary patterns) in order to maintain a healthy body composition, which will later lead to lower risk of chronic diseases, such as type II diabetes, hypertension or cardiovascular abnormalities (J. J. Reilly & Kelly, 2011). Since that more than 90% of the incidents of obesity have idiopathic causes and the rest can be attributed to biological characteristics (Xu & Xue, 2016), this shows that childhood obesity can be modified and potentially treated. As stated in the OECD Obesity Update report, obesity incidents are expected to rise linearly until 2030, in many member countries, such as Spain, France, Italy and United States (OECD, 2017b). This rapid increase in childhood overweight and obesity are highly associated to the contemporary obesogenic environment which exists in many countries (Vanhala et al., 2009).

2.2. Environment, quality and inequity

As stated in the previous section, some causes of obesity are attributed to environmental issues. Since humans grow, live and age in a specific environment, it is important to understand how such a space is built and also how it triggers, by its inherent architecture, behaviours leading to obesity. First of all, the human environment is a very broad concept. Thus, the working definition of *environment*, which is chosen is:

> ”environment is the complex of physical, chemical, and biotic factors (such as climate, soil, and living things) which along the social and cultural conditions, act upon an individual or a community and ultimately determine its form and survival” (Merriam-Webster, 2019)

In addition to this definition, the concept of *environmental quality* should be introduced as well. The working definition for this concept is:

> ”environmental quality is an essential part of the broader concept of ‘quality of life’, the basic qualities such as health and safety in combination with aspects such as ‘cosiness’ and attractiveness” (van Kamp et al., 2003) - (page 7).

The understanding of environmental quality is needed because this poses a positive, ”liveable” boundary in the environment and the way people interact with it. When the environment deteriorates, its quality levels plummet, affecting individuals living within it. The impact of this deterioration is reflected on the *quality of life* people experience which is an aggregation of the local environment state along with the health status of an individual. The definition of this concept which is chosen for the scope of the study is:

> ”quality of life is the factual material and immaterial equipment of life and its perception characterised by health, living environment and legal and equity, work, family, etc.” (van Kamp et al., 2003) - (page 7)

Both environmental quality and quality of life refer to the person, the environment (physical and social) and their relationship. This relationship is not fix but transactional, which makes it harder to define causality. So far, there is not a unique framework for researchers to explore environmental or policy related aspects and this resulted from the wide spectrum of disciplines which have dealt with environmental quality and quality of life topics (van Kamp et al., 2003). Although, the one which is adopted by the Institute for Health and Environment (RIVM) and frequently used is provided in Figure 2.2. Thus, in the current thesis this framework is expanded and enriched based on the findings of the research.

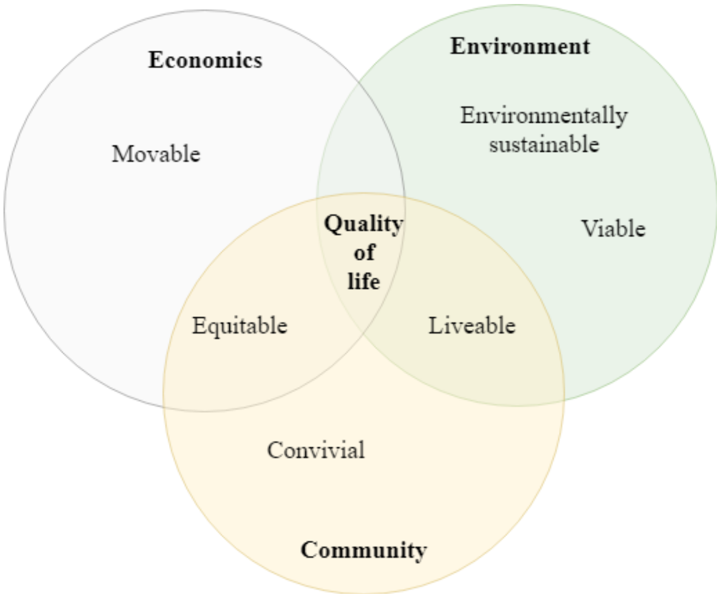


Figure 2.2: Socio-ecological model conceptualised by Shafer et al. (2000) and adopted by the RIVM in 2003 (van Kamp et al., 2003).

The epidemic of obesity is associated with a person's environment through the concept of health inequity. Since the environment is a composite measure of the physical and social, specific structures within it trigger unfair or partial treatment toward those who are in a more disadvantaged position. Then, the logical connection appears between social inequalities which in specific systems, like the health care system, can cause inequitable access or opportunity to care and cure. It is obvious that social inequality (or disparity), can lead to inequity in terms of how a citizen experiences a system, such as the Heath one, within the society. The concepts of inequality and inequity are distinct and the differentiation of them in the health context is crucial. Figure 2.3 illustrates in a naive but straightforward way how these concepts differ. Specifically, the definitions of the concepts are:

> ”Health inequality is the difference in health status or in the distribution of health determinants between different population groups” (WHO, 2019).

Another health-related definition includes the term of disparity, by stating that:

> ”Health inequalities are disparities in health, reflecting either differences in access to a range of promotional, preventive, curative, or palliative health services or differences in outcomes including disability, morbidity, and mortality spanning physical, mental, and social health” (Sadana & Blas, 2013).

From the above definitions is obvious that health inequalities are related not only to biological or genetic factors, but also to social factors which are susceptible to policy and are potentially avoidable given the right actions based on the context (Sadana & Blas, 2013). For example, differences in mobility between elderly people and younger populations or differences in mortality rates between people from different social classes.

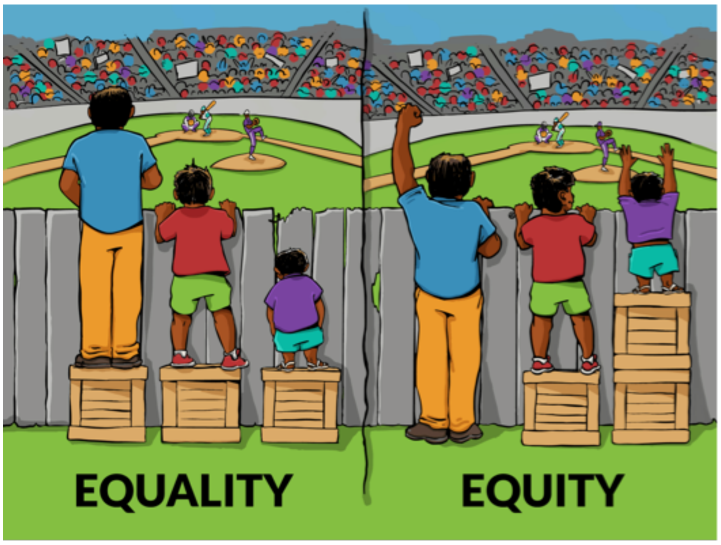
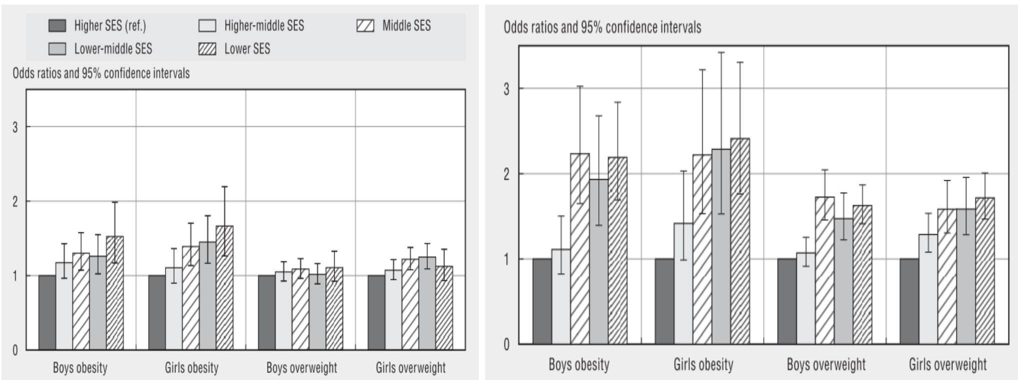


Figure 2.3: Illustrative representation of an equal versus and equitable approach (Milken Institute, 2018)

What is identified from the extensive research of OECD in the report ”Obesity and the Economics of Prevention”, when they studied the social dimensions of obesity is that the socioeconomic level of children is a crucial factor reversely affecting the obesity prevalence. In other words, the less wealthy families of children are the higher the odds of children being prone to be obese or overweight, mainly in western Europe. One of the figures which showed this is used below (see Figure 2.4). In opposition to adulthood obesity, there are no major gender differences identified in childhood obesity. Similar results were observed for diet patterns. Lastly, income and education level were factors which negatively affected the consumption of fruit and vegetables (Sassi et al., 2010).



(a) United Kingdom (b) France

Figure 2.4: Social disparities in childhood overweight and obesity, as identified by Sadana and Blas (2013), in the OECD Obesity and the Economics of Prevention Report.

It is important to distinguish between inequality in health and inequity. Some health inequalities are derived from biological variations or free choice and others are from environmental externalities, conditions mainly outside the control of the individual per se. In the first case it may be impossible or ideologically unacceptable to change the health determinants and hence, the health inequalities are unavoidable. In the latter case, the uneven distribution may be unnecessary and avoidable as well as unjust and unfair, so that the existing health inequality potentially leads to inequity in health (WHO, 2019). The definition of health inequity is:

> ”Health inequity is the difference in health which is considered as unfair, unjust and avoidable. It is often revealed through systemic patterns or gradients in access or outcomes across

populations with different levels of underlying social (dis)advantage. That is, wealth, power, prestige, or other indicators of social stratification" (Sadana & Blas, 2013).

Inequities in a society are determinants related to living and working conditions, as well as the overall macro-policies prevailing in a country or region. For example, mothers in lower socioeconomic groups are more likely to be overweight and less likely to breastfeed. Consequently, their children have tendency to poor eating habits and weight abnormalities themselves in the future. Regarding ethnic inequities, samples from many European countries have been found. For example, in immigrant groups in Germany, socioeconomic and environmental factors explained almost all of the ethnic differences in obesity – especially maternal education levels and excess television viewing. Similar findings were also relevant for the United Kingdom, where single-parent households are substituting fresh fruit and vegetables with cheaper calorie-dense processed food (Loring & Robertson, 2014). What is more, the available evidence suggests that increased energy intake – rather than decreased physical activity – is the main driving force behind the obesity epidemic in lower socioeconomic groups. The data on physical activity suggest that, although levels have declined, the magnitude of the change is unlikely to explain the dramatic rise in obesity at the lower end of the social spectrum. This jump towards higher energy intake is due to innovations in food manufacturing and distribution, leading to increased supply of cheap, palatable, energy-rich foods that are much more accessible, convenient and marketed pervasively.

Healthy food options tend to be less convenient, less accessible and more expensive. In addition, urbanization and increased participation by women in the workforce, result in less time for meal preparation in families (Loring & Robertson, 2014). Consequently, all of these "chain-reaction" inequities result in systemic negative diet change for lower SES groups, posing significant health risks. These reactions are shown in Figure 2.5, where the different determinants are presented and their interactions are shown. The important finding is that the existing causalities affect the distribution of health and well-being thus, deteriorating societal public health. Since health inequities exist because of systemic, preventable differences, the need for appropriate policy interventions which can prevent or decrease their effect is more crucial than ever.

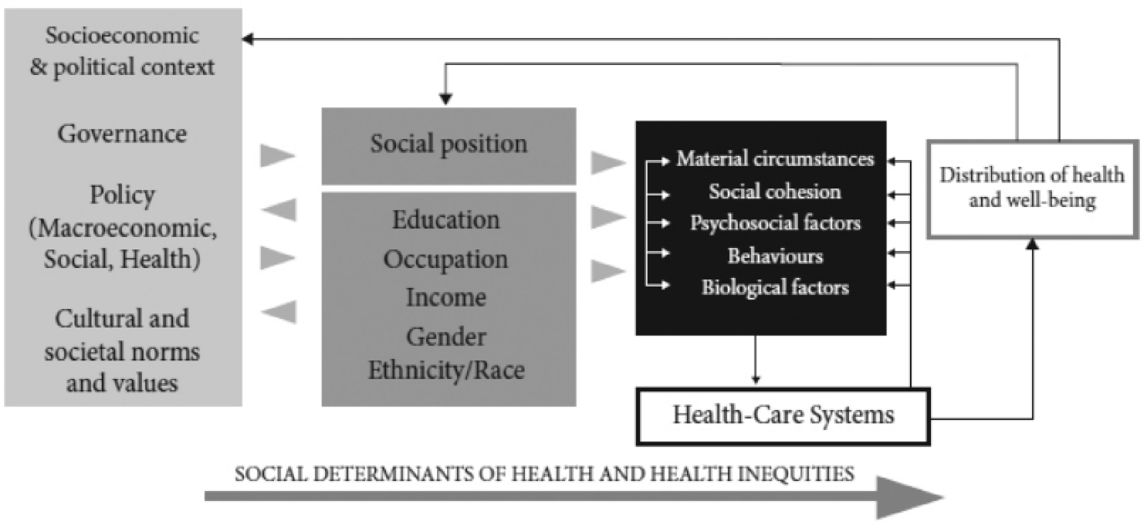


Figure 2.5: World Health Organization Commission on Social Determinants of Health conceptual framework linking social determinants of health and distribution of health (Sadana & Blas, 2013)

2.3. Current State: Globally, Europe, Netherlands

Being in obese or overweight BMI ranges as a child, is one of the most prevalent health issues in developed and developing countries. In addition, it is acknowledged as a dominant factor leading to adulthood obesity (Moghadam et al., 2015). Currently, 38.3 million children globally under five years old are considered overweight, when in 2000 this indicator was at 30.1 million (Hawkes, 2018). Specifically in USA, childhood obesity has reached a staggering 16.9%, and is linked with adult obesity, chronic diseases and increased health care costs (Frongillo et al., 2017). In Latin America, between 42.5 and 51.8 million children, aged 0–19 years, are affected by obesity accounting for almost 25% of the population, with the highest density of obese children to be identified in Mexico (López-Olmedo et al., 2018). In Israel, a comprehensive study was conducted between low-income preschool children, showing that Muslim children were obese at a 19% level, whereas Jewish were at a higher risk, at 25% (Soskolne et al., 2018). Lastly, Spain is one of the European countries with highest prevalence when it comes to childhood obesity, with the rates to be dropping since 2012, but still be over 35% for children aged 8-17 (Sánchez-Cruz, De Ruiter, Jiménez-Moleón, García, & Sánchez, 2018). Despite the magnitude of obesity, cross-national epidemiological comparison studies lack because of the non-representative data samples in many countries and because of differences in study designs (Janssen et al., 2005). To conclude, multiple countries are affected from the epidemic, however differences lie in the causalities which reinforce it at each country.

From the 1980s onward, in the Netherlands, overweight percentages have grown for all population cohorts. In the beginning of 2000s, specifically for children, the levels of obesity were at 9%, whereas as reported in 2014, this rate was at 12.5% (OECD, 2017b). From data regarding 1997-2003, the Central Bureau of Statistics in the Netherlands (CBS) reported that the population between 2 to 19 years old with the most overweight and obese occurrences were the Moroccan and Turkish cohorts (Frenken, 2004). In addition, parental behavioral patterns have a major role in the children' weight. As CBS found children are seven times more prone to be overweight if they grow up with overweight parents (Frenken, 2004). In addition, regarding nutrition, statistics from 2013 show the Dutch daily dietary habits were not compliant with the WHO and FAO recommendations, for the intake in fruit, vegetables, salt and saturated fats (World Health Organization, 2013). Lastly, education levels also play a role in the body composition of Dutch adults. Primary school graduates were found to be four times more prone to be obese compared to university graduates. As of 2016, CBS concluded that no matter the age group, being overweight is a phenomenon manifested more frequently among lower educated citizens (CBS, 2016).

2.4. Globally Implemented Policies

Given the prevalence of childhood obesity around the globe, different countries take action on a community or state level. Frongillo et al. (2017) suggest that investments in community policies and programs (CPPs) which reinforced behaviors and choices in children, related to physical activity and healthy eating, showed evidence of healthier weight. Another study, showed that the access of recreational trails in neighborhoods which are low in crime rate, can tackle childhood obesity whereas if implemented in an environment with high criminality, can lead to detrimental effects (Sandy et al., 2013). In most OECD countries, the implemented policies are focusing on the communication of the contents in food products and restaurants (OECD, 2017b). Some examples include: school-based, workplace and primary care interventions, portion size control and fiscal measures, such as taxation policies. According to this year's report from "The Lancet", only a small amount of countries (namely, Sweden, Germany, Qatar, and Brazil) have designed nutrition guidelines which promote sustainable eating for both human health and environment, while also focusing on the aspect of well-being and social equity (Swinburn et al., 2019).

Specifically in Europe, the topic of food regulations and food claims has been on the front line the since early 2018. On the 11^{th} December in 2018, the European Parliament voted to make risk assessment in the food supply chain more transparent, by revising the General Food Law. This would mean that the non-confidential parts of industry products would be made public right away by submitting the list of ingredients to the European Food Safety Authority (EFSA). Then an authorisation would take place in terms of the contents in food additives, pesticides or GMO. However, this vote is still controversial since some amendments were made to favor industries' confidentiality. Specifically, industries can resort to the ”Board of Appeal” to contest the decisions from EFSA and delay the publication of the ingredients. Also, the other amendment is that industries can claim ”innovative ideas” as an item in the list of potential confidential items without specifying how this will affect consumers' health (The European Consumer Organisation, 2018). In the meantime, on 19th of January in 2019, the European Commission postponed signing a law for imposing nutrient profiles as mandatory by law on all the products. This was decided to be voted as of 10 years ago. Instead, the Commission has launched an ”evaluation ('REFIT') of the Claims Regulation, which will examine whether the profiles are still needed” (The European Consumer Organisation, 2019). By signing such a law, food industries would be hindered from making health claims such as ”healthy”, ”source of calcium”, ”boosts the immune system” on products which are inherently high in sugars and fats. To summarise, laws and regulations become ostensibly stricter, although there is still room for interpretation and ways to get around them for food industries.

The Netherlands undergone a significant increase in childhood obesity the first decade of 2000. This increase was followed by the country's joining the WHO European Childhood Obesity Surveillance Initiative (COSI) after 2013 (World Health Organization, 2013), (WHO, 2018). A number of different policies have been proposed, ranging from consumer goods labelling, physical activity counselling in primary care, physical education in schools and as of 2011, a national program on sport and exercise as part of the “Active Neighborhoods project”. However, only a proportion of them are fully implemented and enforced (World Health Organization, 2013). As of 2017, Amsterdam tackles the issue via educational institution changes (Boseley, 2017). Specifically, Amsterdam's municipality has been dealing with the issue of childhood obesity since 2012. From gathered data, correlations were found between low-income children with migrant and minority ethnic background and weight imbalances. Hence, based on the Global Nutrition Report of 2018, the municipality managed to implement policies such as: restrictions on food advertising, education on healthy eating, treatment for severely obese children and playgrounds during the years of 2012-2017. The rate of childhood obesity successfully dropped by 2.5% withing the years of 2012 and 2015 (IFPRI, 2018).

Nevertheless, these efforts are not yet driven from a systematic national perspective. The causalities behind the sudden spread of the epidemic in the country have not been studied extensively (to the best of the author's knowledge). One study explored the non-biological factors worsening the epidemic, focusing on the potentially obesogenic school environment, with a case of Utrecht, while pointing out that more cross-national studies are needed to explore the topic of childhood obesity (Timmermans et al., 2018). What is more, national initiatives exist and the understanding that the health of children is crucial for the future distribution of health in the country, is well understood. Some of the initiatives include:

1. Partnerschap Overgewicht Nederland (PON), or the Partnership for Overweight in the Netherlands. This institution brings together healthcare providers and patient organizations to ameliorate care for overweight and obese people (PON, 2018).

2. Actieprogramma Kansrijke Start, Promising Start Programme which states that every child ”deserves the best possible start to his or her life and an optimal chance of a good future”. It is stressed that the first 3 years are crucial for a good start in an adult life later on (Rijksoverheid, 2018).

3. Nederlandse Stichting Over Gewicht, a foundation helping people lose weight and become healthier (Gewicht, 2019)

Additionally, the National Institute for Public Health and the Environment (RIVM), writes four-yearly reports on the state of public health in the Netherlands. The addition of the health component across policies is still fragmented, although there is growing interest in the topic at the municipal level (van de Berg et al., 2016). Last but not least, the topic of initiating effective and applicable policies for the issue of childhood obesity is problematic across multiple nations. As mentioned by K. L. Reilly, Nathan, Wiggers, Yoong, and Wolfenden (2018), international research suggests that most schools fail to implement policies for their school canteens and restaurants, despite their existence. A study showed that policy application for school menus in Australia can range from 5% to 63% despite the existence of regulations about school nutrition. Thus, the writers showcase the need for ”actionable” policies and engagement of the decision makers in a more effective way (K. L. Reilly et al., 2018).

2.5. Dutch Health System

Health systems differ from country to country. In order to familiarise the reader with the Dutch health system, this section focuses on explaining its structure, involved actors and institutions. Additionally, it is crucial to identify where pregnant mothers and families with young children interact with the system, so policy can target them effectively.

> A Health System is “the combination of resources, organization, financing and management that culminate in the delivery of health services to the population.” (World Bank, 2007)

The Dutch health system can be characterised as hybrid in terms of its organisational structure. It combines social health insurance, shared governance among the government, professional organizations and health insurers. The addition of regulated competition in 2006, resulted in more actors participating in the system and the government then adopted a role of a supervisor and facilitator of the health market. The tendency of decentralising healthcare and social services has brought the municipalities in a more demanding role. For the government, the initiation of ”market forces” meant less planning and a focus on regulatory frameworks, carried out by local actors, or by self-regulation (van de Berg et al., 2016).

What is more, in an era driven by data, the Dutch government identifies this power by using information to update and inform the health system. The Dutch health policy agenda is partially driven by scientific evidence, since the inclusion of forecasting research is often. Thus, by providing information it can inform the decisions of citizens, for example on choosing a healthcare provider or for decisions regarding primary care.

Since the Netherlands is in the European Union, the regulations existing in healthcare are compliant with the European standards and are made more specific based on the organisational structure of the healthcare system. Broadly, the health related regulations can be categorised in the following groups:

1. public health
2. quality of healthcare services
3. health insurers and healthcare providers
4. rights, complaints and patient participation (European Union wide) (van de Berg et al., 2016).

The history of the social insurance in the Netherlands was conceived in 1941. Then, the insurance scheme was only relevant for the 66% of the population with the lowest income. in the late 1960s, a reform happened with the aim of including into the social insurance scheme the long-term and elderly care. The now known, compulsory health insurance scheme was initiated in the major healthcare reform of 2006, which also redefined the roles of the involved actors. Especially, the role of the government was reduced, and the management of the system was attributed to independent bodies as well as municipalities. The reform which resulted in how the health system is now, was the one of 2015. During this reform, the main criterion was to redesign the system into a more financially sustainable version and also make it more effective (van de Berg et al., 2016).

The introduced changes shifted more responsibility towards municipalities and also added more features into the basic health insurance package. To conclude, the decision making within the system comes from different actors based on the nature of the issue. Specifically for childhood obesity, the government has highlighted the need of designing an integrated approach for the prevention of overweight in children. The power to act upon this lies on the municipalities, leaving room for interpretation by each municipality on the best context-related way to deal with the issue. Some municipalities have acted upon this initiative, by implementing training courses to stimulate intersectoral collaboration in developing such an integrated approach for municipal (local) policy making (Hendriks et al., 2012), whereas other did not. Hence, in Chapter 6, the inter-dependencies and relations are explored further and the healthcare system is mapped in detail.

2.6. Gap identification and research scope

There is not enough evidence that all municipalities are engaging in the treatment and prevention of childhood obesity in a formal, targeted way, even if all evidence from research shows that the epidemic dimensions are growing rapidly. As Timmermans et al. (2018) mentioned, future research should compare larger geographical area and focus on identifying differences between rural and urban areas. In their study, a statistical analysis was conducted for adolescents in the municipality of Utrecht, only focusing on mapping the ”obesogenic environment” around schools (Timmermans et al., 2018). Then, since the causes of the disease are mostly idiopathic, a systematic exploration of the knowledge gaps (see Table 2.1) for the Netherlands is done, with the aim to alter existing policies and improve childhood health in the future. Even the Dutch initiatives mentioned in Section 2.4, do not include data and current state of the epidemic on their website regarding each population cohort. This shows the lack of awareness around this disease and the shows room for improvement.

Obesity is identified as the third “most dangerous global societal burden” after smoking and armed violence”, proving the magnitude of this epidemic (Kersh, 2015). Other researchers claim that obesity is “contagious through social connections” thus, proving that individual behaviors influence our social circle (Ejima, Thomas, & David B., 2018). The societal relevance of childhood obesity is even more crucial and urgent to be tackled. The topic falls under the category of ”Global Health” and it is identified with its respective Sustainable Development Goal (3) from United Nations (United Nations, 2018). The World Health Organization states that a non-action scenario, will lead to 70 million children affected globally by 2025 (Robertson et al., 2016). ”The Lancet”, this year, expanded the problem of obesity into four dimensions: increasing obesity, policy inertia, lack of urgency, and separate action on obesity without cross-sectional help from other industries, exposing the inconsistencies in the so-far policies of governments (Swinburn et al., 2019). Lastly, they raised the issue of dealing with financial challenges, resulting from the costs and insufficient infrastructure in the world’s health care systems to treat unhealthy individuals Swinburn et al. (2019). Consequently, there is an increasing need for interventions to decrease the prevalence of childhood obesity, but also help societies educate their children to maintain healthier figures.

Unveiling the risk factors of the disease for the youngest of the population can help in the early diagnosis and aid the design of preventive interventions for the Netherlands. Given the idiopathic nature of the disease, humans have power over changing the socio-environmental circumstances which drive the epidemic. Given the research gaps, the aim of this thesis is to use governmental data from children and their families along with data for the environment they live in, and explore a set of non-biological attributes leading the manifestation of the epidemic for the Netherlands. An explanatory study takes place to identify non-biological factors or correlations, being able to explain a child’s weight. After all, as proven by the presented review, interventions can happen easier at a pre-school age and have larger effect on the health of children. There is no more room for non-action scenarios and the urgency to raise awareness regarding the factors which increase children’ weight is paramount. Children are the future of our population and their health lies in the hands of decision makers, to change their future by designing and implementing effective policies.

Table 2.1: Main knowledge gaps derived from literature review.

Main findings and knowledge gaps	
Finding	Childhood obesity is mostly idiopathic, genetics and environment are crucial.
Finding	The ”critical periods” of addressing childhood obesity is the age of five.
Finding	Increase in childhood overweight and obesity prevalence is associated with the contemporary obesogenic environment.
Knowledge gap	Health inequities exist because of systemic, preventable differences. Appropriate policy interventions which can decrease their effect can positively influence the health distribution in the Netherlands.
Knowledge gap	The causalities affecting the distribution of health and well-being are location-bound, showing the need to conduct a nation-wide analysis to raise awareness for the features of the population and their environment.
Knowledge gap	The addition of the health component in the Netherlands, across policies is still fragmented, although there is growing interest in the topic at the municipal level (van de Berg et al., 2016).
Knowledge gap	The current socio-ecological model of Figure 2.2 needs to be expanded to analyse childhood obesity more holistically and capture societal inequities.

2.6.1. Research Questions

Following this literature review, the main research question of this thesis is:

How can Dutch government data inform policies for targeted interventions addressing childhood obesity?

In order to answer this question, several sub-questions are formed sequentially and they are presented below:

1. *Who are the involved actors in the health related context of the Netherlands, capable of initiating change for the prevention of childhood obesity?*
2. *What are the non biological factors explaining the weight of children in the Netherlands?*
3. *How can children be earlier identified as obesity risk-prone?*

3 Theoretical Framework

Since the foundations of the basic theory around public health and societal inequities are provided, the theoretical expansion of the framework RIVM uses for health related studies (Figure 2.2) is needed to fill in the knowledge gap. In this way, a new theoretical framework can be designed specifically to address childhood obesity in a more holistic way which represents mostly non-biological factors from their environment. Specifically, to do this, a deeper look into the existing frameworks is required. Then, explanations of potential operationalisation of the aspects of the frameworks are provided to facilitate the variable selection. The outcome of this chapter, a new socio-ecological model, is used as a foundation for the analysis in the current thesis. With the analysis, this new theoretical framework can be tested and the results can inform future research and policy making.

3.1. Health as a Grand Challenge

Health has been identified as one of the Sustainable Development Goals from the United Nations. It is seen as a societal challenge for most countries across the globe. *Grand Challenges* naturally are global, grand in scope and scale, are made up of wicked problems that are difficult or impossible to solve by single actors or by rational planning approaches (Cagnin, Amanatidou, & Keenan, 2012). Singularity University (2019), defines international grand challenges as problems that are urgent for our planet, interrelated and interconnected. Such problems have four main characteristics: time for providing a solution is limited, the problem solvers are also causing the problem, there is not a central authority responsible for solving the problem and lastly irrational discounting occurs which postpones official responses into the future (Levin, Cashore, Bernstein, & Auld, 2012).

Topics related to the health of the youngest of the population, children, also constitute a grand challenge since these individuals "carry" the responsibility of maintaining the human species as healthy and robust as possible for future generations to come. The study and research in health, specifically the health state of children, has a major societal impact and relevance for decision makers. When societies acknowledge the existence of disparities and inequities in their systems and specifically the Health System, the need to address those with appropriate and relevant policies is evident and timely urgent. The current thesis focuses only on a small segment of the grand challenge of health. This is the issue of childhood obesity. Specifically, childhood obesity is a grand challenge because:

1. It is *time urgent*. The fact that obesity exists for many centuries does not mean automatically that it is not urgent to solve. The timing to address the issue is now and this is obvious if someone identifies the upwards trend in the childhood obesity prevalence data.

2. *Problem solvers are problem causers*. The people who are able to initiate systemic change in terms of policies or regulations are also the ones inhibiting the change by letting for

example disparities exist and not accounting for vulnerable age groups and societal segments.

3. There is *no central authority* responsible for solving the problem. This is obvious when it comes to childhood obesity since it is a multi-faceted issue and many reinforcing loops exist within sectors and industries, such as the one from the supply industry or the governance of a country and of course the inherent structure of the health system (Swinburn et al., 2019).

4. There is *irrational discounting* from the decision makers, postponing decision-making in the future. This is also society relevant for the EU member countries since this year the EU Commission failed to pass the law for mandatory nutrient profiles and health claims on processed foods high on fat and sugar (see Section 2.4).

To conclude, the topic of childhood obesity is a societal challenge. By using an inclusive framework to explore data from children, new policy levers can be unveiled which are relevant for the Dutch society and its current state. The topic is a multi-actor complex problem where strategic advice for the future actions of the government and municipalities is needed. Such topics are highly relevant with the scientific domain of the Engineering and Policy Analysis Master's. By approaching the issue with a strategic, data-driven method, long term planning policy advice can be proposed, potentially aiding the decision makers in the Dutch arena of Health.

3.2. Social Determinants of Health

Given the prevalence and the societal urgency of the epidemic of obesity, there is a global effort to tackle it. There has been evidence from people trying to map how health is affected since 1993. Specifically, as it is stated in the report from WHO Europe, the concept of ”Social Determinants of Health (SDH)” was elaborated upon from previous work of the main author, Dahlgren and Whitehead (2006). Specifically, the concept of a set of factors, which when combined, influence public health was presented. It is distilled as rainbow-like schema, with layers of influence. The Figure 3.1, shows the complete range of them.

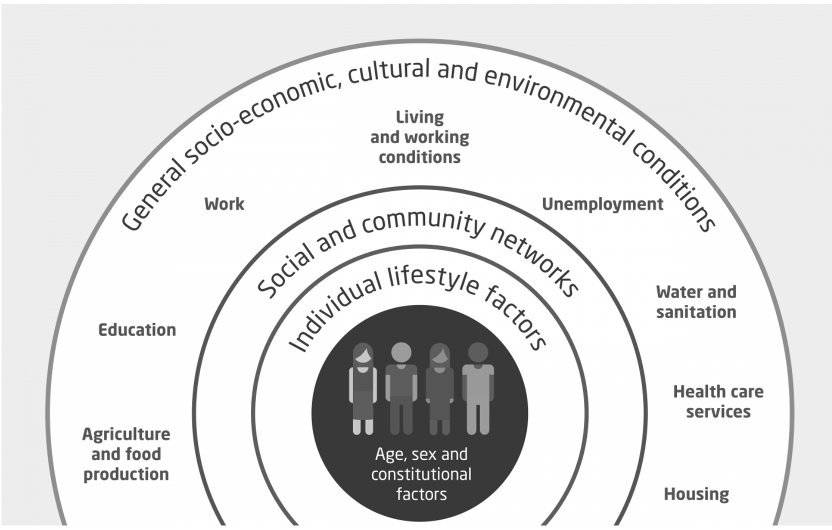


Figure 3.1: Social Determinants of Health (SDH), redesigned from (Dahlgren & Whitehead, 2006).

In order to understand the figure, someone needs to consider all four layers which interact at the same time and affect the health of a given population sample.

- Layer 1: the constitutional characteristics of citizens should be always considered, since they are strictly defined over time. These include age, sex and inherent characteristics influencing their health.

