The Association between Obesity Prevalence and Obesogenic Environment in Europe

An Ecological Study in the Adult Population of Twenty-Five European Countries

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ABSTRACT

Introduction: Obesity and overweight prevalence constitute globally a significant problem for individuals and societies. Central to the rapid emergence of obesity is the obesogenic environment. This study aims to identify factors of the obesogenic environment which form potential associations between obesity prevalence at the national level of 25 European countries.

Methods: An ecological study design is chosen in which multiple linear regression analyses are used to study the association between obesity prevalence and factors of the obesogenic environment for the total, female and male populations. After a review of relevant literature factors from the economical, food, physical and socio-cultural environment were included.

Results: Between countries and genders, the obesity prevalence varied widely. The high obesity prevalence was mostly found in East and South Europe. The low obesity prevalence is found in Nordic countries. Overall, the obesity prevalence in the female populations was higher than the male populations. Significance was only observed once for the availability of fruit/vegetables in the male population. For the male populations, the strongest associations were found for environmental food variables (Available Calories, Fat, and Fruit/Vegetables), GDP, Postsecondary Education, and Passenger Cars. For the female populations, the strongest associations were found for Postsecondary Education, GDP, GINI-Index, and Available Fat.

Conclusion: To define the obesogenic environment more research has to be conducted into underlying mechanisms and interactions between the different environmental variables. The results of this study suggest that the obesogenic environment influences the development of obesity differently based on gender. Therefore, gender-specific definitions of the obesogenic environment should be proposed. Lastly, gender-specific studies are required to investigate how the environment promotes obesity differently in males and females.

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4 INTRODUCTION & LITERATURE REVIEW

Over the past century, social, economic, and technological changes have affected people's lifestyles (1). Coinciding with these changes are shifts in the human diet towards high fat and high energy foods, including food which consists of "empty calories" as for instance sugar-sweetened beverages (2). Additionally, the physical activity decreased due to changing transport, sedentary work, and increased urbanization (3). These new dietary behaviors and lower levels of physical activity are thought to contribute to the global obesity epidemic (4). In 2014, approximately 1.9 billion adults were overweight worldwide. Furthermore, over 600 million adults were considered obese (3). The term "*globesity*" is nowadays used to describe the global epidemic of individuals being overweight and obese (3,4).

Research has shown that being overweight or obese affects the physical, mental and social well-being of a person (2,5). In terms of the physical health of an individual, there is an increased risk on certain non-communicable diseases, such as: diabetes mellitus, certain forms of cancer, cardiovascular diseases, hypertension, and stroke (3). At the population level, these increases in the associated diseases of obesity are observed in the morbidity of these diseases. Other measures showing the effect of obesity on a population level are attributable deaths, years of life lost (YLL), and disability-adjusted life years (DALY) (6). In 2010, obesity and overweight globally caused 3.4 million deaths; contributed to 3.9% YLLs due to premature mortality; and 3.8% DALYs (7).

Furthermore, the consequences of overweight and obesity expedite from an increase in morbidity of diseases. The increase also imposes an economic burden on the health care systems in many countries (7). For instance, Müller, et al. (2008) estimated the economic burden of obesity for countries within Western-Europe. They found that 0.09 to 0.61% of the annual Gross Domestic Income (GDI) of countries within Western-Europe were obesity-related (8). Therefore, the consequences and related costs of overweight and obesity should be viewed as a threat to the public health which requires a national and global strategy of prevention and management (9).

The mechanism of obesity has been thoroughly researched. In essence, obesity and overweight develop due to an imbalance in the energy consumption and expenditure. This means that a person is consuming more food than the body is spending in terms of basic body functions and physical activity (3). Therefore, the approach to explain obesity was first on the level of the individual (10,11). Genetics allowed researches to differences between why certain individuals or populations are more susceptible to develop obesity (1). Furthermore, the individual focus also led to prevention and treatment which focused on pharmacological, educational and behavioral interventions (12). However, the interventions targeted towards individual showed little to no impact (13). Neither could the individual approach explain the upward trend on the population level (10). Therefore, researchers started to theorize and recognize the possible influences of the environment on the obesity epidemic.

The environment which supports the development of obesity is called the "*obesogenic environment*". A major challenge for looking at the environment as an etiological factor for obesity is the missing consensus on how to define the obesogenic environment (10). To define the environment, it is important to note that it is a complex, multi-layered, and dynamic concept. The environment encapsulates all that is external of an individual (5). The broad definition of the environment can affect the well-being of an individual on an emotional, sociological, spiritual and intellectual level (12). In 1999, Swinburg, et al. were one of the first to define the obesogenic environment (10). He explained the "*obesogenicity*" of an environment as: "the sum of influences that the surroundings, opportunities, or conditions of life have on promoting obesity in individuals or populations" (14). In other words, any external influences which promote unhealthy choices leading to obesity.

Accompanied with this definition, Swinburg proposed an overarching framework called: Analysis Grid for Environmental Linked to Obesity (ANGELO). This framework separates the environment on two levels: "micro-environments" and "macro-environments". The micro-environments entail settings where groups of people go for a specific purpose, as: home, work, school, parks, and hospitals. On the other hand, the macro-environments are the supporting infrastructures that influence the food intake and structural planning, for instance: media, urban and rural planning, and health systems. These two levels can be further explored by classifying certain types of categories, as: physical, economic, political and socio-cultural (10,14). The advantage of using the ANGELO framework is that all environmental elements are considered while providing a relatively simple overview (10).

Although the ANGELO framework can give a good overview, it is not widely used in literature. In research where the framework is used, the outcomes often did not include Body Mass Index (BMI), but merely diet and physical activity outcomes (10). By way of illustration, Ferreira, et al. (2007) conducted a systematic review of observational studies on environmental factors and the association with physical activity in youth. Some of the environmental factors included in the study were: cars in household; single parent family; dog ownership; father's and mother's physical activity; social norms; parental Social Economic Status (SES); physical activity related policies; neighborhood hazards; urban vs. suburban; and coastal vs. mountains. The findings of the study suggest an association between father's physical activity, school physical activity related polices and time spent outdoors as potential determinants of physical activity in children. For adolescent potential determinants included: mother's educational level, family income, attendance on non-vocational school and low neighborhood crime incidence (15). Furthermore, van der Horst, (2007) conduced a systematic review between environmental factors and obesity related dietary behaviors. The environmental factors were divided into four categories: household, education, neighborhood, and municipality. They found among others a positive association between the availability and accessibility in children's fruit and vegetable intake. Additionally, positive associations were found for parental education level and fat intake; family connectedness and fruit/vegetable intake (16).

Another systematic review which used the ANGELO framework was conducted by Wendel-Vos, et al. (2007). Some of the environmental factors included in this research were: environment aesthetics, convenience of facilities, access- and availability of recreational facilities, traffic safety, urban sprawl, hills, coastal location, social-cultural environment, frequency of social contact, costs for physical activity, and household income. They classified environmental factors to gain insight in determinants of types and intensity of physical activity among men and women. Firstly, no convincing evidence was found for associations within the economic environment. No studies were included which reviewed the influence of the political environment. However, for the socio-cultural environment positive associations were found. Namely, having social support or a training partner was identified as potential determinants for vigorous physical activity types and intensities. However, most included studies showed no associations between environmental factors and physical activity (17). Both reviews recommend future research with clear standardized definitions. This makes it easier to compare studies and provide evidence of a higher quality for public health and policy-makers (15,17).

However, most studies do not use the ANGELO framework, but use a different approach for studying the obesogenic environment. For instance, a systematic review with a different study design found associations between an increased likelihood of developing obesity and the lack of nearby recreational facilities, absence of sidewalks, spending more time in a car, and residing in an area with lower levels of land-use mix (9). Another systematic review showed that married participants have a higher energy intake then single (2). All the associations mentioned so far are evidence for a potential association between the environment and the obesity prevalence. However, the results are very inconsistent (2,18). The influence of the environment is therefore still debated. Thus, although some research has been done on factors in the obesogenic environment, results are still inconclusive about how the modern environment is fueling the obesity epidemic (2,19)

Hence, there has been a growing consensus among researchers that the obesogenic environment can influence the development of obesity in individuals. However, the results of previous studies are inconclusive (2,16). Each study included a wide variety of different environmental factors which makes comparing results difficult. Further, most studies are conducted on country level and in Australia or the United States (4,9,18). For these reasons, there is still little information about the obesogenic environment and the European patterns.

Therefore, the aim of this study is to examine associations between country-specific obesity prevalence and environmental obesogenic factors in the European adult population. The following research question is proposed: *"What is the association between obesity prevalence and the obesogenic environmental factors in the adult European population?"* The factors can be separated into multiple categories which include: food, physical, economic, and socio-cultural variables. The results in this study will indicate if obesity prevalence data correlates with the obesogenic environment. The potential associations do not describe a causal relationship, but indicates a possible connection between obesity prevalence and the obesogenic environment.

5 METHODS

5.1 DESIGN AND DATA SOURCES

To research the possible association between obesity prevalence and factors from the obesogenic environment in Europe, an ecological study design was chosen. An ecological study is an observational study which can show if there is a possible association between variables in different populations in the same or different timeframe.

The obesity prevalence data and the corresponding European countries were selected for the following reasons. Firstly, the countries had to have age standardized prevalence data available on obesity in the year 2013 in the categories: total (males and females combined), male, and female adults. Adults were divined as persons of 20 year and older. Secondly, the countries were chosen to give an overview on the obesity prevalence in Europe. It was important to include countries with low, average and high obesity prevalence. Lastly, the countries were included if besides the prevalence data, data for the environmental factors was available. This led to the inclusion of the following twenty-five European countries: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and United Kingdom. The data for the obesity prevalence is retrieved from the Global Burden of Disease Study 2013 (20).

The obesogenic factors included in this study were chosen by performing a review of relevant literature. Factors from the economical, food, physical and socio-cultural environment were included. The specific obesogenic factors included in this study as well as their data source can be found in Table 1. The method for this selection can be found at “Environmental Factors”.

5.2 OBESITY PREVALENCE

The obesity prevalence data is retrieved from the Global Burden of Disease Study 2013 (20). Obesity is defined as a BMI higher than 30 kg/m^2 and overweight is defined as a BMI higher than 25 kg/m^2. Obesity and overweight prevalence data in the database are retrieved from surveys, reports and published studies either through self-reports or physical measures. The study covers the period from 1990-2013, but for this research only the most recent year, 2013, was selected (20).

Table 1: Description of Independent Variables with their Sources

Indicator	Year	Unit	Description	Source
Economic variables				
GDP	2013	1000 US$/capita	The sum of the monetary value of all service and goods produced in a year, per person.	World Bank[a]
Postsecondary Education	2010	% of population; Adults of 25+ years	Share of population over 25 which has a Postsecondary Education	HFA[b]
Unemployment	2013	% of total labor force	Share of the labor force which currently does not have a job, but available to work	World Bank[a]
GINI-Index	2012	% between 0 - 100	Distribution of income among individuals or households[h]	World Bank[a]
Food variables				
Available Calories	2009	Kcal per person/ day	Average number of calories per person per day	HFA[b]
Available Fat	2009	Gram per person/day	Grams of fat per person per day	HFA[b]
Available Fruit/Vegetables	2009	Kilogram per person/ day	Average amount of fruits and vegetables per person per day	HFA[b]
Alcohol	2009	Liters per person; Persons of 15+ years	Pure Alcohol Consumption in liters per person (15+)	HFA[b]
Physical variables				
Passenger Cars	2013	1000 Cars[g]	Amount of Passenger Cars	EuroStat[e]
Urbanization	2013	% of population	Share of the population which lives in urban areas	World Bank[a]
Socio-Cultural variables				
Single-Member Households	2013	Number of persons[g]	Number of persons living alone	UN Data[e,f]

[a] World Development Indicators, World Bank Institute
[b] European Health for All database, World Health Organization (WHO)
[e] Passenger Cars in the EU & Poverty and Social Exclusion, EuroStat
[e] Household by type of Household, UNSD Demographic Statistic, United Nations Statistic Division
[f] StatLine: Huishoudens; Personen naar geslacht, leeftijd, en regio, 1 januari *(Household; persons according to gender, age, region, 1 January),* Centraal Bureau voor de Statistiek (CBS)
[g] To transform the absolute numbers from the passenger cars and single-member households. The country numbers where divided by the mid-year population in 2013. The data from the mid-year population was retrieved from the HFA-database.
[h] In the GINI-Index a score of 0 is perfect equality; 100 is perfect inequality.

5.3 ENVIRONMENTAL FACTORS

As described in the introduction, there are multiple frameworks which can help reviewing the obesogenic environment. In this research, the obesogenic environment is divided in multiple categories: physical, economic, food and socio-cultural (Table 1). To decide upon which independent variables (environmental factors) to include relevant literature was researched.

To start a review of relevant literature was conducted. Articles were retrieved from PubMed through a keyword research. Firstly, a Medical Subject Heading (MeSH) search was conducted with the following terms "Environment", "Environment Design" and "Obesity", only English systematic reviews in humans were included in the results. Studies focused on specific groups which were not adults, were not included in the research. The term "obesogenic" is not a MeSH-term. To make sure no systematic reviews were accidently excluded another search within PubMed was conducted. In this search "obesogenic" and "environment" were searched in all fields. In total 16 systematic reviews were found which fit the above criteria. After reading the titles and abstracts 10 more studies were excluded. This was either due to an unrelated study focus or wrong study population. The remaining six studies were examined to summarize the most relevant obesogenic factors from these studies (see Table 2 in results) and potentially compare them with the found associations of this research. During the process of this research, studies outside this review of relevant literature have contributed to adding environmental factors to the research. This was done to make sure that the right variables were included.

5.4 STATISTICAL METHOD

All data was first collected within Microsoft Excel and were required converted into percentage. The analyses discussed below were made in IBM SPSS 24 for Windows. Firstly, a Chi-Square Test has been performed to examine if the country specific values of obesity prevalence and environmental factors from the individual countries differed from each other (Appendix II). The significance level was set on 0.05. To gain better understanding of the data multiple plots of the data were created. Each environmental factor (x-axis) was plotted against the obesity prevalence for the total, female and male population (y-axis) (Appendix III).

After obtaining an overview of the data, several linear regression analyses were conducted. These analyses have been done separately for each environmental factor (independent variable) and the obesity prevalence (dependent variable) for the total, male, and female population separately. The significance level was set on 0.05 (Appendix V).

These regression analyses were followed by an analysis which builds a predictive model for the female and male population. The models were made separately for each gender. The models were build according to the following steps. The R-squared of the simple linear regression analysis determined the order of environmental factors included in the model. The environmental factor with the largest R-squared was entered first in the model. Afterwards in ascending order from large to small R-squared, the other environmental factors were entered in the model. Environmental factors were not included in the model after the increase of the R-squared had stagnated.

From these predictive models a formula could be derived to predict the obesity prevalence for the male and female population. The outcomes of these formulas were compared to the obesity prevalence from the Global Burden of Disease Study (Appendix VI). Two graphs are presented with the known obesity prevalence on the y-axis and the predicted obesity prevalence on the x-axis (Figure 1).

Lastly, for the following environmental factors it was possible to calculate specific numbers for female and male populations: secondary-education, Unemployment, and single-household. However, gender-specific data was not available in all countries. An overview of the included countries and the result can be found in Table 6. The results in this study do not indicate a casual association, but give insight into possible associations. To determine if associations are potentially causal, more research will be required.

6 RESULTS

The results are presented in the following order. Firstly, a summary is given of the obesity prevalence (dependent variable) and a second summary is given of the environmental factors (independent variables). A Chi-Squared Test was performed for both the obesity prevalence and environmental factors. This test shows if the data from the different countries was significantly different from each other. The result of the analysis is given in significance. All tests resulted in a significance level of $p < 0.001$. An example of the results can be found in Appendix II.

The next section of the results moves on to describe the linear regression analyses. The regression analyses consisted of multiple parts which are described in the methods. At first the results of the simple linear regressions are given. This is followed by an examination of the gender-specific linear regression analyses. Lastly, the results of the gender-specific predictive models are presented.

6.1 SUMMARY DEPENDENT VARIABLE | OBESITY PREVALENCE

The obesity prevalence varied widely across the included European countries and between male and female populations (Table 2; Appendix I). The average obesity prevalence for the total (females and males included) population within Europe was 20.9%. The lowest obesity prevalence's for the total populations were found in the Netherlands (14.3%), Austria (18%) and Italy (18.2%). Additionally, Bulgaria (18.6%) had low obesity prevalence too. This low prevalence in Bulgaria is mainly caused by the low male obesity prevalence, even though the female obesity prevalence is quite high. Norway and Sweden also had low obesity prevalence. However, both countries had a relative high obesity prevalence in the male category compared to the Netherlands, Austria and Italy. For the total populations, the highest obesity prevalence's were found in Estonia (22.8%), Luxembourg (24.9%), United Kingdom (25.0%), and Malta (28.3%). Estonia high obesity prevalence is mainly caused by the high female obesity prevalence of 25.6%.

When the female and male populations are viewed separately, it becomes evident that the obesity prevalence for the female populations are higher than the male populations. The average obesity prevalence for the female populations within Europe was 21.7%. Whereas the average obesity prevalence for the male population was 19.7%. The only exception is Malta; here the male population has an obesity prevalence of 29% while the female population has an obesity prevalence of 27.5%. The countries with low female obesity prevalence differ from the countries with a low male obesity prevalence. The countries with low female obesity prevalence are the Netherlands, Austria, Norway and Italy. The countries with the highest obesity prevalence are the United Kingdom, Estonia, Latvia, Luxembourg and Malta. The lowest male obesity prevalence is found in the Netherlands, Bulgaria, Latvia, Slovakia and Italy. Luxembourg, United Kingdom and Malta, have the highest male obesity prevalence (Appendix I).

Table 2: Summary of Obesity Prevalence in Europe

	Included Countries	Year	Unit	Mean	Minimum	Maximum
Total	25	2013	%	20.9	14.3 Netherlands	28.3 Malta
Male	25	2013	%	19.7	12.7 Netherlands	29.0 Malta
Female	25	2031	%	21.7	15.9 Netherlands	27.5 Malta

6.2 SUMMARY INDEPENDENT VARIABLES | ENVIRONMENTAL FACTORS

In total, elven environmental factors were included in the research. The included variables are: Gross Domestic Product (GDP), Postsecondary Education, Unemployment, Passenger Cars, Urbanization, and Single-Member Households. Furthermore, Available Calories, Available Fat, Available Fruit/Vegetables and Alcohol Consumption were included as environmental food variables. The description of these independent variables can be found in Table 1. The environmental factors varied greatly among the European countries. Therefore, to give an overview Table 3 has been included. The table shows a summary of the mean, minimum, and maximum values per environmental factor.

Table 3: Summary of Environmental Factors (Independent Variables)

Factors	Included Countries	Year	Unit	Mean	Minimum	Maximum
Economic variables						
GDP	24	2013	1000 US$/capita	36774.30	7136.00 Bulgaria	103506.20 Luxembourg
Postsecondary Education	25	2010	% of population	29.2	12.8 Italy	75.6 Luxembourg
Unemployment	25	2013	% of total labor force	9.8	3.5 Norway	26.1 Spain
GINI-Index	23	2012	% between 0-100	31.3	25.6 Slovenia	36.0 Bulgaria & Portugal
Food variables						
Available Calories	25	2009	Kcal per person/ day	3374	2791 Bulgaria	3800 Austria
Available Fat	25	2009	Gram per person/day	133	90 Estonia	166 France
Available Fruit/Vegetables	25	2009	Kilogram per person/ day	213	105 Bulgaria	312 Italy
Alcohol	25	2013	Liters per person	10.26	6.2 Norway	15 Lithuania
Physical variables						
Passenger Cars	24	2013	1000 Cars	9855.5	43851 Germany	256 Malta
Passenger Cars	24	2013	% of population with car	48.2	21.0 Romania	65.5 Luxembourg
Urbanization	24	2013	% of population	73.1	97.8 Belgium	49.8 Slovenia
Socio-Cultural variables						
Single-Member Households	21	2010	Total persons living alone	2330681	34635 Malta	13764955 Germany
Single-Member Households	22	2010	% of population	12.5	7.3 Slovenia	17.3 Norway

6.3 SIMPLE LINEAR REGRESSION ANALYSIS

A linear regression analyses was conducted to test if there is an association between the environmental factors and the obesity prevalence within Europe. The regression analyses are done for three separate groups, namely: the total, female and male population. The results are presented in Table 4. In this table, the R-squared (R^2) and the regression coefficient (B) with the Confidence Interval (CI) are given.

Table 4: Simple Linear Regression Analysis

	Total		Female		Male	
	R^2	B (95% CI)	R^2	B (95% CI)	R^2	B (95% CI)
Economic variables						
GDP	0.007	0.008 (-0.035-0.051)	0.017	-0.015 (-0.064-0.035)	0.134	0.037 (-0.005-0.079)
Postsecondary Education	0.103	0.067 (-0.018-0.152)	0.131	0.079 (-0.009-0.167)	0.050	0.052 (-0.046-0.149)
Unemployment	<0.001	-0.001(-0.255-0.252)	0.006	0.049 (-0.217-0.315)	0.010	-0.067 (-0.348-0.214)
GINI-Index	0.090	0.185 (-0.076-0.445)	0.121	0.248 (-0.047-0.544)	0.018	0.086 (-0.198-0.370)
Food variables						
Available Calories	0.021	0.002 (-0.003-0.006)	0.005	-0.001 (-0.006-0.004)	0.133	0.004 (-0.000-0.009)
Available Fat	0.012	-0.014(-0.068-0.040)	0.095	-0.041 (-0.096-0.014)	0.022	0.021 (-0.039-0.081)
Available Fruit/Vegetables	0.087	0.016 (-0.006-0.038)	0.008	0.005 (-0.019-0.030)	0.230	0.029 (0.006-0.058)*
Alcohol Consumption	0.020	0.207 (-0.424-0.838)	0.092	0.473 (-0.166-1.113)	0.006	-0.127 (-0.836-0.582)
Physical variables						
Passenger Cars	0.061	0.069 (-0.050-0.189)	0.020	0.041 (-0.087-0.169)	0.111	0.104 (-0.026-0.234)
Urbanization	0.001	-0.005 (-0.087-0.077)	0.011	-0.022 (-0.117-0.072)	0.012	0.021 (-0.064-0.107)
Socio-Cultural variables						
Single-Member Households	0.080	-0.228 (-0.589-0.134)	0.056	-0.197 (-0.577-0.182)	0.083	-0.263 (-0.671-0.145)

* The asterisks indicate if an association is significant

The R-squared provides an indication of the strength of the relationship between the obesity prevalence and an environmental factor. In short, the R-squared gives the proportion of the obesity prevalence which can be explained by the individual independent variables. The values of the R-squared presented in the table are low. The highest R-squared for the total (10.3%) and the female (13.1%) population is for the Postsecondary Education. For the male population, the R-squared value for the Postsecondary Education is just 5.0%. Contrastingly, the male population has multiple other R-squared which have a value higher than 10%. The GDP, Available Calories, Available Fruit/Vegetables, and Passenger Cars all have a R-squared value higher than 11%. Hence, Table 4 shows that several factors are explaining the obesity prevalence in female and male populations. Furthermore, the low R-squared values indicate the association of the independent variables to the obesity prevalence, individually, to be very low. The found associations are most likely weak associations.

Secondly, the results of the economic variables show that they are influencing the obesity prevalence within Europe. As discussed above, Postsecondary Education shows to be an important environmental factor for the total ($p = 0.117$) and female population ($p = 0.075$) due to the high R-square and low p-values. For the male population, the GDP has the largest R-squared and lowest p-values ($p = 0.078$) (Appendix V). Furthermore, in the graphs of both Postsecondary Education and GDP a similar pattern can be observed. In countries with a lower GDP and Postsecondary Education, the variance in the obesity prevalence is limited. Countries with a higher GDP and Postsecondary Education level, the variance in obesity prevalence is large. For example, the Netherlands and United Kingdom both have a similar high GDP and education level. However, the United Kingdom has very high obesity prevalence and the Netherlands very low. The Nordic countries (Sweden, Denmark, Norway, and Austria) also have similar high GDP and education level, but are closer to the obesity prevalence from the Netherlands than the United Kingdom. Ireland, Germany, and Finland are all closer to the United Kingdom (Appendix III).

The other two economic factors show very different results. Unemployment does not show any clear patterns in the plots or the regression analysis (total $p = 0992$; female $p = 0.708$; male $p = 0.284$) (Appendix V). On the other hand, the GINI-Index appears to have a significant role specifically in the female population. For the total and female population, the more perfect the equality of the country is (lower score on the GINI-Index), the lower the obesity prevalence (Appendix IV).

Thirdly, the most interesting results of the environmental food variables are associated with availability of fruit/vegetables; the availability of fat; and availability calories. The availability of fruit/vegetables is positive significant associated to obesity prevalence in the male population ($p = 0.015$). This pattern is not observed for the total or female population. In the female population, the plot shows that when the available fruit/vegetable is below 200 grams, countries often have a higher obesity prevalence (Appendix III). While when the availability is over 200 grams, the obesity prevalence ranges from low to high. Furthermore, for the total and female population the availability of fat shows to be negatively associated to obesity prevalence. Although this pattern is not observed in the male population, there is still one similarity. In all plots France, Italy, and Austria show to have a high availability of fat while having a low obesity prevalence (Appendix III). Additionally, the R-squared and plot of Available Calories in the male population present a positive (non-significant) association. This association is not observed in the total or female population. Lastly, in none of the plots a clear pattern appears for Alcohol Consumption. Overall, the male population has stronger associations to the environmental food variables than females.

Lastly, the social-cultural and physical variables have a weak association to obesity prevalence in all populations. Apart from the R-squared of 11.1% for Passenger Cars in the male population, the R-squared are values below 10%. The plots of these physical variables do not show patterns. Additionally, neither for the single-member household variable patterns are observed. However, the plots do show a clustering of countries within the total, female and male population. The clustered countries with a similar obesity prevalence and single-member household level are: Norway and Austria; and United Kingdom and Luxembourg. There are also two clusters of countries which have a comparable single-member household level, but have a diverse obesity prevalence. These two clusters are: Portugal, Poland, Spain, Ireland, Romania, and Slovakia; and Italy, Bulgaria, and Czech Republic (Appendix III).

6.4 GENDER-SPECIFIC LINEAR REGRESSION ANALYSES

Gender-specific data was available for the following variables: Postsecondary Education, Unemployment, and single households. None of the results indicate a significant association between the dependent and independent variable. Additionally, the R-squared values also indicate overall a weak association between the variables. For the female population the R-squared increased for all variables, but the largest increase was viewed for Postsecondary Education. For the male population, the gender adjusted data lead to a decrease of the R-squared in all environmental factors. The results are summarized in the table below.

Table 5: Results of Gender-Specific Linear Regression Analyses

	Female			Male		
	Included Countries	R^2	B (95% CI)	Included Countries	R^2	B (95% CI)
Postsecondary Education	25	0.131	0.079 (-0.009-0.167)	25	0.050	0.052 (-0.04-0.15)
GA: Postsecondary Education	8[a]	0.416	0.613 (-0.112-1.339)	8[a]	0.005	-0.052 (-0.787-0.683)
Unemployment	25	0.006	0.049 (-0.217-0.315)	25	0.010	-0.067 (-0.35-0.214)
GA: Unemployment	24[b]	0.009	0.055 (-0.196-0.305)	24[b]	0.002	-0.001 (-0.232-0.230)
Single Households	22	0.056	-0.197 (-0.577-0.182)	22	0.083	-0.263 (-0.67-0.15)
GA: Single Households	18[c]	0.062	-0.197 (-0.604-0.210)	18[c]	<0.001	-0.019 (-0.483-0.445)

GA: Gender Adjusted Data
[a] Included countries: Belgium, Finland, Latvia, Lithuania, Netherlands, Poland, Sweden, United Kingdom
[b] All countries included except: Malta
[c] All countries included except: Czech Republic, Denmark, France, Netherlands, Slovenia, Spain, Sweden

6.5 GENDER-SPECIFIC PREDICTION MODELS

Two gender-specific models were generated after studying the results found in Table 4. The value of the R-squared determined the inclusion order of the environmental factors in the models.