- Layer 2: community and environment characteristics where individuals interact and are affected by them, defining a lifestyle profile.
- Layer 3: living and working conditions, food supply, and access to essential goods which enable individuals' ability to maintain their health.
- Layer 4: economic, cultural and environmental influences prevail and affect the overall society.

The emphasis is placed on the fact that individuals are inherently embedded in a set of socio-technical systems and their studying cannot be separate from these conditions, which in turn are associated with the broader socioeconomic and cultural environment (Dahlgren & Whitehead, 2006). This implies that when conducting a health-related study, a whole spectrum of inputs can inform better the outcome of the study.

It is worth exploring how and to what extent these determinants are being influenced by other factors of the environment people have created and live in. The categorisation as provided by Dahlgren and Whitehead, is done based on what effect the factors have on the health. In other words, if the effect is positive, negative or just protective against the worsening factors.

- Positive health factors: Contribution to the maintenance of health. For example, economic stability, food security, rewarding positive human relationships.
- Protective factors: Contribution to the resistance to disease. For example, immunisation, healthy diet or psycho-social support.
- Risk factors: Contribution to health conditions or diseases which are potentially preventable. For example, smoking, air pollution, drug abuse, poverty, income inequality or social segregation.

These factors are example variables to be modelled. For the upcoming analysis proxies to measure them are selected based on data availability and suitability.

In Europe, a goal to improve health has been designed since 2012 and is in implementation phase, namely the "Health 2020" policy framework (World Health Organization, 2019). It builds upon the social and environmental determinants of health since they enable to address many inequalities effectively. The main key message is to design policies which are: intersectoral, participatory, inclusive and financially sustainable (World Health Organization Europe, 2013). The four areas of focus of this policy initiative are:

- invest in life-long health practices
- tackle Europe's major disease burdens
- empower people-centred health systems and public health capacity
- design resilient communities.

The need to re-think population health, especially for the youngest of the population is crucial. By informing the current framework, used by the Dutch institute for Health and Environment, with work from other researchers regarding the SDH, the exploration of new causalities explaining children' weight can be unveiled.

3.3. Determinants of Social Inequities in Health

Since the concept of "Social Determinants of Health" is clear (Section 3.2), the root causes which lead to social inequities in health are crucial to be identified and mapped. Since humans are vital parts of a system, the "initial conditions" where they grew up with, largely impact their development and health condition. Thus, the most important determinants of health could differ for different socioeconomic groups of a population (Dahlgren & Whitehead, 2006). Consequently, in order for researchers to capture the differences between population segments and measure their performance in *Social Determinants of Health Framework* indicators, awareness for the determinants which cause inequity, is a prerequisite. Five categories or ”pathways”, as mentioned by Dahlgren and Whitehead, have been mapped and explained, while, Figure 3.2 summarises them.

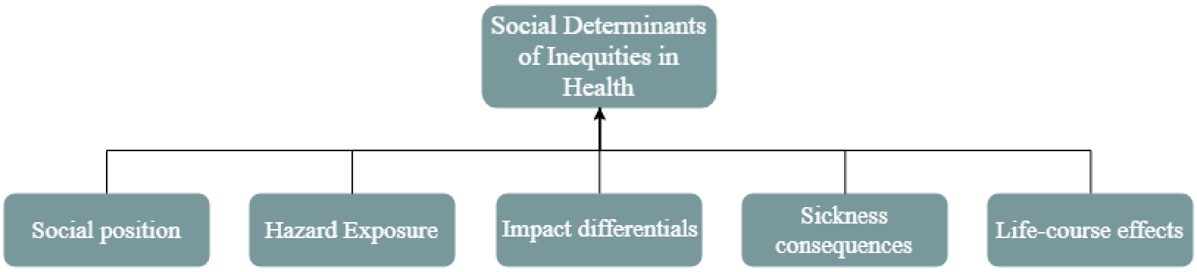


Figure 3.2: Determinants of Social Inequities in Health (Dahlgren & Whitehead, 2006).

First of all , *social position* is defined as a composite measure of education, occupation or economic resources. In other words it is the socioeconomic status (SES) of an individual. It applies significant influence on the type, degree and distribution of health risks experienced by a person. Groups that are higher on that status usually have more resources to pick choices leading to a healthy lifestyle compared to less privileged groups. Societies where income or education disparities are more evident, have more attenuated stratification of socioeconomic groups thus, this index leads to higher health inequities. Secondly, *hazard exposure* is relevant in the context of work environment and socioeconomic status. An inverse relationship between the exposure to most risk factors (material, psycho-social and behavioural) and social position has been observed. This results in defining this exposure metric as a variable which needs attention and careful design in order to minimise its impact on people who do not own resources to enable them avoid risks or diseases.

Additionally, *impact differentials* are mentioned as a unique concept of the different impact a person can experience given his/her own socioeconomic status (SES). It is usually stemming from the social, cultural and economic environment. The concept of this factor encapsulates the greater likelihood of low-income groups being exposed simultaneously to several risk factors. This means that there is a simultaneous existence of factors reinforcing each other and ultimately impacting the individual on a higher scale. Such an example is when literature refers to obesity as a ”syndemic” disease, meaning that there is an dual nature to it; synergy of underlying epidemics with common drivers (Swinburn et al., 2019). What is more, the authors continue by highlighting the importance of *sickness consequences*. They are defined as a factor which is also bounded to the SES of the people. The relationship is inverse, meaning that the lower the socioeconomic status, the higher the sickness consequences for an individual. This is reflected upon the loss of income an individual may face in the case of sickness and how this loss will impact his/her ability to cope in similar future situations. This should be especially a focus when a country has a lack in financial ”safety nets” for those unable to be employed due to poor health condition. Last but not least, a final overarching pathway which is connected to all the above mentioned is the *life-course effects*. With this term, the cumulative outcome of all the pathways mentioned as they interact and operate over a lifetime. Unfortunate events in childhood could lead to poor health in adulthood. Combined with resource deprivation in early life this results to a strong predictor of future health.

3.4. Inclusive Quality of Life Framework

This section creates the informed, expanded socio-ecological framework with the concepts presented above is designed. The Social Determinants of Health and Health inequities are reflected on the framework which is used by the RIVM for health-related studies. The knowledge presented so far regarding health distribution and epidemics is fragmented. By bringing in the existing frameworks and expanding the most fundamental of them, a new theory can be tested and different variables can be explored for the issue of childhood weight abnormalities.

As research shows, policies designed for childhood obesity are usually not effective or broadly applied (see Section 2.4). Then, it is interesting to think how can better research be formulated to result in more effective policies, which are also ”closer” to the health issues societies face. This is the main reason why in the current thesis attention is paid in the theory and the creation of a new inclusive socio-ecological model. By bringing in the concepts presented in the previous sections, tests can be performed to identify significant factors explaining a child's weight. What is more, from a medical point of view, researchers believe that obesity is idiopathic. This statement shows that it is highly affected by the environment people and children live and develop in. By identifying significant factors for the Dutch environment, policies can be better targeted and children can enjoy a more healthy lifestyle.

The theory behind the logical connection of the concepts is that *social inequalities cause inequities* in health and consequently affect the determinants of health for different population segments. By using and expanding the model RIVM uses, the aim is to capture new factors contributing to childhood weight gain. The outcome of this chapter is used for the rest of the quantitative analysis for the variable selection and model building. Apart from that, in Chapter 9, the policy proposal is accounting for the inter-dependencies presented in the model and the areas where mixed, inclusive policies can happen (see Figure 3.3).

In order to make the following conceptual model, the Social Determinants of Health and the Determinants of Social Inequities in Health are considered (Dahlgren & Whitehead, 2006). Then, these combined resulted in a more informed Quality of Life framework, which embeds more concepts regarding the research in Public Health compared to the one presented by van Kamp et al. (2003). By investigating the concepts which affect the health state of children in the Netherlands and by understanding how an equitable health system can be achieved, the research design is informed. Also, a contribution to the existing theory and literature for Public Health is achieved by updating the existing framework RIVM uses to advise the Ministry of Health, Welfare and Sport.

The new model is strictly based upon the previous one by keeping the main structure of the three components which are intertwined in the **Quality of Life** concept. The main aspects still remain to be the **Economics** part, the **Environment** part and the **Community** part. If someone considers carefully the newly designed model, it is obvious that the factors which can be considered and analysed quantitatively can now go beyond the initially considered concepts. For example, the model takes into account under the Economics component, the *governance* and the *policy* or the *sickness consequences* which can then later be reflected in variable proxies which can be used for analysis and policy proposal. What is more, for the Environment component, the addition of *Behaviors* factor is crucial, since some eating or physical activity or television viewing habits can be ”silently” linked to the built environment characteristics of the area people reside in. Lastly, the component of Community is extended with the factors of *Impact differentials* and *Life-course events*, which can unveil chronic conditions or a health issue which is caused because of the effect of the socioeconomic status of an individual. What is also added here is the factor of *Ethnicity* and *Social position*. These factors are important for consideration since they guide the interactions between patients, their culture and the way medical professionals interact with them. Such factors in the initial design of the framework where not immediately considered and by expanding the theory and enriching this framework, new insights can potentially be driven from future analyses. The new conceptual model, presented in Figure 3.3, guides both the analysis and the policy section of this thesis.

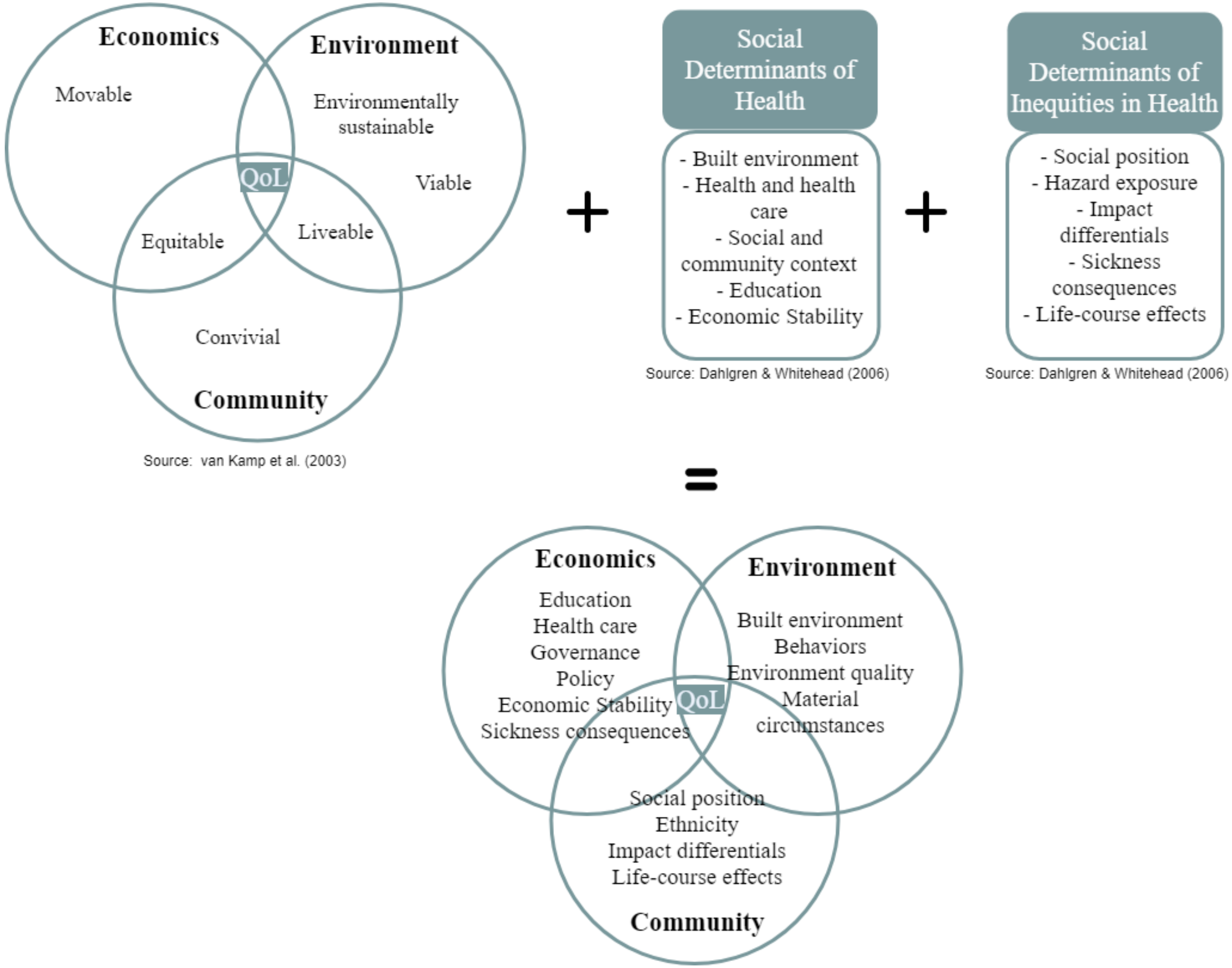


Figure 3.3: Redesigned Quality of Life framework, informed by the current research

4
Governmental Data

This chapter aims to explain the way the dataset is acquired, its nature and the pre-prosessing which took place to bring it to a model readiness level. At the end of the chapter, the conceptualisation to match the modeling needs is explained. More material regarding the data and analysis is found in Appendix C.

4.1. Data architecture

For the current research, a dataset acquired from the National Institute for Public Health and the Environment (RIVM) is used. This dataset is the result of a national survey, GECON, where individuals answered a set of questions regarding their nutrition, activity and other habits, such as smoking, drinking or biking (Centraal Bureau voor de Statistiek, 2018). This survey was conducted during the years 2014-2017 but the years which have a comparable questionnaire structure and cover a broader set of variables are the last two, namely 2016-2017. In case of a parent answering the survey, different questions about his/her children and their health were obtained. Thus, by collecting the responses regarding the children, a new, child-focused, dataset can be formed to explore potential factors leading to an increase in their current weight.

After the selection of survey data is complete, a merge with national microdata from CBS is conducted. This is required, since variables such as household income, postcode related socioeconomic-status or the ethnicity of the mother, are not available from the survey. RIVM collaborates with CBS and they have a dataset in their possession which includes different data gathered from insurance companies and midwife databases. The followed approach to obtain and merge data is shown in Figure 4.1. This helps minimise the data quality issues. The main ones being: validity and completeness. The process of combining the data is done with the use of a unique encrypted identity number each person has, RIN, which is based on the burgerservicenummer (BSN) all Dutch citizens own. Additionally, by merging with microdata, socio-economic variables of the household are obtained which are taken from a source which is reliable and secondly, the variable of the birth weight of children is substituted, to avoid self-report human error. The final merge of this data was discussed and decided along with the RIVM advisor. After these merges, the data is ready to be pre-processed and continue with the next steps of analysis. Finally yet importantly, the dataset since it is owned by the government is strictly confidential. This entails that all actions of the researcher should not, by any means, compensate the privacy of individual data. Visualisations, or publication of results which relate to specific datapoints or to a small group of individuals (< 10) is prohibited. This restriction is affecting the reporting style of the current research since in the quantitative sections, namely Chapters 7 and 8, the results are in some cases simply described or the presented graphs are made on an aggregated form, to avoid presenting actual values of individuals.

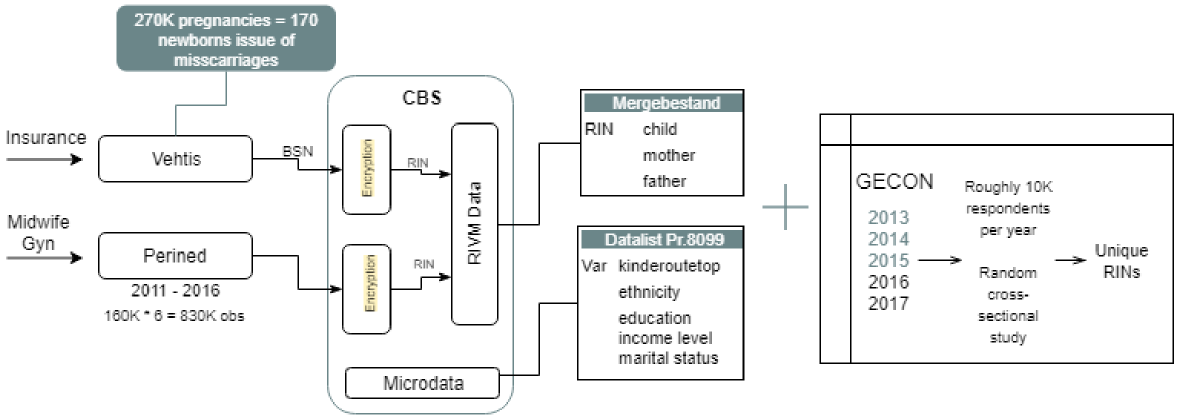


Figure 4.1: Data architecture

4.2. Missing Data

Another issue which needs to be addressed is missing data. The visual presented in Figure 4.2, showcases the extent of missing responses for specific variables. The left side of this figure shows the percentage of missing data. On the right, a map of the dataset is made, where yellow means a cell is empty.

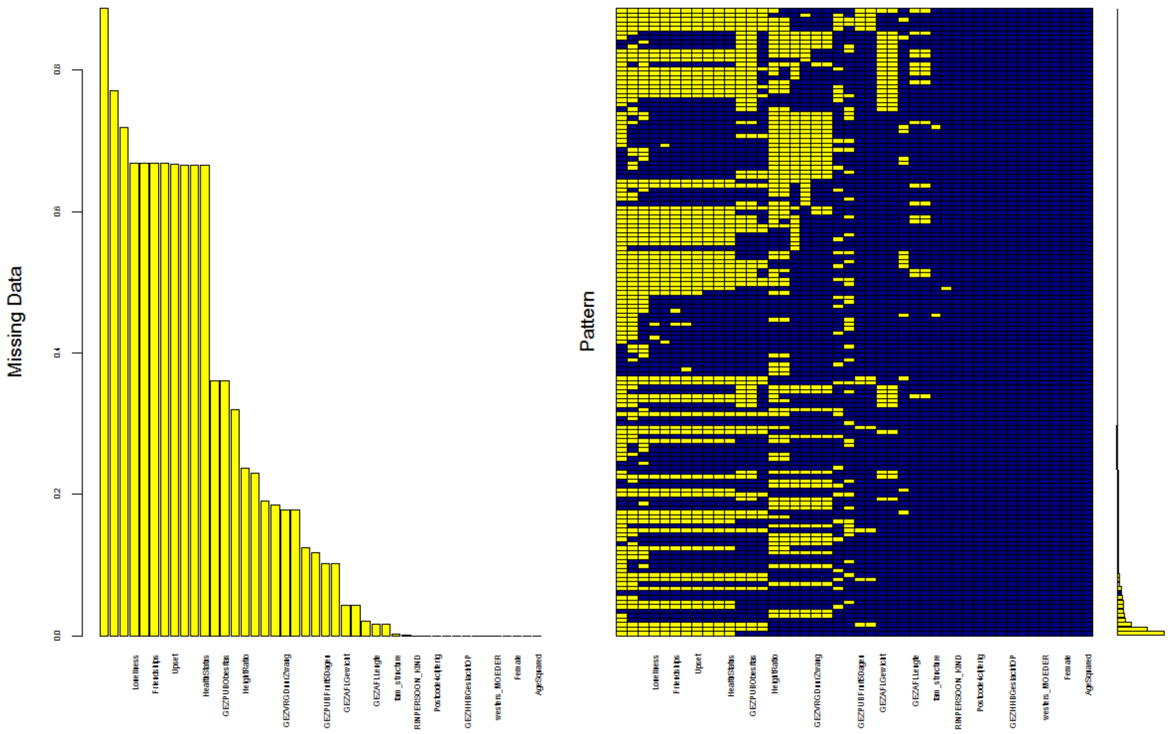


Figure 4.2: Visualisation of missing data

The fact that the data collection method is a survey has, inherently, the consequence that blocks of values for different concepts miss simultaneously. This probably shows that the respondents were able to skip a whole section of questions if they felt they did not want to respond to those kind of questions. On the left side of the figure, the variables with percentages of 60% and above, are the ones regarding health, psychology and psychical activity. What is more, for some questions, there was the option to respond as ”Niet van toepassing” which means ”Not applicable”. For Figure 4.2, these values have already been transformed into null cells and are perceived as such.

4.3. Data pre-processing

The pre-processing mostly focuses on cleaning the data and transforming alphanumeric values to numeric. Cleaning entails bringing the dataset to the state where is ready for further manipulation. Firstly, only the relevant years are read (2016 and 2017) and then the parents need to be removed from the responses. For this, the dataset called *Mergebestand* can help since it includes two columns, one with the RIN number of parents and for the children's. Then, based on the encrypted RIN number, by merging with the column which corresponds to the child's RIN number, the parents are filtered out of the data, leaving a dataset which only relates to children between ages of 0-6 years old. The age is between 0-6 years old since the Mergebestand is the result of a documentation from the *Perined* data, which started to be documented in 2011 and the GECON survey is run during the years of 2013 to 2017 (see Figure 4.1). Thus, only children which are born within the time "window" of 2011 - 2017 is be part of the final dataset. This directly results in a minimum value of age of children to be 0 and the maximum to be 6 years old.

One issue which is encountered is that some responses to lifestyle and psychology questions are non-numeric. For those questions a transformation is done. For the variables with multiple levels, the assigning of numeric values is ranged from -2, +2 and for each question the "positive side" of the response is linked to the +2 value. For example, one question asks how often the child is upset during the past four weeks. The parent has to pick from a five-level multiple choice response, which states "Never", "Almost never", "Sometimes", "Most times", "Always". This is translated to values from +2 to -2 since the "Never" answer is the most positive for the child and the "Always" answer is related to the worst psychological state for the child. The questions regarding nutrition standards or the existence of a sports subscription or not, the "No", "Yes" responses are encoded with binary, 0-1 values.

When the pre-processing of the data is done, some initial exploration is conducted to identify trends and potential signs of correlation in the data. By making histograms for main biological variables, the normality of the data can be quickly assessed. Scatter plots of variables are also done to observe if the relationship between factors looks linear and additive. At this stage no significant issues are identified, however, more quantitative assessment has to be conducted. These plots cannot be provided since they show individual datapoints. Lastly, the interaction terms for the analysis are created. Interaction terms are created since some biological variables are associated immediately with others. This applies for the age and height, since they are highly correlated during childhood years due to the rapid development of the child. Lastly, the correlation of the data is explored (see Figure 4.3). From the outcome no unexpected correlation occurs between the variables of the analysis. Where correlation is high, the model performance is compromised and this has to be considered in the modeling design.

4.4. Conceptualisation

Before the beginning of the analysis, it is crucial to set the grounds and conceptualise the problem. For this objective, the definition of the architecture, the proxies of measurement for the different variables and the operationalisation of the theoretical framework are needed.

4.4.1. Entity relationship diagram

Firstly, the formal relationships of the variables are designed. A short version is found in Figure 4.4, whereas for a full one the reader can refer to Appendix C. It is important to understand that there are variables which measure features for the child but also variables which are inherited from the mother of the child, since a child is directly affected from the status and behavior of its caregivers. These variables are found under the class "mother". For the variable explanation and measurement, the reader can refer to the same appendix, since a full data dictionary is available.

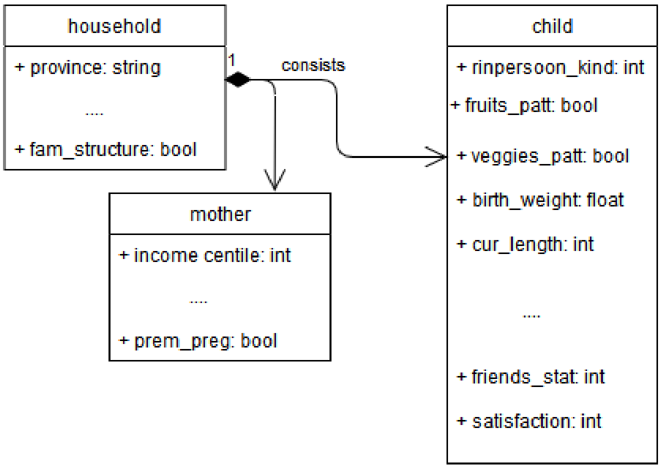


Figure 4.4: Short entity relationship diagram for the analysis of childrens' weight

4.4.2. Measurement Proxies

To come up with the variables for the analysis from the survey data, the conceptual framework is used (Figure 3.3) along with the data dictionary which is available from CBS for the GECON data (Centraal Bureau voor de Statistiek, 2019). Since the data dictionary is in Dutch, the concepts are discussed and analysed with my supervisor from RIVM and one of his colleagues, who prefers to stay anonymous. Then, when the concepts of measurement are clear, the variable selection is the next step.

The concepts which need to be measured are approximated with the use of different variables or proxies. For the reader's convenience, the operationalization of the conceptual framework is presented in this section and the different measured concepts are placed onto the framework, see Figure 4.5. The selection of variable proxies is conducted based on the theory and data availability. Since it is the first time this dataset is used for research, the most appropriate variables are chosen based on data availability and suitability. For example, Figure 4.5 shows that the activity and nutrition patterns are selected as some concepts which lie in the pillars of Economics and Environment.

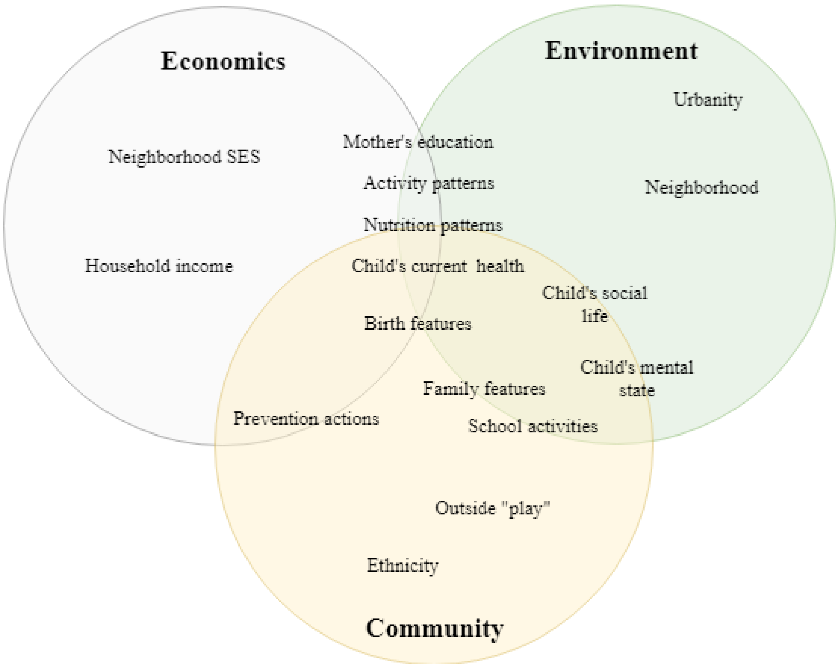


Figure 4.5: Conceptual Framework for the children analysis,variables under study and their relationship within the framework

Next, the data dictionary is parsed manually to identify which section of the survey refers to such concepts and then the most relevant variables are selected. Since the survey had a lot of questions for those concepts, CBS creates aggregated variables to facilitate research. One distinct example is the existence of multiple questions for the sports a child may take part in. Then, these questions are aggregated in one variable which takes into account the answers to all of the relevant questions and is boolean in nature, showing if a child has a sports membership or not, without specifying the exact sport it takes part in. Similar variables are used for nutrition patterns as well. This is shown in the table with the detailed documentation below, namely Table 4.1. The reader can see the pillar of the framework, the general concept which is aimed to be measured and with which variable proxies this is achieved. For a full data dictionary, where more details are stated regarding the nature of the variables, the reader is advised to visit Appendix C.

Table 4.1: Table for the definition of proxies for measurement of different concepts regarding childhood obesity.

Pillar	**Concept**	**Proxy variable**
Econ	SES	Neighborhood SES Family income percentile Mother's education level
Econ - Envir	Activity patterns	Sports membership Fitness subscription
Econ - Envir	Nutrition patterns	Aggregated vegetables consumption based on Dutch nutrition standards Aggregated fruits consumption based on Dutch nutrition standards
Econ - Envir - Com	Child's current health	Current weight Current height Child's health state as perceived from the parents Age BMI
Econ - Envir - Com	Birth features	Birth weight Birth height Pregnancy duration Premature pregnancy Gender
Envir - Com	Family features	Family structure Smoking patterns of the 1st caregiver Biking duration of the child outside of transportation
Envir - Com	Child's social life	Child's friendships state Child's loneliness levels
Com	Culture	Western mother

Pillar	Concept	Proxy variable
Econ - Com	Prevention actions	Consultation visits to YFC
Envir - Com	School activities	Minutes biking to school Minutes playing at school
Envir - Com	Child's mental state	Child's satisfaction levels Child's irritability levels Child's nervousness levels
Envir	Neighborhood	Province Municipality Urbanity index

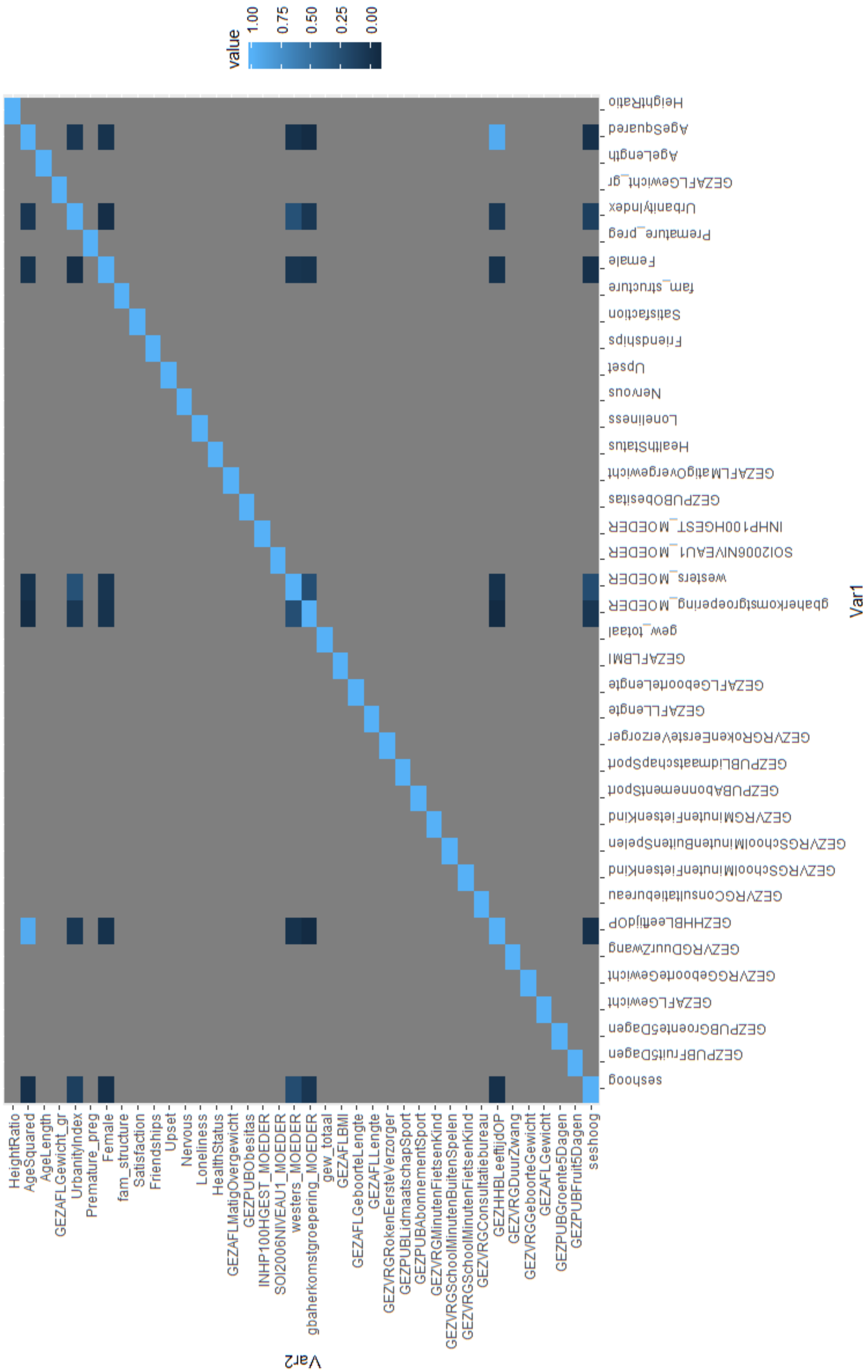


Figure 4.3: Correlation heatmap for the variables included in the analysis

5 Methodology

The aim of this Chapter is to present the scientific methods selected for the current thesis. The method for each sub-research question is different thus, the need to defend and discuss them is crucial for the reader to understand the selected choices. As mentioned in the introduction and the literature review, the Dutch Health System is decentralised, providing executive power to municipal decision makers. By answering sequentially all the sub-research questions, the main research question is addressed at the end of the analysis.

5.1. Qualitative Approach for identifying initiators of change

For the first sub-research question, interviewing technique and actor analysis are employed to understand the stakeholders involved in childhood obesity, their perceptions and their interests. An interview with field experts is employed to gain knowledge which is hard to capture from literature. The interview can enrich the actor analysis since it provides valuable insights for the motivation of decision makers, healthcare specialists and their interrelations. The first sub-research question is:

> *Who are the involved actors in the health related context of the Netherlands, capable of initiating change for the prevention of childhood obesity?*

Nature of the sub-research question

The nature of the current sub-research question is purely qualitative. For this purpose, there is the need to capture the current state of the Dutch health arena. In order to do this, actor analysis is the main approach, which is enriched by conducting a semi-structured interview to help identify information which is not available in literature. Since health care systems are uniquely designed by the society they belong to, different principles and values govern them. Thus, desk research supports the actor analysis where needed. For example, specific regulations, acts, norms and beliefs maybe present in the Dutch health care system, whereas in other European countries do not. When proposing policies, awareness and information about the Dutch case are key features to make the policies more possible to be adopted. At the end of the chapter, the main actors are plotted on a map, which facilitates a Dutch municipality to identify potential collaborators for alliances or to target policies more effectively.

5.1.1. Expert interview

To collect information from experts regarding the health care system of the Netherlands, interviewing technique is selected. The experts are professionals from the field of epidemiology and health sciences. Consulting them can provide with knowledge around the practices of general practitioners, their limitations and their challenges. Additionally, a better understanding of the practices or norms during pregnancy and when a child is born, can enhance the knowledge and understanding of the parents' perspective in the Dutch society.

Interviews are the most commonly used data collection method and the semi-structured format is the most frequently used interview technique in qualitative research. Specifically, it is one of the most preferred techniques for research in the healthcare context. It has been confirmed to be both versatile and adaptable (Kallio, Pietilä, Johnson, & Kangasniemi, 2016). Its major advantage is that it can be combined with both individual and group interview methods. In the current thesis, the academic professionals who are considered, preferred to conduct a group interview. Hence this is one of the key reasons why this technique is selected to facilitate the experts, apart from fitting the healthcare context.

A semi-structured interview is an interview with pre-set questions, which still allows more scope for open-ended answers. The researcher has a set of main questions ready to be raised before the interview takes place, also allowing considerable flexibility about how and when these issues are raised. The questions are open-ended but still aim at obtaining a specific detail or opinion and in some cases also closed-ended questions can be used (McLaughlin, 2006). What is more, a reasonable amount of additional topics are usually initiated in response to the dynamics of the dialogue (Hannan, 2007). The use of semi-structured interviews requires a certain level of previous study in the research topic area because the interview questions are based on previous knowledge of the interviewer (Kallio et al., 2016), (Barriball & While, 1994). For this reason the interview took place after the largest part of the literature review was completed. The role of the interviewer is to inquire from the participants upon their response to provide with more perspectives and details on the topic (McLaughlin, 2006). After the interview is complete, it is the interviewer's role to de-code the script and translate it from text to qualitative and quantitative data, exploring similar or opposing positions across the responses.

The method has significant benefits. With the semi-structured discussion, it is possible to focus on the issues that are crucial for the participants, leaving room for diverse perceptions and opinions to be stated (Kallio et al., 2016). In this way, they interviewees feel able and allowed to ”drift” to topics which come up during the discussion, if they feel that the topic is important for the research. On the opposite, this method has its limitations. To begin with, human factor affects the quality of the prepared questions, or the answers the interviewer collects based on the readiness, the time of day for the interview and time constraints of the interviewees (Barriball & While, 1994). What is more, the interview is conducted as a group with two experts at the same time and this factor can potentially affect the answering style of the experts. All of the above should be considered when interpreting the results.

5.1.2. Actor Analysis

Actor analysis is a method where the entities involved in a case are analysed in terms of interests, perspectives, perceptions and power on initiating change for the issue. An actor is a ”social entity, a person or an organisation, able to act on or exert influence on a decision” (Enserink et al., 2010). This method is preferred for the issue of childhood obesity, since as the literature stated, the dynamics in the Dutch Health care system are slowly evolving towards more empowered municipalities and advisory bodies and less involved government in the arena of health. In addition, the fundamental assumption in such systems is the notion that no individual actor is capable of independently imposing their solution onto others. Hence, by identifying the objectives of the involved actors common ground is more probable to be found. In the current case, the stakeholder is a household with children, which is highly interested in the issue, while it has a few means of influencing the final decision-making.

Since the steps of extra desk research focused on health frameworks and interview with experts is done, the foundation for actor analysis is laid. For the actor analysis, firstly the client perspective is provided and then the rest of the actors and inter-relations are mapped. Then, the aim is to create a power versus interest diagram (Enserink et al., 2010) which can inform the client of the situation. With such a diagram, the client, a municipal decision maker, can understand who to target for the design and implementation of new interventions. Since childhood obesity has been characterised as a social epidemic (Kersh & Elbel, 2011), (Shultz, Deforche, Byrne, & Hills, 2011), (Janssen et al., 2005), understanding the perspectives involved actors, more effective policy change may happen.

Employing actor analysis can help in the research of the issue and in providing recommendations relevant to the involved actors, but most importantly to the client, namely a Dutch municipality. What is more, the feasibility of potential policies can be assessed by mapping the resources or the interests actors have. This approach has also its limitations. One of the main limitation is information. In the analysis there is a deterministic amount of information which can be included, given the available resources, literature and connections to the involved actors. It is also strictly relevant for the time it is conducted in. This means that it acts as a "snapshot" of the current situation, since opinions, relations and perceptions about the issue are fluid and prone to change (Enserink et al., 2010). The dynamic of an actor arena changes and such unpredictable actions are hard to be captured by an actor analysis, limiting the timely validity of the result. Nevertheless, if the reader acknowledges the limitations, it is still a powerful tool to represent a multi-actor problem and identify relevance for the society. For the current actor analysis, literature and an interview is used, which maybe does not reflect that much what the client faces when making decisions since the interview and the literature have the academic point of view and not the political.

5.2. Quantitative Approach to explore non-biological factors explaining a child's weight

For the rest of the thesis, inductive approach is preferred. The research first focuses on understanding and analysing the "world", such as data and then, reason from it and come up with a statement which potentially describes it (Arthur, 1994). This approach allows the exploration of the factors leading to an increase on the target variable, namely children' weight. Currently, there is not a single set of causes driving the growth of the obesity epidemic in the Netherlands. Given the location-based nature of the disease, meaning that the environment where children grow up can empower or inhibit healthy behaviors (Chalkias et al., 2013), explanatory analysis is employed with the aim to understand the causalities driving the weight gain in preschool children. The chosen methods are descriptive statistics and statistical learning, which both are considered inductive. The literature regarding childhood obesity approves of applying such methods for the identification of correlations and causalities of the disease (Hope, Deighton, Micali, & Law, 2018), (Williams et al., 2018). The quantitative analysis is conceptually based on the theoretical frameworks presented in Figure 3.3.

5.2.1. Explanatory Modelling

In this section, the sub-research question regarding the identification of the potential factors leading to childhood overweight and obesity prevalence is identified. These questions are presented below:

What are the non biological factors explaining the weight of children in the Netherlands?

Nature of the sub-research question

For the above sub-research question, the dataset described in Chapter 4 is used. Specifically, for the children in the dataset, social, economic, demographic, biological and health dimensions are included and explored to identify factors related to the target variable, namely the *child's current weight*. The weight is selected as a target variable because of the research focus of the thesis. The aim is to explore what can describe the weight of the children, so obesogenic tendencies can be identified early on. Inherently, the nature of the dataset is diverse. This implies that the children participating in the survey are not all following biologically the Dutch growth curve standards. Thus, judging their weight with the national standards fails to capture correctly the state they belong to, making the BMI z-score an ambiguous criterion. This is also supported from literature and it is concluded that this categorisation is not enough for the description of a child's health and body composition at such early childhood (Cole et al., 2000). For these reasons, the selection of the weight is supported.

The other alternative was to choose the boolean (binary) variable of being overweight / obese as a target variable. As justified in the article from Cole et al. (2000), the classification for overweight and obesity in the early years of 0 to 2 years old is not possible. However, excluding the children aged 0-2 from the current dataset was considered not a desirable choice since they are a significant proportion of the total sample. The definition of the labels found in the data were made with the use of the adult BMI cutoff numbers, posing potential risk to mislabeling the children and basing the model on a variable which is not valid. The research from Cole et al. (2000) enriched the literature by conducting a multicultural survey and coining a new definition for overweight and obesity for children and teenagers by using the adult BMI cutoffs of 25 for overweight and 30 for obesity to produce new BMI cutoffs for children between the age of 0-18 years old. This contribution shows that potentially there is room to improve the labeling of children. To conclude, for all the above reasons, the selected variable is the weight. This can lead to the exploration of factors able to explain it. In this way, more awareness can be brought into the causalities of the factors which can influence it, no matter the segment of the growth chart a child currently belongs in.

In terms of the analysis, firstly, descriptive statistics and visualisation are performed to understand the context and nature of the data. Key insights are drawn, which can inform the modeling decisions later on. After the statistics, the modeling takes place. The methodology to approach the problem is to use the expanded framework for variable selection presented in Figure 3.3. This model is built based on the literature review regarding the topic expanded the Quality-of-Life framework the RIVM uses for health-related studies. The conceptual framework guides the generation of multiple models which are built sequentially. By selecting variables which belong in specific groups and exploring the influence they have in the target variable, the most crucial ones can be identified. The aim is to understand the causalities and explore the non-biological factors which can explain weight and then propose relevant policies to help in the screening and prevention of childhood obesity. It is important to mention that since the data are derived from a survey the missingness is high for specific variables. This imposes risks to the modeling, since fitting a model with only a few datapoints has the risk of introducing bias, derived from the social profile of the people who tend to answer all the questions.

For the nature of the research question and the target variable of the study, the chosen modeling method is multivariate linear regression. Specifically, the weight of children is a continuous quantitative variable, making linear regression suitable for its prediction. In the literature, the fellow researchers choose methods such as logistic regression since their predicted variable is the label of obesity or not (binary nature) or the weight percentile of a child (Vanhala et al., 2009), (Grow et al., 2010), (Williams et al., 2018). Thus, for their research design and nature of the predicted variable the choice of those models is more suitable than for the current research. What is more, the interest is in exploring multiple different interactions between variables derived from a specific pool of concepts (see Figure 3.3), is supported with this modeling approach. Since the total amount of variables available for analysis is greater than p=10, the total model combinations is greater than $2^{10} = 1024$ models which is unfeasible. Therefore, unless p is very small, we cannot consider all 2^p models. Instead we need an efficient approach to choose a smaller set of models. The literature for such purposes suggests three approaches and they are all applicable to the principles of linear regression, namely, forward, backward and mixed selection of variables. The current approach is the *forward and mixed selection* depending on the stage of modelling (James, Witten, Hastie, & Tibshirani, 2013). This approach of variable selection enables the exploration of all potential theoretically meaningful proxies which can later unveil useful policy levers for decision-makers.

Multivariate Linear Regression Modeling

For the theory of this chapter the book by James et al. (2013) is considered. This book offers the theory for different modeling approaches and provides examples for implementation in open source software. The problem of childhood obesity conceptually has a specific amount of distinct predictors, let p, and a predicted continuous variable, then the multiple linear regression model is preferred. Its generic form is as stated below:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_p X_p + \epsilon \qquad (5.1)$$

In this generic example of a multiple linear regression model, the coefficients $\beta_1, \beta_2, \dots \beta_p$ of the predictor variables: $X_1, X_2, ...X_p$, are unknown and will be calculated. Given the estimates $\hat{\beta_0}, \hat{\beta_1}, ...\hat{\beta_p}$, predictions can be made for the target variable, if needed, using the formula:

$$\hat{Y} = \hat{\beta_0} + \hat{\beta_1}x_1 + \hat{\beta_2}x_2 + ... + \hat{\beta_p}x_p \tag{5.2}$$

These parameters are estimated using the least squares approach. This principle is one of the most common ways of measuring *closeness*. The criterion of the *least squares* states that the aim of the modeling is to find such $\hat{\beta_0}, \hat{\beta_1}, ...\hat{\beta_p}$ that the resulting regression line is as close as possible to the available data points. In order for the reader to understand the least squares criterion, the definition of the residuals is needed. For a predicted value, let $\hat{y_i}$, which is calculated from a unique i^{th} set of predictors with the use of equation (4.1) and can be represented as:

$$\hat{y_i} = \hat{\beta_0} + \hat{\beta_1}x_{1i} + \hat{\beta_2}x_{2i} + ... + \hat{\beta_p}x_{pi} \tag{5.3}$$

then the residual is the difference between the actual and the predicted value of the target variable, namely the child's weight. It is denoted with the letter e and is calculated by:

$$e_i = y_i - \hat{y_i} \tag{5.4}$$

If the residuals are known for the whole model, someone can compute the *residual sum of squares (RSS)* by using the following equation:

$$RSS = e_1^2 + e_2^2 + ... + e_n^2 \tag{5.5}$$

Then, the model picks the unique combination of $\hat{\beta_0}, \hat{\beta_1}, ...\hat{\beta_p}$ to minimize the RSS score. The equation above is operationalised as is shown in equation (4.6), and the algorithm then minimizes practically that score.

$$\sum_{i=1}^{n}(Y_i - X_{1i}\beta_1 - .... - X_{pi}\beta_p) \tag{5.6}$$

The natural meaning of a β_i is the average effect on the predicted variable Y of a single unit increase of the variable it relates to, namely X_i, when holding all other predictors fixed. In order for a linear model to be applied, the assumptions of the appropriate use of it are crucial to be considered. Based on (James et al., 2013), the main assumptions are:

1. The relationship between the independent and dependent variables is additive and linear. It is also important to account for outliers since linear models are sensitive to outlier effects.

2. There is little or no collinearity in the data. Collinearity occurs when the independent variables are too highly correlated with each other. This can easily be computed with the variance inflation factor for each independent variable.

3. There should be little or no correlation between features of data. Correlation occurs when the residuals are not independent from each other.

4. The assumption of homoscedasticity. This means that the error terms are expected to have a constant variance, $Var(\epsilon_i) = \sigma^2$. If the error terms increase with the value of the response then there is heteroscedasticity and it is identified if the shape of the residual plot is like a funnel.

Hypothesis definition

For the case of the current thesis, a series of models is designed based on the theory which guides the mixed selection of variables. In order to evaluate the models the hypothesis is made based on the simplest form of linear regression hypothesis in mind (James et al., 2013). The generic hypothesis behind a multiple linear regression model is:

Hypothesis 0: *There is no relationship between the predictors and the predicted variable.*

Hypothesis 1: *There is some relationship between the predictors and the predicted variable.*

The hypothesis assesses whether there is a relationship between the response and the predictors. To test this hypothesis, the computation of the F-statistic is performed on the residuals of the model.

$$F = \frac{(TSS - RSS)/p}{RSS/(n-p-1)} \tag{5.7}$$

where $TSS = \sum(y_i - \bar{y})^2$, RSS is already defined in equation (5.5), n is the sample size and p is the amount of predictors (independent) variables. If there is no relationship between the response and predictors, meaning the H_0 is observantly true, one can expect the $F-statistic$ to take a value close to 1. In the case where the H_1 is true a greater than 1 value is expected. When the $F-statistic$ is high, this suggests that at least one of the predictors must be related to the response variable.

When H_0 is true, and the errors ϵ_i have a normal distribution, the $F - statistic$ follows the F-distribution. Then it is easy to calculate for a given n and p, the $p - value$ associated with the statistic using the distribution. Based on this $p - value$, which refers to the whole model, the analyst can determine whether or not to reject the H_0. When the $p-value$ is lower than the chosen level of significance, then there is strong evidence that at least some of the predictors are associated with the predicted variable. In the current case, since the study is a socio-technical and the subject is health, the confidence interval is set at 95%, leading to a 0.05 level of significance. The $F - statistic$ adjusts for the number of predictors, thus it is safe to conclude for the existence of significant relationship for the whole model parameters. The approach of using an F-statistic to test for any association between the predictors and the response works when p is relatively small, and certainly small compared to n. This holds true for the models conducted in the current analysis (James et al., 2013).

Modeling Cycle

For the implementation of the modeling, the opensource programming language R is used. The following modeling groups are designed with the extended framework in mind (see Figure 3.3. The approach is summarised below:

- Model Group A: only the child's biological data
- Model Group B: A + pregnancy related data
- Model Group C: B + socio-demographic related data
- Model Group D: C + parents lifestyle proxies
- Model Group E: D + environment proxies (based on postcode)
- Model Group F: E + dietary patterns of the child (since they closely relate to the surroundings, it is a continuation of model E2)
- Model Group G: E + physical activity patterns
- Model Group H: A, E or D + psychological state of the child

For the model groups presented, multiple model combinations are made based on the variables available from the data. All models are analysed with the built in residual plots from the linear regression in R. The residuals of the selected models for hypothesis testing are also visualised against the predictor of Age*Length to gain more understanding on the nature of the high residual individuals, namely outlier values. What is more, the observation of patterns showing non-linearity is facilitated. An outlier is a point for which Y_i is far from the value predicted by the model. Outliers can arise for a variety of reasons, such as incorrect recording of an observation during data collection, which is for the current case extremely possible (James et al., 2013). For the outliers specifically, visual inspection is done to see which keep showing up in the models and descriptive statistics are provided. More on the outcome analysis of the outliers is provided in Chapter 7.

When the complete modeling cycle is complete, the results are gathered and the crucial variables are identified. The results are collected by saving the *summary model objects*, the *model coefficients*, the *confidence intervals* and lastly the *criteria values*. From the collected metrics, it is interesting to notice which are the variables having a significant impact on the predicted variable, by observing the $p - value$. In addition, for each model the *residual standard error*, RSE is calculated, which shows the average amount that the dependent variable deviates from the true regression line. It is worth noting that for these calculations the total amount of the datapoints which were used for the model is reflected in the summary model object with the value of the *degrees of freedom*. The degrees of freedom are calculated by the equation:

$$DOF = n - k$$

where n is the sample size and k is the amount of independent variables selected for a given regression model.

One issue which needs to be addressed is the missingness of data. The more complex the models become, the less amount of data exists to regress on. This occurs because some of the variables regarding the dietary and activity patterns of the child were selected based on theory, but had a high missingness score. This is an inherent limitation which exists by default when survey data are used for modeling. This causes implications when conclusions are derived from models which due to missing data, run on less amount of observations. The variables which are then seemingly important may have not been, if a complete dataset existed. This needs to be addressed in the validation of the modeling cycle.

Evaluating a multiple linear regression model

Let us assume that the model is now computed for a given set of predictors and observations. The next natural step is the evaluation of the model. Evaluating the model is necessary to understand the model performance and also to identify which variables contribute significantly in explaining the target variable. For these purposes, for each model the *residuals* are plotted against the predicted values of the target variable. The residuals represent the variation which is left unexplained by the model. Residual plots are contributing as well to the assessment of the nature of the fitted model. In the case where there are clear underlying, second degree patterns in the plot, it may mean that the model has a problem with non-linearity in the data. If this is the case, the use of another modeling paradigm can be considered.

By using the built-in plot function of the programming environment, the first plot which assesses the goodness-of-fit is drawn. This plot draws the following subplots for each model object:

1. Scatter plot residuals vs fitted values. The red line should be identical with $y = 0$.
2. Scatter plot standardised residuals vs fitted values. The red line should be identical with $y = 1$.
3. Normal QQ plots. They assess the normality of the standardised residuals. The values should lie on the diagonal, namely, $y = x$.

4. Scatter plot standardised residuals vs leverage. High leverage points are the observations with an unusual value of x_i, thus affecting the outcome of the regression line. With this scatter plot heteroscedasticity and non-linearity can be identified. The spread of standardized residuals should not fluctuate as a function of leverage. By looking at Cook's distance, the effect of deleting a point on the combined parameter vector can be inferred.

In addition to these graphical means of evaluation, a series of metrics is calculated for the models. Specifically for each model the metrics explained below are calculated:

1. Residual Standard Error (RSE). This is a measure of the lack of fit of the model to the selected data. If the predictions obtained using the model are very close to the true outcome values, then RSE is small, and it is safe to conclude that the model fits the data very well.

$$RSE = \sqrt{RSS/(n-2)} \tag{5.8}$$

where RSS is the residual sum of squares presented in equation (4.5) and n is the sample size.

2. Training Mean Squared Error (MSE). This criterion is defined as:

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{f}(x_i))^2 \tag{5.9}$$

where $\hat{f}(x_i)$ is the prediction that $\hat{f}$ gives for the i^{th} observation. The MSE will be small if the predicted responses are very close to the true responses, and will be large if for some of the observations, the predicted and true responses differ substantially. The MSE is computed using the training data that are used to fit the model. Literature suggests that the training MSE is not good enough by itself for model selection. Hence, additional metrics are used to facilitate model selection and compensate for the sample size used.

3. Adjusted R^2. This criterion is defined as:

$$AdjR^2 = 1 - \frac{RSS/(n-d-1)}{TSS/(n-1)} \tag{5.10}$$

where d is the amount of variables considered in the model, n is the sample size and RSS is the residual sum of squares presented in equation (4.5). A high value indicates a model with a low test error. Therefore, theoretically, the model with the largest adjusted R^2 consists of only correct variables and no noise variables.

4. Akaike's Information Criterion (AIC). This criterion is defined as:

$$AIC = \frac{1}{n\hat{\sigma}}^{2}(RSS + 2d\hat{\sigma}^2) \tag{5.11}$$

where $\hat{\sigma}$ is an estimate of the variance of the error ϵ associated with each response measurement and n the sample size. A small value indicates a model with a low test error.

5. Bayesian Information Criterion (BIC). This criterion is defined as:

$$BIC = \frac{1}{n\hat{\sigma}}^{2}(RSS + log(n)d\hat{\sigma}^2) \tag{5.12}$$

where d is the amount of predictors, n is the sample size and $\hat{\sigma}$ is an estimate of the variance of the error ϵ associated with each response measurement. It is worth noting that BIC replaces the term of $2d\hat{\sigma}^2$ used by AIC with a $log(n)d\hat{\sigma}^2$ term. Since $log(n) > 2$ for any $n > 7$, the BIC statistic generally places a heavier penalty on models with many variables, and hence, results in the selection of smaller models than AIC. A small value indicates a model with a low test error.

6. Variance Inflation Factor (VIF). This criterion is defined as:

$$VIF(\hat{\beta}j) = \frac{1}{1 - R^2_{X_j|X-j}} \quad (5.13)$$

where $R^2_{X_j|X-j}$ is the R^2 from a regression of X_j onto all of the other independent variables. This statistic helps identify the existence of potential *collinearity* in the model between variables. A simple way to detect collinearity is to look at the correlation matrix of the predictors, but not all issues can be found with visual inspection of the correlation matrix. When collinearity exists between three or more variables even if no pair of variables has a particularly high correlation then this phenomenon is collinearity. The threshold for no collinearity is when $VIF < 5$.

Lastly, to infer about the significance of single variables the model performs on each individual predictor a $t - statistic$ test and reports back a $p - value$. The result informs about whether a single individual predictor is related to the response, without accounting for the other predictors. Each of these tests are comparable to the $F - test$ (for the whole model) that omits that single variable from the model, leaving all the others in. In other words, it reports the partial effect of adding that variable to the model. Usually, the response is only related to a subset of the independent variables. The process of defining which independent variables are associated with the dependent one, in order to fit a single model involving only those predictors, is referred to as variable selection. Nevertheless, variable selection for the purpose of prediction lies outside of the scope of the thesis. The definition of the test is:

$$t = \frac{coefficient}{standarderror} = \frac{\hat{\beta_i} - 0}{SE(\hat{\beta_i})} \quad (5.14)$$

This statistic follows a t-distribution. Then, when this value is computed for the β_1 coefficient, for the given confidence interval. Based on this, the inference on the $p - value$ is done. To reach this, the table with the critical values of the t-distribution, for the given degrees of freedom of the model is used. Then the $p - value$ is found by choosing the appropriate level of significance, in the current case 0.05 and then by looking at the value of the degrees of freedom. If the $p - value$ of the $t - statistic$ is less than the level of significance, then there is strong evidence that this variable is related to the response variable.

Validating a multiple linear regression model

After the modeling cycle is conducted with the use of the existing data, conclusions are drawn. Next step is validating the model, to assess its performance under other data. The inherent issue with data obtained from surveys is that there is a hypothesis for a specific profile of users who tend to not fill out the whole form with attention and accuracy. This issue came up during the current research as well. After consulting a healthcare expert, the topic of addressing the missing values is identified as crucial. The method to address this is *data imputation* and is considered as the most appropriate for the health-related nature of the study[1]. This method aids with the missing values. The other issue is the hypothesis that people responding to national surveys are usually the ones with access to digital equipment, are technology literate and mostly originate from high socioeconomic status. This implies that there is an intrinsic under-representation of the lower socioeconomic and literate people in the gathered data. The implications which then can result from analysing such dataset concern the results of the linear models and the conclusions which are drawn upon them.

Data imputation helps in the existing dataset where missing values appear. Missing values are regarded as one of the major challenged of machine learning and prediction modeling. Even if the scope of this thesis is to explore causalities for children' weight and not predict it, still it is an issue, since it compromises the results by limiting the observations the model is fitted on, resulting to information loss. For this purpose, an algorithm is used which is found in one of the programming language's libraries. This algorithm[2] uses additive regression, bootstrapping and predictive mean matching to fill in the null values of the data. The

[1] J. Struijs, personal communication 4 June 2019.

[2] The $aregImpute()$ function from the $Hmisc$ library from R is used to perform the imputation of the dataset.

reason why this algorithm is selected is that it performs well under mixed data measurement types. In other words, there is no need to split the data into qualitative and quantitative and then apply the algorithm separately. With the bootstrapping different samples are selected for each imputation round. Then, a non-parametric regression model is fitted on samples taken with replacement from the original data. The missing values are predicted using the non-missing values from the same variable with a predictive mean matching approach (Harrell, 2019). For categorical variables, the flexible transformation is Fisher's optimum scoring method. However, there are also limitations. Specifically, one of the assumptions of the algorithm is that the imputed variables are linear and additive. This may not always be the case, leaving room for improvement in the imputation process. Nevertheless, after the imputation, a complete dataset is acquired and a second modeling cycle starts with the use of a mix of imputed and real values. Thus, the results from the second round (real + imputed data) can be compared with the results from the first round (real data) and then more robust conclusions can be drawn.

Lastly, the overall validity of the results can be assessed with external validation. This is the comparison of the results with other studies of similar nature. If the results are comparable and similar conclusions are drawn, then the outcome is validated. Such a validation method is useful when using a new sample is not feasible. Additionally, since the models are not built for prediction, typical validation techniques do not not seem appropriate for the current modeling cycle, for example by spitting training the model and testing on the remaining unused data. The aim is to validate if the unique framework which guides the analysis has led to meaningful outcomes and how these outcomes can relate with existed scientific work.

Acknowledging limitations

The analysis is conducted with the use of open source programming language, R. Regarding this methodology the benefits are that the exploration of factors which contribute to children' weight is done is a data-driven way. Clearly patterns and correlations from the given dataset can be identified, helping decision makers with the selection of appropriate policies. In addition, the level of reproducibility is high, increasing the transparency of the study. When it comes to disadvantages, the statistical models have levels of significance and errors. What is more, every single model or algorithm which is applied has specific assumptions which are taken for granted. This implies that in the case where these assumptions are compromised, so do the outcomes of the analysis.

On the other hand, this is why so many different model evaluation metrics are used to account for such errors. Additionally, in order to explain the factors contributing to a child's weight a single model is not enough to reason from. For this reason, an iterative approach of variable selection, model building, testing and data imputation is employed. An overview of all the modeling steps can be found in Figure 5.1. The nature of the problem is the analysis of human weight based on diverse factors from different fields, specifically for young children. Health related studies in this domain are inherently more complex compared to other scientific fields and thus for the sake of understanding the inter-relations a seemingly less ”good-fitting” model may be preferred.

Regarding the proxies used for each concept, their nature and completeness affect the credibility of the outcome of the model. This is bounded to the availability of data and the current design of the questionnaire and cannot be fully overcome. Lastly, the results showing correlation between variables do not always imply causation. Thus, conclusions about direct causation cannot be made without raising the appropriate limitations and implications of the data and models used.

5.2.2. Childhood obesity identification

For this last section of the methodology the research question which is tackled is the one regarding the screening and early identification of obese-prone children. There is special difficulty in identifying risk-prone children, since the early childhood is a very sensitive growth period, which also imposes a lot of medical difficulties for doctors to identify risk-prone children with only the use of the growth charts. The sub-research question for this part, is as follows:

How can children be earlier identified as obesity risk-prone?

Nature of the sub-research question

The aim of this research question is to assess the identification of overweight and obese children found in the data. Specifically, in the dataset, there are two variables regarding the state of the child. One refers to if a child is overweight and the other if a child is obese or not. These variables are constructed by the standards used by CBS for the GECON dataset, more details can be found in the provided data dictionary by the Centraal Bureau voor de Statistiek (2019). They are defined only for the children in the data where the current biological data are available, namely current height, age and weight. The thresholds which are used are the adult measurements for overweight (BMI ≥25) and obesity (BMI ≥30)[3]. Although, as stated in the literature, there is a need to redefine the way to assess the existence of excess weight for early childhood ages (Section 2.1).

For this reason, the definition from Cole et al. (2000), is selected as the theoretical foundation on which on the new labelling of the children is based on. The need for a different labelling of children regarding the epidemic of childhood obesity is clear, especially since with these labels other researchers can estimate and predict future trends for the epidemic. If not proper care and definitions are used to derive the labels, which in essence are binary variables, then prediction models for the spread or prevalence are inherently flawed. After all, there is this famous quote for modeling and data quality which states *"garbage in, garbage out"* (Verbraeck & Pruyt, 2018). The authors with this quote stress out the importance of taking enough time and effort to complete the data collection and pre-processing before feeding the data to a model. No matter the model algorithm or complexity, the outcome will only be valid if the data accuracy and quality are up to specific standards. What they also mention, which is the case for the used data, is that the processes followed to clean and document the data are rarely transparent, accurate or even available to researchers. This impedes the full understanding of the analysts of the past steps taken to reach the current data quality and availability. The scope of the analysis is to implement a labelling algorithm which is based on literature which is medically more relevant and apply this to re-label the children. This algorithm is the digital implementation of the outcome chart from the research paper from Cole et al. (2000). Then, this computation helps compare the two different scientific approaches.

Comparison of scientific definitions for childhood obesity prevalence

In order to compare the two different approaches for the labeling of children, one applied by CBS and the other from Cole et al. (2000), first a pre-processing of the dataset is needed. When the missing values for sex, age and BMI for the children are eliminated and all these attributes are available the labelling takes place. The algorithm which is employed is based on the Table 5.1, which is based on the diagrams presented in the research from Cole et al.. Their study is preferred since they addressed the issue of childhood obesity with a multicultural sample and a new approach for the definition of the cutoffs for age and sex specific values.

[3]CBS Microdata, personal communication 7 August 2019

Table 5.1: Table for obesity thresholds based on the research from Cole et al. (2000)

Numeric thresholds				
Age	**Overweight males**	**Obese males**	**Overweight females**	**Obese females**
0 - 2	NA	NA	NA	NA
2	18.5	20	18	20
3	18	19.5	17.5	19.5
4	17.5	19	17	19
5	17	19	17	19
6	17.5	20	17	20

Based on these values, the labeling is conducted and the outcomes are two new columns with the definition of overweight and obese children based on their study. What is more, not only is it important to identify such kids when they reach such a state but also is crucial to prevent this health issue. For this purposes the idea to expand Cole's definition is conceived. Thus, the screening done from health practitioners or doctors can be facilitated and an extra warning sign can be useful. After all, is easier to prevent a child from being overweight than having to reverse the weight gain. Health professionals can subsequently nudge the parents and inform them as a precautionary warning for their child's health state. For these purposes for each age, sex an extra variable is calculated to identify the children who are 1 BMI unit away from being overweight for their cohort. This calculation aids the understanding of the state of the children in the dataset, but also raise awareness for the disease.

The desired outcomes from this analysis are mostly visualisation of the childhood obesity problem for the given dataset. The comparison of the results from the CBS labeling and the labeling from (Cole et al., 2000) clarifies the differences in the understanding of the existence of the epidemic for the Netherlands. It also, brings awareness into the ongoing discussion about this topic within decision-making arenas in the country. By highlighting the risk-prone children, the current research contributes in the literature by bringing light to the amount of individuals who are at the threshold of being overweight. What is more with visualisations such as bar plots, the features and characteristics of these kids can be communicated to medical and policy professionals. For the design and implementation of this algorithm, the open-source programming language R is used.