Table 6: Building Predictive Models for Obesity Prevalence in Females & Males

Model	Female			Male		
	Environmental Factor	R^2	B[a] (95% CI)[a]	Environmental Factor	R^2	B[a] (95% CI)[a]
1	Postsecondary Education	0.131	0.231 (0.058-0.405)	Available Fruit/Vegetables	0.230	-0.008 (-0.049-0.033)
2	GINI-Index	0.303	-0.007 (-0.311-0.297)	Available Calories	0.236	0.002 (-0.006-0.009)
3	Available Fat	0.360	0.028 (-0.042-0.098)	Passenger Cars	0.267	-0.026 (-0.181-0.128)
4	Alcohol Consumption	0.406	-0.325 (-1.194-0.543)	Single-Member Households	0.324	-0.307 (-0.782-0.168)
5	GDP	0.517	-0.117 (-0.237-0.004)	Postsecondary Education	0.360	0.088 (-0.050-0.226)
6	Single-Member Households[b]	0.526		GDP[c]	0.388	0.007 (-0.085-0.099)
7	Passenger Cars[b]	0.532		Available Fat	0.433	0.045 (-0.051-0.142)
8	Urbanization	0.534		GINI-Index	0.435	
9	Available Fruit/Vegetables	0.534		Urbanization	0.440	
10	Unemployment	0.534		Unemployment	0.440	
11	Available Calories	0.583		Alcohol Consumption	0.467	
Intercept of model[d]			18.736 (7.096-30.376)			11.126 (-6.644-28.968)

[a] The B-coefficient and CIs presented are retrieved from the regression analysis of the model. This means only the environmental factors above the thick black line in the table are entered in the model. The environmental factors below the line do not influence the B-coefficient or CIs.

[b] Originally the R-squared of GDP was smaller than the R-squared of Single-Member Households and Passenger Cars. However, in the current model GDP has a larger effect on the R-squared then single-member household or Passenger Cars. Therefore, GDP has been set above these two independent variables.

[c] Originally the R-squared of GDP was larger than the R-squared of Available Calories, Passenger Cars, and Single-Member Households. However, when GDP is inserted in the model in the original order it has a negative effect. When the increase of the R-squared of the model started to stagnate, the influence of GDP was analyzed again. GDP now did show to have a positive effect on the R-squared of the model.

[d] The intercept is retrieved from the regression analysis of the model. This means only the environmental factors above the thick black line in the table are entered in the model. The environmental factors below the line do not influence the intercept.

When environmental factors were included in the model the R-squared increased. The larger the R-squared, the better the obesity prevalence is explained by the environmental factors and the better the model will predict the obesity prevalence. The R-squared from the female model was larger with less environmental factors included in the model compared to the male model. Furthermore, the included environmental factors for males and females are different. However, variables which can be found in both models are: Postsecondary Education, Available Fat and GDP.

The models generate formula's which can compute a predictive obesity prevalence for the included European countries. The following formulas are derived from the gender-specific models:

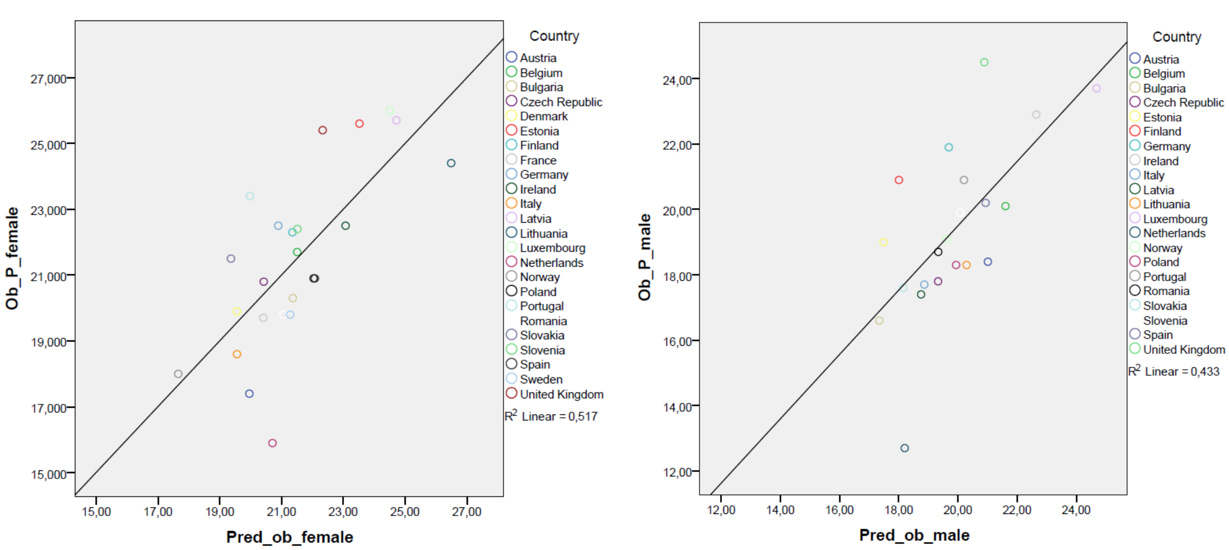
$$\hat{y}_{Female} = 18.736 + (\text{Postsecondary Education} * 0.231) + (\text{GINI-Index} * -0.007) + (\text{Available Fat} * 0.028) + (\text{Alcohol} * -0.322) + (\text{GDP} * -0.117)$$

$$\hat{y}_{Male} = 11.126 + (\text{Available Fruit/Vegetables} * -0.008) + (\text{Available Calories} * -0.002) + (\text{Passenger Cars} * -0.026) + (\text{Postsecondary Education} * -0.088) + (\text{GDP} * -0.117) + (\text{Available Fat} * 0.045)$$

Two plots which compare the obesity prevalence retrieved from the data and computed predictive obesity prevalence are shown below. The closer the predicted obesity prevalence is to the line, the better the prediction the model of the model.

Figure 1: Gender-Specific Scatterplot of Obesity Prevalence and Predicted Obesity Prevalence
X-axis = predicted obesity prevalence (%) Y-axis = obesity prevalence from data (%)

Female **Male**



The female and male scatterplots above and Table 12 show that the models seem to be good predictors of obesity prevalence (Appendix VI). Most countries have a predicted value close to the actual obesity prevalence. For the female population, the countries deviating from the predict value most are Austria, Estonia, Finland, Latvia, Lithuania, and Portugal. In the male population, the countries for which the predictions were less in line with the known obesity prevalence were the Bulgaria, Estonia, Latvia, Lithuania, Poland, and the Netherlands. Countries which followed the model very well in the female and male population are Belgium, Ireland, Italy, Luxembourg, Norway, and Spain.

7 DISCUSSION

7.1 OBESITY PREVALENCE IN EUROPE

In this study twenty-five European countries with varying obesity prevalence in the year 2013 were examined. The obesity prevalence from the included countries ranged from 14.3% in the Netherlands to 28.3% in Malta. In both males and females, the lower obesity prevalence's were found in North and West European countries. Although overall, most West European countries have low obesity prevalence; although the United Kingdom, Ireland, Luxembourg, and Germany have the highest obesity prevalence. East and South European countries, as Spain and Portugal, also have an elevated obesity prevalence. These findings are in line with previous studies which observed a difference between South-East Europe, and West-North Europe (21,22). However, in contrast Berghöfer, et al. (2007) found a very high obesity prevalence in the Czech Republic and Italy for both males and females (21). While the data used in the current research, the Czech Republic and Italy appear to have one of the lowest obesity prevalence (Appendix I).

7.2 ENVIRONMENTAL FACTORS

The aim of this study was to see if the obesogenic environment is a part of the explanation of the between-country variations in obesity prevalence. Multiple environmental factors were chosen after reviewing the existing literature. For each of the potential environmental factor a regression analysis was conducted. Below the results are discussed and compared to previous research. The results of this research and existing literature are used to propose a definition for the obesogenic environment.

7.2.1 GDP

Firstly, the results of the GDP show a very weak relation to obesity prevalence. For the total population, a non-significant positive association can be observed. When the GDP increases, so will the obesity prevalence of a country. This is not necessarily in line with findings of other studies. Other studies suggest that in developed countries populations have access to an elevated level of health education, sufficient income to buy healthy foods, time for leisure and physical activity, and access to health care (23). Additionally, a study conducted ten years ago found a significant inverse association between obesity and European countries with a higher GDP. They proposed that due to technologically advancement and availability of goods and service in

European countries, promote healthy behaviors. In other words, create an atmosphere which promotes low obesity prevalence (9). Furthermore, they describe that especially for women an inverse relation between income (as part of social economic status) and obesity exist (9). This negative associations also presented as non-significant in their research. Further, the association between GDP looks stronger for males than females. A similar result was found by Wells, et al. (2012) found stronger associations for male than females regarding obesity and GDP. Additionally, they found a weak non-linear positive association for males, but no association for females (24). Although this study included countries less developed than European countries, the similarity in the findings might suggest that potential association between GDP and obesity prevalence exist.

7.2.2 Postsecondary Education & GINI-Index

The results found for the Postsecondary Education are surprising, because non-significant positive associations between Postsecondary Education and obesity prevalence are observed. By way of illustration, Luxembourg, a country with the third highest obesity prevalence, has the largest percentage of population following a secondary education (Table 3; Appendix I). These results are surprising due to the prediction that a higher education would lead to a better understanding of health and personal care (23).

The results of previous studies suggest that in general stronger increases of obesity are found in populations with a low education compared to populations with a high education (25). The study performed by Rabin, et al. (2007) also indicated a negative non-significant association between Postsecondary Education and obesity prevalence (9). A proposed underlying mechanism could be that a higher level of education is often association with a higher body dissatisfaction. The social standard of attractiveness and health influence the pursuit of a healthy and thin body. Education influences these social standards and implies the expectation to personally achieve the socially accepted appearance (26). Hence, with this proposed underlying mechanism an inverse association between education and obesity prevalence would be expected. Nevertheless, this research does not support these findings.

The potential reason why the findings of this research suggest a positive association might be due to inequality in countries. For example, Italy has a low education level and low obesity level while Luxembourg has both high obesity prevalence and education percentage. However, both Italy and Luxembourg score relatively high on the GINI-Index. The GINI-Index gives an estimate on how much the population deviates from an equal distribution of wealth. Countries which follow the expected pattern of a high education combined with a low obesity prevalence are the Netherlands, Sweden and Norway. These countries score much lower on the GINI-Index compared to Italy and Luxembourg. If the data is investigated it shows that countries with high education and high obesity prevalence, overall have a high score on the GINI-Index (Appendix IV) (27). Hence, the unequal distribution of wealth might explain that although the education level is high, not everyone is able to enjoy the benefits of their education.

7.2.3 Unemployment

Unemployment is not significantly associated with obesity prevalence. Additionally, the R-squared of Unemployment is very low indicating a very weak or no association. Rabin et al, (2007) also did not find an association between obesity prevalence and Unemployment in European countries (9). However, in an Australian, Finnish, and Swedish research Unemployment was associated with a greater BMI. On the contrary, a greater BMI was also found in shift workers of developed countries (28). The contradicting results between Unemployment and BMI could partially be explained by the missing underlying mechanism. It is unclear if obesity causes Unemployment; Unemployment causes obesity; or if there are any unknown mediators (29). More research is required to examine the potential effects of working environment and occupational status on the development of obesity.

7.2.4 Passenger Cars

The Passenger Cars were included to explore the potential association between transportation as part of the urban planning and obesity prevalence in Europe. Passenger Cars support an inactive attitude compared to for instance public transport and biking (23). The findings in this study are not conclusive, but show a non-significant positive association between the amount of Passenger Cars and obesity prevalence. Additionally, previous studies also indicate that motorized transport promote a sedentary life-style (11,30). For instance, a study which examined the time spend in a car per day, and another study which measured the distance travelled in a car per day and the number of minutes commuting; both found significant positive associations between the measured indicators and risk on obesity (5).

7.2.5 Urbanization

The results of this study show no association between Urbanization and obesity prevalence. Nevertheless, in previous studies indicators closely linked to Urbanization have been found to link the built environment to obesity (31). Especially in developing countries (in this research none of the countries is considered developing), Urbanization is thought to be one of the key factors. Groups of citizens within developing countries move from rural to urban areas which majorly affects their energy balance by mostly decreasing the energy expenditure (11). In developed countries, studies regarding the urban environment have been conducted. However, these studies miss a consensus on how to measure the urban environment leading to inclusion of many different indicators. For instance, studies conducted in the United States have shown a positive correlation between urban sprawl and obesity. Another study in the United States associated land-use mix negatively with obesity (31). A last example is a study which found living in an urban area associated with a high takeaway consumption (4). Other studies also included factors as: access or distance to shops; proximity of fast food outlets or supermarkets; and rural vs. urban living (2,4). Hence, the physical environment is measured with many different indicators which makes it difficult to compare results and draw conclusions. However, from the findings of this studies the results do not show an association between obesity and Urbanization.

7.2.6 Single-Member Households

Single-Member Households were non-significant negatively associated with the obesity prevalence in Europe for the total, male and female population. Additionally, this was still the case when the data was adapted for female and male data. However, it is important to note that the association is very weak according to the present findings. The study by Rabin, et al. (2007) found a significant negative association between females living in single households and obesity prevalence in Europe (9). While a study by Giske, et al. (2007) linked participants living alone with higher fat intakes compared to married couples(2). In addition, this review showed that men living alone have a higher energy intake then men who live with others. Women on the other hand, have a lower energy intake compared to those living with others (2).

7.2.7 Food

Overall, the environmental food factors all presented weak associations between the factor and obesity prevalence. The most noteworthy results were associated to availability of fruit/vegetables, the availability of fat and availability calories. Firstly, the availability of fruit was positively significant associated to the obesity prevalence in males. In the total and female populations, the outcome of the regression analysis was non-significant positive. These findings contradict the findings of Rabin, et al. (2007) who found a significant inverse association for all populations (9). The positive associations found in the populations in this research are against expectations. Research by Pomerleau, et al. (2002) estimated that dietary factors directly contribute to 8.3% of the burden of disease in Europe. Half of this is due to a low fruit and vegetable intake. They found that a diet with lots of fruit and vegetables helps against heart disease and certain cancers. These numbers have caused that political views to change and recommend an individual intake of 400 grams of fruit or vegetables a day (32). However, our data showed that the average of the included European countries was just above 200 grams. Italy had the highest intake, but still did not reach this recommended 400 grams a day.

For the availability of fat, the total and female populations resulted to be negatively associated to obesity prevalence. Contrastingly, the male population showed a positive association. Previous studies are not conclusive on how and if dietary fats promote obesity development (33). There are many kinds of fats which all have a different effect on the human body. Therefore, the intake of fats, as saturated and trans-fatty acids, should be reduced. While the consumption of polyunsaturated fats should be higher (34). However, in general unhealthy energy dense diets are associated with high fat intakes. Energy dense diets are often relatively fast prepared and cheap foods which increase the risk on obesity. The energy density of this foods comes from the many fats and sugars it contains (35). This might offer the explanation for the positive association between Available Fat and male obesity prevalence. In contrast, Italy, France, and Austria all have a very high availability of fats in all three populations. However, the obesity prevalence in these countries is low. Previous research has proposed the concept of the "*Mediterranean diet*". This diet is rich in fruits, vegetables and monounsaturated fats which are predominantly found in olives. More research is required to understand the beneficial aspects of this diet (33,34).

Lastly, the associations between the food variables and the male population are stronger than the associations to the female population. The R-squared of the male population is higher than the R-squared of the female population in all environmental food variables. This is also true for the Available Calories. In addition, the female predictive model includes less food variables than the male model. The difference in inclusion of food variables indicates that the food variables influence male populations stronger. One of the potential explanations is given below and entails that females often still have a key role regarding food in the family and easier access to food (9,22,26). A limitation of using food variables in this research, is an increasing number of modified-foods. Nowadays, the food industry can produce foods which are low fat and contain little calories. However, the energy density of these products is still as high or even higher due to missing fibers and water (33). The intake of fats might go down, but the risk on obesity does not decrease.

7.3 Gender-Specific Comparison

The obesity prevalence data showed that the male obesity prevalence is lower than the female obesity prevalence. Malta is the only exception for the included countries in this study, here the male obesity prevalence is higher than the female obesity prevalence. Previous researches propose multiple theories to explain this difference. The first theory explains the difference in obesity prevalence between females and males comes from a biological perspective. Some specific genetic factors and hormones of females might make them more inclined to develop obesity due to certain obesogenic factors in the environment (9). Additionally, females have more fat than males and have a different metabolism which works in their disadvantage (35). Another proposed explanation is that females are often in charge of buying and preparing the food. Although gender-roles have altered over the past years, females often keep this special role within the family. Hence, females have an easier access to the food (9,26,35).

Furthermore, a study by Ferretti & Mariani (2017) showed that the obesogenic environment can be biased towards either males or females within a society. This bias is caused by the level of human development and gender inequality. The level of development and inequality within a society influences the obesogenic environment. Persons make decisions regarding their health within the obesogenic environment. However, the potentially biased environment can cause an obesity prevalence which is higher for female than males and vice versa (36). The overall higher obesity prevalence for females compared to the males in this research can therefore be an indicator of gender discrimination and inequality. Multiple studies have shown that increasing a women's social economic status can lead to lower obesity prevalence which also fits the theory of Ferretti & Mariani (36,37). Additionally, females with a high social position are more likely to value a thin body type, due to the set social standards of today's society (26,37). The prediction model in this research, also indicated the importance of the social economic status of women in relation to the development of obesity.

Next to the difference in obesity prevalence, the results indicate a stronger relation between the male obesity prevalence and the obesogenic environment compared to the females. However, when the data is adjusted stronger relations are found for females than males.

7.4 GENDER-SPECIFIC PREDICTION MODELS

From the scatterplots, regression analysis and previous literature, it appeared that environmental variables influence the female and male population differently. Therefore, two gender-specific predictive models were created. The plots in Figure 1 and Table 12 (Appendix VI) show that the models are very good at predicting the obesity prevalence, but there are still countries which do not follow the model.

Firstly, the female model includes three economic variables and two food variables. The importance of education, inequality and GDP in relation to the development of obesity in women, is also stressed in previous literature. As discussed above, obesity in females can be decreased when their social-economic status increases (35, 36). Additionally, women have till this day still a bigger influence on what food is prepared and better access to food. This might explain why less food variables are present in the current model compared to the male model. The most surprising variable in this model is Alcohol Consumption. Previous studies have not found conclusive evidence whether Alcohol Consumption promotes the development of obesity. Research concerning the association between BMI and alcohol are hard to conduct without any errors. Measurements often have reporting errors and are easily influenced by cultural differences (38,39). Nevertheless, alcohol is thought to be associated to obesity due to the energy density of the drink and the interaction of the products of alcohol within the human body (40).

Secondly, the male model included more environmental variables than the female model to approach a similar R-squared. As discussed above in the food variables and gender-specific comparison, males are more heavily influenced by environmental food variables than women. Additionally, the GDP and education most likely plays a role in the development of obesity in males too. The more surprising variables included in the male model are Passenger Cars and Single-Member Households. As previous studies explain populations from countries with a high GDP are less physically active due to mechanized labor, sedentary occupations and motorized transport (23). The Passenger Cars in this model might be an indication of the sedentary lifestyle which influences the male population.

7.5 Strength and Limitations

Most limitations in this study are regarding the collected data. The data was collected from multiple databases. Not all databases had data available for all included countries, from the year 2013, age adjusted, or gender-specific. In the obesity prevalence data, adults were considered persons older than 20 years. In other variables adults had a different age. By way of illustration the Alcohol Consumption was measured in individuals older than 15 years. Especially, the missing gender-specific data has impacted the results of this study. The results show that the environment influences the development of obesity in females and males differently. However, due to the missing data the associations could be over- or underestimated. BMI is used in this research to measure obesity. However, experts have agreed that there are much more accurate measures. Examples for measures are: total body fat, waist circumference, and percent of body fat (41). The reason for using BMI in this research is that data on BMI is widely available and mostly used in previous research.

Another limitation concerns the inclusion of countries and environmental variables. Countries from all European regions are included, but the Slovenia, Slovakia, Romania and Bulgaria are the only countries in Eastern Europe. Furthermore, only a limited number of environmental variables are included. The variables are chosen after reviewing literature, but most previous research is conducted in Australia and the United States (4,9,18). The obesogenic environment might be different in these continents compared to Europe. In addition, to for instance retrieve a good overview of the influence education not solely Postsecondary Education should be included. To gain a complete overview also primary education data, secondary education data and variables which measure the quality of the (health) education should be included. The ANGELO framework, normally, also analyzes cultural and political variables. Nevertheless, these are not included in this research due to difficulties retrieving population-level data. Cultural and political variables should be converted to be able to be compared between countries; this exceeded the expectations of this research. Lastly, the population-level data might generalize within-country differences.

Strengths of this study are the inclusion of many European countries. As described, most studies concerning the obesogenic environment are conducted in Australia and the United States. The inclusion of the environmental variables has been based on existing literature. Therefore, the results of this study are more easily compared to the literature which also has been done within the discussion. Furthermore, looking separately to the female and male populations gave insight into gender-specific associations. Lastly, this research does not give any casual relations. However, the found associations are a good indication for possible follow-up research.

7.6 Conclusion | Defining the Obesogenic Environment

The aim of this study was to investigate the associations between country-specific obesity prevalence and the obesogenic environment. The ecological study design made it possible to explore the potential association between the included variables. Overall, weak associations were found between obesity prevalence and the included obesogenic environmental factors. In the total population, the most promising findings were regarding the Postsecondary Education, GINI-Index, Available Fruit/Vegetables and Single-Member Households. For the female population the Postsecondary Education, GINI-Index, Available Fat shown to influence the obesity prevalence. Additionally, the predictive model presented the importance of the GDP. For the male population, the environmental food variables, except from Alcohol Consumption, presented to be important. Additionally, GDP, Passenger Cars and Single-Member Households appeared from the regression analysis and predictive model.

This research shows that the environmental factors which influence females are different from the factors which influence males. Based on these results, two separate definitions of the obesogenic environment should be provided. The obesogenic environment is all what is external of an individual and promotes the development of obesity. For the female European population, the Social Economic Status (Postsecondary Education and GDP), equal distribution within a country (GINI-Index) and Available Fat should be in the definition of the obesogenic environment. For the male population, the availability of food (Available Calories, Fat, and Fruit/Vegetables), social economic status (GDP and Postsecondary Education), and sedentary lifestyle (Passenger Cars) could contribute majorly to their obesogenic environment. Interestingly, in the simple linear regression analysis associations between obesity and environment seemed stronger for males. However, the predictive model presented a higher R-squared for the female population. Hence, the obesogenic environment most likely influences the development of obesity differently for males and females.

The results of this study seek to call attention of researchers to continue the exploration of the obesogenic environment. The observed differences between genders ask for more research investigating the differences in these associations. Additionally, the results of this research indicated that the role of inequality and intake of fruits could have a major influence. More research into these two factors is required. This research does not look in to within-country differences. It is possible that the obesogenic environment for a part of the population is completely different from another. Therefore, this research might generalize an entire population. Country-specific research might be able to find associations which are overlooked in this research. Hence, there is a lot of literature on the different environmental factors, but little consensus on the underlying mechanisms or the interaction with other environmental factors. To be able to define the obesogenic environment research on the underlying mechanism and interaction of variables is required.

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9 APPENDICES

9.1 APPENDIX I | OVERVIEW OBESITY PREVALENCE IN 25 EUROPEAN COUNTRIES

Table 7: Obesity Prevalence in 25 European Countries

Countries	Total		Female		Male	
	Obesity Prevalence	(95% CI)	Obesity Prevalence	(95% CI)	Obesity Prevalence	(95% CI)
Netherlands	0.143	0.134-0.153	0.159	0.144-0.174	0.127	0.116-0.140
Austria	0.18	0.166-0.194	0.174	0.156-0.194	0.184	0.166-0.203
Italy	0.182	0.168-0.194	0.186	0.169-0.204	0.177	0.159-0.195
Norway	0.186	0.171-0.200	0.18	0.161-0.200	0.191	0.171-0.214
Bulgaria	0.186	0.172-0.200	0.203	0.183-0.225	0.166	0.149-0.185
Sweden	0.194	0.179-0.209	0.198	0.177-0.219	0.189	0.170-0.210
Romania	0.194	0.180-0.208	0.198	0.178-0.221	0.187	0.169-0.206
Czech Republic	0.194	0.181-0.209	0.208	0.472-0.527	0.178	0.160-0.196
France	0.195	0.182-0.209	0.197	0.177-0.217	0.193	0.174-0.214
Slovakia	0.197	0.183-0.212	0.215	0.193-0.237	0.176	0.157-0.195
Denmark	0.198	0.184-0.213	0.199	0.177-0.220	0.196	0.177-0.219
Poland	0.198	0.185-0.213	0.209	0.189-0.232	0.183	0.165-0.203
Spain	0.207	0.194-0.220	0.209	0.190-0.231	0.202	0.185-0.221
Belgium	0.209	0.194-0.225	0.217	0.195-0.241	0.201	0.180-0.221
Slovenia	0.212	0.197-0.227	0.224	0.202-0.249	0.199	0.179-0.22
Finland	0.217	0.202-0.233	0.223	0.203-0.246	0.209	0.189-0.232
Lithuania	0.218	0.203-0.234	0.244	0.222-0.269	0.183	0.164-0.202
Latvia	0.221	0.206-0.238	0.257	0.233-0.282	0.174	0.157-0.191

Germany	0.222	0.209-0.237	0.225	0.205-0.247	0.219	0.202-0.238
Portugal	0.223	0.207-0.240	0.234	0.210-0.259	0.209	0.190-0.231
Ireland	0.227	0.212-0.243	0.225	0.204-0.247	0.229	0.208-0.250
Estonia	0.228	0.213-0.245	0.256	0.232-0.281	0.19	0.172-0.210
Luxembourg	0.249	0.232-0268	0.26	0.236-0.287	0.237	0.213-0.263
United Kingdom	0.25	0.242-0.259	0.254	0.242-0.266	0.245	0.234-0.257
Malta	0.283	0.266-0.303	0.275	0.249-0.301	0.29	0.264-0.316

9.2 APPENDIX II | CHI-SQUARE TEST

Below an example of the performed Chi-Square test is provided.

9.2.1 Total Population Obesity Prevalence

0 = Part of population without obesity

1 = Part of population with obesity

	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Country * Yes_No	485506319	100,0%	,020	0,0%	485506319,0	100,0%

Country * Yes_No Crosstabulation

			Yes_No		
			0	1	Total
Country	Austria	Count	6951329	1525901	8477230
		% within Country	82,0%	18,0%	100,0%
		% of Total	1,4%	0,3%	1,7%
	Belgium	Count	8842143	2336293	11178436
		% within Country	79,1%	20,9%	100,0%
		% of Total	1,8%	0,5%	2,3%
	Bulgaria	Count	5913804	1351311	7265115
		% within Country	81,4%	18,6%	100,0%
		% of Total	1,2%	0,3%	1,5%
	Czech Republic	Count	8471640	2039079	10510719
		% within Country	80,6%	19,4%	100,0%
		% of Total	1,7%	0,4%	2,2%
	Denmark	Count	4498245	1110539	5608784
		% within Country	80,2%	19,8%	100,0%
		% of Total	0,9%	0,2%	1,2%
	Estonia	Count	1017494	300503	1317997
		% within Country	77,2%	22,8%	100,0%
		% of Total	0,2%	0,1%	0,3%

		0	1	Total
Finland	Count	4258715	1180257	5438972
	% within Country	78,3%	21,7%	100,0%
	% of Total	0,9%	0,2%	1,1%
France	Count	51354257	12439851	63794108
	% within Country	80,5%	19,5%	100,0%
	% of Total	10,6%	2,6%	13,1%
Germany	Count	62742285	17903325	80645610
	% within Country	77,8%	22,2%	100,0%
	% of Total	12,9%	3,7%	16,6%
Ireland	Count	3550486	1042639	4593125
	% within Country	77,3%	22,7%	100,0%
	% of Total	0,7%	0,2%	0,9%
Italy	Count	49271369	10962579	60233948
	% within Country	81,8%	18,2%	100,0%
	% of Total	10,1%	2,3%	12,4%
Latvia	Count	1567852	444795	2012647
	% within Country	77,9%	22,1%	100,0%
	% of Total	0,3%	0,1%	0,4%
Lithuania	Count	2312913	644776	2957689
	% within Country	78,2%	21,8%	100,0%
	% of Total	0,5%	0,1%	0,6%
Luxembourg	Count	408063	135297	543360
	% within Country	75,1%	24,9%	100,0%
	% of Total	0,1%	0,0%	0,1%
Malta	Count	303600	119831	423431
	% within Country	71,7%	28,3%	100,0%
	% of Total	0,1%	0,0%	0,1%
Netherlands	Count	14401398	2403034	16804432
	% within Country	85,7%	14,3%	100,0%
	% of Total	3,0%	0,5%	3,5%
Norway	Count	4135255	944911	5080166
	% within Country	81,4%	18,6%	100,0%
	% of Total	0,9%	0,2%	1,0%
Poland	Count	30501367	7530263	38031630
	% within Country	80,2%	19,8%	100,0%
	% of Total	6,3%	1,6%	7,8%