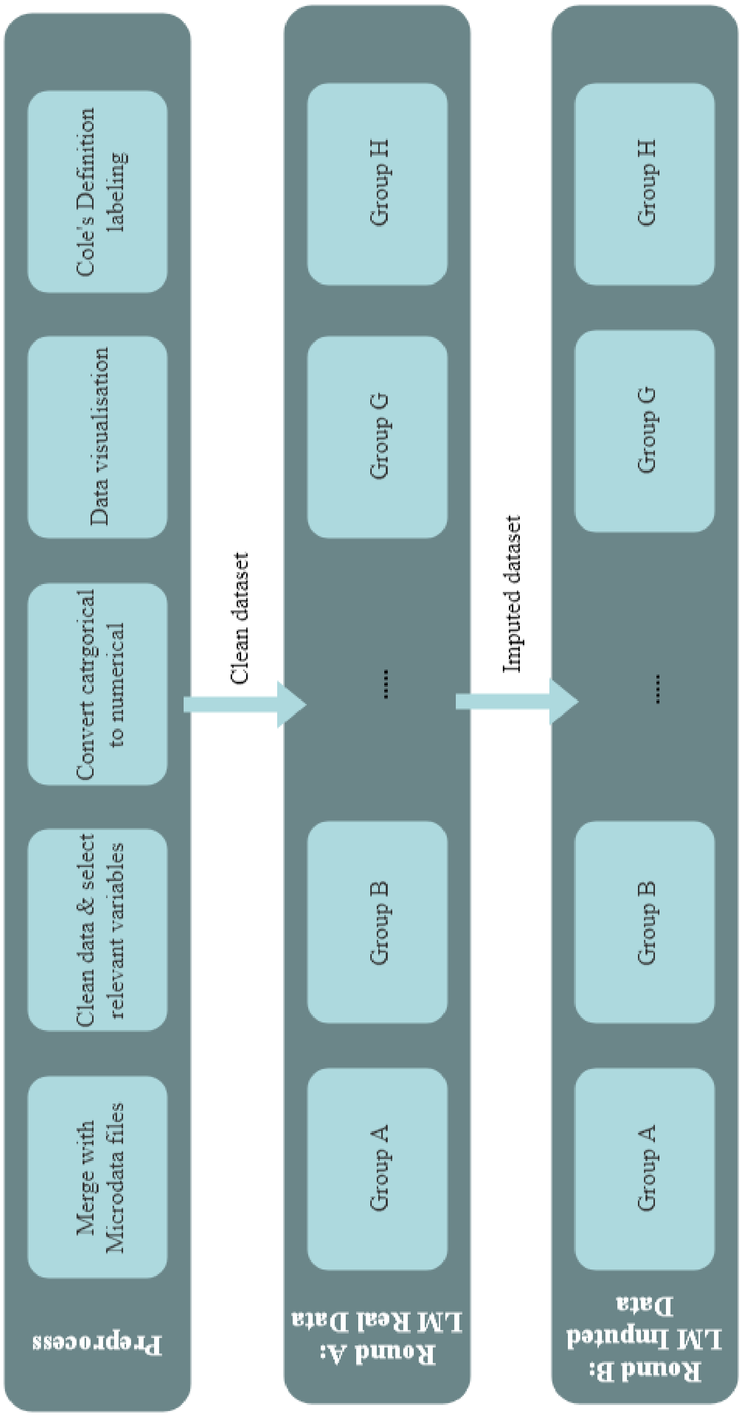


Figure 5.1: Overview of modeling steps, for second sub-research question.

6
Initiators of change

The purpose of this chapter is to identify the context of the Dutch society wherein actors of the health system of the country, interact, form alliances or partnerships and take action towards the complex issue of childhood obesity. Firstly, an interview is conducted to identify knowledge which lies within the academia and then the actor analysis takes place. The use of actor analysis, unveils new potential actions for the client of the study hence, creating a new policy space which can be explored. This chapter addresses the first sub-research question of this study. Namely:

> Who are the involved actors in the health related context of the Netherlands, capable of initiating change for the prevention of childhood obesity?

6.1. Experts Consultation

For the purpose of understanding the health context specifically from experts in the fields of Public Health and Epidemiology for the Netherlands, a semi-structured interview is conducted. The full transcript of the interview can be found in Appendix B. In this section the main findings of the interview are presented. These findings help understand the motivation and interest of the Dutch health system actors in the issue of childhood obesity. Later, these finding are informing the framework which guides the quantitative analysis of the following chapters.

Table 6.1: Summary of the interview findings with Dutch Public Health Experts

Main Findings	
Initiatives (primary prevention strategies)	Obesity School Programme (evaluation stage currently). Primary and secondary school ”Vignette” programme (not mandatory, neither seems as necessary to all school directors). The school involvement to such initiatives varies per municipality and even per district.
Medical Professionals	General practitioners (GPs) are challenged when faced with overweight children, because of limited time to address all issues. The GPs would appreciate a special team to refer kids who accidentally diagnosed as overweight from a visit regarding another cause.

Main Findings	
	The medical community understands that a closed loop of monitoring needs to be in place to support the screening of high-risk children. The GPs when a child is between 0-3 can only provide advice, not do interventions. During pregnancy there is no formal monitoring of the weight of the pregnant woman, only indicators such as blood sugar levels and pressure are followed closely.
Decision makers	Almost all municipalities agree on the existence of a screening procedure for youth health care. Some municipalities agree to collaborate with the commercial sector to redesign the environment around schools. The Ministry of Health has a general tendency of assigning more power to municipalities, so policies can be context-related. The Youth Health Centers develop protocols abiding by the guidelines of the Ministry of Health to tackle obesity.
Policy	The socio-ecological approach for policy is recognised as necessary. There is a national protocol for school growth checks for children at 5-6 and 8-9 years old, the ones identified as overweight get advice and potential referral to a dietitian. The school programmes are not mandatory for all schools. Amsterdam realised the importance of partnerships and created a healthier environment for children and now, they reap the benefits of the redesign by the decreased obesity prevalence. None of the heath checkups are mandatory for new mothers and children. All are still covered by the basic insurance scheme. There is no guideline to communicate the 32 weeks check results of the unborn child to the GP who will handle it when born.
Analysis	Current identification of overweight obese children based on growth curves. There is the need to change these standards, the definition from Cole et al. (2000) is more appropriate for the categorisation of young children.

Main Findings	
	Premature birth is when the gestational age is less than 37 weeks.

These findings are split in segments, based on the key message and the actor or stakeholder it relates to. In the following section, the actor analysis uses the findings from the interview to reach to timely and scientifically relevant conclusions, for the Dutch society.

6.2. Actor Analysis

From the analysis so far, it is evident that the environment of the Dutch society can act to affect the prevalence of childhood obesity. For the current thesis, the focus is on the Dutch society, the Health Care system, the involved actors and the regulations around them. This is called *system of interest* wherein interactions can change its state. Many professionals, organisations and mostly decision-makers can influence it. In the current section the analysis of actors who can influence or initiate change is conducted. With the term *stakeholders* or *actors* "individuals, organisations, or groups capable of autonomous and intentional actions that have an impact on a problem or system of interest" are indicated (Hermans, Cunningham, de Reuver, & Timmermans, 2018). The term *stakeholder*, is mostly used to refer to families or parents who have a very high interest although, do not own a lot of means to influence final decisions.

The actors participating in the arena of the complex issue of childhood obesity in the Netherlands are analysed. The scope is to understand their perspective, interest and objectives and then, identify what are their capabilities on the issue and how they can initiate policy change. The main theory and context for the current section is derived from the *Health Systems in Transition* report, by van de Berg et al. In addition to this report, the knowledge distilled from the interview with the experts (see Appendix B) is used to encapsulate any additional information which is not present in the literature (J. Kiefte de Jong, R.C. Vos, personal communication, April 25, 2019).

If someone carefully observes the main messages from the interview presented in the section above, it is clear that there is a fragmentation in the strategies municipalities and actors pick. This is encapsulated from the findings in the sections of *Policy* and *Decision makers* from Table 6.1. Not all municipalities recognise the need to take mandatory actions towards childhood health and not all schools engage in the different programs such as the *Vignette*. With the power shift from the government to the municipalities, it is of utmost importance to make sure that they all align to help ameliorate children' health. In the paragraphs below, the current knowledge for the status quo of the main actors is presented.

Government and advisors

As stated in Chapter 2, Section 2.5, the Dutch society is characterised by the notion of *shared governance*. This means that the tendency of decentralising healthcare allows more actors apart from the Ministry to take decisions and act upon growing issues. In addition, the past few years years, the Dutch national government has underlined the concern of developing a holistic approach for the prevention of excess weight specifically for the youngest of the populations (Hendriks et al., 2012). They get advisory services from bodies such as the Health Council or the RIVM which provide with research and expertise for issues regarding welfare and Health. Thus, the Ministry relies on the directions and outcomes these bodies produce, to adjust and strategically plan future decisions. Thus, it is obvious that such advisory bodies have a crucial role in bringing awareness in the topic of childhood obesity. They have the power and means to conduct research which can inform the Ministry of the current situation in different provinces and bring meaning to the already collected governmental data. Such actions can be helpful since currently as stated by Hendriks et al. (2012), governments do not deem themselves accountable for providing with urban leptogenic environments via the implementation of such policies.

Municipalities

In the current research, as already stated, the *client* is a Dutch municipality who is willing to design policies for health and fitness. A municipality's objective is of course to provide quality of life to its inhabitants via health, livability of the environment and also provide with equitable access to its services. It can be stated that a municipality is the *problem owner* since, the municipal decision makers are asked from other actors, to address childhood obesity with policies relevant to tackle or prevent it. What is more, outside of the health-related spectrum, there are always goals around sustainability, resource efficiency, transportation accessibility, resilience and economic growth. As it is obvious, the "heart" of a municipality are its citizens, thus, a top priority is to care for them and provide infrastructure or services for the people in need.

However, as stated in the interview findings in Table 6.1, the understanding Dutch municipalities have for the issue of childhood health is not uniform. Some municipalities such as Amsterdam or Utrecht, are taking measures and spend resources to conduct research and promote intersectoral tactics to address childhood overweight and obesity, whereas others do not even consider important to include such actions to the agenda since they do not perceive them as pressing. Improving intersectoral relations and collaboration, is a challenge for the Dutch society since 2012, according to the research from (Hendriks et al., 2012). It is stated that even if some Dutch regional officials engage in training activities by regional Public Health Service (PHS), to improve their knowledge about the implementation of such collaboration, the outcomes in terms of health policies regarding overweight prevention are discouraging. To conclude, municipal decision makers can affect the regulations for other actors, such as schools, or the Youth and Family Centers, greatly impacting how parents and children interact with the system of health and prevention.

Medical professionals and Insurance sector

The broader medical sector includes health care professionals (GPs, physicians, nutritionists and nurses) who work in hospitals or in Youth and Family Centers across the country. When parents have young children up to preschool age, they have a support network from GPs, Youth and Family Centers to help them monitor the growth of the child (Appendix B). As mentioned from the interview findings especially the GPs face a challenge in their daily practice. They have a limited time to address issues when they treat young children and if they identify excess weight they feel like they cannot address all of the issues in one visit. What is more, the Youth and Family Centers have a limited amount of walk-in hours. The webpage of the center for the central neighborhood of the Hague, has opening hours only during business hours (Centrum Jeugd & Gezin Den Haag, 2019). This potentially is a barrier for working mother whose maternity leave is over and have a tight work schedule. The broader medical community, bears the responsibility and the means to conduct the screening of children and bring awareness to the parents for the growth of their offspring. Lastly, someone can consider the insurance companies part of the same group of actors. They closely work with medical professionals and the basic insurance scheme covers the costs of the visits to GPs plus vaccines.

Educational institutions

Educational institutions play a significant role in the final years of the early childhood for all children. Specifically for the ages of 5 - 6 and 8 - 9 years old, schools conduct growth checks based on the standards each municipality has (see Appendix B). This process aims at screening the children and identifying the ones who are in a risky-trajectory of gaining weight. Then, each school has its own regulations on how to follow up with the findings and how to approach the issue of a child gaining excess weight. In addition, children spend roughly 1/3 of their day at school, meaning that their nutrition patterns are affected by the availability of foods in the school environment. Some schools voluntarily follow programs for creating a healthier environment but other do not feel the urge to do so. Schools and kindergartens are considered as a critical actor in the arena. They have power over the issue of childhood obesity but are not necessarily eager to act upon it. One research unveiled that the World Health Organisation recommends schools as a crucial space for forming public nutrition and reducing the occurrence of unhealthy weight gain, nevertheless only a few institutions take active action to employ such practices (K. L. Reilly et al., 2018). Schools as mentioned by Thaler and Sunstein (2008), have the power to influence public behavior by employing “nudging” practices, towards a healthier diet for the pupils.

Food Industry

The food industry has the both power over the arena of the issue of childhood obesity but also interest. This stance stems from the main objective they have, continuity of business. Industries do not necessarily care about the health of children per se, at least not all of them. They are mostly driven by profit no matter from what products it originates from. However, they have a very powerful resource, the products themselves affect the buying behavior of the customers and their health as well. This is possible since the labels of the products affect consumer engagement and the contents along with the regulations for the ingredients affect consumer health. As mentioned in the literature review, Section 2.4, past January, the European Commission postponed again the law on mandatory existence of nutrition profile on all products. This allows for a more ”creative” approach to labeling from the part of the industries, as for example it is very commonly seen that labels and nutritional value corresponds to a full dish which consumers can potentially make with the specific food item and not directly to the contents of the product. This only creates more confusion for the customer who is willing to read a nutrition label since the actual contents of the product are ”hidden” and is almost impossible to extract the actual percentages of fat, sugars or carbohydrates. The pressure for postponing the signing comes from the food industry itself. The lobbying power large food industries have is so large, that the Commission cannot move forward with this law, since this would immediately affect the obligatory existence of the nutrition profile and the regulation of the claims they can print on the food packaging and in the long run will most definitely affect net sales.

Stakeholder

The stakeholder of the analysis is the family of a child who could potentially face weight abnormalities. This choice is defended by literature since children at preschool age are not capable of initiating change in their lifestyle by themselves (Ersfjord, 2018). The challenge however, is to understand how parents from different culture, origin and with different experiences, identify or perceive child thinness. For example, Hispanic parents perceive it as a negative factor towards their child’s health and mental happiness (Stang & Bonilla, 2017). Similarly, other cultures may be more aware of the benefits of maintaining a lower weight at these ages because of the social norms of the society they grew up in. Social norms are “rules and standards that are understood by members of a group and that guide and/or constrain social behavior without the force of laws” (Pettigrew, Jongenelis, Miller, & Chapman, 2017). For example, there is the general norm in the Netherlands, that people prefer to bike for a major part of their daily transportation. This norm is definitely not the case for example for countries such as Greece or USA, which have different infrastructure but also cultural background (21.5% and 31% respectively for these countries is the total overweight and obesity rates in adolescents as of 2014 data (OECD, 2017b)). In such cases of parents with experiences and perceptions different that the typical Dutch mentality, it could be more complicated for the actors from the education, or from medical practitioners to influence or advise them.

All of the above described actors, perceptions and means of interaction or information flow, are described in the organisational chart presented in Figure 6.1 (van de Berg et al., 2016). The only actors who are not included, are educational institutions and food industry. The first has an important role in the screening of children as a preventive strategy. The latter affects consumer behavior and health. Hence, both these actors indirectly affect the overall state and functioning of the health system. In the figure, the different information or material flows are evident, and a better understanding of the interconnections and points of collaboration for the Dutch society can be established. The above information for the actors and the stakeholder is summarised in Table 6.2.

Table 6.2: Summary of actors and their features for childhood obesity in the Netherlands.

Actor Scan				
Actors	**Strategic Objectives**	**Problem-Bound Objectives**	**Problem Interest**	**Resource**
Ministry of Health, Welfare and Sport	Well-being of the country	Healthy children for a healthier future population.	High	Money, Genaral authority
Municipality	Public health, prosperity and economic growth	Prevention and cure of overweight children.	Medium	Authority, organisation, local legislative power
RIVM	Advise the Ministry of Health on all kinds of issues	Acknowledges the issue of quality of life but does not address yet the issue of childhood obesity nationwide.	Medium	Information, expertise
Youth Family Centers	Aid young parents with issues related to their children	Conduct screenings and perform growth checks for young children.	Medium	Skills
Healthcare Professionals	Serve their best so as to maintain a healthy population	Check the growth of children.	High	Expertise
Education institutions	Educate young children	Conduct growth checks, educate and inform children. If something is unexpected they need to contact health professionals.	Medium - High	Knowledge, High influence position
Insurance Companies	Continuity of business	Reimburse families for medical purposes related to overweight or obese children.	Low	Money

Actor Scan

Food Industry	Continuity of business	Continuity of sales in terms of the changing nutrition demands and food standards.	High	Money, Behavioral power over citizens
Household with children (stakeholder)	Raise healthy children	Strive for healthy children, although lack of information regarding healthy lifestyle is potentially an issue.	High	No significant resources, apart from expressing their concerns to educational institutions or YFC

Key Messages
From the above analysis, the outcome for the client, a Dutch municipality, can be mapped in a *power versus interest* diagram. The diagram of Figure 6.2, is a schematic way to summarise the position of the actors within the arena of interest and visualise inter-dependencies. In addition to that, it communicates easily the critical actors and the dedicated actors in this complex system[1] (Enserink et al., 2010). This map can be used for the policy proposal and can help in the identification of partnerships and coalitions. By identifying dedicated and critical actors, opportunities and threats can be then acknowledged when consulting the client. Lastly, by acknowledging the current state and position of these actors in the system, the client can motivate specific actors and initiate a change of their quadrant-position in the *power vs interest* diagram. This can help the municipality utilise its resources to help the tackling and prevention of obesity. One example is to incentivise an actor of low interest and high power, ie educational institutions, in order to increase the amount of *key players* within the arena.

Figure 6.2: Power versus interest diagram for the arena of childhood obesity in the Netherlands.

[1]Critical actor: power ↑. Dedicated actor: interest ↑

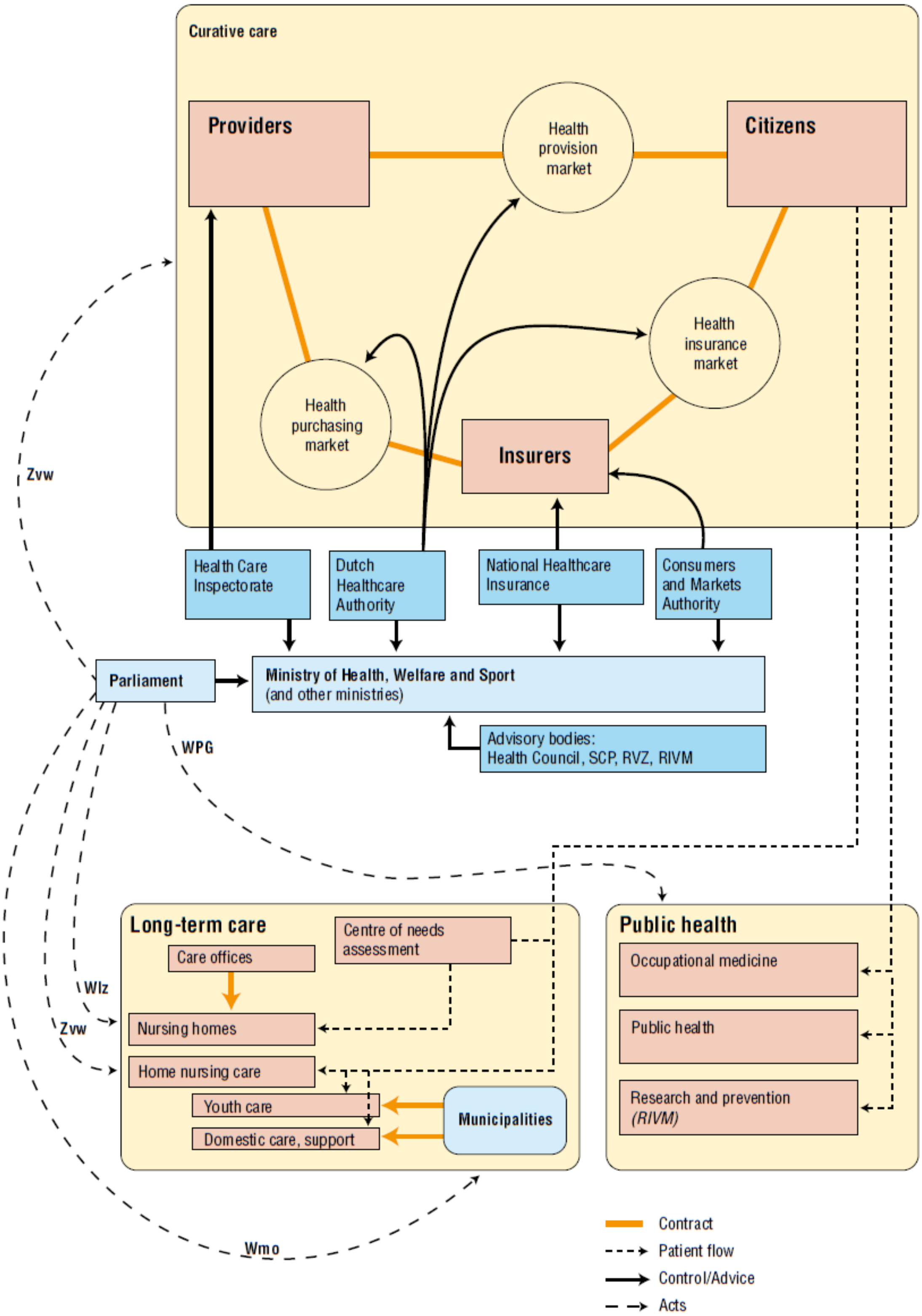


Figure 6.1: Organisational structure of the health system in the Netherlands, as designed from van de Berg et al. (2016).

7

Non-biological factors exploration

In order to identify factors leading to weight gain, personal data are analysed concerning preschool children. Specifically, data obtained from the Central Bureau of Statistics Netherlands and the RIVM, are used to explore biological and socioeconomic features which could be linked to an increased weight for pre-school children. The specific research question is:

What are the non biological factors explaining the weight of children in the Netherlands?

The unit of granularity for this analysis is, hence, a single *individual*. The overarching framework for the analysis is based on the socio-ecological approach and the framework presented in Figure 3.3. For the details on the used dataset, the reader can refer to Chapter 4.

7.1. Assumptions

For transparency purposes the assumptions of the modeling approach need to be declared. Some of the assumptions relate to the concepts and other relate to the variables. These assumptions are made because of resource limitations.

- The data which come from the survey are inherently not 100% true and valid. Human error is included and this limits the outcomes of the research. The exploration is done on this premise and conclusions are drawn with this assumption in mind. Variables which could be substituted with the same ones but from other sources within CBS, is the preferred way to address some of the validity issues.
- Data regarding sensitive information about the children are reported from their parents. This may potentially affect the validity of the selected variables since parents may not be willing and/or able to acknowledge fully the state their child is in. This is specifically the case for the mental health variables.
- The cultural aspect of the child is approximated only with the variable of the mother ethnicity. This variable is a binary one, measuring if the mother is western or not. This obviously limits the effects of exploring diverse cultural backgrounds and totally excludes the effects of the father's origin.
- Regarding the nutrition patterns, the aggregation of the variables is done by CBS thus they are believed as valid.
- The prevention strategies that could be linked with municipal offerings to young parents are approximated with the use of the variable for the consultation visits to the Youth Family Centers. No other variables could be identified as relevant.
- The selection of variables for the mental state of the children is done based on the theory presented by Desmet, Romero, and Vastenburg (2016). The consideration of multiple the questions covering both the negative and positive side of the axis *unpleasant - pleasant* is done to make sure that such a complex variable is captured as adequately as possible.

7.2. Hypothesis definition

The hypothesis formation follows an approach which gradually becomes more complex. First of all, the hypothesis which needs to be tested is the simplest one someone can think of. In other words, the people who believe the weight of the children is random and does not depend on any specific variables, meaning factors from a child's biometrics or environment. This hypothesis is selected as the one to be tested first since it is the simplest to confront and refute. For **Test A**, models from the *Group A* are employed. This is chosen since in this group of models, different variations of growth related variables are picked with the approach of forward selection. If the results are significant even for one of the models from this group, then the alternative hypothesis $H1$ will be accepted.

Test A:

Hypothesis 0: *There is no relationship between any factors and the weight of children.*

Hypothesis 1: *There is a relationship between some factors and the weight of children.*

As a natural next step, someone can claim that the weight of a child has an association with biological factors but also factors which relate to the family environment and the behaviors of the parents or caregivers. This theory can be tested by assessing the following hypothesis. For **Test B**, models from the *Groups B, C, D* are employed. This is chosen since in these groups, models with different combinations of biological and parents lifestyle related variables are involved. Specifically for group C, socioeconomic factors are introduced, since they also affect the pregnancy by introducing inequities (Dahlgren & Whitehead, 2006). Similarly, the approach of forward selection is applied as well.

Test B:

Hypothesis 0: *There is no relationship between biological factors and the weight of children.*

Hypothesis 1: *There is some relationship between biological factors and the weight of children.*

Lastly, the most complex theory is that the weight of children can be explained by a set of different factors origination from their immediate environment, namely their family, but also from their surroundings. It is crucial to sate that the word *environmental* is multifaceted and does not limit the factors only to urban related proxies (see Section 2.2). The family environment, the school / kindergarten environment are also included in the environment of a child since it spends a significant proportion of its days there. This is the ultimate hypothesis for the exploration of non-biological factors which could explain a child's weight. By testing and exploring this theory, the research question for this chapter can be tackled. For **Test C**, models from the *Groups E, F, G, H* are employed. There is a significant amount of more models required to test this hypothesis since different variable interactions require to be tested and the amount of the variables is aggregated in different model groups. If the results are significant even for one of the models from the two groups, then the hypothesis $H1$ will be accepted.

Test C:

Hypothesis 0: *There is no relationship between environmental factors and the weight of children.*

Hypothesis 1: *There is some relationship between environmental factors and the weight of children.*

If by the end of the modeling cycle, there is enough evidence given the dataset, for an association of factors from a child's environment with its weight, then useful conclusions can be drawn for decision makers and professional dealing with the issue of childhood obesity. Such results can be also useful for people from medical field or urban development, trying to create healthier environment for citizens. Of course more analysis should be conducted, but still this outcome is enough to shed some light onto the complex nature of the preschool weight gain.

7.3. Introduction to analysis

The analysis is conducted with a dataset which is confidential. Thus, no scatter plots or non-aggregated data can be presented as visualisations or in the results section of the current chapter. Consequently, visuals are used only on a higher level of aggregation and when is necessary. The cohort of the analysis are children between 0 and 6 years old and from the selection of the data the total sample size is 1062 children. This is because of the design of the data collection and hence, the age of the children is treated as a factor variable. The survey was a national one, but it is interesting to see the provinces the respondents originate from, in Figure 7.1.

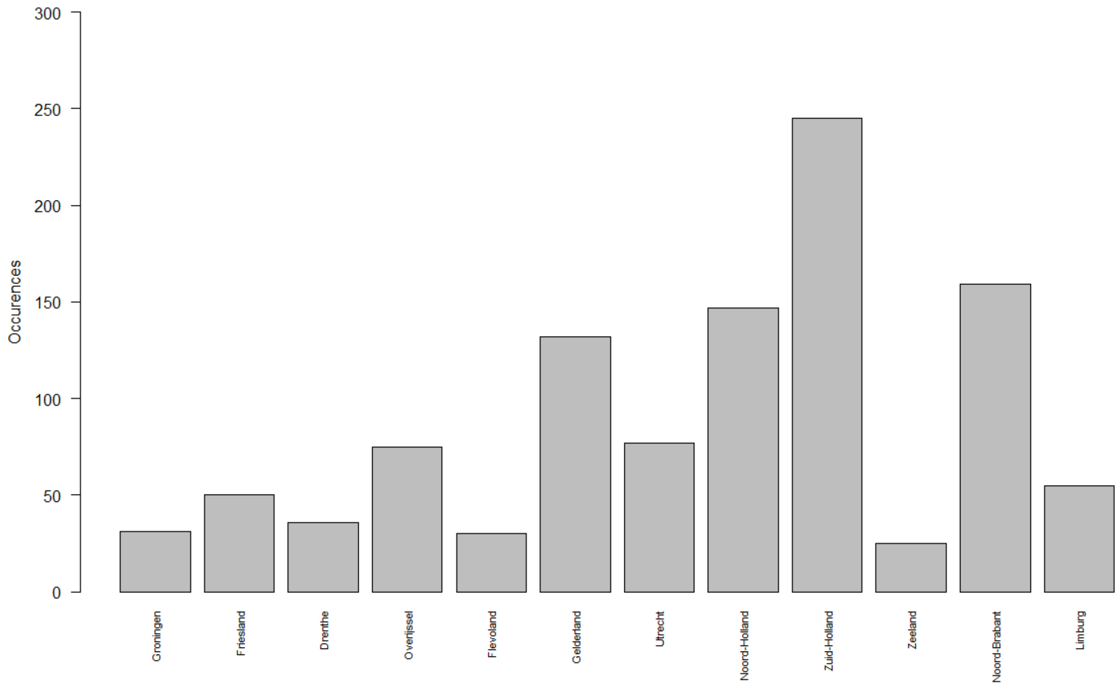


Figure 7.1: Chart of the total occurrences of the provinces of the participants

It is obvious that some provinces are more popular in the responses but this is directly correlated to their total population. Regarding the ages of the children, below is a histogram presenting the variation of age for the current sample (Figure 7.2). We see that there are a lot of young children, between the ages of 0 to 2 years old, where for those children is almost impossible to identify obesity trends since the development of the child is rapid. Medical literature states that is inappropriate to judge for weight conditions such as childhood obesity.

What is more, it is interesting to observe the gender of the children and the socioeconomic status chart for the cohort. In Figure 7.3, it is obvious that there is a big under-representation of respondents living in neighborhoods below the Dutch standards for poverty. Regarding the gender of the children, male children are in absolute terms more, however this difference is not significant.

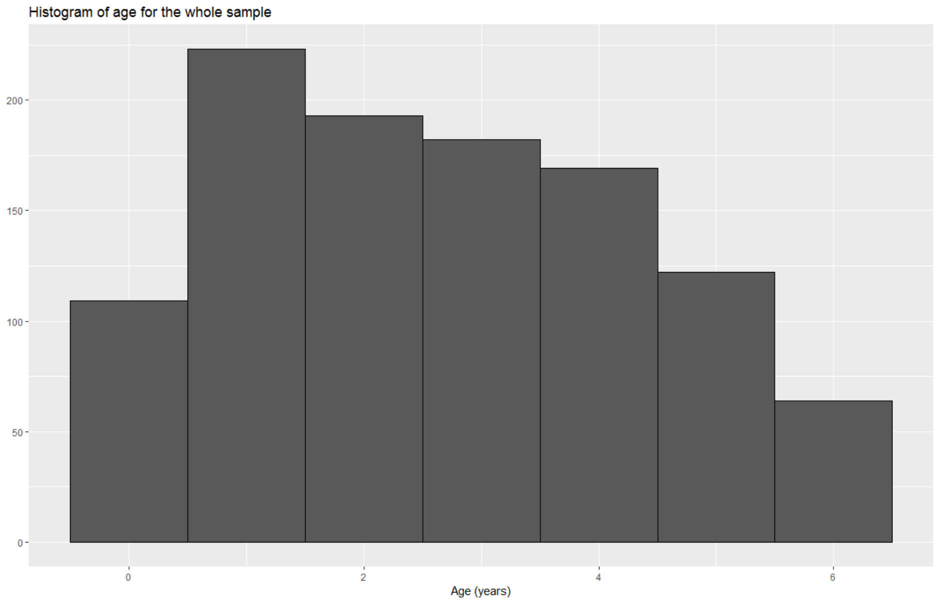
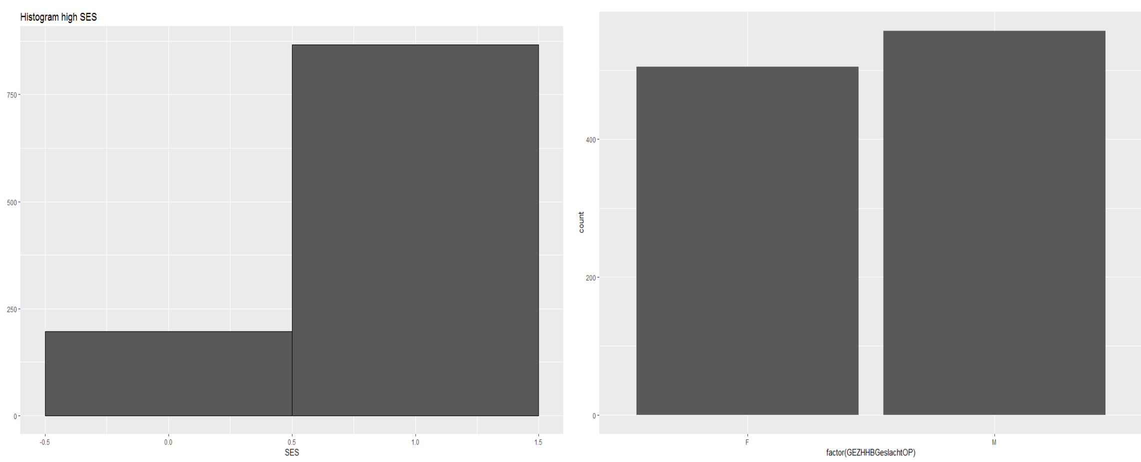


Figure 7.2: Age histogram of participating children



(a) Socioeconomic proxy of the neighborhood (b) Gender

Figure 7.3: Bar charts of neighborhood SES and gender for the sample

The following analysis has the weight of the children as a target variable. The unit of measurement for the predicted variable is *kilograms (kg)*. Then this implies that when referring to the meaning of the regression coefficients the difference in the target variable is *1 kg*.

7.4. Results from Round A

The aim of this section is to present the steps which are taken to address the defined hypotheses. First and foremost, at the beginning of the analysis, the idea is to utilise all of the survey years from 2013 -2017. However, the survey structure was significantly different and the use of only 2016 and 2017 datasets is considered appropriate due to the amount and diversity of the questions asked. More details on these choices the reader is advised to consult Chapter 4. In addition, the psychology and the physical activity of the children were only measured during those years and these variables are crucial to the analysis.