			0	1	Total
	Portugal	Count	8125318	2331977	10457295
		% within Country	77,7%	22,3%	100,0%
		% of Total	1,7%	0,5%	2,2%
	Romania	Count	18022037	4337811	22359848
		% within Country	80,6%	19,4%	100,0%
		% of Total	3,7%	0,9%	4,6%
	Slovakia	Count	4346955	1066438	5413393
		% within Country	80,3%	19,7%	100,0%
		% of Total	0,9%	0,2%	1,1%
	Slovenia	Count	1622582	436532	2059114
		% within Country	78,8%	21,2%	100,0%
		% of Total	0,3%	0,1%	0,4%
	Spain	Count	36948436	9644800	46593236
		% within Country	79,3%	20,7%	100,0%
		% of Total	7,6%	2,0%	9,6%
	Sweden	Count	7737905	1862473	9600378
		% within Country	80,6%	19,4%	100,0%
		% of Total	1,6%	0,4%	2,0%
	United Kingdom	Count	48079242	16026414	64105656
		% within Country	75,0%	25,0%	100,0%
		% of Total	9,9%	3,3%	13,2%
Total		Count	385384690	100121629	485506319
		% within Country	79,4%	20,6%	100,0%
		% of Total	79,4%	20,6%	100,0%

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	1739928,58[a]	24	,000
Likelihood Ratio	1747705,061	24	,000
N of Valid Cases	485506319		

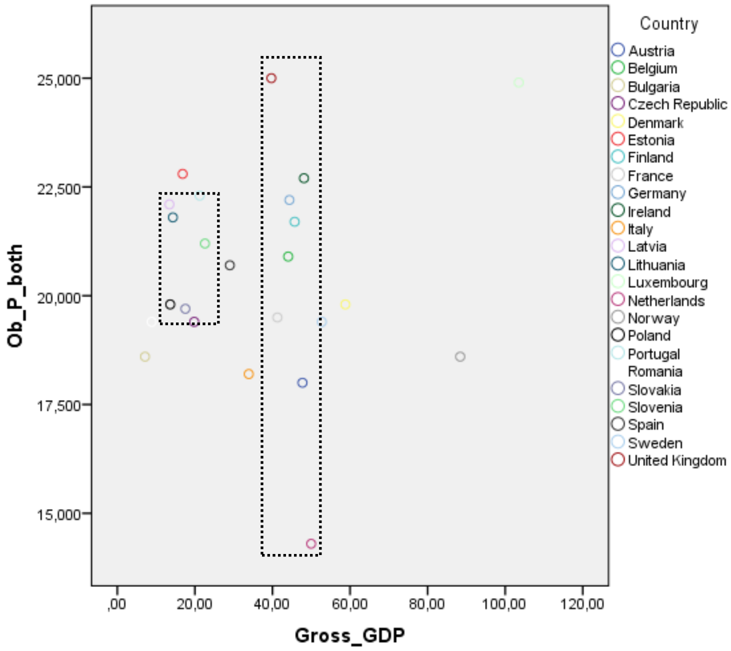
a. 0 cells (,0%) have expected count less than 5. The minimum expected count is 87320,39.

9.3 Appendix III | Plots Obesity Prevalence and Environmental Factors

9.3.1 Total Population

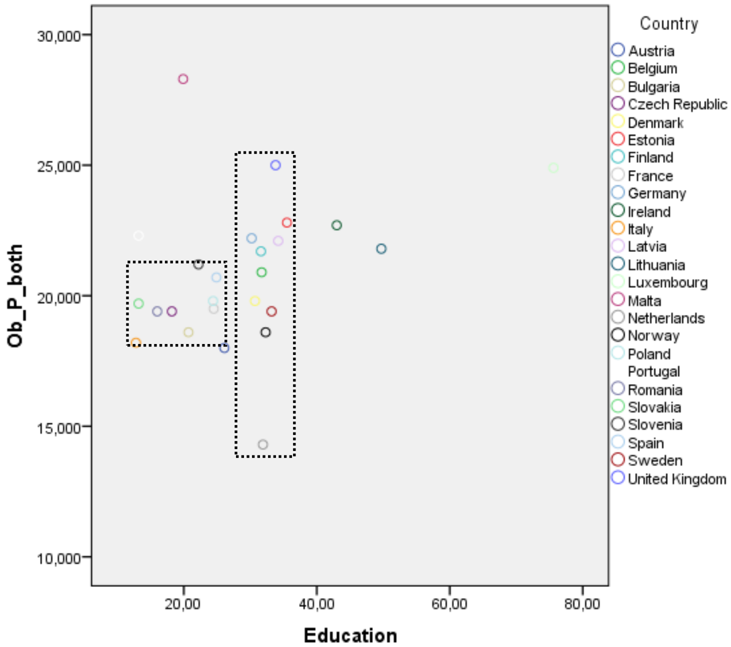
The plots below have the following axes. The x-axis is obesity prevalence for the total population (%). The y-axis shows the environmental factor. The units used for the environmental factors can be viewed in Table 1.

9.3.1.1 GDP



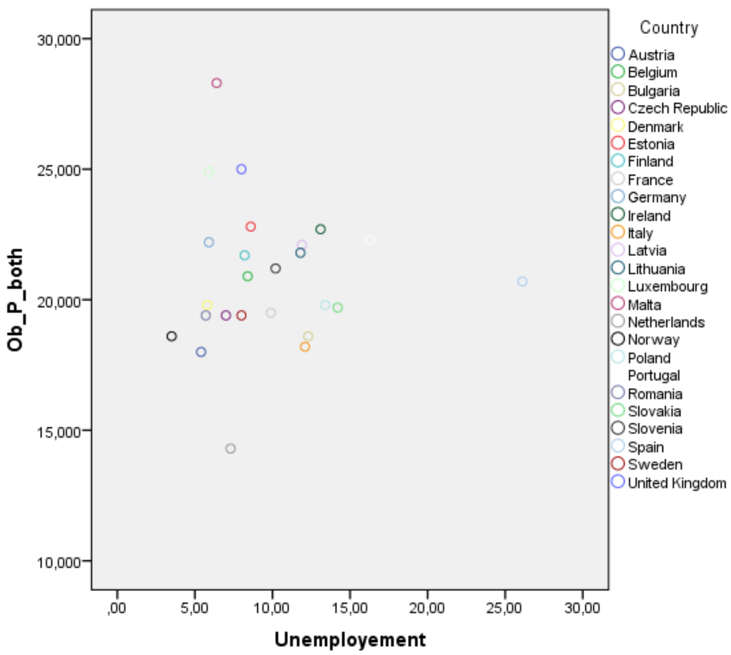
Higher GDP is associated with a larger variance in the obesity prevalence compared to countries with a lower GDP.

9.3.1.2 Education

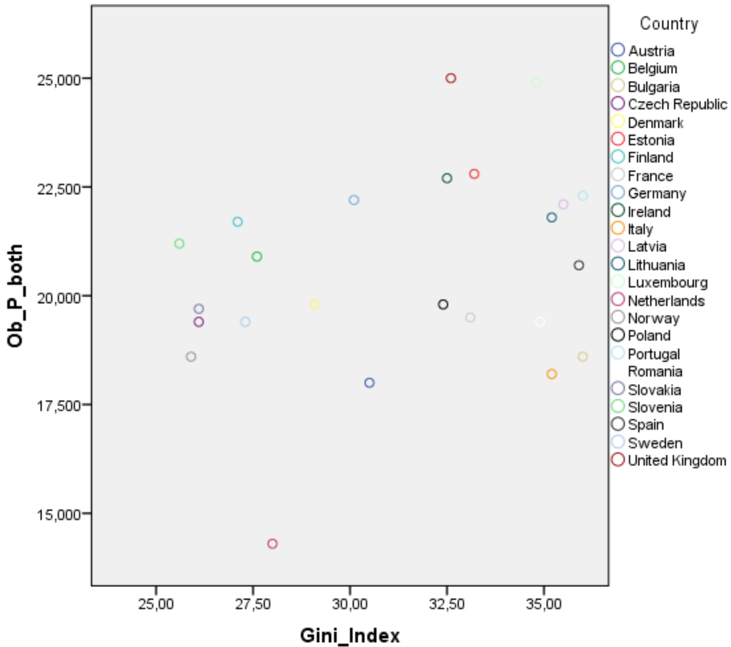


When a larger part of the population has had a Postsecondary Education, this is associated with a larger variance in the obesity prevalence compared to countries with a smaller part enjoying a Postsecondary Education.

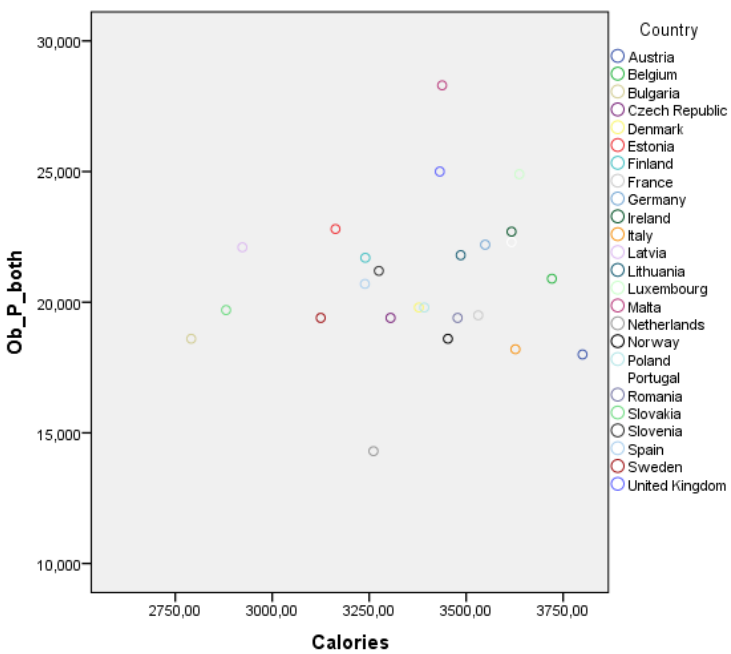
9.3.1.3 Unemployment



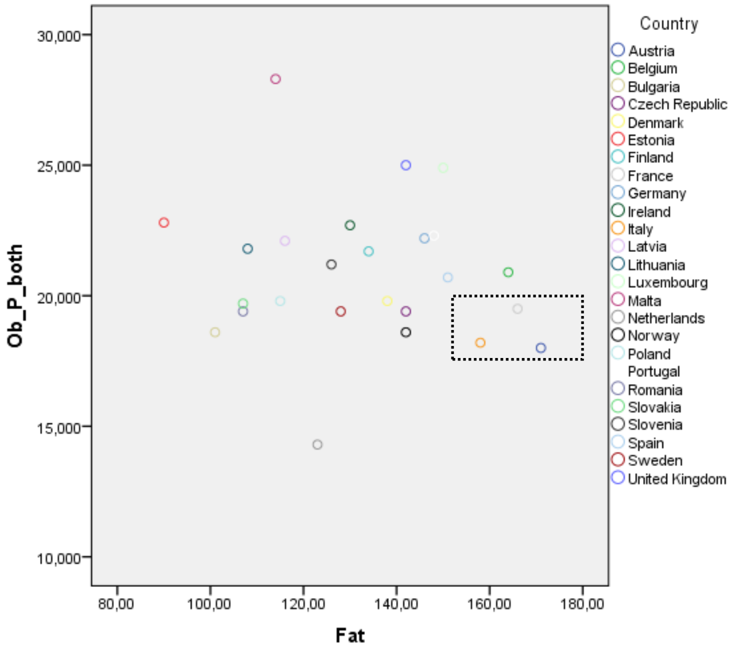
9.3.1.4 GINI-Index



9.3.1.5 Available Calories

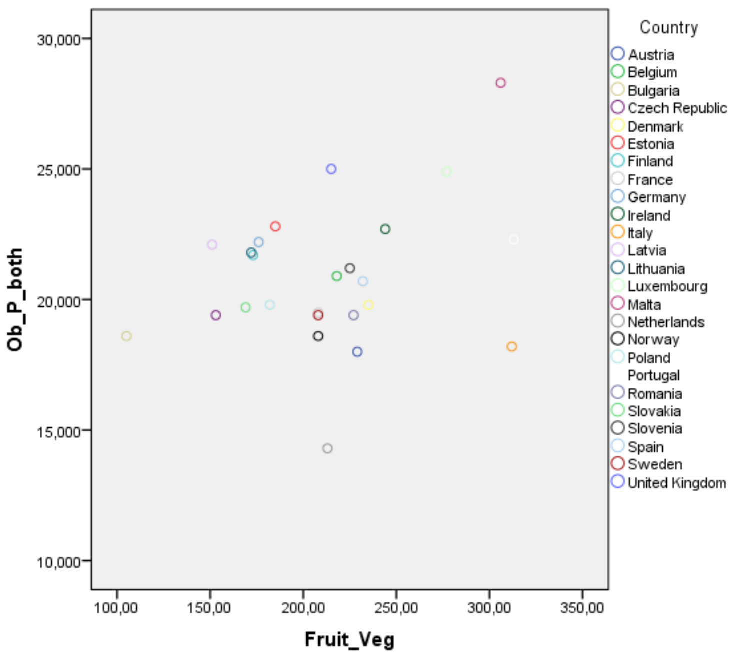


9.3.1.6 Available Fat

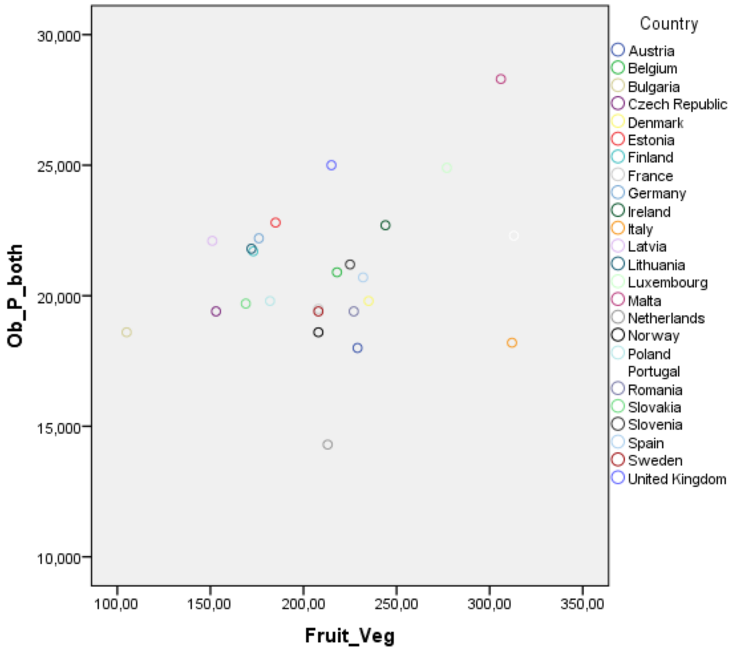


Italy, France and Austria have a high fat intake while the obesity prevalence is relatively low.

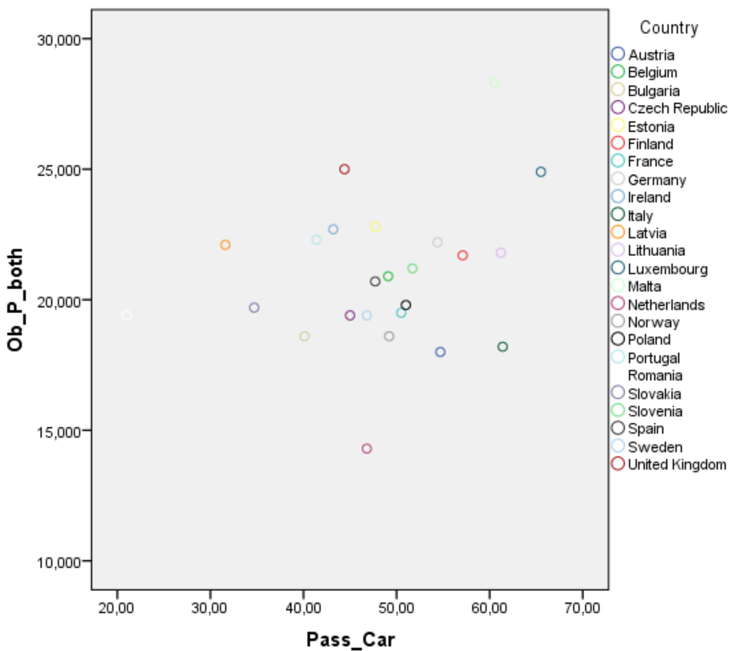
9.3.1.7 Available Fruit/Vegetables



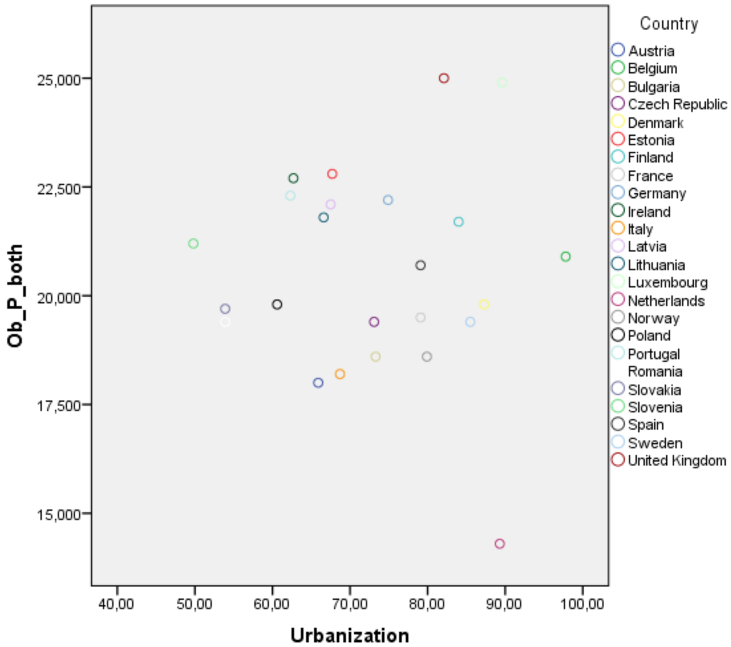
9.3.1.8 Alcohol Consumption



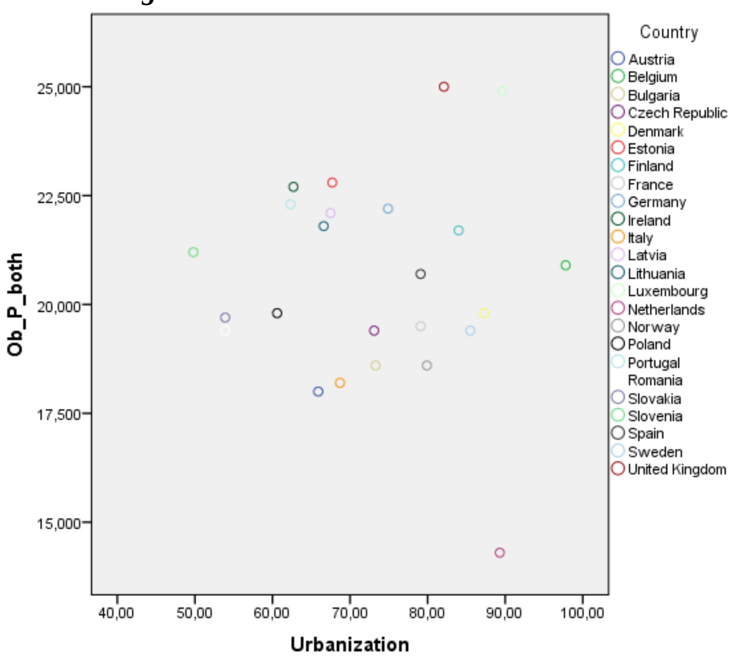
9.3.1.9 Passenger Cars



9.3.1.10 Urbanization



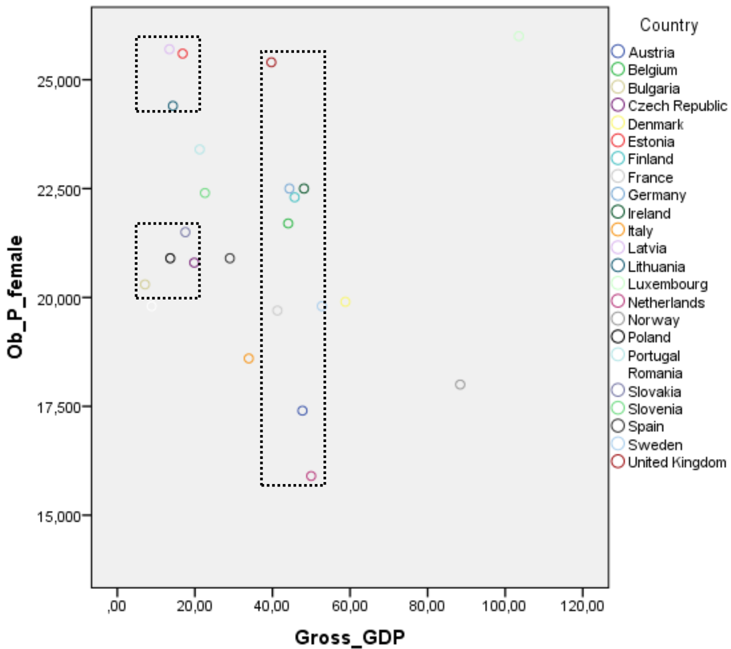
9.3.1.11 Single-Member Household



9.3.2 Female Population

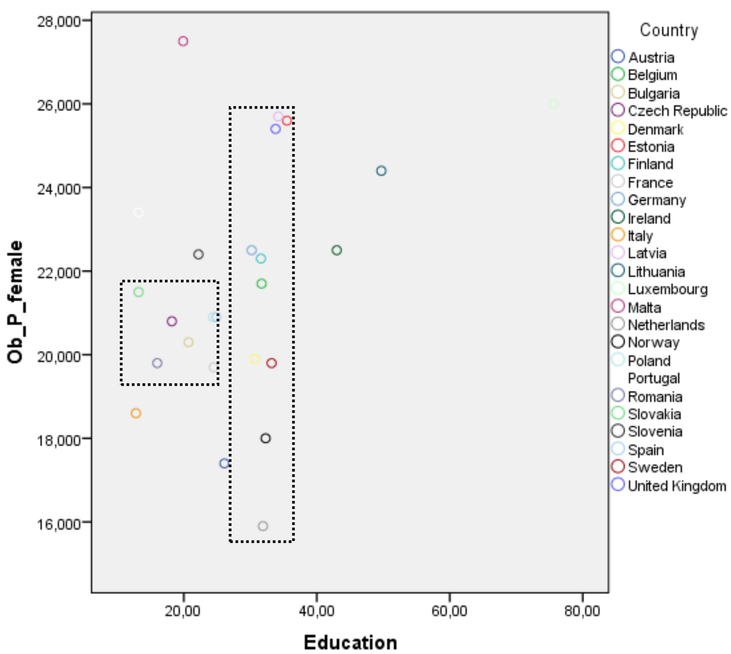
The plots below have the following axes. The x-axis is obesity prevalence for the total population (%). The y-axis shows the environmental factor. The units used for the environmental factors can be viewed in Table 1.

9.3.2.1 GDP



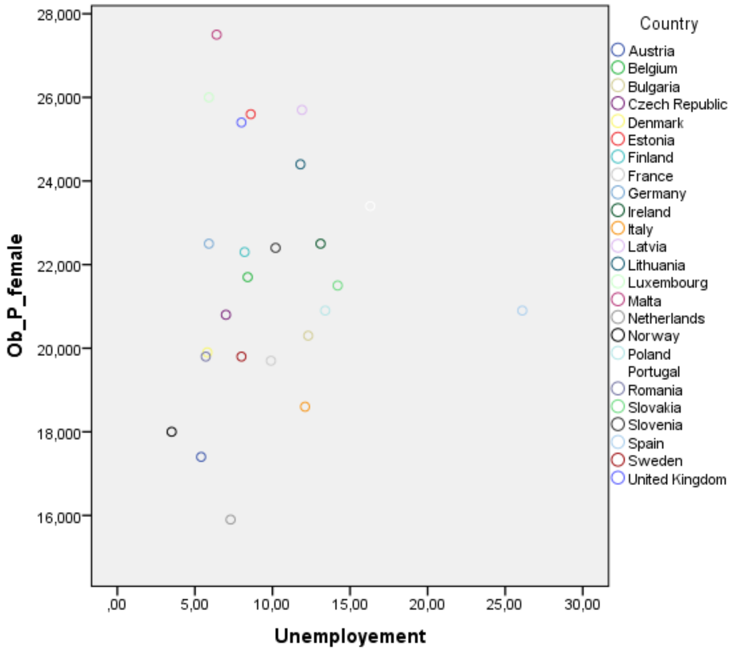
Higher GDP is associated with a larger variance in the obesity prevalence compared to countries with a lower GDP. The countries with a lower GDP cluster just above average and at a very high obesity prevalence.

9.3.2.2 Education

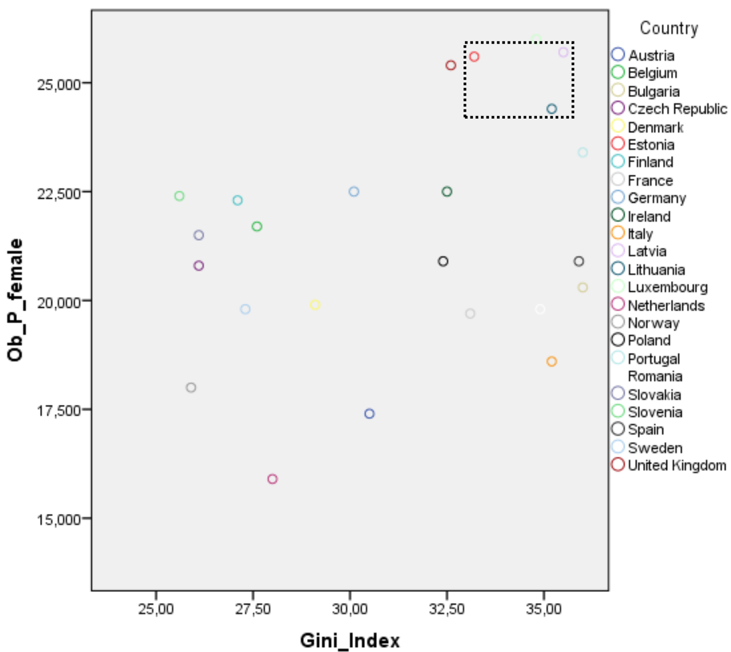


When a larger part of the population has had a Postsecondary Education, this is associated with a larger variance in the obesity prevalence compared to countries with a smaller part enjoying a Postsecondary Education.

9.3.2.3 *Unemployment*

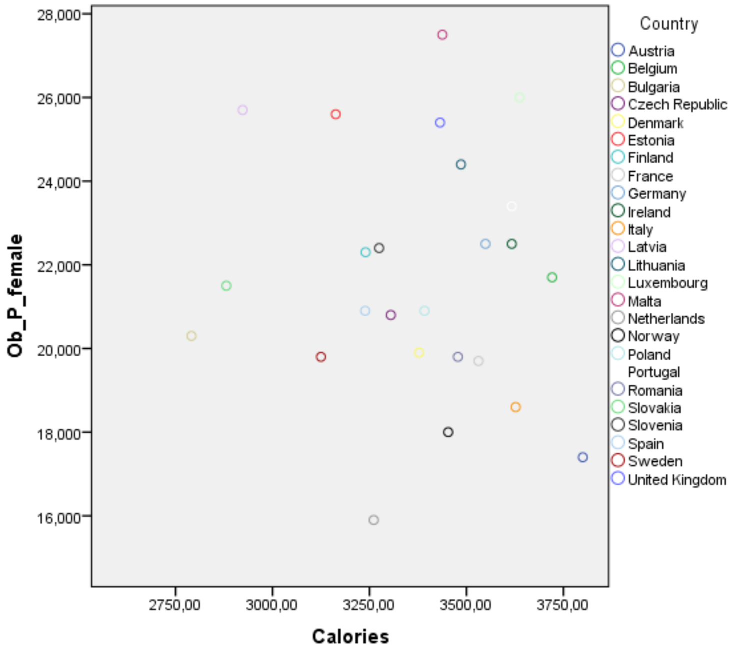


9.3.2.4 *GINI-Index*

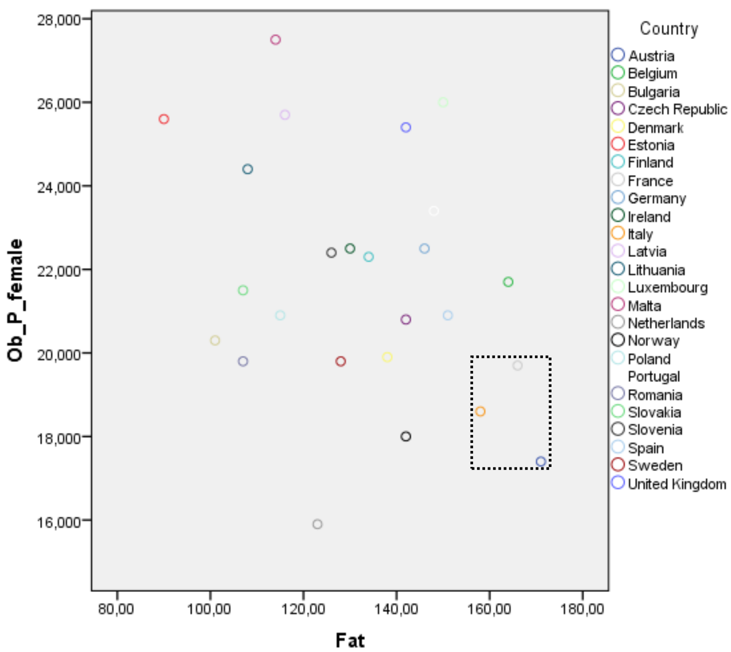


Estonia, Lithuania and Latvia are countries with low GDP, relatively high Postsecondary Education, and high obesity prevalence. The GINI-Index shows that the wealth is not distributed equally. Hence, these countries follow the proposed mechanism in the discussion which hypothesized inequality might be a key factor in the development of obesity.