Some descriptive statistics are calculated to give a general image about the nature of the data (Table 7.1). Since the dataset is confidential, there is the limitation of not disclosing data points which could compensate the privacy of an individual. Thus, for the whole analysis, single values directly linked to individuals are avoided (min, max, median), unless the variable under study is non-disclosing in nature, as for example factor variables.

Table 7.1: Descriptive statistics table for the original dataset with n = 1062 (modeling round A).

Descriptive statistics							
VarName	**Min**	**1st Q**	**Median**	**Mean**	**3rd Q**	**Max**	**NAs**
Age	0	1	3	2.66	4	6	-
Female	0	0	0	0.4755	1	1	-
Birth weight (g)	-	3.110	-	3.424	3.800	-	1
Birth length (cm)	-	49	-	50.47	52	-	244
Current weight (kg)	-	12	-	15.32	18	-	45
Current length (cm)	-	85	-	96.94	110	-	17
BMI	-	14.18	-	15.57	16.62	-	383
Overweight	0	0	0	0	0	0	339
Obese	0	0	0	0.0353	0	1	383
Pregnancy duration (w)	-	38	-	39.28	41	-	189
Premature pregnancy	0	0	0	0.063	0	1	189
Consultation visits	0	1	2	2.85	4	25	202
Postcode high SES	0	1	1	0.8154	1	1	-
Western mother	0	1	1	0.8569	1	1	-
Income centile	-	37	-	55.62	77	-	132
Mother education level	1	4	5	4.545	5	7	125
Family structure	0	1	1	0.9217	1	1	2
Smoking (1st caregiver)	0	0	0	0.2356	0	1	22
Fruits consumption	0	0	1	0.6055	1	1	109
Vegetables consumption	0	0	1	0.745	1	1	109
Biking to school (min)	0	10	16	17.38	20	50	942
Outside play (min)	0	0	20	17.45	30	50	764
Biking (min)	0	5	20	19.42	30	55	818
Fitness subscription	0	0	0	0.1352	0	1	707
Sports membership	0	0	0	0.2141	0	1	707
Urbanity index	1	2	2	2.617	4	5	-
Perceived health status	-1	1	1	1.206	2	2	707
Loneliness	-1	2	2	1.722	2	2	710
Nervous	-1	1	1	1.199	2	2	710
Upset	-1	0	1	0.9633	2	2	708
Friendships	0	1	1	1.304	2	2	710
Satisfaction	-1	1	1	1.443	2	2	710

Another important point to address is the existence of interaction terms. Such a term can be thought as a synergy effect between two variables which in real life are reinforcing or affecting each other (James et al., 2013). In the current case, such variables are the age and height. These variables combined reflect the growth of a child more accurately since there is a clear link between them at all times, especially during the preschool age of a child. For more information on those variables the reader is advised to see Chapter 4.

7.4.1. Hypothesis Testing

For the exploration of the factors explaining the weight in children of ages between 0 - 6 a series of models is conducted. In this chapter only selected models are presented which help accept or refute the statistical hypotheses set in the previous section. For the full cycle of modeling, the reader is prompted to visit the Appendix C. The tests presented above, are tested in this section with specific models. The decision on whether to accept or not the H_0 hypothesis are done based on the $p - value$ of the models, which is derived from the F-test score. The typical level of significance is used, namely 0.05.

Hypothesis Test A:

This hypothesis tests if the weight of preschool children is totally random. This is the simplest and most informative hypothesis test for someone who is not familiar or skeptical with the topic. To conduct this test, the following model is used:

Weight = lm(Weight ~ birth weight + AgeLength + AgeSquared + Female)

The model $p - value < 2.2e^{-16}$. As the p-value is much less than 0.05, this means that the model is significant and thus, the null hypothesis (H_0) that a child's weight is random ($\beta_i = 0$) can be refuted on this dataset. Hence there is a significant relationship between the independent variables of the linear regression model and the weight of children for this dataset.

The final regression equation is:

$$Weight = 7.436 + 0.569 * birthweight + 0.037 * AgeLength$$
$$-0.401 * AgeSquared - 0.918 * Female + \epsilon$$

From the used predictors the ones which are statistically significant on a 0.05 level are the Age*Length, AgeSquared and the Female variable. The birth weight did not appear statistically significant. The model evaluation is presented in Table 7.2. An aggregation of all the metrics is presented. What is non-satisfactory but is expected is the high VIF value, which is observed between the factor of Age*Length and AgeSquared which shows collinearity.

Table 7.2: Evaluation metrics of model A6, round A

Metrics							
Pvalue	F-stat	Adj R^2	RSE	MSE	AIC	BIC	max VIF
< 2.2e-16	101.3	0.284	6.221	38.513	6559.27	6588.77	19.9

Residuals description:
Here there are some comments regarding the four diagnostics plots from the linear regression.

1. Residuals vs Fitted values: No patterns suggesting non-linearity from this plot. Except of a few outliers which still did not affect the end result of a linear scatter at y=0. An extra residuals plot is designed and it is obvious that children with weight>25 kg here were really standing out of the model. These outliers need more exploration.

2. Normal QQ: The observations show that they follow a line (not at $y = x$, more at an 30°), the points in the -3,+3 quantile deviate from this line. This is a suggestion that the distribution of the residuals had a thicker tail than normal. The residuals do not pass the normality check.

3. Scale – Location: From this plots homoscedasticity can be observed. For this model an horizontal line is formed at (y = 0.5). This is a sign of a uniform variance of the residuals.

4. Residuals vs Leverage: From this plot, observations with big influence on the outcome of the regression can be observed. No values fall outside of Cook's distance dotted lines, which means that no observation is really drastically affecting the outcome of the model.

From the above results someone can conclude that the weight is not random. Of course the QQplot shows a clear sign of not perfect normality, however, there are not second degree patterns but nevertheless the fit could be improved. To conclude, there is an association between the weight in preschool children and biological factors such as the interaction term of Age*Length which shows the growth of the child and the gender of the child. This association is adequate to continue the exploration with a more complex model.

Hypothesis Test B:

This hypothesis tests if the weight of preschool children is related to pregnancy specific variables and also with variables related to the mother or the household. To conduct this test, the following model is used:

> Weight = lm(Weight ~ birth weight + AgeLength + AgeSquared + Female + pregnancy duration + premature pregnancy + western mother + mother education level + household income centile + family structure + Consultation visits + Smoking mother)

The model $p - value < 2.2e^{-16}$. As the p-value is much less than 0.05, this means that the model is significant and thus, the null hypothesis (H_0) that a child's weight is not related to pregnancy or family socioeconomic status, can be refuted based on this dataset. Hence, there is a significant relationship between the independent variables of the linear regression model and the weight of children for this dataset.

The final regression equation is:

$$Weight = 5.93 + 0.5 * birthweight + 0.05 * AgeLength -$$
$$0.81 * AgeSquared - 1.19 * Female - 0.096 * Pregnancyduration -$$
$$0.564 * PremPreg + 1.572 * westernmother + 1.781 * mothereducationlevel(2) +$$
$$4.066 * mothereducationlevel(3) + 2.629 * mothereducationlevel(4) +$$
$$1.98 * mothereducationlevel(5) + 1.443 * mothereducationlevel(6) +$$
$$2.699 * mothereducationlevel(7) + 0.01 * householdincomecentile -$$
$$2.297 * familystructure(1) + 0.737 * Consultationvisits -$$
$$0.848 * Smokingmother + \epsilon$$

The model evaluation is presented in Table 7.3. An aggregation of all the metrics is presented. The Adj R^2 is not satisfactory. However, the scope of the models is not prediction but exploration. the VIF levels show collinearilty. They appeared for the variables of the biological grow of the child (AgeLength, AgeSquared) and this moderates the performance of the model.

Table 7.3: Evaluation metrics of model D2, round A

Metrics							
Pvalue	F-stat	Adj R^2	RSE	MSE	AIC	BIC	max VIF
< 2.2e-16	9.769	0.189	7.27	51.43	4362.49	4447.19	20.47

The factors appearing statistically significant are: the Age*Length, the AgeSquared, the Female, the western origin mother, the family structure and the consultation visits. Family structure (both parents staying in the household) shows statistically significance of 0.01 level. This is an indication that the family choices affect the state of the child which is also supported by other studies from other countries (Adams et al., 2018), (Hope et al., 2018). The variables for the growth of the child an the consultation visits are the most significant, on a level lower than 0.001. Lastly, the origin of the mother (western) is statistically significant on a 0.05 level.
Residuals description:
Here there are some comments regarding the four diagnostics plots from the linear regression.

1. Residuals vs Fitted values: There is a pattern of non-linearity. The scatter plot is not concentrated at y=0, since it has a slight downwards linear trend. The model underestimates the target variable.

2. Normal QQ: The observations show that they follow a line (not at $y = x$, at an 30°), the points in the -3,+3 quantile deviate from this line. This is a suggestion that the distribution of the residuals had a thicker tail than normal and also the fact that the line is not at the $y = x$, this is a sign of a skewed distribution. The residuals do not pass the normality check.

3. Scale – Location: Heteroscedasticity is observed for this model. A slightly concave curve is formed. This is a sign of a non-uniform variance of the residuals.

4. Residuals vs Leverage: From this plot, observations with big influence on the outcome of the regression can be observed. No values fall outside of Cook's distance dotted lines, which means that no observation is really drastically affecting the outcome of the model.

From the results someone can conclude that the weight is of the children is associated with factors from the family. The QQplot shows a clear sign of not perfect normality. There are not second degree patterns but nevertheless, the fit could be improved. To conclude, there is an association between the weight in preschool children and the family structure which is adequate to continue the exploration with a more complex model.

Hypothesis Test C:

This hypothesis tests if the weight of preschool children is related to their environment and other factors of their daily habits, such as physical activity, nutrition, or specifics of the neighbourhood they grew up in. To conduct this test, the following model is used:

> Weight = lm(current weight ~ AgeLength + Female + Premature pregnancy + western mother + mother education level + household income centile + family structure + Consultation visits + smoking mother + Health status + Loneliness + Satisfaction + Friendships + Upset + Nervous)

The model $p - value = 2.32e^{-10}$ which is much less than 0.05. This means that the model is significant and thus, the null hypothesis (H_0) that a child's weight is not related to its environment ($\beta_i = 0$), can be refuted and the H_1 can be observably accepted based on this dataset. Hence, there is a significant relationship between the independent variables of the linear regression model and the weight of children.

The final regression equation is:

$$\begin{gathered} Weight = 21.07 + 0.041 * AgeLength - 1.341 * Female - 0.704 * prematurepreg + \\ 0.69 * westernmother - 3.265 * mothereducationlevel(3) - \\ 4.106 * mothereducationlevel(4) - 4.542 * mothereducationlevel(5) - \\ 5.847 * mothereducationlevel(6) - 4.949 * mothereducationlevel(7) + \\ 0.018 * householdincomecentile - 2.547 * familystructure(1) - \\ 0.56 * Consultationvisits - 0.412 * smokingmother + \\ 0.017 * healthstatus(0) + 0.358 * healthstatus(1) + 0.853 * healthstatus(2) - \\ 1.469 * loneliness(1) - 1.478 * loneliness(2) - 8.993 * satisfaction(1) - \\ 9.208 * satisfaction(2) - 1.883 * Frienships(1) - 1.828 * Friendships(2) - \\ 0.522 * Upset(0) - 1.059 * Upset(1) - 1.699 * Upset(2) - \\ 1.762 * Nervous(0) - 1.838 * Nervous(1) - 1.482 * Nervous(2) + \epsilon \end{gathered}$$

The model evaluation is presented in Table 7.4. An aggregation of all the metrics is presented. The Adj R^2 is really high compared to the other models. This is due to the fact that this model has only 89 DOF since a lot of observations were dropped from the model due to increased missing data rates. The VIF shows very low collinearity in the data, which helps the model perform better.

Table 7.4: Evaluation metrics of model H4, round A

Metrics							
Pvalue	F-stat	Adj R^2	RSE	MSE	AIC	BIC	max VIF
2.32e-10	5.591	0.5235	2.46	4.57	574.32	657.44	1.9

From this model, the factors about the growth of the child, the gender, the education levels of the mother (levels 4-7), the family structure, the consultation visits, the satisfaction levels and the friendships proxy appear statistically significant on a level equal or below the 0.05 level. It is interesting that an increasing education level of the mother leads to a more negative association with the weight of the child. This potentially captures the importance of having knowledge as a parent and be aware about different nutrition and health issues. Also, this could potentially mean that educated mothers are more prone to follow health advice since they could acknowledge the importance of medical advice to a higher extent compared to people who are less literate when it comes to statistics, trends and medical practices in general. Other studies about childhood obesity showed similar results regarding the education (Chalkias et al., 2013), (Grow et al., 2010). The consultation visits are also affecting the weight negatively and this also proves that the Youth and Family Centers provide with advice and educate the new parents about the important aspects they should consider when growing up children.

Another significant finding has to do with the proxies for the mental health of the child. Both satisfaction levels and friendship status show statistical significance of less than 0.05. This is a crucial finding about the association with the weight. It proves that the psychology of the child, which can be affected by different factors, can directly decrease a child's weight, the more "positive" and social the child is. Psychology is hard to measure since it is such a complex state, but nevertheless in the current dataset it is observantly very crucial in the weight of preschool children.

Residuals description:
Here there are some comments regarding the four diagnostics plots from the linear regression.

1. Residuals vs Fitted values: No patterns suggesting non-linearity from this plot. There are only a few outliers at the lower end of the fitted values for which the residuals are higher. Overlall, the red line follows almost a horizontal trend around $y = 0$.
2. Normal QQ: The observations show that they follow a line exactly at $y = x$. This is a sign of a perfect normal distribution of the residuals.The residuals pass the normality check.
3. Scale – Location: Slight heteroscedasticity is observed for this model. Uniform variance is not indicated, since the line formed slightly curved, showing heteroscedasticity. This is a sign of a non-uniform variance of the residuals.
4. Residuals vs Leverage: From this plot, observations with big influence on the outcome of the regression can be observed. No values fall outside of Cook's distance dotted lines, which means that no observation is really drastically affecting the outcome of the model.

From the results someone can conclude that the weight of children is affected by their environment. The environment here is approximated by the use of the psychology proxies, since the children grow, live and play in different environments, thus getting affected by them. A strong influence exists for the consultation visits of the parents to the Youth and Family centers. This is an indication of how much the parents used the free services municipalities offer for educating and informing them about different health topics or "good practices".

7.4.2. Outliers analysis and discussion

Since the first modeling round is completed, the need for a close inspection of the outliers is needed. For most models, there are specific observations coming up and making the model to not perform that well or affecting significantly via the high Cook's distance the slope of the regression. Even if the scope of modeling is not prediction, but exploration, it is still important to see why these values show so distinct difference from the rest of the data. From visual inspection of the diagnostic plots 14 outliers are identified as the ones which show up as high leverage point or the ones which deviate a lot from the normal QQ plots. In the Table 7.5, the descriptive statistics are calculated.

Table 7.5: Descriptive statistics table for the outlier values of the dataset, n = 14.

Descriptive statistics							
VarName	**Min**	**1st Q**	**Median**	**Mean**	**3rd Q**	**Max**	**NAs**
Age	0	4	4	3.357	4	4	-
Female	0	0	0	0.0714		1	-
Birth weight (g)	-	3252	-	3488	3692	-	-
Birth length (cm)	-	49	-	50	52.25	-	2
Current weight (kg)	-	17	-	38.07	32	-	-
Current length (cm)	-	91.25	-	100.36	112.25	-	-
BMI	-	13.62	-	19.51	21.62	-	3
Overweight	0	0	0	0	0	0	3
Obese	0	0	0	0.3636	1	1	3
Pregnancy duration (w)	-	38.25	-	39.36	40	-	-
Premature pregnancy	0	0	0	0	0	0	-
Consultation visits	0	1	1	3.643	3.5	25	-
Postcode high SES	0	0.25	1	0.7143	1	1	-
Western mother	0	1	1	0.8571	1	1	-
Income centile	-	42.25	-	59.36	84	-	-
Mother education level	2	4	2	4.286	5	6	-
Family structure	0	1	1	0.8571	1	1	-
Smoking (1st caregiver)	0	0	0	0.2143	0	1	-
Fruits consumption	0	1	1	0.7692	1	1	1
Vegetables consumption	0	0	1	0.6923	1	1	1
Biking to school (min)	6	10	15	15.75	20	30	6
Outside play (min)	0	15	30	23.27	30	45	3
Biking (min)	0	27.5	30	25	30	30	6
Fitness subscription	0	0	0	0.09	0	1	3
Sports membership	0	0	0	0.1818	0	1	3
Urbanity index	1	1	3	2.714	4	5	-
Perceived health status	0	1	2	1.455	2	2	3
Loneliness	1	2	2	1.909	2	2	3
Nervous	0	1	2	1.364	2	2	3
Upset	0	0.5	1	1	1.5	2	3
Friendships	0	1	1	1.182	2	2	3
Satisfaction	1	1	2	1.6	2	2	4

What is interesting to notice is, the outliers are mostly male children. What is more there is a distinct profile showing up here. The psychical activity proxies all indicate very active children compared to the summary statistics of the whole dataset. They may not all have sports or fitness subsctipions but these children show really high biking activity on a daily basis (see rows of: *Biking to school (min)* and *Biking (min)*). The mean values for the transportation minutes is 15.75 minutes biking and for the other, they show a mean value of 25 min. These indicators show a highly active child on a daily basis. Similar results are observed for the daily ”play” of the child, variable *Outside play (min)*, with a mean of 23.27 min which is a very healthy and feasible time for a child to be active and engage in a mind and body activity. This is all supported since the parents have responded with a very positive *Perceived health status* with a mean of 1.455 out of 2. Lastly, the nutrition patterns are really good compared to the overall data, since there is a mean of 0.76 and 0.69 respectively for *Fruits consumption* and *Vegetables consumption*, where 1 would mean that these children fulfill the Dutch nutrition standards.

In addition to these findings, the *Urbanity index* is on average at 2.714 which is a sign of a moderate urban environment. This indication supports and likely facilitates the amount of time these children engaged in physically involving activities. The odd observation is, however, the weight or the BMI of these group of children. Of course specific observations cannot be disclosed, but from the current bio-metrics rows it is clear that these children are on a higher level of BMI, with the 3^{rd} quartile to be equal with 21.62 which justifies the mean value of 0.36 for the obesity index (*Obese* variable). Possibly, these children have either a very high weight for their age and they still manage to keep a healthy lifestyle or the other hypothesis is that these children fall under the category of an invalid datapoint. Since the data originate from a survey it is possible that the person filling in the questionnaire for the child misspelled the weight thus, leading to a wrong BMI value and now computationally these children end up in the outlier of the initial 1062 sample. Nevertheless, no matter the case, these observations are selected to stay in the study for completeness and for testing the hypothesis that potentially some of these children are indeed with correct weight and height. After all, the scope is not to eliminate those children to achieve a better performance score for the models, but to include them and explore with an open mind what can the data reveal for the Dutch society.

7.4.3. Discussion of Modeling Round A

The first round of models is completed after designing 23 different models and selecting three of them to be used for the hypothesis testing. Of course there are limitations to the models in terms of data quality and missingness, but it is clear that an association for the Dutch children between family characteristics, neighborhood environment and a preschool child's weight, exists. The variables which showed to be significant are supported from the theoretical framework. Namely, the biological growth interaction variable Age*Length, parents characteristics, such as family structure, consultation visits and mother's education levels. It is interesting to see that the higher the level of education of the mother, the more negative its beta coefficient becomes. In this model, the absolute value of the beta coefficients of the education level of the mother, ranged from -3.265 up to -5.847 in *kg*, which shows that this is a high magnitude variable.

Outside of the family environment, the important ones are the psychology proxies. When variables regarding the psychological state of the child are included, in most iterations they appear statistically significant. For these iterations the factors which have the highest significance levels are child's satisfaction and friendships. The variables regarding the mental state of the child are something rarely explored in literature. This can be due to the fact that is very hard to measure such variables. To get such measurements, the GECON survey asked the parents of the children to assess the state of their child being happy, lonely or social in the course of the last month. This measurement has its limitations , since it doesn't reflect the mental state across a long period of time, however, it is the best solution for the given situation. These variables can include bias since the parents respond for the state of their children but nonetheless, the parent is the best source available to get such information from, given the age of the subject of the survey.

For the models which are run but not documented in the hypothesis testing, some have interesting results. Firstly, the variable of urbanity in some models is significant on a level equal and less than 0.05. The levels of urbanity showing these results are the levels 2, 3 and 4. These are the strong urban, urban, moderate and less urban. This index is assigned by CBS, based on the urbanity levels which are calculated from the absolute address density of a km^2 area of land. Lastly, it is expected for the variables measuring physical activity to be influential on the target variable , however this is not the case. The same applies for the variables describing the nutrition patterns of the children. This lack of significance may be attributed to actual insignificance or to the extreme lack of data for those variables. The models where these variables where included run with a very small sample size, thus, the results could have been different if a whole sample was available.

7.5. Results from Round B

For every model the missingness of data is a crucial challenge. Thus, data imputation is considered as the way to address this. For this round of modeling, the same hypotheses are tested on a mixed dataset with both real and imputed values. The presented models are built for exploration purposes and not for prediction purposes. Thus, the interest lies in identifying important variables in the explanation of a child's weight during his/her early years and to compare this round with artificial data to the one conducted with the real data. The new updated descriptive statistics are presented in Table 7.6. The labels *Overweight* and *Obese*, are not imputed since such an action makes no sense, given the nature of the variable and the fact that these variables are not used in the modeling round.

Table 7.6: Descriptive statistics table for the imputed dataset with n = 1062 (modeling round B).

Descriptive statistics							
VarName	**Min**	**1st Q**	**Median**	**Mean**	**3rd Q**	**Max**	**NAs**
Age	0	1	3	2.66	4	6	-
Female	0	0	0	0.4755	1	1	-
Birth weight (g)	-	3.110	-	3.424	3800	-	0
Birth length (cm)	-	49	-	51.67	53	-	0
Current weight (kg)	-	12	-	15.4	18	-	0
Current length (cm)	-	85	-	96.99	110	-	0
BMI	-	14.51	-	16.11	17.36	-	0
Overweight	0	0	0	0	0	0	339
Obese	0	0	0	0.0353	0	1	383
Pregnancy duration (w)	-	38	-	39.34	41	-	0
Premature pregnancy	0	0	0	0.057	0	1	0
Consultation visits	0	1	1	2.508	3	25	0
Postcode high SES	0	1	1	0.8154	1	1	-
Western mother	0	1	1	0.8569	1	1	-
Income centile	-	38	-	55.78	77	-	0
Mother education level	1	4	5	4.559	5	7	0
Family structure	0	1	1	0.9209	1	1	0
Smoking (1st caregiver)	0	0	0	0.2316	0	1	0
Fruits consumption	0	0	1	0.5942	1	1	0
Vegetables consumption	0	0	1	0.7589	1	1	0
Biking to school (min)	0	10	20	17.4	20	50	0
Outside play (min)	0	0	15	16.63	30	50	0
Biking (min)	0	0	20	18.99	30	55	0
Fitness subscription	0	0	0	0.1017	0	1	0
Sports membership	0	0	0	0.178	0	1	0
Urbanity index	1	2	2	2.617	4	5	-
Perceived health status	-1	1	1	1.135	2	2	0
Loneliness	-1	2	2	1.753	2	2	0
Nervous	-1	1	2	1.515	2	2	0
Upset	-1	0	1	0.8493	1	2	0
Friendships	0	1	1	1.266	2	2	0
Satisfaction	-1	1	1	1.339	2	2	0

7.5.1. Hypothesis Testing

The same hypotheses are used again to explore the differences in the results when the imputation of the missing values is done. This can unveil variables which can potentially be significant but due to the extreme missingness for specific observations, they face information loss. One major example is observed in the dramatic decrease of the degrees of freedom in the model used for *Test C* in Round A. The selected model run on 118 observations, when the total dataset is composed of 1062 observations. Thus, the aim of this section is to observe how the missing data affects the outcomes so far, by conducting the same hypotheses tests again.

Hypothesis Test A:

This hypothesis tests if the weight of preschool children is totally random. To conduct this test, the following model is used:

Weight = lm(~ birth weight + AgeLength + AgeSquared + Female)

The model $p - value < 2.2e^{-16}$. As the p-value is much less than 0.05, this means that the model is significant and thus, the null hypothesis (H_0) that a child's weight is random is refuted on this dataset and thus, the alternative hypothesis, H_1 can be accepted. Hence there is a significant relationship between the independent variables of the linear regression model and the weight of children for this dataset.

The final regression equation is:

$$Weight = 7.22 + 0.616 * birthweight + 0.037 * AgeLength$$
$$-0.409 * AgeSquared - 0.871 * Female + \epsilon$$

The model evaluation is presented in Table 7.7. An aggregation of all the metrics is presented. What is non-satisfactory but expected is the high VIF value, which is observed between the factor of Age*Length and Age*Squared which show collinearity. This impedes the performance of the model, however it still clearly shows that all included variables are statistically significant below the 0.05 level.

Table 7.7: Evaluation metrics of model A6, round B

Metrics							
Pvalue	F-stat	Adj R^2	RSE	MSE	AIC	BIC	max VIF
< 2.2e-16	108.1	0.287	6.177	37.98	6888.4	6918.2	19.59

Residuals description:
Comments regarding the four diagnostics plots from the linear regression.

1. Residuals vs Fitted values: No patterns suggesting non-linearity from this plot. Except of a few outliers which still did not affect the end result of a linear scatter at $y = 0$.

2. Normal QQ: The observations show that they follow a line (not at $y = x$, more at an 25°), the points in the -2,+2 quantile deviate from this line. This is a suggestion that the distribution of the residuals had a thicker tail than normal. The residuals do not pass the normality check.

3. Scale – Location: From this plots homoscedasticity can be observed. For this model an horizontal line is formed at (y = 0.4). This is a sign of a uniform variance of the residuals. Roughly 10 outliers exist, which still do not affect the final plot.

4. Residuals vs Leverage: From this plot, observations with big influence on the outcome of the regression can be observed. No values fall outside of Cook's distance dotted lines, which means that no observation is really drastically affecting the outcome of the model.

From the above results someone can conclude that the weight is not random. Of course the QQplot shows a clear sign of not perfect normality of the residual values. There are not second degree patterns but nevertheless, the fit can be improved. To conclude, there is an association between the weight in preschool children and biological factors such as the interaction term of Age*Length, AgeSquared which shows the growth of the child. What is more, the gender of the child also shows significant and specifically on a 0.01 level. This association is adequate to continue the exploration with a more complex model.

Hypothesis Test B:

This hypothesis tests if the weight of preschool children is related to pregnancy specific variables and also with variables related to the mother or the household. To conduct this test, the following model is used:

Weight = lm(Weight ~ birth weight + AgeLength + AgeSquared + Female + pregnancy duration + premature pregnancy + western mother + mother education level + household income centile + family structure + Consultation visits + Smoking mother)

The model $p - value < 2.2e^{-16}$. As the p-value is much less than 0.05, this means that the model is significant and thus, the null hypothesis (H_0) that a child's weight is not related to pregnancy or family socioeconomic status, can be refuted based on this dataset. Hence, the alternative hypothesis, H_1 is accepted and this means that there is a significant relationship between the independent variables of the linear regression model and the weight of children based on this dataset.

The final regression equation is:

$$Weight = 8.03 + 0.78 * birthweight + 0.048 * AgeLength-$$
$$0.56 * AgeSquared - 0.771 * Female - 0.1 * Pregnancyduration-$$
$$0.341 * PremPreg + 0.772 * westernmother + 0.283 * mothereducationlevel(2)+$$
$$0.915 * mothereducationlevel(3) + 0.044 * mothereducationlevel(4)-$$
$$0.396 * mothereducationlevel(5) - 0.883 * mothereducationlevel(6)-$$
$$0.97 * mothereducationlevel(7) + 0.005 * householdincomecentile-$$
$$1.482 * familystructure(1) + 0.632 * Consultationvisits-$$
$$0.327 * Smokingmother + \epsilon$$

The model evaluation is presented in Table 7.8. An aggregation of all the metrics is presented. What is non-satisfactory but expected is the high VIF value, which is observed between the factor of Age*Length and Age*Squared which show collinearity and impedes the model of performing best. However, regarding significance of variables, the ones which show significance of below 0.05 are the birth weight, the Age*Length, AgeSquared, the gender, the united family structure and the consultation visits. Comparable results are shown with the run on the actual data on, presented in Section 6.4, showing that the imputation did not produce irrelevant conclusions.

Table 7.8: Evaluation metrics of model D2, round B

Metrics							
Pvalue	F-stat	Adj R^2	RSE	MSE	AIC	BIC	max VIF
< 2.2e-16	30.17	0.318	6.041	35.88	6854.09	6948.48	23.93

Residuals description:
Comments regarding the four diagnostics plots from the linear regression.

1. Residuals vs Fitted values: No patterns suggesting non-linearity from this plot. Except of a few outliers, 5 specific observations, which still did not affect the end result of a linear scatter at $y = 0$.

2. Normal QQ: The observations show that they follow a line (not at $y = x$, at approximately 25°), the points in the +2 quantile and above deviate from this line. This is a suggestion that the distribution of the residuals had a thicker tail than normal. Also the different intercept angle is a skewness sign. The residuals do not pass the normality check.

3. Scale – Location: From this plots homoscedasticity can be observed. For this model an horizontal line is formed at (y = 0.4), no specific outliers. This is a sign of a uniform variance of the residuals.

4. Residuals vs Leverage: From this plot, observations with big influence on the outcome of the regression can be observed. For this model only 2 observations fall outside of the Cook's distance plots. The one falls outside of the 1^{st} line of Cook and the other

outside of the 2^{nd}. These observations are the ones deviating significantly in the Normal QQ plots. Both these datapoints have extreme weight values, showing signs for data collection issues or mistakes in the typing of the weight, since the data is self-reported.

From the results it can be concluded that the weight of the children is associated with factors from the family. Although the pregnancy factors are expected to affect the weight of young children more, this is not the case. In this model the education of the mother does not show significance, where in the real data (Modeling Round A) it did. The statistically significant factor in this model are the birth weight, the Age*Length interaction term, the AgeSquared and the gender of the child. All of these are statistically significant on a level of 0.05 and less. The other significant variable is family structure. It has a negative correlation with the weight which shows when parents are living together, the child can probably maintain a healthier weight. Furthermore, the consultation visits appear extremely significant, on a level of less than 0.001. This is very interesting since it shows that even with the algorithm of imputation, the variable is a crucial to the explanation of a child's weight. In terms of the diagnostic plots, the QQplot shows a clear sign of a skewed distribution with thicker tails. There are not second degree patterns but nevertheless the fit could be improved or a transformation of the data could be considered. This is a sign that the linear model here is not the perfect choice. To conclude, there is an association between the weight in preschool children and the family structure which is adequate to continue the exploration with a more complex model.

Hypothesis Test C:

This hypothesis test is designed to assess if the weight of preschool children is related to their environment and other factors of their daily habits, such as physical activity, nutrition, or specifics of the environment they grew up in. To conduct this test, the following model is used:

> Weight = lm(~ AgeLength + Female + western mother + mother education level + household income centile + family structure + Consultation visits + neighbourhood SES + Urbanity Index + Minutes biking + Minutes biking to school + outside play + Fitness subscription + Sports membership)

The model $p - value < 2.2e^{-16}$. As the p-value is much less than 0.05, this means that the model is significant and thus, the null hypothesis (H_0) that a child's weight is not related to its environment or family condition, can be refuted based on this dataset. Hence, the alternative hypothesis, H_1 is accepted and this means that there is a significant relationship between the independent variables of the linear regression model and the weight of children based on this dataset.

The final regression equation is:

$$\begin{gathered} Weight = 9.95 + 0.02 * AgeLength - 1.006 * Female - 0.959 * PremPreg + \\ 0.975 * westernmother - 0.736 * mothereducationlevel(2) + \\ 0.303 * mothereducationlevel(3) - 0.559 * mothereducationlevel(4) - \\ 1.039 * mothereducationlevel(5) - 1.618 * mothereducationlevel(6) - \\ 1.132 * mothereducationlevel(7) + 0.003 * householdincomecentile - \\ 1.301 * familystructure(1) + 0.442 * Consultationvisits - 0.403 * neighbourhoodSES(1) - \\ 0.031 * Urbanityindex(2) + 1.107 * Urbanityindex(3) - 0.399 * Urbanityindex(4) - \\ 0.202 * Urbanityindex(5) + 0.016 * MinBiking + 0.01 * MinBikingSchool - \\ 0.018 * MinOutsidePlay + 1.245 * FitnessSubscription - 0.123 * SportSubscription + \epsilon \end{gathered}$$

The model evaluation is presented in Table 7.9. An aggregation of all the metrics is presented. The VIF value is significantly lower, no collinearity is observed.

Table 7.9: Evaluation metrics of model G2, round B

Metrics							
Pvalue	F-stat	Adj R^2	RSE	MSE	AIC	BIC	max VIF
< 2.2e-16	20.86	0.291	6.159	37.12	6900.11	7019.34	1.78

Residuals description:
Comments regarding the four diagnostics plots from the linear regression.