9.3.2.5 Available Calories

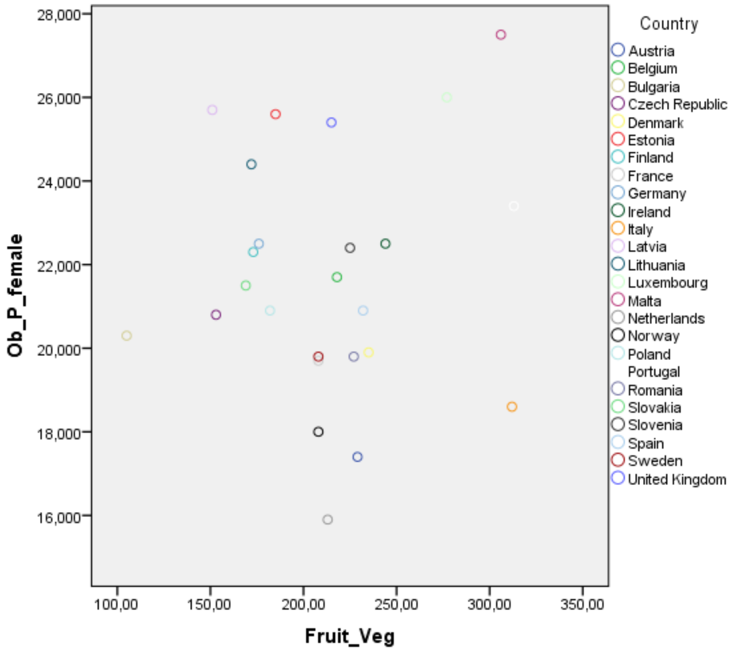


9.3.2.6 Available Fat

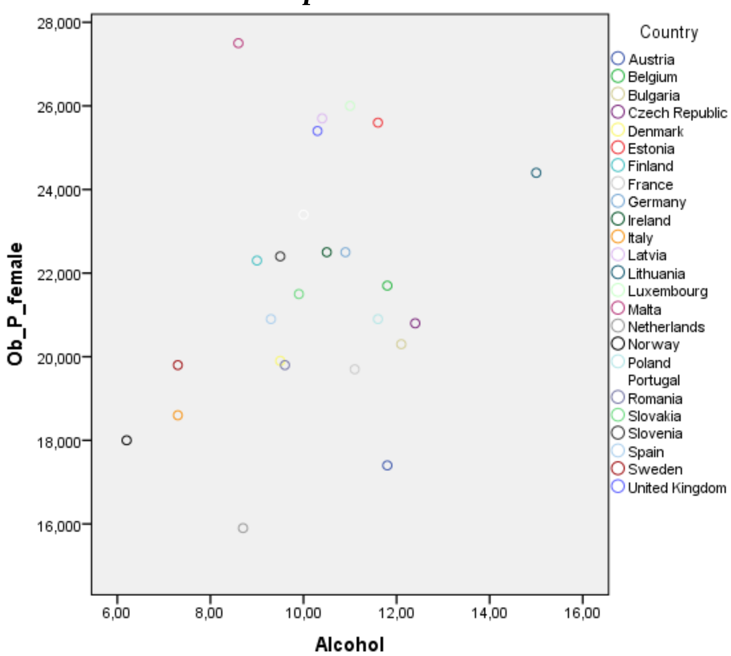


Italy, France and Austria have a high fat intake while the obesity prevalence is relatively low.

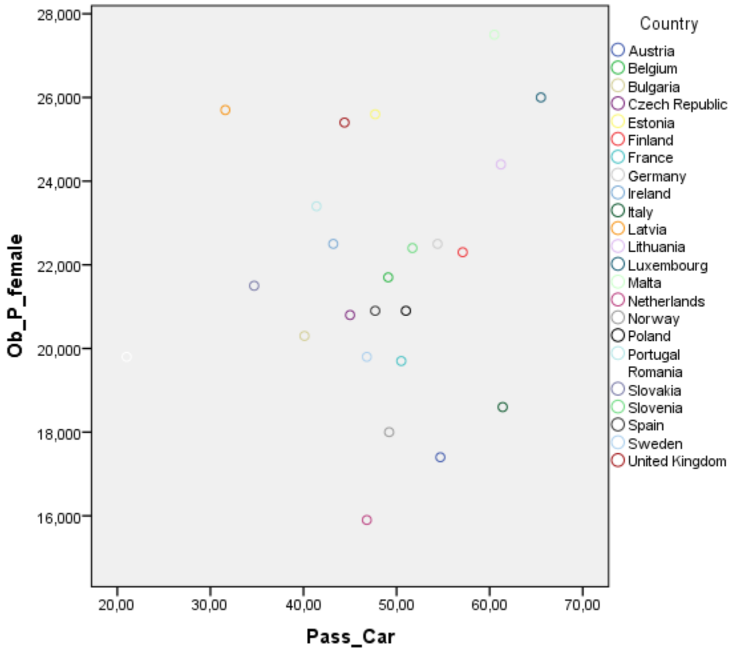
9.3.2.7 Available Fruit/Vegetables



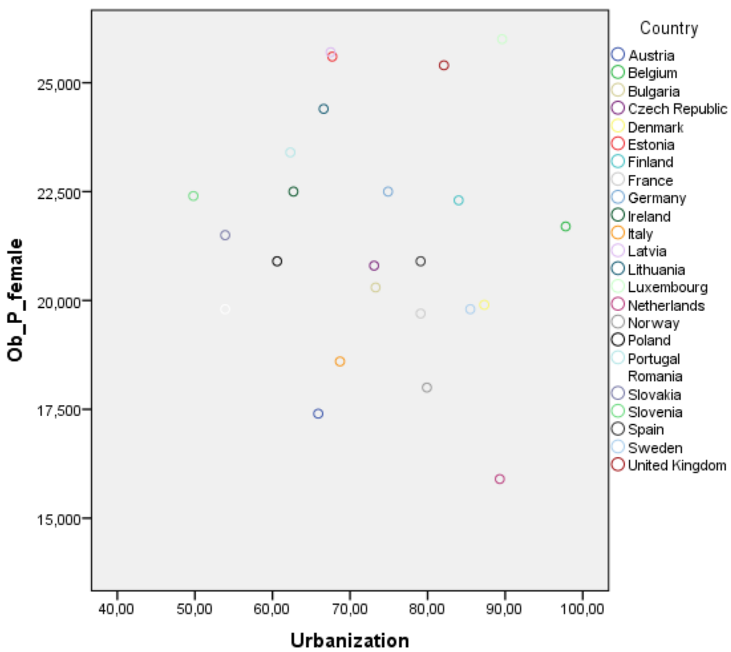
9.3.2.8 Alcohol Consumption



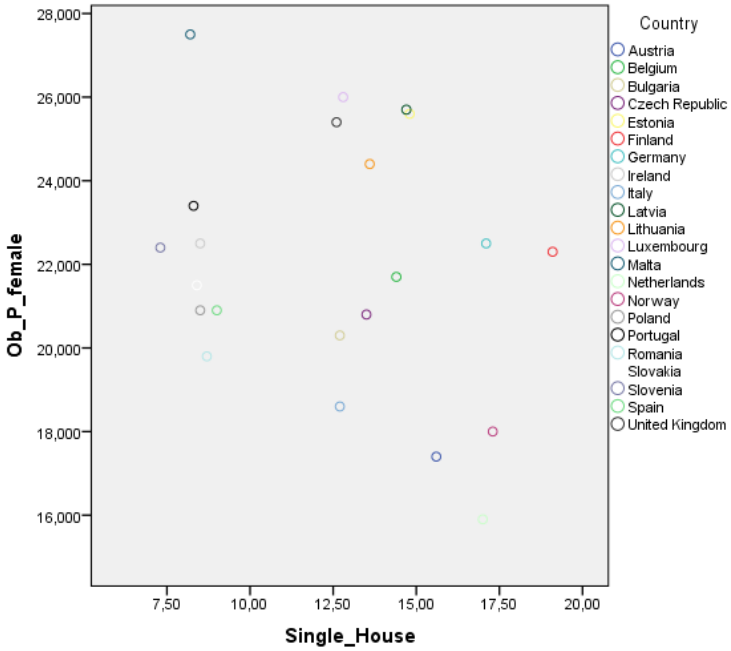
9.3.2.9 Passenger Cars



9.3.2.10 Urbanization



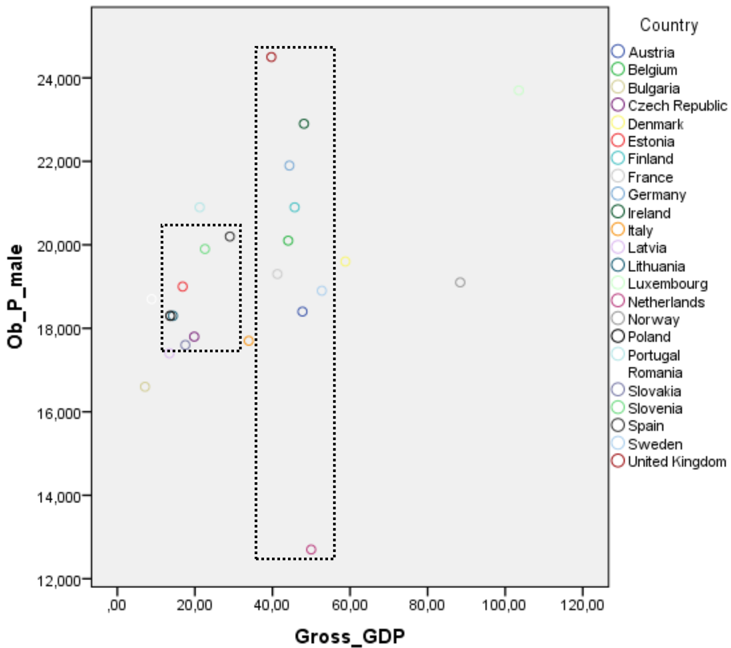
9.3.2.11 Single-Member Households



9.3.3 Male Population

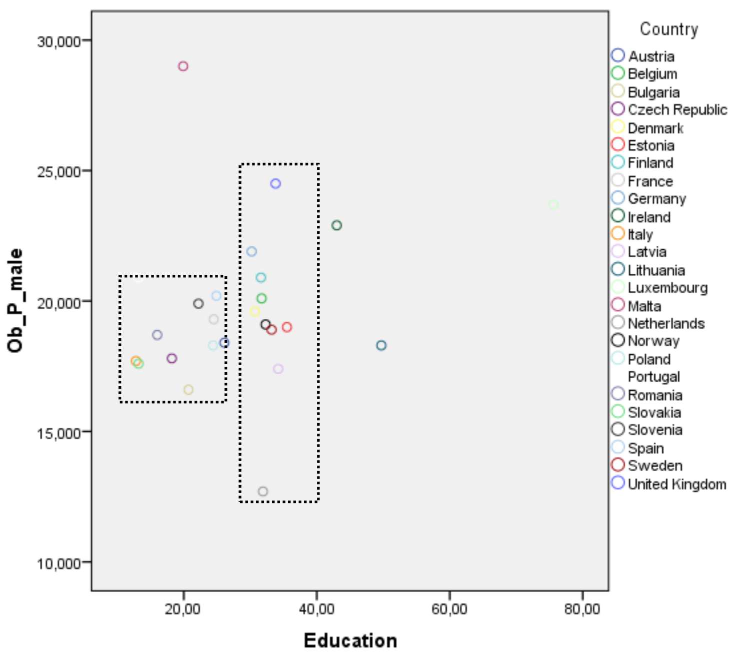
The plots below have the following axes. The x-axis is obesity prevalence for the total population (%). The y-axis shows the environmental factor. The units used for the environmental factors can be viewed in Table 1.

9.3.3.1 GDP



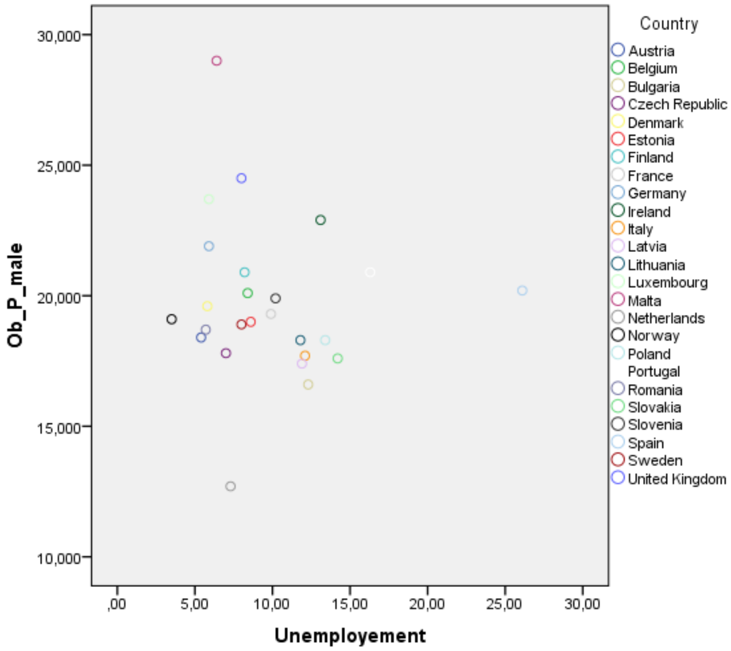
Higher GDP is associated with a larger variance in the obesity prevalence compared to countries with a lower GDP.