1. Residuals vs Fitted values: No patterns suggesting non-linearity from this plot. Except of a few outliers after the weight of 30kg which deviate from the horizontal scatter. This is still considered as a linear scatter at $y = 0$.
2. Normal QQ: The observations show that they follow a line of 20°slope and not at $y = x$. There are some observations at the +2 quantile and upwards which deviate from this line. This is a sign that more children with heavier weight are concentrated on the tails of the distribution. These data points include the ones showing up on the outliers analysis presented in 7.4.2. Hence, the residuals do not pass the normality check.
3. Scale – Location: From this plots homoscedasticity can be observed. For this model an additive linear trend is created, at about y = 0.8. It is not concave, however after weight of 20 kg, there is a slight upwards trend of 5°. Perfect uniform variance of the residuals is not maintained, but it is still very satisfactory with no major deviations from homoscedasticity.
4. Residuals vs Leverage: From this plot, observations with big influence on the outcome of the regression can be observed. Two values fall outside of Cook's distance dotted lines. These observations are the ones which usually show up in the extremities of the other diagnostic plots as well. These values are the ones explained in the Section 7.4.2, where the outlier analysis is done.

From the results it can be concluded that the weight of the children is associated with factors from the family and the environment. This model experimented with the addition of physical activity proxies, which show less influence than expected. Additionally, for environmental proxies this model includes the urbanity index and the neighborhood socioeconomic status. From the fit with the imputed data, the significant variables which have a level of statistical significance equal or less than 0.05 are the gender, the Age*Length growth variable, the united family structure, the consultation visits, the urbanity level (3) which is the moderately urban and the fitness subscription of a child.

This outcome is in accordance with the analysis framework, since the Environment and Community pillar are two very important pillars when it comes to how they affect daily patterns of a child. The family structure variable continues to have a negative association with the weight, exactly as in Modeling Cycle A, which shows that a stable home environment can help children maintain a healthier weight. What is more, clearly in terms of available time for raising a child, when tasks are divided over both parents this potentially allows for better options for the health and lifestyle of the child. The urbanity index of moderately urban areas and the fitness subscription show a positive relationship, which is not so logical, since someone might think that these variables would allow for a more active childhood lifestyle with a lower weight. However, since the model is assessing the weight and not the obesity of a child, a claim that these variables are associated with unhealthy weight cannot be made. The important finding is that a statistically significant association exists, shedding light into the complex nature of weight gain of preschool children.

In terms of the diagnostic plots, the QQplot shows sign of a non-normal distribution, which is skewed and has thicker than normal tails. This means that the choice of modeling is not so appropriate and there is room for data improvement (data transformation or scaling) or selecting another model. The imputation helps to explain some variables which from the real data models faced information loss due to missing values. Specifically, it helps understand the existence of relationships between psychical activity patterns which earlier were not discernible. However, imputed data is not a panacea solution. In case of a real dataset with higher completeness levels the analysis needs to be conducted again to validate the relationships between the predictors of the weight in children. To conclude, there is an association between the weight in preschool children and their broader environment.

7.5.2. Discussion of Modeling Round B

The second round of models is completed after designing 23 different models and selecting three of them to be used for the hypothesis testing. The data which is used for this round is the initial dataset with filled in missing values with the use of multiple imputation. The quality issues which limited the analysis in the previous modeling round, are less prominent when the imputed dataset is used. The models are able to consider more observations, thus limiting extreme non-linear patterns which are observed in the first modeling round, with behavior which is linear and closer to normality.

Some relationships, such as the one with the fitness memberships variable are unveiled, however, the biking patterns of the child were expected to be significant and appear not. What is also brought into light from the use of the imputed data is a statistically significant relationship with the consumption of fruits and the weight of children. This model is not documented in the results but it is nonetheless worth mentioning (see Appendix C, model F). The association is significant at a level of 0.01 and is associated positively with the weight. Thus, further research is required into the nutritional patterns and the weight of children. Potentially better proxies can be used in future studies. This outcome would have not been possible to be identified if it was not for the data imputation, since during Modeling Round A, these variables faced extreme information loss.

Additionally, when someone closely compares the Tables 7.1 and 7.6, where the descriptive statistics of the datasets are presented, for both modeling rounds, it is clear that the imputed values are really close to the real ones. The 1^{st}, 3^{rd} quartile and the $mean$ values are consistent up to the first decimal point, in most cases. This shows that the imputed dataset does not include significantly more variance in the data than the original, but it still adds bias, which originated from the algorithm's assumptions. As mentioned by Mittag, the researcher is confronted with a dilemma of bias from omitting all-together the variables which are high in missingness, or bias from the imputation algorithm assumptions. In the current case, dropping the variables which had high missing data rates, is not considered as viable, since these variables conceptually are very important for the analysis framework (for more details see Chapter 4). The magnitude of bias "depends on the signal-to-noise ratio and is larger the lower this ratio is" (Mittag, 2013). Hence, the imputation is necessary to facilitate the linear model performance and to fully explore the extend the psychological, nutritional and fitness related variables have on the weight of children. The inherent assumptions of the imputation algorithm may have been violated, since not all variables are linear in nature, which then introduces bias in the model, by filling in with new values while assuming linearity. Another issue is that imputation introduces uncertainty, beyond the sample's variation to the model (Mittag, 2013). What is meant by this is that the variation from the imputed values, does not represent the variation from the real world, introducing thus another component of uncertainty.

To conclude, it is clear that an association for the Dutch children between family characteristics, neighborhood environment and a preschool child's weight, exists. Even with the use of imputed data, the relations with the growth variables and the gender are maintained in this modeling round as well. The findings about family structure, urbanity and consultation visits are also maintained. What is interesting is that the association with the mother education level and the psychology proxies is eliminated. This could be a sign of a poor imputation, however the improvement of the data imputation algorithm is outside of the scope of the current thesis. On the other hand, after the imputation, the variable for fruits consumption and the variable for the fitness subscription are identified as significant, showing the need for a more detailed research into these relations with a fuller real dataset. For these reasons, imputation of data is desirable (and highly suggested for survey datasets on health

(Siew et al., 2013), (Mittag, 2013)) in the current case and helped with the validation of the results. However, the interpretation of the results should be careful, especially when it comes to proposing policies.

7.6. Validation

The validation method of the full modeling cycle is composed of two main components: internal validation of the models with comparison of the results of the real data (Modeling round A) with the outcomes of the imputed data (Modeling round B) and external validation with conceptual comparison of the current work with relevant studies regarding childhood weight and obesity. First and foremost, the analysis is driven by the use of a custom framework, expanded from the Quality-of-Life framework, RIVM uses for health related analyses. This framework use is first documented in 2003 by van Kamp et al. and its expansion is done with the use of frameworks from 2006 capturing specifically determinants of health and health inequity, defined by Dahlgren and Whitehead. Hence, the analysis conceptually is relevant to the latest research approaches to mitigate public health risks and ameliorate the overall health quality and equity.

In addition, regarding the internal validation, as it is mentioned in the discussion of the Modeling round B, the results from the imputed dataset are meaningful and no sign of extreme irrelevant values is shown (Table 7.6). The variables which appear statistically significant in both modeling rounds are:

- Birth weight: the registered birth weight of a child
- Age*Length: interaction variable showing the growth of a child
- AgeSquared: variable representing the age of a child
- Female: the gender variable
- Family structure: variable showing if both parents reside with the child
- Consultation visits: variable showing the amount of visits the parents did to the municipal Youth and Family Center.
- Urbanity index: variable indicating the level of address density.

This shows that the imputation confirms the results for the variables which are mostly complete by default. The variables which are observantly statistically significant in Modeling Round A but had a high level of missingness do not seem significant in the imputed dataset modeling round, B. This is a point for future research. The data imputation algorithm if it is fed with data high in missing values, the accuracy is compromised. More validation needs to be conducted to check the actual significance of the results with the use of another real dataset.

Lastly, the external validity is proven since other studies come up with similar results. Especially for the factors which are not concluded in both the modeling rounds as significant, it is shown that it is worth exploring and assessing the nature and inter-relations of such proxies. For example physical activity variables are shown significant in the study by Vanhala et al. (2009). What is more, from the literature the consumption of fruits and vegetables is supported in such studies (Vanhala et al., 2009), (Hope et al., 2018), (Franchetti & Ide, 2014). Similarly, research has proven the significance for socioeconomic variables (Grow et al., 2010), (Sharifi et al., 2016), (Williams et al., 2018). Nevertheless SES proxies were only found significant during modeling round B, with the use of imputed data. In terms of education, the results from the analysis are matching with what CBS has concluded in previous years. They mention that no matter the age group, being overweight is a phenomenon which is more popular among lower educated citizens (CBS, 2016). Last but not least, as far as the mental health of the child proxies are concerned, no specific study can be found. The only relatively similar is a British study of maternal distress and its association with obesity in late childhood, at the age of 11 years, where they concluded that the mental state of the mother affects the child (Hope et al., 2018). This can also be reflected in the current dataset since, from modeling round A, the variables of child satisfaction and friendships appeared to be negatively associated with a child's weight.

7.7. Final Discussion

This chapter presents the main parts of the analysis and the respective findings. Its structure is guided by the use of three main hypotheses regarding the weight of children and how it is affected from diverse, mainly non-biological factors. The hypotheses sequentially become more and more complex, showing the multifaceted nature of child weight gain. During the hypotheses exploration, discussion about the specifics of each model is presented. Additionally, comments about the performance or and the suitability of the method are provided. To summarise, the statistically significant factors from the full modeling cycle are presented in Table 7.10. The name of the variables, the statistical significance and the magnitude (the value of the beta coefficient of the variable from the model results) are stated. The last column specifies the modeling round where the result is observed. It is important to know in which modeling round the results refer to, since variables which are observantly significant only in Modeling Round B, with the imputed data, the policy interpretation should be done with caution.

Table 7.10: Table for significant variables from all models and both modeling rounds.

Significant Variables			
Name	**Significance level**	**Magnitude (kg)**	**Modeling Round**
Birth weight	< 0.001	0.5 - 1.9	A, B
Height ratio	< 0.001	0.45 - 9	A, B
Age*Length	< 0.001	0.02 - 0.05	A, B
AgeSquared	< 0.001	-0.56 - 0.81	A, B
Female	0.01	-0.66 - -1.3	A,B
Family structure	0.01	-1.3 - -2.5	A,B
Consultation visits	< 0.001	-0.56 - 0.73	A, B
Urban Index (3)	≤0.01	1.1 - 2.7	A, B
Urban Index (4)	0.01	-0.39 - 2.9	A, B
Fitness subscription	0.05	1.24	B
Satisfaction (0,1,2)	≤0.01	-8 - -12	A
Friendships (1)	0.05	-1.8 - -1.9	A
Mother education (4 - 5)	≤0.05	-3.92 - -4.54	A
Mother education (6 - 7)	≤0.05	-4.65 - -5.63	A
Household income	0.01	0.005 - 0.018	A
Western mother	0.05	0.69 - 1.57	A, B
Fruits consumption	0.01	0.87	B

There are variables appearing observantly significant in both modeling rounds, without and with imputed data. These variables are the main variables which are used as policy levers, to address the final research question of the thesis. The variables which appear statistically significant in modeling round A are also be used for policy proposal since they stem from the real dataset. The variables supported only by the round B, are reflected upon with caution, since the use of imputed data could potentially not capture well enough the reality of the Dutch society. When it comes to interpreting model parameters two factors need to be considered. First of all, the absolute value of the beta coefficient has to be taken into account since it reflects the magnitude of the effect of this variable. This shows the *policy significance* of a variable. Additionally, the *statistical significance* has to be considered, since it shows how important the variable is in the model. For policy proposal, statistical significance is not enough for decision makers to consider a variable. Apart for this, they are interested in the magnitude of the variable in case they select it for a *policy lever*. From the current results, someone needs to consider the unit of analysis (kg) and the average weight of children between the ages of 0 – 6 years old. The mean value of the *current weight* from Table 7.1, is 15.32 kg. The 1^{st} quartile value is 12 and the 3^{rd} quartile is 18. Thus, when the beta coefficient is around 1.5 - 3 kg then this covers half or all the spectrum of the quartile. Such a change in weight is worth investing in, since it is highly impactful for the weight of the child, especially at such a young age.

From the results in Table 7.10 and the reasoning presented above, the variables which are policy significant are the ones which decision makers can expect to yield the most considerable change. What is meant with this term is that if resources are allocated on such variables, then the change which can occur will be most probably visible on a societal level. For these reasons, variables such as birth weight, height ratio, family structure, western origin are constitutional characteristics which need to be considered at all times by the actors in the arena of childhood obesity and health. Since these features are the core of the *Social Determinants of Health* framework (Figure 3.1), they should at all times be used to drive the design of all policies. For the second layer, which refers to environment characteristics, the important policy lever is the urbanity index. The urban levels 3 and 4 (moderate and less urban respectively), showed to increase a child's weight by 1 to about 3 kg, which could potentially be useful to be used when designing policies and guide also further research to why there is such a correlation.

The third layer, refers to living conditions. Under this layer, the psychology proxies of satisfaction and friendships are included since the psychological state of a child is the closest proxy found to be policy significant from the modeling. It is observed during the real dataset modeling round and it showed the highest magnitude of all variables on weight. This could be observed because of the information loss since those models run on a segment of the data, based on the respondents who provided full answers. During the imputed modeling round, the significance is not maintained. This can be due to a non-valid imputation or due to a true lack of significance on a bigger sample. More research needs to be conducted with real data to validate those results. Lastly, the last layer of general socioeconomic factors, corresponds to the policy significant result of mother's education. All levels of from 4 - 7 (pre BSc - doctorate or similar degree), show an impact of 4 - 5.5 kg decrease. This is a very significant change in weight, especially for such ages and the highest the education level, the higher the absolute magnitude of the beta is. Similarly as with the psychological proxies, these variables are observed as policy significant during Modeling Round A solely. Nevertheless, this variable appears significant from the literature review for the health of a child. Thus, it is interesting why with the imputation, the significance is lost.

The issue of missing data needs to be discussed. As the data is derived from a survey, it is clear that humans affect the missing values. For this reason, two modeling cycles are conducted, both consisting from the same models. The only difference is that Modeling Round B uses the original data after they have been imputed. In this way, the results can be compared, more robust explanations about the drivers of the weight can be provided. However, every method has its own assumptions and limitations. The algorithm used for data imputation assumes linearity in the variables being predicted and this is a strong, limiting assumption. The numerical variables which are predicted with this software are not all perfectly linear and this can lead to breaking the assumption of the algorithm. No matter the restrictions or the introduced bias, including imputed data in the models minimised non-linear behaviors from Modeling Round A and also provided some more insights in the predictors of the weight. Thus, this choice benefited the current research.

As it is seen from the *outliers analysis* presented in Section 7.4.2, there are children with weight above 80kg at the age of 4. In this study these observations are not removed and all the models include them (see Chapter 4). There are two potential explanations for such values. Firstly, they can be a potential data mistake. Since the data are collected via a survey and the current weight is self reported, the parents or caregivers filling-in the survey could have potentially misspelled the weight of their child. If indeed this is the case, removing those observations and repeating the modeling cycle can bring results which are more accurate. For the scope of the thesis, the removal of the outliers is not considered, based on the possibility that could be real data. Maybe some of these outlying children are actually heavier that their peers. In that case they are severely obese. If this true, there is one more reason to keep the observations, since otherwise the sample of children consists of only ”healthier” individuals.

These outlier values keep showing up in all the diagrams which are assessing the regression model fit. In other words, from all the used datasets (real and imputed dataset) some specific outliers show up in the extremities of the diagnostic plots. Specifically, some of them keep appearing in the extreme regions of ”Residuals vs Leverage” plots. These plots show which points of your data have a larger *Cook's distance* which indicates higher influence of the regression model outcome. Thus, deleting them would change the model significantly. Some of these observations sometimes appear at the boundaries of 0.5 - 1 unit of Cook's distance and some, in specific models, fall outside of those limits with a distance higher than 1. This shows that careful consideration should be taken when removing those points and then the repetition of the modeling can lead to improved performance and different results in terms of the beta coefficients of the variables.

Another aspect from the data that could benefit from extra detail is the ethnicity. In the current study, the ethnicity is approximated with the use of a pre-made variable from another researcher from RIVM. This variable is a simple boolean representation of the origin of the mother, stating if it is western or not. From the whole modeling cycle it did not show up as very influential, with only a level of significance at 0.05 and a factor of max +1.5, for the western mother origin children. This could be due to the data or because of the simplification of the ethnicity aspect. However, from the discussed literature, the ethnicity is an aspect which affects the perceptions of parents, regarding the weight of their offspring. How thinness is perceived is something which is greatly related to culture and tradition (Stang & Bonilla, 2017). This discussion is also very relevant to the medical community. Doctors face a challenge when screening the children and then communicating the right information with the right tone to the caregivers of the child. Being culturally aware as a medical professional can facilitate the process of prevention strategies and potentially make them more effective, thus more detailed research is needed.

Another very interesting finding of the modeling cycle is the factor of the family structure. This proxy is measured from the question regarding the form of the family. Then, the transformation to a boolean variable is done if both parents reside in the household or not. The legal marital status is not appropriate since a couple can have children and still not be legally married. Thus, the family structure only represents if both parents stay together. Its influence remained negative for all models, but varied in terms of absolute values. In terms of the preventive policies variable, namely consultation visits, an overall similar absolute value is observed. Its influence is relatively low and positive, but highly significant in all models where is used.

The use of proxies for nutrition style and physical activity did not show the expected response. Very weak associations are observed for all these variables. Maybe this behavior stems from the dataset, since imputed values are covering these variables for their biggest proportion (the level of missingness is around 80%). If the algorithm fails to find a pattern and predict based on this, this potentially can lead to results of poor validity. The only statistically significant result is found from modeling round B, regarding the fitness subscription variable of the child. For the psychology variables, satisfaction levels and friendships had the higher significance, affecting the most the child's weight. For most models, the more positive the child scores, the more these variables are negatively associated with its weight.

7.8. Conclusions

In this chapter, the aim is to provide a relevant answer for the Dutch society regarding the factors which explain the weight in a child's early years. The approach to solve this question is explanatory modeling and multiple models are built and tested to identify important patterns which show association. Two modeling rounds are done, one with the original and one with imputed data in order to identify differences in the results.

The focus from this modeling study is to explore variables which are usually not considered in similar studies for childhood weight or obesity exploration. By expanding the framework of analysis what is found as important is the psychological state of the child and thus, variables measuring it are included in the modeling cycle next to other more popular variables which are usually selected for such studies. These variables reflect family but also community effects on the child, thus managing to capture more holistically potential existence of inequities which are reflected on the psychological state of the child. Including factors which approximate such inequities is a crucial addition to the literature since their effects are prominent in a lot of European counties (Sadana & Blas, 2013). As literature shows, obesity can lead to mental diseases thus, a happier child can be overall more robust to an unhealthy weight gain. From the current results, the more satisfied the child or the less lonely, the more negative the association which exists with its weight. What is more, the same applies for the factor measuring how much parents perceived the child to be upset.

What is surprising, the income percentile and the Western culture of the mother did not show a high magnitude association with the weight of the child. This could be bounded to the specific sample, since other studies find significant differences or could be explained since the Dutch society has a variety of prices regarding food options and this could potentially explain this outcome. Another important finding concerns the mother's education. The more educated the mother, the higher the magnitude of the impact to decreasing the child's weight. This finding is reasonable and proves how much proper awareness and education regarding parenthood, nutrition choices and health can affect a child's weight from such an early age. Regarding preventive measures, the factor of consultation visits to Youth and Family Centers, is significantly correlated with the weight, but on a low magnitude. What is interesting however is that this association during both rounds had an absolute value of about 0.5 kg. This finding is deviating from what is expected, potentially because not many respondents use this offering of the Dutch municipalities. Regarding the environment, less urban environments are associated with smaller absolute value of coefficient. This means that in less urban areas for reasons which are not currently explored, a child's weight is affected on a smaller effect. This could be linked to issues of perceived safety or infrastructure. More research is needed to capture such factors for the Dutch environment since they are not covered in this study.

As research shows, obesity is not a single cause, neither a single solution disease. Gaining weight, especially from an early age, is attributed to a series of factors contributing their fragment at the weight of an individual. However, the increase of weight can happen due to fat or muscle gain. This study focused on exploring in general the factors explaining it and future models can focus specifically for the prediction of obesity prevalence. Addressing the issue holistically, can help tackle obesogenic tendencies which are inherent in some environments, by designing policies for fitness. This is one of the reasons why the target variable of this study is the weight and not the binary value of being overweight or not. A broader approach can bring more awareness and insights into what overall explains the weight of children based on Dutch governmental data.

In terms of the selected proxies of measurement (see Table 4.1), the choices which are made, are based on the available variables from the survey and also from an available dataset belonging to *CBS Microdata*. Improvement to the proxies can take place if more precise variables are considered for the *nutrition patterns* of the child. Variables such as snacking or consumption of sweetened beverages can be in the future included in the models to identify more specific links to nutrition which can lead to weight gain. In addition, more *family features* can be included. Variables like sleeping patterns of the child or active play with the parents could be a way to capture better the overall environment in the family. *Culture* is also one aspect of the analysis which is not fully captured. The selected variable measures if the mother of the family is western or not. In the future, one suggestion is to include more detailed variable to measure this, to capture more effectively the different cultures and how they affect (or not) the weight of children. For the *prevention actions*, features such as the level of insurance or proactive visits to doctors can be asked, to check the awareness of the parents to take care of the health of the child. Such variables are also exposing inequities in health since people who are from lower SES may not be able to provide with such actions to their offspring. Lastly, *neighborhood* features like criminality, perceived safety or green spaces will definitely provide a clearer idea of the relationship between children and environment.

8
Identifying childhood obesity

The screening of children happens by different actors and at different ages. Specifically when a child is less than 6 months old, a general practitioner does that. When the child is above 1 year old but below 5, then it is the task of the Youth and Family center and after this age, schools conduct the screenings. In the dataset for this analysis, there are variables defining overweight and obesity. The question is then how are these variables defined and if they are compared with the definition from Cole et al. (2000), do they result in the same outcomes regarding the identification of excess weight at any stage for preschool children? The research question for this matter is:

> *How can children be earlier identified as obesity risk-prone?*

8.1. Numeric comparison

To address this question, first of all the BMI of the children needs to be computed from scratch since a lot of empty cells have missing values when the current weight and height is known. Thus, for the children where the pair of (weight, height) is known the BMI is re-calculated and saved. Then, for these children, the sex, age, and BMI are stored in temporary variables and then the stratification proposed by Cole et al. (2000) is applied sequentially. Children between 0 and 2 years old cannot be included since it is medically irrelevant to talk about obesity at those ages.The outcome of this algorithm is the creation of two new columns for the overweight and obese children based on this medical standard which is by literature more appropriate to judge a young's child health state than the use of weight percentiles. What is more an extra column is calculated. This column shows the children which are risk-prone based on the definition which is used. The risk prone, as mentioned in Chapter 5, is defined as up to 1 BMI unit away than the overweight threshold for specific (sex,age) values. The outcomes of the algorithm are shown in Table 8.1 and a total sample of 1010 observations is used. For the rest 50 children, either the weight or the height is unknown, making the BMI calculation impossible. For the variables where sensitive information is included the values which point to specific individuals are removed (min, max and median). The last 5 rows of the table show the results for the different methods used, namely CBS and Cole definition.

Table 8.1: Descriptive statistics table for the data used to explore the obesity and overweight labeling and prevalence, n = 1010.

Descriptive statistics							
VarName	**Min**	**1st Q**	**Median**	**Mean**	**3rd Q**	**Max**	**NAs**
Age	0	1	2.5	2.623	4	6	-
Current height (cm)	-	85	-	96.57	110	-	-
Current weight (kg)	-	12	-	15.32	18	-	-
BMI	-	14.3762	-	16.4331	17.0064	-	-
Family structure	0	1	1	0.9216	1	1	2
Postcode high SES	0	1	1	0.8178	1	1	-
Western mother	0	1	1	0.8574	1	1	-
Urbanity index	1	2	2	2.621	4	5	-
CBS Overweight label	0	0	0	0	0	0	331
CBS Obesity label	0	0	0	0.0353	0	1	331
Cole's Overweight label	0	0	0	0.0787	0	1	324
Cole's Obesity label	0	0	0	0.0508	0	1	324
Cole's risk-prone label	0	0	0	0.1312	0	1	324

The sum of the results from this calculation of both methods for the identification of obese and overweight children are presented in Figure 8.1. CBS uses for the overweight and obese column, adult BMI thresholds. As it is shown, the method CBS is using is not identifying any overweight children whereas the one from Cole et al. (2000) identifies 54 kids out of the 1010 sample size which is available. For obesity the results are more aligned. The methods identify 24 and 28 children respectively.

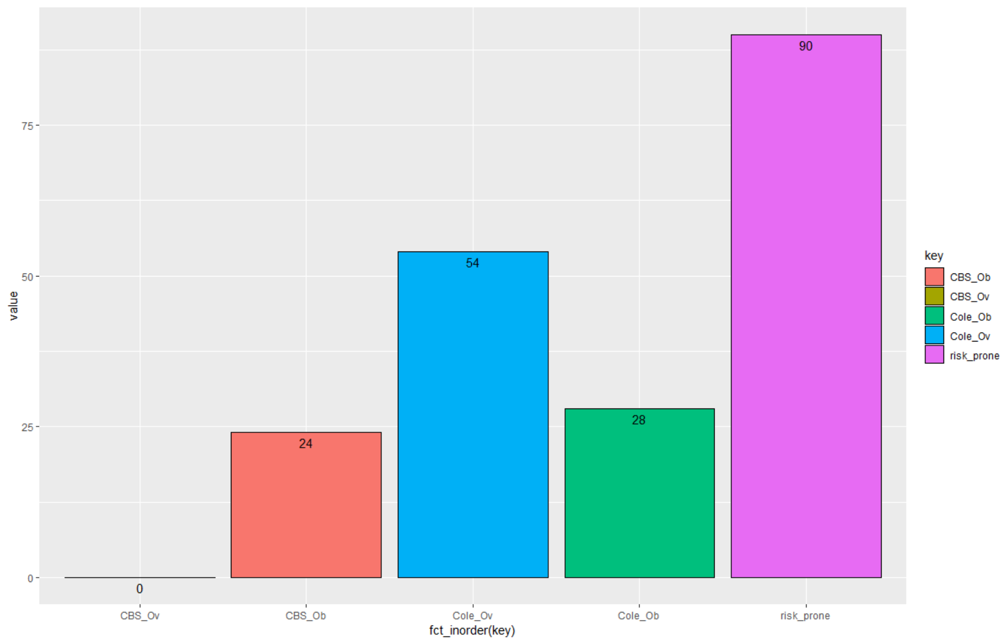


Figure 8.1: Total sums for the comparison of two approaches for the identification of overweight and obese

The definition of overweight children is drastically different. This is clearly a sign of disagreement from a value threshold for the definition of overweight children. Since the medical community advocates for earlier identification of risk-prone children, with the argument that is easier to treat the disease of obesity when it is still at an early stage, a stricter filtering of children can lead to a higher success rate of the treatment and prevention of the disease. What is also very interesting, is the column of the risk prone children. This shows that 90 children are 1 or less BMI unit away from becoming medically overweight at their age. This adds more value for medical professionals but also decision makers. This is a sign that these children can benefit from prevention strategies and lifestyle interventions since they are already approaching the overweight thresholds at such an early stage. Treating the disease, when the signs of it are small, is less costly but also less psychologically challenging for a young child, based on the literature from Chapter 2.

It is interesting to measure the differences in the agreement of the two methods. For this purpose, an agreement score is computed. It is the percentage of times the two sets of thresholds (one applied by CBS researchers and one applied for the purposes of this thesis with the use of Cole's definition) agree on the labeling for the health state of a child. It is interesting that despite the fact that the GECON survey is conducted with both adults but also children, the BMI thresholds for overweight and obesity, are only calculated based on adult measurements. This implies that the $BMI > 25$ shows overweight and $BMI > 30$ shows an obese individual. Anything lower than $BMI < 18.5$ is a healthy weight. This is a major limitation of data processing when it comes to storing children data. Because of this computational difference, the agreement is created. The final results are presented in Table 8.2.

Table 8.2: Results for the labeling of children.

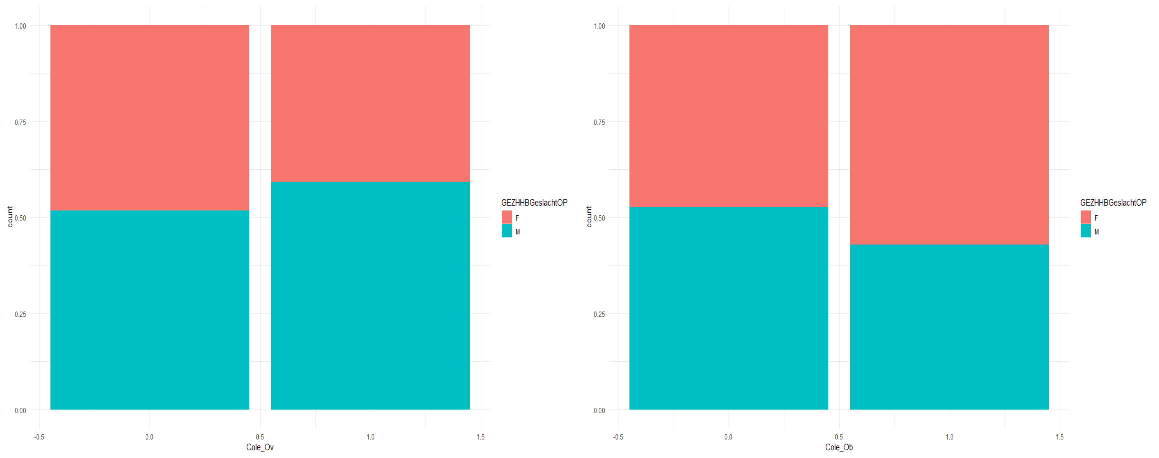
Percentages of children		
State	**CBS opinion**	**Cole's opinion**
Normal	97.623 %	91.881 %
Overweight	0 %	5.3465 %
Obese	2.3762 %	2.7722 %
Risk-prone	-	8.91089 %

Regarding the above table the *risk-prone* segment only concerns the *normal* weight children and is a proportionate percentage of this group. The total sample is 1010. Then the outcome is:

Disagreement of the methods: 58 times or 5.74 %

8.2. Insights

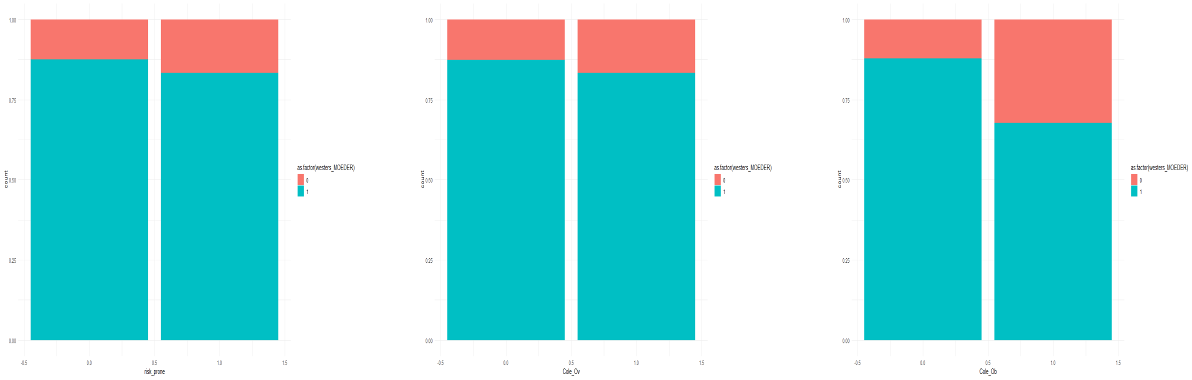
Apart from the calculations, it is interesting to observe socioeconomic and environmental differences for these children. First of all, the gender is explored. It is clear that female are more prone to obesity and male are more prone to being overweight (Figure 8.2). The male are with blue color and the female are with the coral color. This can be due to metabolic functions at that age or it can also mean that more care needs to be taken when it comes to female children exercising or playing and interacting with other individuals in a physically engaging style.



(a) Overweight (b) Obese

Figure 8.2: Gender proportional variation for overweight and obesity, by (Cole et al., 2000)

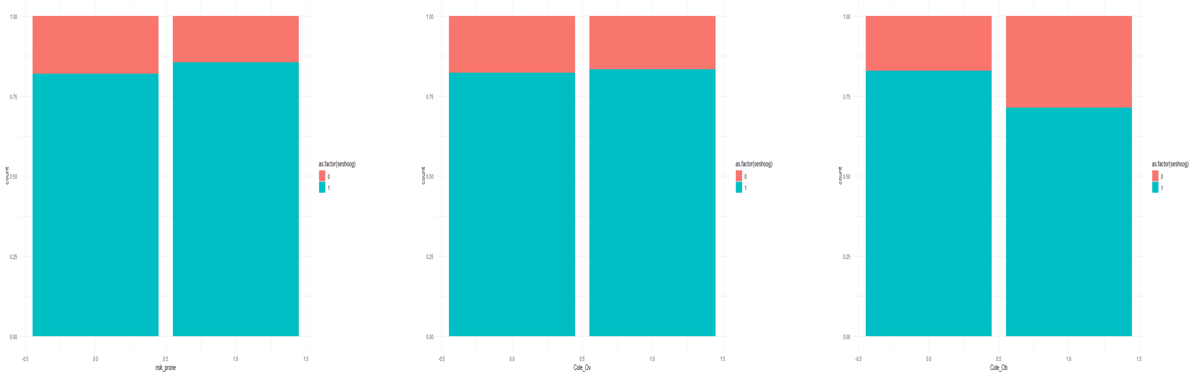
Additionally, the mother's ethnicity is explored. Figure 8.3 shows how the proportional existence of non-western mother is expressed in the data. The color coding is blue for the western origin mothers and coral for the non-western mothers. First, for the risk prone and overweight children we see that there is a slight tendency for the kids who are on the positive side to be from a non western mother. However, for the obese children it is clear that the proportion is not the same. The obese children are more likely to be originating from families with non-western mother. This is even more interesting if someone takes into account that the mean of the sample for ethnicity is 85% western origin children.



(a) Risk prone children (b) Overweight children (c) Obese children

Figure 8.3: Ethnicity of the mother

Now the same plots are explored for the socioeconomic status of the neighborhood the families reside in. If someone looks at Figure 8.4, the coral colour coding is for the low socioeconomic status neighbourhoods. It is interesting that similar results as with the ethnicity of the mother are observed. For the risk prone and for the overweight category the status of the neighborhood is not changing the outcome between the (non) risk prone or the (non) overweight. However, when it comes to the obese children then a higher proportion comes from lower socioeconomic status neighbourhoods. For the current sample the mean value of children originating from high SES neighborhoods is 81%.



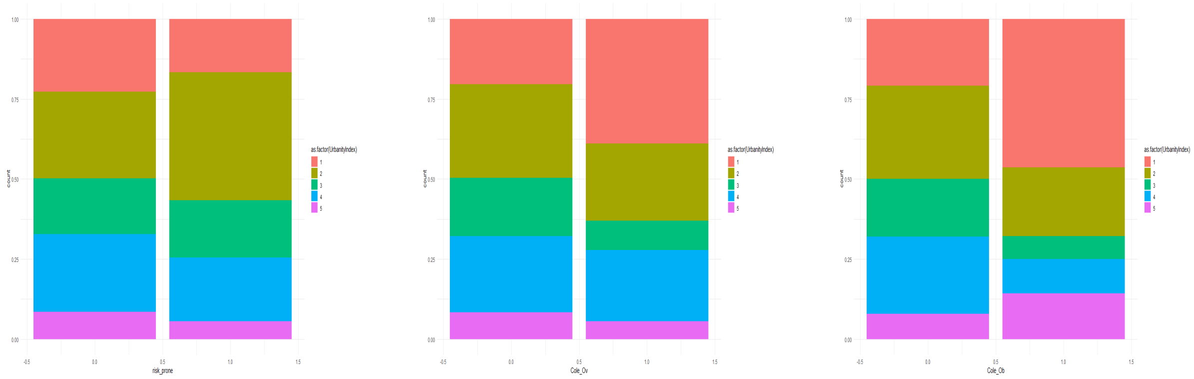
(a) Risk prone children (b) Overweight children (c) Obese children

Figure 8.4: Neighborhood socioeconomic proxy

Similarly, the final aspect of interest is the urbanity level of the environment children grow up in. The neighbourhoods are categorised based on the environmental address density (EAD). The EAD is equal to the amount of addresses per km^2. Then, for the urbanity index, 5 levels of classification exist in the Dutch governmental data. Each neighbourhood gets one urbanity class awarded based on the defined urbanity levels. The following class division has been used by CBS to conduct the urbanity index classification.

1. very strong urban> = 2500 addresses per km^2;
2. strong urban 1500 - 2500 addresses per km^2;
3. moderate urban 1000 - 1500 addresses per km^2;
4. less urban 500 - 1000 addresses per km^2;
5. non-urban <500 addresses per km^2.

The same classification applies to Figure 8.5, where the coral corresponds to the highest urbanity level (1) or very strong urban, the olive green corresponds to the strong urban (2) and the green color corresponds to the moderate urban (3). The blue and the purple correspond to the least urban levels (4, 5) respectively. What can be observed from the figure is that the urbanity levels which are more often appearing at all categories of non-healthy weight children are the *very strong urban* and the *strong urban*, levels (1) and (2). This is not surprising since the urban environment and its characteristics impact on the health of the children for the country of the Netherlands as well. From the graph for the risk prone children, 56% of the ones who are identified as risk prone, live in neighborhoods identified as very or strong urban. The results are more staggering for the children who are already overweight or obese. For the first, 63% come from the two most urban classes and for the latter, the rate is at roughly 69%. These numbers are a crucial sign for the health state of the children if we consider that the sample these calculations are based on, only consists of children from 0 - 6 years old.



(a) Risk prone children (b) Overweight children (c) Obese children

Figure 8.5: Municipality level urbanity index

8.3. Discussion

First and foremost it is crucial to remind the reader that the sample of this analysis is slightly limited, compared to Chapter 7. 1010 children are incorporated out of a 1060 sample size, due to lack of data. What is more, the scope of this chapter is to answer the question of how can children be earlier identified as obese or risk-prone for the disease. This analysis compared two different screening methods which are based on BMI values. The one which is used by CBS for the labelling of young children, uses the same cutoff points for BMI values as for adults. This method shows that there are important limitations. Not only are children mislabeled but also this data processing method stays in the CBS datasets for all researchers to base next studies upon it. The implication at first may not seem considerable, but if someone carefully sees that 6.24% of the times a child got mislabeled, then when conducting prediction models for obesity prevalence in children, not accurate data will be fed in a model, leading to similarly not accurate results.

In addition, by applying stricter standards for filtering and identification of risk-prone children, prevention strategies and policies can be used when there is time and room for improvement. As mentioned in Chapter 2, the fat cell generation period is approximately taking place around the age of six, thus the earlier the identification of such vulnerable children the higher the chances for them to mimimize the fat cells which will be ”carried into” adulthood. Also, the environment plays a significant role for the pathway of growth children are entering. Even if the Netherlands have great biking infrastructure and most of its big, highly urban cities show up as the most bike-friendly in the world (Colville-Andersen, 2019), there is still the indication from the used data that those children are the ones who are most risk-prone or already identified as overweight/obese at such a young age. The literature showed how important is to address weight abnormalities the soonest possible, thus medical professionals along with educational institutions and parents need to collaborate to create a healthier lifestyle for all children no matter the state of their current BMI.

Last but not least, obesity is mostly idiopathic and there is not a single cause driving it. There is always a synergy of factors working together to explain a child’s weight. These synergy effects are more pronounced the more inequities exist in a society. As explained in Chapter 3, inequities make the inequalities in a society more pronounced. If this is the case, people who belong in more vulnerable societal groups could face in a greater extent the lack of ie. green spaces where the children can play, or the lack of healthy, affordable grocery stores, where parents can buy fresh produce for their children. The more such synergistic effects exist in a neighborhood the more extreme are the effects they have on humans’ health and specifically for children.

9
Data informed policies

In the current thesis, the the issue of childhood weight and obesity for the country of the Netherlands is explored. First of all, the client of the study is a hypothetical municipality which realises the need for policies to improve the quality of life of the youngest citizens. To address this issue, initially the involved actors in the arena of childhood health are mapped. Then, modeling of the children's weight is implemented, to identify factors which are affecting it, for preschool children. In addition, a relatively new medical definition for childhood obesity is applied, allowing the comparison of two methods which use different criteria to identify overweight and obese children. Last but not least, with this definition and extension to calculate the risk-prone children is conducted and then visualisation of different characteristics of those children is done to communicate the results. In this chapter, the aim is to propose policies which are informed from evidence found in data to design interventions to prevent and mitigate childhood overweight and obesity and create in general an overall healthier environment.

9.1. Policy proposal

In this section, the main research question of the thesis regarding policies is addressed, given the results from the analysis. The main research question is as follows:

> How can Dutch government data inform policies for targeted interventions addressing childhood obesity?

The client of the study is a Dutch municipality, however, advising a single panacea policy proposal is not attainable, neither would it be possible to address such a complex issue as childhood obesity. Different data-informed policies are designed to tackle the epidemic more effectively and allocate resources where needed most. Since the funds are limited and the health systems are increasingly burdened, acknowledging the factors contributing to the weight increase for children can benefit policy and decision makers. After all, as mentioned in multiple studies, prevention of childhood obesity is better than cure (Pandita et al., 2016), (Baker et al., 2017), (Robertson et al., 2016). A summary of the proposed policies is found in Section 9.2. The current chapter is divided into two sections. Section 9.1.1, includes the policy proposal for political decision makers and Section 9.1.2 includes the suggestions for the medical professionals.

9.1.1. Political decision makers

In this section, advice is provided for the political leaders of municipalities. The advice is informed from the patters and findings identified from the dataset collected from the GECON survey (Centraal Bureau voor de Statistiek, 2018). The advice is structured in different themes, based on the pillars of the analysis framework.

Economics

From the whole modeling cycle one of the variables which appears as influential to a child's weight, is the mother's education level. However, it is hard to influence this factor as a municipality. What is proposed, is to stimulate life-long learning. When mothers are in maternity leave they have the energy and time to invest in preparing for the child. Youth and Family Centers (YFC) can approach expecting mothers and provide courses on nutrition, its benefits and explain the impact pregnancy and first years of childhood have on the generation of fat cells for a young child. This can bring more awareness into the complex processes which take part when a human body transitions is at its very early years and showcase that this disease is something which is treatable and preventable if proper action is taken at an early point.

This is also in accordance to the findings that the factor of consultation visits to YFC is significant to explain a child's weight. Nevertheless, it is interesting that from the data the mean consultation visits are very low for both high (Figure 9.1a) and low SES (Figure 9.1b) neighborhoods. However, on average, the low SES neighborhoods have a higher mean of visits per province. The sum of visits per province, disaggregated based on low and high postcode SES, are presented in Table 9.1 [1]. It is clear that based on the GECON data, the variance in consultation visits is quite big in the total sums. What is more, a lot of Provinces present really low sums, sign which indicates that the YFCs are mostly underutilised for reasons which are not known in the current thesis. This policy to create such centers is totally aligned with the plan of the Ministry of Health, Welfare and Sport for the creation of a "promising start" for all new-born children. As mentioned by van de Berg et al. (2016), policy makers believe that the cornerstone to a child's health is its parents. Since the mean fluctuates around 2 visits per mother for the high SES and around 3 for the low SES neighborhoods when the 3^{rd} quartile value is at approximately 10[2]. This shows room for improvement of the operation of such centers. The centers may not serve the need they are designed to. Hence, a way which is appropriate for the lifestyle of the 21-century parent is conceived and proposed.

Table 9.1: Consultation visits to Youth Family Centers per Province, for high and low postcode SES.

Sum of visits		
Province	**High SES**	**Low SES**
Drenthe	43	33
Flevoland	57	NA
Friesland	82	44
Gelderland	248	67
Groningen	31	34
Limburg	68	39
Noord-Brabant	316	47
Noord-Holland	318	40
Overijssel	69	64
Utrecht	185	NA
Zeeland	43	NA
Zuid-Holland	516	99

The idea which results from this research, is to design a new digital app with tips and information for parents regarding nutrition, exercise and other parenting advice. In that way useful material can be found in this digital repository at the tip of their hands, without the need of going to the YFC if this is hard to manage. An app like this promoted by all YFC can potentially engage young parents more and create a digital place for sharing information and useful techniques regarding parenthood. This could also be a solution for working parents, since as seen on the page of the central YFC of the Hague (Centrum Jeugd & Gezin Den Haag, 2019), the center has walk-in hours which overlap with most business hours, making

[1] Where there is NA means that the value is below 10 visits thus, it cannot be published for privacy reasons.

[2] The min and max values are omitted from the graph for privacy reasons.

it impossible for parents to be present at that time. A proposal to change the working hours of a center and observe if there is change in terms of the appointments book can also be considered, however such a policy may not be preferable by the the nurses and midwifes working at the YFC.

What is more, in the context of life-long education, gamification can work for educational institutions and YFC for teaching children. Children from the moment they go to kindergarden are able to engage in games and conversation. Then, explaining the idea of following a balanced diet, low in fats and sugars, can be more easily achieved via a game. By engaging children in a playful activity, motivating them to try to eat more wholesome foods could be more effective than simply imposing ”no-sugar” foods policies within the premises of an educational institution. In addition, even a child who grows up with parents who are unaware regarding nutrition can be introduced to this knowledge and maybe slowly alter its nutrition towards healthier options. After all, following a balanced nutrition is a habit which can be trained and maintained when practiced on a daily basis. This is supported from the data since, when the issue of missing values is tackled, fruit consumption patterns shows significant. Regarding the real data, nutrition proxies from the descriptive statistics had means of 0.7 for the vegetables and 0.6 for the fruits (see Table 7.1), which are especially low for such an early age. This implies that the Dutch baseline of nutrition standards is not reached.

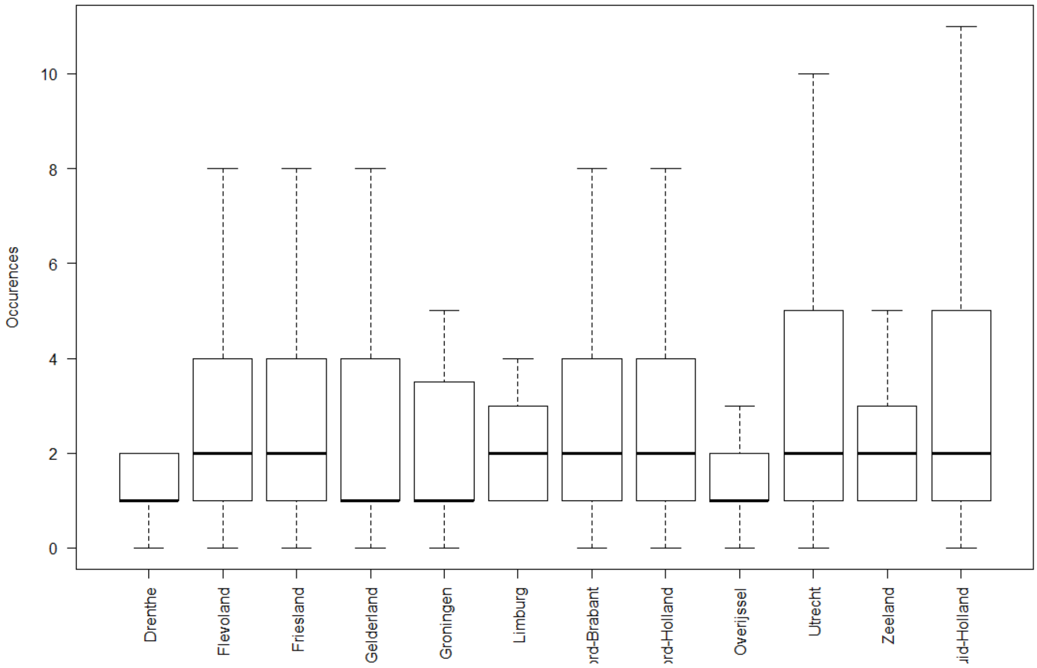
Environment

Urbanity is another variable which when it is lower[3], meaning that the neighborhood level is very urban, then the association with the weight is more positive in magnitude. This finding is significant for medical but also municipal decision makers. The urbanity of a district (wijk) is a a metric which is familiar with all municipal decision makers. Thus, by acknowledging the association with a child’s weight, more research can be initiated to identify what exactly is the factor which leads to this high additive relation. In the mean time, such districts can start awareness campaigns to promote physical activity initiatives for schools such as the *Vignette programme*. From the interview it is found that some schools are unaware of such measures (Table 6.1). However, municipalities can ”nudge” schools by creating financial or resource-based incentives, so they join and engage children more on physical activity promoting initiatives.

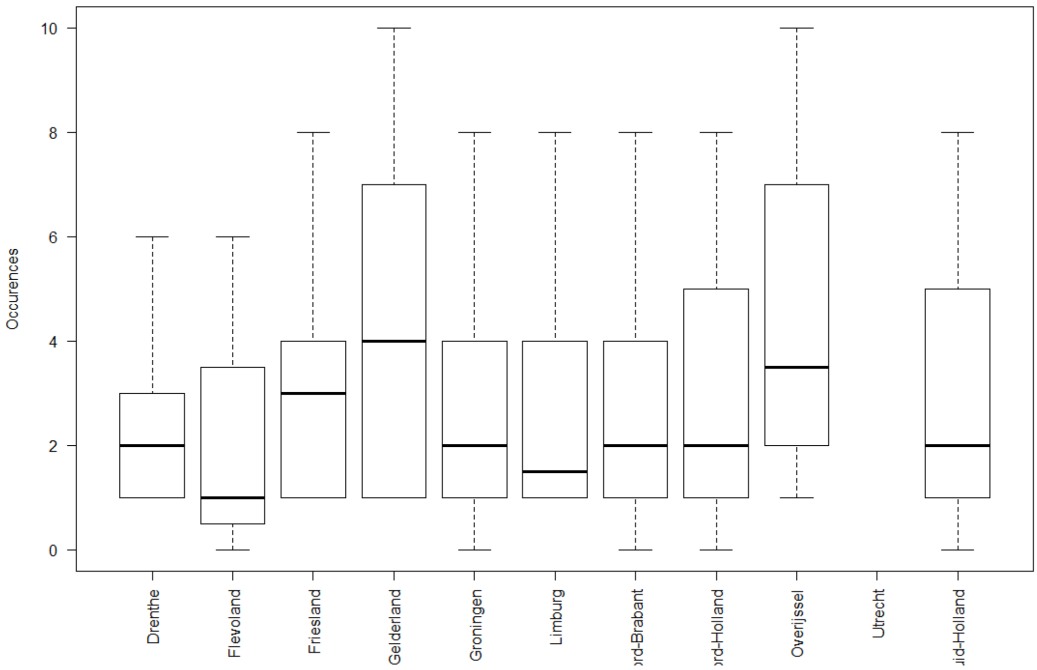
The need to identify factors which lead to this association is also important. The findings from Chapter 8, clearly show that more than 50% of obese and overweight children come from the two most urban areas of the sampled regions. The same applies for children identified as risk-prone. This evidence is enough for municipalities to investigate what is triggering this trend. Since environment is such a complex definition, composed of psychical , chemical, biotic , cultural etc components (see Section 2.2), more proxies can be used in the future to capture more of its aspects quantitatively.

Potentially parents perception of the district as polluted (air, noise, traffic) or unsafe, could limit the activity they allow children to have. Not enough evidence is observed for the psychical activity proxies of the current sample, but more research is needed to prove such associations. Youth and Family Centers can maybe help in this direction, since they are an official but ”relaxed” space, where municipal services meet citizens. Asking parents during their visit for the main reasons they might deter their children from playing ie. in a park, or playground is suggested. Such a quick polling can help identify local patterns without having to conduct a nation wide survey. After all, such level of granularity can be missed-out when conducting official nation-wide surveys.

[3]Based on the definition for urbanity index by CBS.



(a) High SES postcode neighborhoods



(b) Low SES postcode neighborhoods

Figure 9.1: Boxplot of consultation visits, per municipality in the Netherlands for the years 2016, 2017. Min and max values are omitted. Data from: GECON survey.

Community

To address the issue of obesity at a community level, specific features of the individuals who live in it need to be considered. The social position, the socioeconomic status and ethnicity are the main features that need to be taken into account when designing urban environments for fitness and population wellness. Social and community features affect citizens' lives thus policies should be aimed at all the environments where people ”live, work and play” (Bryant et al., 2015). This is crucial since people from different backgrounds respond in different ways to policies. As it is stated by Loring and Robertson (2014), consumers with low literacy in terms of numbers and statistics are potentially less responsive to numbering systems or pure numerical food labels and more intuitive with policies such as ”traffic-light labelling”. Alternatively for such target groups, a skills class could be more beneficial. Another example, is the different perceptions for healthy weight since some cultures associate thinness with unhappy individuals, thereby requiring different policy approaches (Stang & Bonilla, 2017). Knowing and including such factors in policy-making, can shed more light on how children's physical activity levels are formed since there is a close link with engagement in free play and sport (Watchman & Spencer-Cavaliere, 2017). Adopting a holistic approach when it comes to designing such policies or campaigns for wellness and fitness, can lead to higher engagement levels from the audience they are targeted to.

The findings of Chapter 8, given the sample, show that the proportion of female children, with non-western mother and from low SES neighbourhood is higher for the obese scale than for the risk prone or overweight. This finding supports the hypothesis that a single factor cannot explain the disease and it is the accumulation of multiple features which lead to a child not being on a healthy weight. This is a proof for the existence of *impact differentials* as it is mentioned in Chapter 3. These differentials can be treated with community-inclusive policies which engage people into experiences and make healthy nutrition more affordable and attainable for them. Parents face challenges on a daily basis and experience decision fatigue, which makes them prone to unhealthy advertisements. Hence, a municipality which acknowledges that, can work closely with businesses and form alliances, to eliminate unhealthy food advertisements and promote healthier ones, showing wholesome foods, which is shown to increase their popularity even for children (Pettigrew et al., 2017).

Sassi et al., in the OECD report of ”Obesity and the Economics of Prevention”, state clearly that a multi-actor approach with alliances and partnerships is the only way to confront the issue of a poor food supply chain. Up until today, the food industry resists on having to disclose all ingredients and nutritional information on the package (The European Consumer Organisation, 2018). However the government and municipalities need to initiate the cooperation with the food industry, since are the only actors holding more power than the food industry over legislative issues. The Hague has already identified the importance of partnerships and specifically they stated that the ”municipal development process becomes more transparent and accountable, increasing the likelihood of delivering the expected strategic results and contributing to improved quality of life” (VNG International, 2010). An example of a partnership between business, kinder-gardens and municipality can be to collect almost ripe fruits and vegetables or the ones which do not comply with the aesthetic standards of food supply chain and distribute them to kinder-gardens and primary schools. In that way, food waste is eliminated and these institutions can provide almost cost free healthy snacks to the pupils. This idea can tackle inequities, since the consumption of enough fruits and vegetables is decreased when income and education level are low (Sassi et al., 2010).

Apart from those features, the family structure is another factor which is also supported significantly from the data, as a united family is associated with reducing the weight of a child in early childhood. Raising a family as a single parent can be time-consuming and hard to manage, thus, the caregiver could be prone to decision-fatigue regarding health choices, either due to lack of time or financial resources. When implementing policies the percentage of single parents households with children is known, since CBS provides such information online, hence targeting closely those neighborhoods via the YFC or the local medical professionals, more attention can be placed when screening or checking the growth of such children. What can also be considered, is to offer free nutritional advice to such households since being more aware of the issue of poor nutrition can prevent over-consumption of high-caloric foods.

From the results of Chapter 7, the positive psychology factor of the child is shown to be negatively associated with the weight. Specifically the satisfaction and the social ability for friendships were both significant factors negatively associated with the weight. This shows the importance of taking care of the child's psychical but also mental needs, since the balance between the two is fragile especially at that age. An idea which is implemented in the USA to firm community bonds and raise the availability of cheaper fresh produce is to make community gardens (Liburd, 2018). This could be an appropriate solution for the Netherlands as well for three reasons. First of all, gardening is a family-friendly activity which tights the bond between children and parents. It also increases the fresh produce available to the citizens of the community and lastly, educates children on how their food is produced while broadening their horizons in terms of the variety and seasonality of fruits and vegetables. Since children can increase the exposure to nature and to a calming activity such as gardening, their mental health could be improved and new relationships with the local people can be formed enhancing the social cohesion of the neighbourhood. Then, this produce can be sold based on money or by "exchanging it" with hours of social work at the garden. This proposed policy is in accordance with the results from Frongillo et al., where they concluded that community policies and programs (CPPs) are decreasing children's BMI and waist circumference, with a magnitude of public health importance, making them a worth-to-invest policy.

9.1.2. Medical Professionals

In order to tackle the issue of childhood obesity, the municipality and the actors cannot work alone without collaboration from the medical sector of health and lifestyle professionals. After all, doctors and medical practitioners are an important "context setter" actor who can be utilised when approached appropriately. In other words, by informing the findings about the importance of taking extra care for children originating from single parent families, lower socioeconomic urban environment families and less educated parents then, they are aware of the increased risk these children face and they are more careful when conducting growth checks or even when they notice it in another visit. Also another aspect is the urbanity. Since the more urban, the more positive is the association with weight, medical professionals who operate in such areas can underline the importance of maintaining an active lifestyle to their patients.

The other aspect which shows up as positively associated with weight is the psychology of the child. The more social a child is rated by its parents, the more negative is the factor associated with his/ her weight. This shows the great impact mental health and stability can have on a child's weight and overall health. Thus, another advice for medical professionals is to ask such questions to parents, except for assessing only the psychical aspect of a child's health. Then, by advising for a child's positive mental health, there is significant findings that the weight can be reduced. In addition, from the interview with medical experts, the issue of improving the screening process of GPs for children with weight abnormalities is identified. If the GP has not the time to address it (s)he can log that information in the new electronic patient record named Care Infrastructure (Zorginfrastructuur) and this is shared within care providers, GPs, pharmacists and medical specialists. Of course, the exchange of data from patients can only happen for citizens who have explicitly provided consent (van de Berg et al., 2016). For this reason, the exploration of the agreement for labeling overweight and obese children is done in Chapter 8. The results show that a stricter definition agrees on the obesity aspect of the disease but highly disagrees on the overweight. By employing a more appropriate standard for overweight, the disease can be measured more accurately and epidemic models can produce more useful and valid results. After all, it is easier to prevent than having to apply interventions in already obese child cohorts.

Last but not least, an epidemiological system is in place in the Dutch medical arena, whose role is to alert the existence of infectious diseases to the Infectious Diseases Surveillance Information System (Infectieziekten Surveillance Informatie Systeem, ISIS) (van de Berg et al., 2016). Obesity can be included in the list of infectious diseases, since research shows that it is also transmitted through social connections (Ejima et al., 2018). Notes can be kept from medical professionals if overweight children show up at their practice. By designing a new alert system for risk-prone or overweight children, a potential existence of obesity spread in a neighborhood can be early identified, so action can be taken by health experts, educational institutions and parents early in advance. Since there is an Information Committee (Informatieberaad) which is responsible to provide information regarding health care, this can act as an ”entrance point” to discuss the epidemic of childhood obesity and raise awareness for the most vulnerable of the population. This is timely relevant to the European policy framework of *Health 2020*, which since it reaches an end, a policy ”window” is created to bring up discussions about the so far progress and future actions.

9.2. Summary of policy proposal

This section aims to summarise the proposed policies in the form of a table, to facilitate the reader.

Table 9.2: Policy proposal summary.

Framework pillar and policies	
Economics	Life-long learning education for mothers and children. Mobile application to help YFC with their mission. Development of a game to help children understand nutrition.
Environment	Urban districts could promote programs for physcial activity stimulation for children in kindergarten and primary schools. YFC can use quick polling techniques to identify local context risks for potential limiting of physical activity in the neighborhood.
Community	Acknowledge social position, SES and ethnicity in campaign or promotion design of municipal actions. Form alliances with businesses to eliminate advertisements of unhealthy foods and advocate for healthier foods instead. Distribute fruits and vegetables which do not comply with the aesthetic standards to schools. YFC and medical professionals can be more aware of single parent households when conducting screening checks. Implementation of community gardens to improve social cohesion, mental health and nutrition.
Medical Community	Train medical professionals to be more aware of the SES effects to health and pay more attention to such families. Adopt a stricter definition for childhood overweight and obesity. Medical professionals can assess the mental state of the child during the screenings.

Framework pillar and policies	
	Include obesity in the epidemiological list of diseases to early identify local contagiousness. Initiate discussion for childhood health and obesity in the medical arena by reaching to the Information Committee.

"It is not the strongest of the species that survives, nor the most intelligent. It is the one that is the most adaptable to change." (Charles Darwin)

10
Limitations

10.1. Limitations

For the current thesis, a combination of theory and methods are employed to reach the desirable results. Inherently every method and how researchers apply it to the data creates unique limitations. For the used theory, the choices made in the current thesis, follow the notion of the Social *Determinants of Health* and assume the existence of health inequities in a society. This assumption is applicable to most developed countries given the existence of inequalities in the modern societies. This approach is more holistic and proactive compared to health studies which do not take such matters into account. However, in societies where inequalities are not so evident this approach may not add significant benefits.

First of all, for the first sub-research question, actor analysis is the main method. The main introduced limitation is the bias of the researcher on how the problem is perceived. This bias governs the design of the actor analysis. Of course by using the interview, such biases are diminished, however this analysis is the perception of the issue of childhood obesity and its policy arena seen through the ”eyes” of the analyst. Additionally, the actor analysis is conducted at a specific time, hence it is a ”snapshot” of the health system and it should be re-conducted in case the issue of obesity in the Netherlands is revisited in the future.

To address the second sub-research question, explanatory statistical modeling and specifically, multiple linear regression models are used. This model family assumes normality in terms of the relationships between predictors and target variable, in terms of the distribution of the target variable for small samples ($n < 3000$) and for the distribution of the residuals. These are all strict assumptions and dealing with those needs special consideration. In the sections for the modeling results, Section 7.4, Section 7.5, comments about the assumptions and the visual inspection of the fit for the used models are provided. Nevertheless, even if most models appear significant the normality is sometimes violated and this could be explained because of lack of perfect Gaussian normality for the target variable. A Shapiro test for normality is conducted, but because this test is very strict when it comes to this assumption, for modeling literature suggests to assess the residuals since they show a clearer picture of the performance. For this reason and since the scope of the thesis is not prediction, the modeling continued, visual inspections of its fit is done and commentary about the assumptions of the linear modeling is provided for all cases.

Limitations are also introduced because of the data and their collection method. Since Dutch governmental data is used, the reproducibility and transparency of the study is minimised because of the confidential nature of the sample. One main limitation is the design of the survey which changed over the years. In 2013, when the survey was first launched, the design was different than in the years of 2014, 2015 and the final design was set in 2016 and repeated in 2017. Hence, before exploring the data, this was not known and the expectation of a larger sample was assumed. When the final merge of the years 2016 and 2017 was done, the pre-processing showed the quality and the missingness of information. This leads to information loss for any kind of model. These issues are typical when data gathered from surveys are not properly stored to ensure compliance with one standard and good quality.

What is more, the issue of data missingness because of people who prefer to not respond to questions is tackled with the use of a multiple data imputation algorithm. This is very often the case for the current dataset especially for physical activity and nutrition patterns of the respondents. Data imputation has inherent assumptions about linearity in the variables which in some cases may be not the case, however this is very hard to assess. Additionally, validity is compromised because the used data originate mostly from self-reported sources, which introduces human error. Typing errors is one of the reasons why outliers exist in this study. These outlier data, when used in a model create high leverage points, affecting significantly the outcome of the regression. Lastly, the validation method by comparing the results from the two modeling rounds is not perfect. The approach is based on comparing results from the real-dataset modeling, with the ones from the imputed dataset. No strange, non-logical outcomes are observed, however the use of a new full dataset is advised. Lastly, the GECON implementation maybe limits the amount of people responding it in terms of SES and education level, since it required computer use. This can be tackled if another person from a facility (hospital or community center) helps with the questionnaire process, to help include more responses from lower SES households.

10.2. Future research

Future research should focus on including more detailed proxies for environment measures. Currently, the urban environment is approximated with the use of the urbanity index and the SES postcode status. To expand and increase the understanding of the environmental impact, some suggestions would be to consider using proxies for criminality, perceived safety, traffic and air pollution. Such proxies are not occurring often combined in studies about obesity prevalence or the prediction of childhood weight. Thus, by exploring them, new directions can be set for the design of urban health and fitness policies.

Additionally, the nutrition proxies which are used in the current study only seem significant in a single round of the imputed data (Modeling Round B). More correlation was expected, and for this reason, exploring in more detail the snacking and food patterns of the children is suggested. This is also suggested by Timmermans et al. (2018) in their research of Utrecht's obesogenic environment. Regarding other potentially obesogenic behavior, an idea is to include sleep and television time patterns. However, these variables are not included in the current thesis. Lastly, the used ethnicity variable of the mother, can be improved to capture more cultural differences by making it into a factor variable depending on a more detailed definition than the boolean western proxy. Culture is hard to measure hence, more improvement in this modeling aspect can take place.

What is more, another modelling approach can be proposed for a continuation of this study. After the comparison of the methods for identifying overweight and obesity in children, at Chapter 8, a significant difference is identified when it comes to the definition of overweight in children. Missing out on children who are at risk because no distinction is made to properly classify them as unhealthy or not, could undermine future research which is based on such binary variables as being overweight / obese or not. A natural future step, is the design of a predictive logistic regression modeling approach, to identify national trends based on the significant variables concluded from the current exploration and the labeling from Cole et al.. This could bring the research and awareness around childhood obesity one step further.

11 Conclusion

11.1. Research Objectives

In the current research, an exploration of mostly non-biological factors driving preschool children weight is conducted. This is interesting for understanding what factors can trigger weight gain and lead to childhood overweight and obesity. The objectives were to identify the involved actors in the policy making arena of the Netherlands, explore factors which are significant to the weight of children and lastly, explore if there is any technique which can lead to early identification of children, risk-prone to obesity. These three research components aid the suggestion of data-informed policies to a hypothetical Dutch municipality which is willing to tackle the issue of obesity and health inequity, specifically for the youngest population segment (see Chapter 9).

11.2. Recommendations

What is identified throughout the scientific research is that knowledge around obesity is fragmented. This is due to two main reasons: the disease is mostly location-bound, meaning that the environment of a country influences the factors and the extent of influence they have on individuals. The second reason is that when analysing obesity or childhood weight, the used methods are covering a very wide broad conceptual selection of variables to capture the complexity of the disease, without using a systematic method. This is why in the current thesis, the chosen framework for analysis is the one the advisory of the Ministry of Health, Welfare and Sport, RIVM, uses for quality of life and health studies. This framework is expanded to fit the concepts of social determinants of health and the health inequities. These concepts are the cornerstone of the framework, if an analysis expects to unveil society-relevant results which can potentially reduce growing social inequalities. Including such factors is considered mandatory for the suggestion of data-informed policies which are relevant for the Netherlands. This is due to the already known statistics for the country, stating that people with obesity frequently feature lower SES and education levels. The outcomes of the data analysis are communicated to policy and decision makers, to potentially aid early diagnosis and interventions for childhood obesity prevention.

The key message from the policy section of this analysis is to increase participation of multiple actors and encourage partnerships, by focusing on policies which mainly prevent the occurrence of obesity before it occurs. The prevention of childhood obesity is crucial before the child reaches the age of six, since at this period the fat cell generation starts and ends around adolescence. What this implicates is that the child will be in the ”pathway” of having more fat cells, which if they continue to be generated because of its eating habits, then at the end of the adolescence a higher amount will be accumulated. A larger adipose tissue can lead to higher chances of adulthood obesity (Callahan, 2017). What is more, during childhood, the establishment of eating habits takes place (Robertson et al., 2016). Hence, it is easier to alter a child’s nutrition preferences at this stage than later in life. Lastly, prevention measures or interventions of obesity are cost-wise more affordable since an obese individual shows health care expenditures at least 25% higher than normal weight individual (Sassi et al., 2010).

Regarding the pillar of *Economics*, focusing on life-long education polices for both parents and children can help increase the awareness for healthier eating. The creation of a digital mobile application to support the work of Youth and Family Centers is another way to bridge the gap between the people who are working parents and do not afford to visit the center during business hours. For the *Environment* pillar some of the proposed policies include to identify very urban districts and promote physical activity programs more in those areas. Schools can also be part of this movement and can be incentivised by the municipality.

For the *Community* pillar, first and foremost is to use open governmental data to identify the citizen profiles which exist on each district. Then, with this information in mind, the design of health awareness campaigns and promotions for fruits and vegetables can be customised on the profile of the citizens and hence, higher engagement can be achieved. Another point for the YFC, is to pay attention to the socio-demographic characteristics of the people visiting the center. Single parents should be treated with more care, since data shows that the united family is more robust in maintaining a healthier, more satisfied child. Some areas may require more resources and data can help allocate money where is needed the most. The idea of creating community gardens is also proposed, to increase the bonding within districts and to help bring parents and children closer to the nature with gardening of foods.

11.3. Scientific Contribution

At the end of the literature review three main knowledge gaps are identified for the challenge of childhood health and obesity. First and foremost, the identification that health inequities affect the health distribution of a country is made. Then, since health inequities exist due to systemic features, the need to address those and prevent health deterioration seems as the most effective way to mitigate epidemics, including obesity. By suggesting appropriate policy interventions, the health distribution of the Netherlands can be improved. All the policies which are suggested have in mind to increase intersectoral collaboration. As it is mentioned by *"The Lancet"*, policy inertia and lack of collaborative action are two main characteristics which keep obesity to an epidemic state, while exposing current policy fragmentation (Swinburn et al., 2019).

Towards this reason, the framework RIVM uses for such studies is expanded and factors which lead to identify inequities are included. This framework is defined on a general health-oriented level, making it a useful tool for researchers who are interested in other health issues apart from obesity. Secondly, this framework guides the quantitative analysis of governmental data. The data, originating from a nation-wide survey, is used to model the factors affecting childhood weight and to explore the causalities between the pillars of the framework.

By exploring the weight with multiple linear models, more robust conclusions are drawn for the significant variables. The causalities which exist for the Netherlands are captured and based on the quantitative results, data-informed policies are proposed for a Dutch municipality. By using data from a national scale, the gap which is identified from a fellow researcher for the scientific field of childhood obesity is a bit more clear after these findings. Timmermans et al. (2018) suggested future research to "include a more sensitive SES measure, including more area-level SES categories and compare rural ares with urban". The ideas behind this statement were to explore the different features of the urban environment and how they could affect the health of children. Of course, the environment is such a complex topic, but the first steps towards a nation-wide understanding of what drives preschool children's weight are completed. Last but not least, the proposed policies contribute towards the *Health 2020 Framework* goals, European Union set, to tackle the grand challenge of *Good Health and Wellbeing* set by the United Nations.

A

Theory Appendix

This appendix supports the literature review chapter, namely Chapter 2. The aim is to present some medical information about the issue of childhood obesity which does not need to be in the main text. Specifically, the consequences of childhood obesity are presented, as were identified from literature. Apart from that, the aspect of United States on the Social Determinants of Health is presented, to showcase that Europe is not the only continent adopting a society-driven approach to tackle health challenges.

A.1. Health consequences of childhood obesity

Childhood obesity has detrimental consequences on health and well-being for children. Different aspects of children health can be affected and create issues with both physical and mental state. Numerous medical studies have already taken place to identify, categorise and evaluate the side effects of the epidemic. An extensive literature review on those was conducted by Pandita et al. (2016). Other studies also reviewed the consequences of obesity in childhood and how this defines a trajectory of health for future years (Bryant et al., 2015), (Robertson et al., 2016). The table below shows the combination of the findings.

Table A.1: Summary of consequences associated with childhood obesity (Pandita et al., 2016), (Robertson et al., 2016), (Bryant et al., 2015).

Categories and examples	
Acute	Type II diabetes Hyperlipidemia Hypertension Precocious puberty Ovarian hyperandrogenism Gynecomastia Cholecystitis Pancreatitis Fatty liver Renal disease
Orthopedic disorders	Slipped capital femoral epiphysis Tibia vara Musculoskeletal problems Blount disease
Liver and bladder dysfunctions	Elevated transaminases Cholecystitis

Categories and examples	
Psychosomatic	Depression Eating disorders Social isolation Sleep disorders
Cardiovascular and endocrine	Hyperinsulinaemia Endothelial dysfunction Increased blood clotting Hypercholesterolemia Hypertriglyceridemia Low levels of high-density lipoprotein Hypertension Polycystic ovary syndrome Coronary artery disease Left ventricular hypertrophy
Cancer	Colorectal carcinoma
Long term	Ischemic heart disease Short life span Asthma Stroke Chronic inflammation

From the Table A.1, it is obvious that the consequences which have been identified so far are diverse and cover the whole span of physical and psychological health. A striking statistic is that childhood obesity is associated with a 16-fold increase in risk for diabetes compared with individuals who are not obese (Stang & Bonilla, 2017). Thus, treating obesity from an early age is sensible for maintaining a healthy physical, social and emotional functioning for children (Robertson et al., 2016). Apart from the individual health benefits, the social circles of the child are also less prone to bully normal weighted peers, since stigma can potentially be associated with differences in appearance, namely a ”heavier” figure (Ersfjord, 2018).

Research suggests that the beginnings of adult obesity lie in the preschool years (Stang & Bonilla, 2017). Since the two phases of fat cell generation, also lie in the preschool age of a child, it is evident that changes to the body composition have larger impact and are easier implemented if done within those time-frames (Callahan, 2017), (Lundahl et al., 2014). However, one crucial issue which occurs, is that many parents fail to identify the disease in their offspring (Robertson et al., 2016). Consequently, the question which keeps occurring in the medical field is how the medical practitioners can address the topic when parents seem unaware of the issue.

A.2. Social Determinants of Health: United States perspective

It is interesting to know that not only Europe, but also USA, understand the importance of the Social Determinants of Health in societies. A policy implementation framework has been initiated in the United States of America. It is called ”Healthy People” and has been initiated in early 2000, every decade ever since they adapt it to new goals and standards (HealthyPeople2020, 2010). Currently, the focus lies in the upcoming goal of ”Healthy People 2030”. The framework is built also upon the concept of Social Determinants of Health (HealthyPeople2020, 2010). However, the framework they follow is is less detailed and complex compared to the WHO European Office (Dahlgren & Whitehead, 2006). The definition provided by this initiative for the SDH is presented below:

> ”Social determinants of health are conditions in the environments in which people are born, live, learn, work, play, worship, and age that affect a wide range of health, functioning,

and quality-of-life outcomes and risks. Conditions (e.g., social, economic, and physical) in these various environments and settings (e.g., school, church, workplace, and neighborhood) have been referred to as “place.” ” (HealthyPeople2020, 2010)

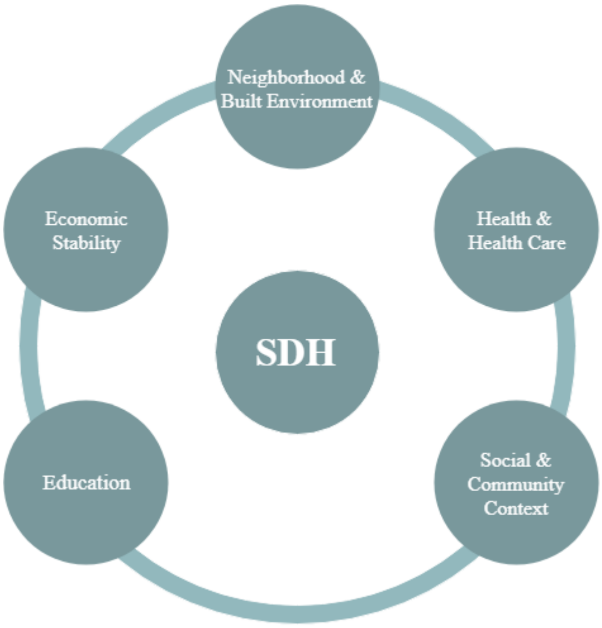


Figure A.1: Social Determinants of Health (SDH), adapted from (HealthyPeople2020, 2010).

In order to operationalise and understand the measures or proxies which can be inferred from the framework (Figure A.1), the examples for factors which compose the different determinants are presented in Table A.2.

Table A.2: Social Determinants of Health (HealthyPeople2020, 2010).

Main pillars and proxies	
Neighborhood and Built Environment	Access to Healthy Foods Crime and Violence Environmental Conditions Quality of Housing
Health and Health Care	Access to Health Care Access to Primary Care Health Literacy
Social and Community Context	Civic Participation Discrimination Incarceration Social Cohesion
Education	Early Childhood Education and Development Enrollment in Higher Education High School Graduation Language and Literacy
Economic Stability	Employment Food Insecurity

Main pillars and proxies	
	Housing Instability Poverty

Since the examples presented for the different factors composing the SDH are interconnected and interdependent, policy interventions are potentially more effective if they are targeted to multiple levels. In other words, targeting individuals and communities at the same time. Their proposed approach is to integrate prevention into education, from the earliest ages on (of Disease Prevention & (HHS), 2011).

It is interesting to mention how this framework can be applied to the issue of obesity. In the study published in 2015 by Bryant et al. (2015), they addressed the social determinants of health operationalised to reduce obesity prevalence in USA. Their aim is to propose feasible policies and changes with the aim to improve the health care system, since it is considered as a SDH itself. These suggestions fall under the pillar of "Health and Health care" from the SDH Framework (Figure A.1). They focused on nurse practitioners and how they can tackle with simple practices, such as awareness, the lack of knowledge and understanding of obesity within vulnerable populations. Their conclusions focused on training the nurses to:

- be culturally competent
- include in their routine the explanation of SDH to the patients
- emphasize on explaining preventive practices to patients for sustaining healthy weight

To summarise, the above research of "Social Determinants of Health", proves the existence of understanding around the concept of different factors co-existing and affecting health. Both the European and the American frameworks conceptualise similar factors. Both countries even if they have set slightly different health goals, understand the significance of an holistic approach to tackle health challenges, such as childhood obesity.

B

Expert Consultation

For the purposes of this thesis, a semi-structured discussion took place with experts on the field of Public Health. They both work with Leiden University Medical Centre and they agreed to the scope and the purpose of the meeting. Also, their consent to use the outcomes for academic purposes only was given. The scope of the discussion was dual:

1. Identify the actors and their power in the law and policy making in the Netherlands.

2. Identify the health check-ups women take to make sure their pregnancy and the new-born child are healthy. The scope of understanding this process is to get acquainted with how mothers' perceive the community provided services and to inform the quantitative analysis.

Below is a free text form of the discussion which took place. Also, at the end of the discussion visual means were used to depict the timeline of the medical and prevention check-ups which happen during and after the pregnancy respectively. The result from the sketches is organised and presented in figure B.1.

B.1. Transcript

Location: TU Delft, The Hague Campus
Date and time: 25 April, 15.20 – 16.00

Members:
Facilitator, Interviewer: Violetta Matzorou
Expert 1: Rimke Vos, Senior Researcher at Department of Public Health and Primary Care, Leiden University Medical Center
Expert 2: Jessica Kiefte de Jong, Full Professor of Population Health with emphasis on lifestyle and lifecourse epidemiology

Affiliation with interviewees: Both experts have been acquainted with the topic of the current thesis and the scope of this interview in advance. Since there were informal meetings with both of them, the introduction of myself and of the topic was not necessary.

Language: It should be noted that English is not the native language of any of the participants of the following interview.

Disclaimer: The text provided is a free transcript from the meeting and not an exact word-by-word text. Both participants agreed on record for the conduction of the interview and its use for academic purposes only.

B.1.1. Actors and Policies

Interviewer: Are there any school policies or regulations to prevent obesity apart from the ones appearing in the reference sheets from WHO? If yes, who initiates them?
Expert 2: The school program around obesity is just now starting to be evaluated (activities related to PE, PA, diet and other initiatives to reduce obesity). The school approach is starting to be evaluated, the Regional Health Service just started to deal with the topic, the Healthy School.

Expert 1: Example: In Utrecht, within a project involving GPs, academics and we were discussing the existence of a Case Manager from the Youth and Family Institution. The aim was to solve the problem of GPs when they see a kid for another reason but identify that is also overweight. Then what is the role of him/her? Do they need to discuss with the kid and parents? What are then the barriers and the facilitators? They really have a limited time window to help them with the other main question but still they have to address the obesity. The aim is to spot overweight/obese children, when going to GPs and then try to discuss with them or refer them to a Case Manager who has a multidisciplinary team so as to address the issue. The team is composed usually with professionals from the Youth Health System, Physiotherapist, Lifestyle Coach, Dietitian. The aim is to define a unique role for the GP in a multidisciplinary team and find ways to improve communication between all involved health professionals, including assigning a Case Manager who will oversee each patient. Thus, a closed loop between the Lifestyle team and the GP is useful so all of them can collaboratively target the children who follow a Lifestyle intervention.

Expert 2: The school involvement or not varies per region and municipality. There is a general consensus in the Netherlands that the approach to obesity prevention should follow the socioecological approach (see framework from RIVM). Activities related to the framework vary a lot per municipality. All municipalities agree that there should be a form of screening for high-risk children in Youth Health Care. Thus, at 5-6 and 8-9 years old there are visits at schools (including primary) to measure the children and identify the growth. These checks follow a national protocol. After that the children who are above the growth rates, need to be referred for further action either to a dietitian or just be given some lifestyle advice.

The other part is the primary prevention strategies. This varies a lot per region. There is the school vignette initiative where schools based on criteria get this vignette. The criteria are levels of PA, healthy food options, regulations of the food kids can bring at school. It is not obligatory and there is a map even for the whole country to see which schools have it or not. It refers to primary and secondary schools. See it is interesting to see what are the criteria to obtain this but also it is interesting to see which schools have this. Such activities even vary across the neighborhood level. Under the same umbrella, some neighborhoods even implement urban related restrictions of what is allowed to exist close-by to schools. There are some regulations then set to “protect” the schools. These regulations are derived from a national level but it is not mandatory for every municipality. Overall, the primary prevention strategies are often partly implemented since the last decision maker to enforce them is the municipality. Another initiative is this.

Expert 1: There is the possibility that there are schools which qualify for this vignette but do not bother to apply for it. Maybe not every school finds it necessary to apply for such a “label”.

Interviewer: Why are the primary prevention strategies left for enforcement to the municipalities? Is it hard to frame them on a national level? IE, it is sensitive to enforce them since they refer to children’ body image, weight, parental behavior, culture etc?

Expert 2: Well, I think it is more the commercial issue. What each municipality wants to prohibit (for example in terms of urban measures and food at school) will affect the businesses at the neighborhood.

Expert 1: It is more sort of a movement, we lately have, on a national level, they want to give more the authority at the regional level. Thus, the policies and interventions can be more context-related. It is also more customisable, each municipality can make their own local policies. This movement apart from kids, also affects the policies and actions for elderly care and for people with mental and physical limitations.
Expert 2: Amsterdam is also a good example. They have of course screening procedures in place but also there is a big group of partners and alliances (local, primary and prevention initiatives). They put in place a general agreement between supermarkets, commercial partners and the municipality, to create a healthier environment in general for the children. They are a very good example since the efforts they put in the past years have been fruitful now and they are the only ones who observe a decline in childhood obesity.
There is a protocol where:

- When do you refer/identify that a kid has obesity or overweight? Just based on growth curves and the standard deviation.
- But then there is a new definition from Cole et al. for obesity, which can inform better the medical screening process.
- There is also the grey area between 0 – 3 years old where the GPs cannot really do a lot, except from just providing the parents with advice. If you exceed the growth curves at 2 years old they do not appoint you to a specialist but only focus to nutrition choices.
- For the Netherlands, the primary prevention strategies are just scattered around the country.

Interviewer: Which is the law where it is decided that the government cannot act upon these laws and it is the municipalities task to act upon?

Expert 2: It comes from the Ministry of Health. They have just a very general statement that it should be something done based on the socioecological model. The more detailed activities will be described in protocols developed by Youth Health professionals and are done on a municipal level.

B.1.2. Health check-ups

Interviewer: There are differences between the administrational layers of public cure or prevention, people follow different steps dependent on the needs they have. How are the steps pregnant and new moms have to follow?

Expert 1: The checkup moments for new moms are national and also fixed in terms of the dates but not mandatory. Each mother has the freedom to do more or less based on how she feels. Later on, the rest of the checkups when the child is older are also suggested to be done in this frequency but again nothing is obliged.

Interviewer: Let us design the flowcharts for pregnant and new moms with the critical points of checkups and the actors who conduct them.
Disclaimer: The conversation which led to the creation of this figure is omitted.
Medical Treatment Timeline:

- It is not mandatory, but it is suggested.
- It is covered by the insurance scheme each woman has.
- The checkups are conducted from a GP.
- Emphasis is placed on the mother's blood sugar levels and blood pressure, not really on her weight gain.

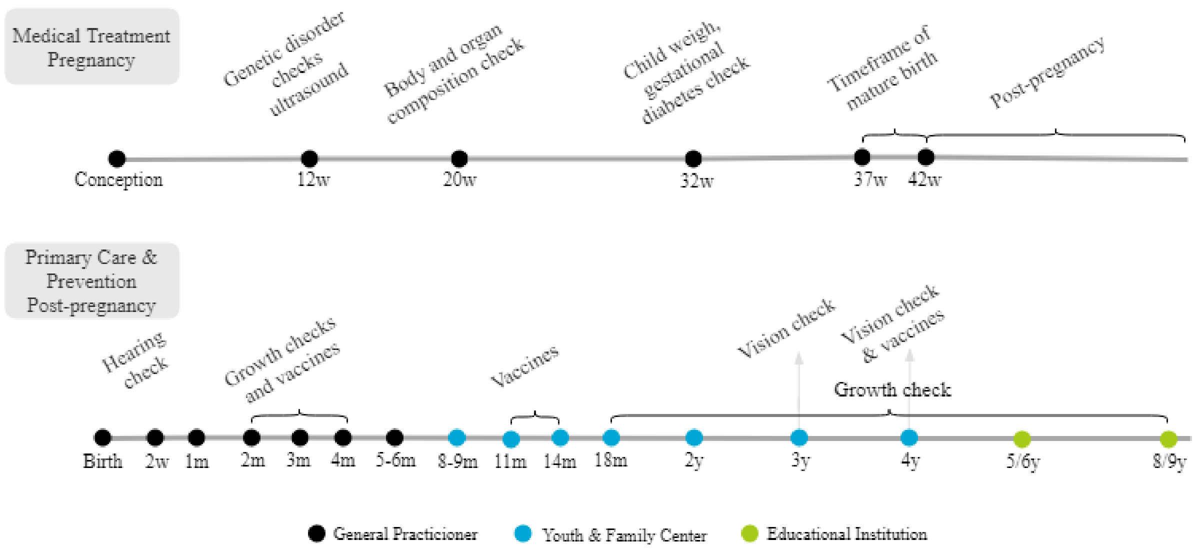


Figure B.1: The timeline of check-ups mothers follow during and after pregnancy, as identified by the experts consultation session.

- The weight gained from the pregnancy is not really monitored and it is not part of the protocol.
- At 32 weeks the gestational diabetes which affects the growth of the child is tested. Also the child is checked for macrosomia.
- Between 37 – 42 weeks is the safe time-frame of birth. If the baby is born earlier due to all kinds of complications then the growth is usually impacted.
- No matter the results from the medical records of the pregnant mom, these numbers are not followed up by later checks after the pregnancy to ensure a safe recovery.
- No advice or follow up is done to any of the high-risk or obese mothers. This is an issue, these conditions are not documented to their General Practitioners as well for monitoring.

Primary Care and Prevention Timeline:

- Not mandatory but usually done.
- The checks for a child are conducted by a GP up to 6 months old.
- After 6 months – 3 years the checks for children are done in the municipal Youth and Family Centers.
- From 5/6 – 8/9 years old, the checks for children are conducted at schools based on the protocols each municipality follows.
- Whatever was diagnosed at the check-up of the 32 weeks in pregnancy for the child's health is not communicated to this stage. This is also a very counter intuitive issue in health care. Academics and individual initiatives are trying to solve such issues and bridge the gap between pregnancy issues and how the future health status of the child will be impacted. It needs more attention.

C Analysis Supplement

The scope of this appendix is to provide to the reader any supplementary information regarding the analysis presented in chapter .

C.1. Entity Relationship Diagram

A full entity relationship diagram is provided and the variables under each entity and their type is provided. The diagram below shows the relationship between the variables and their relationship.

C.2. Data Dictionary

The full data dictionary used for the analysis is provided below.

Table C.1: CBS and RIVM Data Dictionary for the variables under study.

Data Dictionary			
VarName	**Data Type**	**Measurement Type**	**Explanation**
Rinpersoon_Kind	int64	Discrete	Unique, encrypted, numerical identification of the child
Province	string	NA	The name of the province the household of the child is registered at
Municipality	string	NA	The name of the municipality the household of the child is registered at
Postcode	int	Discrete	The 4-digit postcode of the household the child is registered at
SES_hoog	boolean	Binary	If the SES of the postcode is above the poverty line
Urban_index	int64	Ordinal	Urbanisation index of the postcode
Family_structure	boolean	Binary	Indication if both parents reside in the household or not

Data Dictionary			
Income centile	int64	Ordinal	Relative index for the income of the household
education_mother	int64	Ordinal	Levels of the education level of the mother of the child
consultation_vis	int64	Nominal	Absolute number describing the consultation visits of the mother to the municipal family center
smoking	boolean	Binary	Variable describing if the first caregiver smokes or not
western_mother	boolean	Binary	Variable showing if the mother is western or not in terms of biological origin
pregnancy_dur	int64	Nominal	Amount of pregnancy weeks
prem_preg	boolean	Binary	Variable showing if the pregnancy was premature or not (threshold at the 37 weeks)
fruits_patt	boolean	Binary	Aggregated variable if the child has enough fruits or not based on the Dutch nutritional guidelines
veggies_patt	boolean	Binary	Aggregated variable if the child has enough vegetables or not based on the Dutch nutritional guidelines
cur_weight	int64	Ratio	The current weight of the child (gr)
birth_weight	float64	Ratio	The birth weight of the child (gr)
cur_length	int64	Ratio	The current length of the child (cm)
birth_length	int64	Ratio	The birth length of the child (cm)
age_length	float	Ratio	The current length of the child (cm) multiplied by the age
age_squared	int64	Ratio	The current age of the child (cm) squared

Data Dictionary			
height_ratio	float	Ratio	The current length of the child (cm) divided by the birth length (cm)
BMI	int64	Ratio	The current BMI of the child
age	int64	Ordinal	The current age of the child. It just takes values between 0-6 because of the nature of the data
sex_female	boolean	Binary	Variable defining if the child is female or not
mins_bike_sch	int64	Ratio	Number of minutes of bike transportation to school, if applicable
mins_play_sch	int64	Ratio	Number of minutes of outside play at school, if applicable
mins_biking	int64	Ratio	Number of minutes of bike except to go to school, if applicable
fitness_sub	boolean	Binary	Variable defining if the child has a fitness subscription
sports_mem	boolean	Binary	Variable defining if the child has a sports membership
health_status	int64	Ordinal	Variable defining the child's perceived health from its parents
loneliness	int64	Ordinal	Variable defining the child's loneliness perceived from its parents
nervous	int64	Ordinal	Variable defining the child's nervousness perceived from its parents
upset	int64	Ordinal	Variable defining the child's upset moments perceived from its parents
friends_stat	int64	Ordinal	Variable defining the child's friendships status perceived from its parents

Data Dictionary			
satisfaction	int64	Ordinal	Variable defining the child's satisfaction levels perceived from its parents

C.3. Modelling Approach

Modelling iteration approach and variables addition, based on the extended conceptual framework:

- Model Group A: only child's biological data
- Model Group B: A + pregnancy related data
- Model Group C: B + socio-demographic related data
- Model Group D: C + parents lifestyle proxies
- Model Group E: D + environment proxies (based on postcode)
- Model Group F: E + dietary patterns of the child (since they closely relate to the surroundings, it is a continuation of model E2)
- Model Group G: E + physical activity patterns
- Model Group H: A, E or D + psychological state of the child

Linear Models Group A
Y is the current weight of a child, we use variables from the biological data only.

1. Y = lm(birth weight + birth length)
2. Y = lm(birth weight + height ratio)
3. Y = lm(birth weight + Age*Length)
4. Y = lm(birth weight + height ratio + Age*Length)
5. Y = lm(birth weight + Age*Length + AgeSqured)
6. Y = lm(birth weight + Age*Length + AgeSqured + Gender)
7. Y = lm(birth weight + height ratio + Age*Length + AgeSqured + Gender)

Linear Models Group B
Y is the current weight of a child, we use the variables of group A plus pregnancy characteristics.

1. Y = lm(birth weight + Age*Length + AgeSqured + Gender + pregnancy duration)
2. Y = lm(birth weight + Age*Length + AgeSqured + Gender + pregnancy duration + premature pregnancy)

Linear Models Group C
Y is the current weight of a child, we use the variables of group B plus socio-demographic data

1. Y = lm(birth weight + Age*Length + AgeSqured + Gender + pregnancy duration + premature pregnancy + western mother)
2. Y = lm(birth weight + Age*Length + AgeSqured + Gender + pregnancy duration + premature pregnancy + western mother + mother's education level + household income percentile)

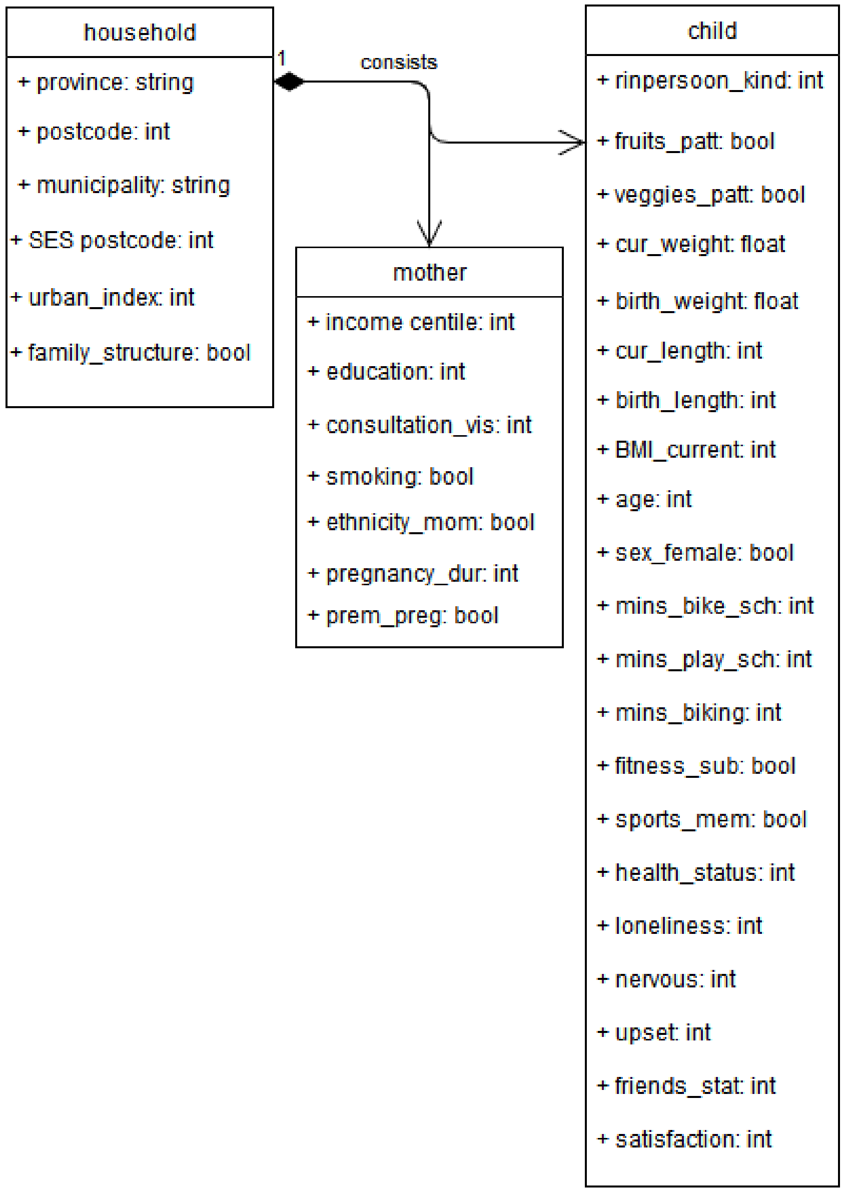


Figure C.1: Extensive entity relationship diagram for the individuals data analysis

3. Y = lm(birth weight + Age*Length + AgeSqured + Gender + pregnancy duration + premature pregnancy + western mother + mother's education level + household income percentile + family structure)

Linear Models Group D
Y is the current weight of a child, we use the variables of group C plus variables describing the lifestyle of the first caregiver.

1. Y = lm(birth weight + Age*Length + AgeSqured + Gender + pregnancy duration + premature pregnancy + western mother + mother's education level + household income percentile + family structure + consultation visits)
2. Y = lm(birth weight + Age*Length + AgeSqured + Gender + pregnancy duration + premature pregnancy + western mother + mother's education level + household income percentile + family structure + consultation visits + smoking 1st caregiver)

Linear Models Group E
Y is the current weight of a child, we use the variables of group D plus variables describing the child's / household's environment based on 4-digit postcode.

1. Y = lm(birth weight + Age*Length + AgeSqured + Gender + pregnancy duration + premature pregnancy + western mother + mother's education level + household income percentile + family structure + consultation visits + postcode SES)

2. Y = lm(birth weight + Age*Length + AgeSqured + Gender + pregnancy duration + premature pregnancy + western mother + mother's education level + household income percentile + family structure + consultation visits + postcode SES + urbanity)

Linear Models Group F
Y is the current weight of a child, we use the variables of group E plus variables describing the child's dietary patterns.

1. Y = lm(birth weight + Age*Length + AgeSqured + Gender + pregnancy duration + premature pregnancy + western mother + mother's education level + household income percentile + family structure + consultation visits + postcode SES + urbanity + vegetables consumption + greens consumption

Linear Models Group G
Y is the current weight of a child, we use the variables of group E plus variables describing the physical activity proxies of the child.

1. Y = lm(Age*Length + Gender + western mother + mother's education level + household income percentile + family structure + consultation visits + postcode SES + urbanity + daily minutes biking + minutes biking to school)

2. Y = lm(Age*Length + Gender + western mother + mother's education level + household income percentile + family structure + consultation visits + postcode SES + urbanity + daily minutes biking + minutes biking to school + minutes of outside play at school + Fitness subscription + Sports membership)

Linear Models Group H
Y is the current weight of a child, we use the variables of group A, E or D plus variables describing the child's psychology to identify potential causalities.

1. Y = lm(Age*Length + AgeSqured + Gender + health status + loneliness + satisfaction)

2. Y = lm(Age*Length + Gender + pregnancy duration + premature pregnancy + western mother + mother's education level + household income percentile + family structure + consultation visits + postcode SES + urbanity + health status + loneliness + satisfaction)

3. Y = lm(Age*Length + AgeSqured + Gender + pregnancy duration + premature pregnancy + western mother + mother's education level + household income percentile + family structure + consultation visits + postcode SES + urbanity + health status + loneliness + satisfaction + friendships + upset + nervous)

4. Y = lm(Age*Length + Gender + pregnancy duration + prematurepregnancy + western mother + mother's education level + household income percentile+ family structure + consultation visits + smoking 1st caregiver + health status + loneliness + satisfaction + friendships + upset + nervous)

For the full code implementation for the analysis of the current thesis, the reader is referred to my *Github* page by the following link: `https://github.com/violettii`

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