9.3.3.2 Education

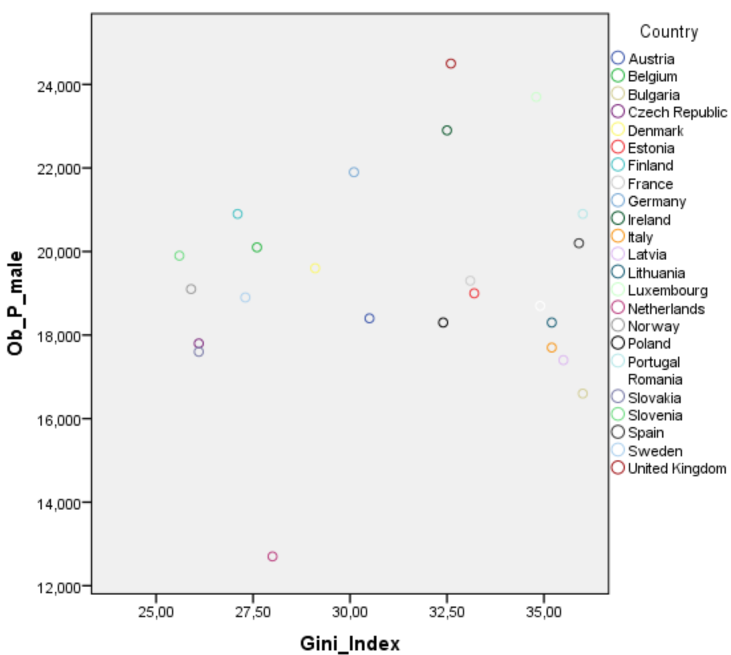


When a larger part of the population has had a Postsecondary Education, this is associated with a larger variance in the obesity prevalence compared to countries with a smaller part enjoying a Postsecondary Education.

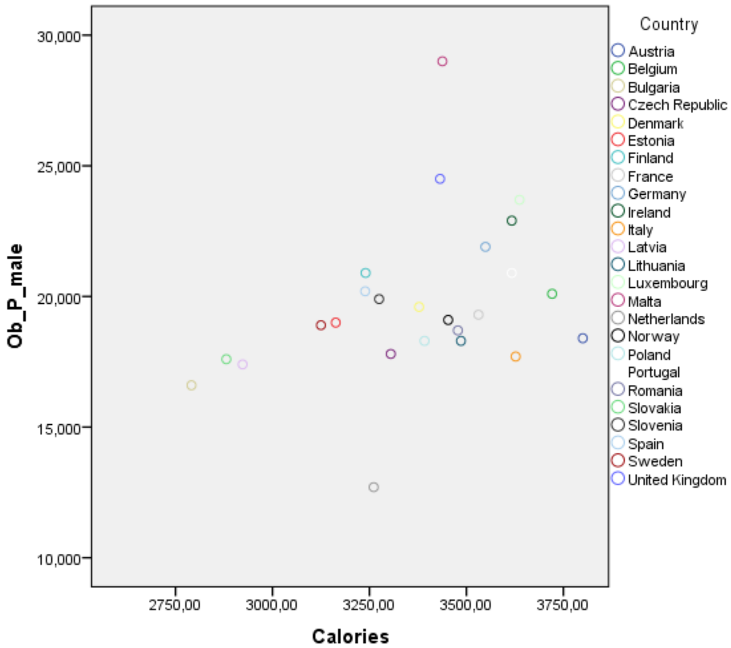
9.3.3.3 *Unemployment*



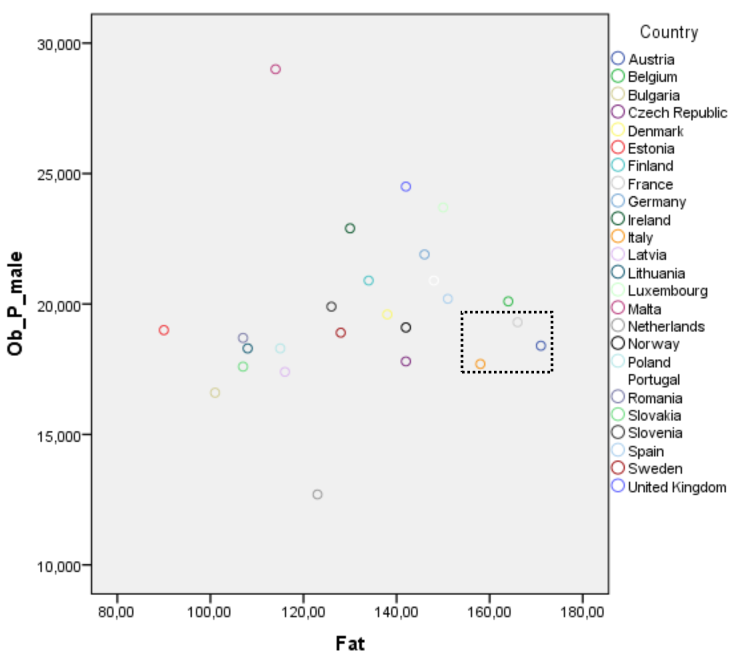
9.3.3.4 *GINI-Index*



9.3.3.5 Available Calories

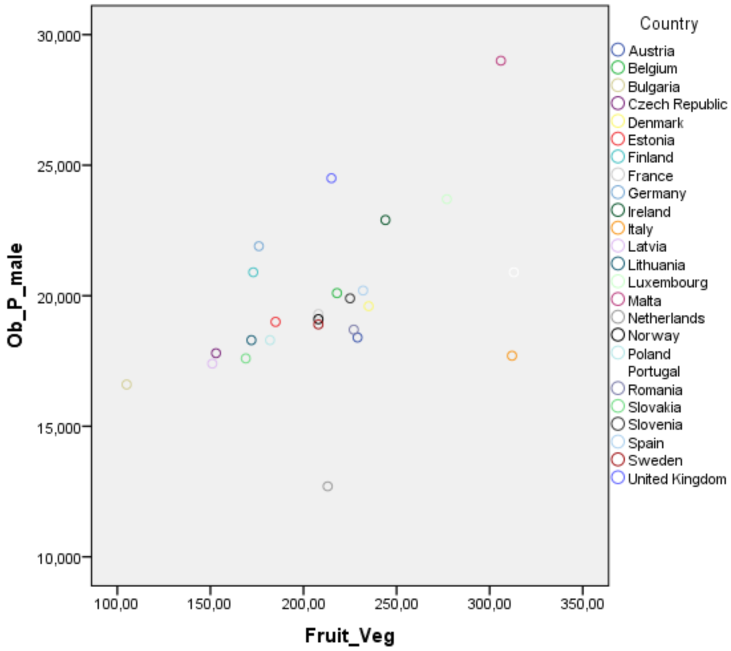


9.3.3.6 Available Fat

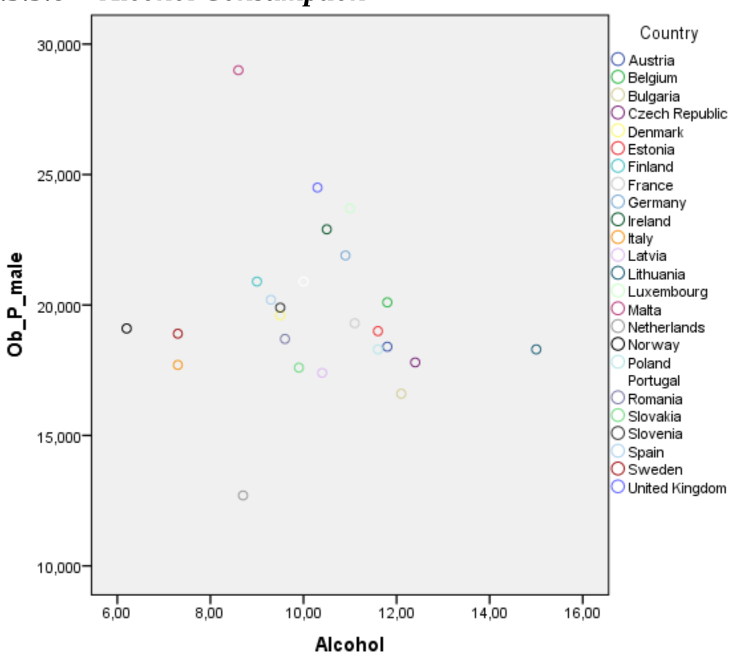


Italy, France and Austria have a high fat intake while the obesity prevalence is relatively low.

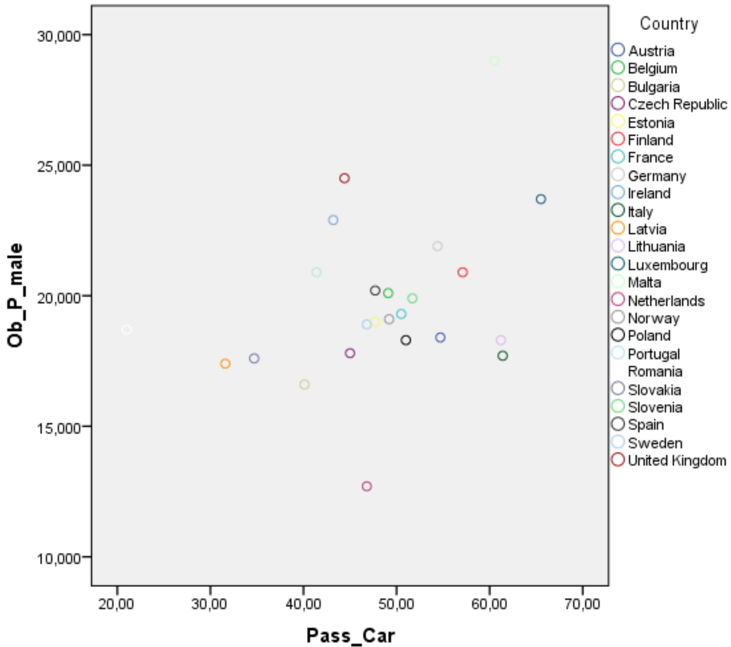
9.3.3.7 Available Fruit/Vegetables



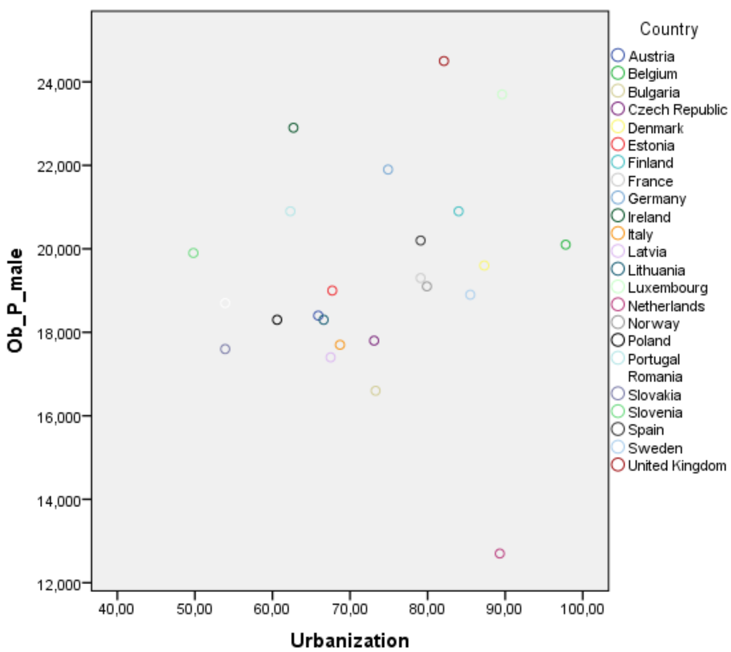
9.3.3.8 Alcohol Consumption



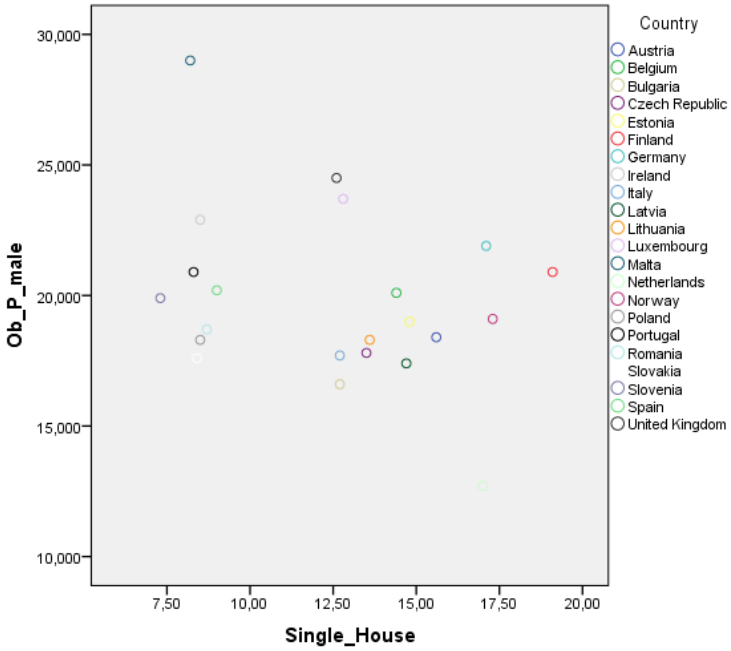
9.3.3.9 Passenger Cars



9.3.3.10 Urbanization



9.3.3.11 Single-Member Households



9.4 APPENDIX IV | GINI-INDEX

9.4.1 Table of GINI-Index

Table 8: Summary of GINI-Index

Country	Obesity Prevalence Total Population	Code[b]	GINI-Index
Netherlands	14.3	1	28
Austria	18.0	1	30.5
Italy	18.2	1	35.2
Bulgaria	18.6	1	36
Norway	18.6	1	25.9
Czech Republic	19.4	2	26.1
Romania	19.4	2	34.9
Sweden	19.4	2	27.3
France	19.5	2	33.1
Slovakia	19.7	2	26.1
Denmark	19.8	2	29.1
Poland	19.8	2	32.4
Spain	20.7	2	35.9
Belgium	20.9	2	27.6
Slovenia	21.2	3	25.6
Finland	21.7	3	27.1
Lithuania	21.8	3	35.2
Latvia	22.1	3	35.5
Germany	22.2	3	30.1
Portugal	22.3	3	36
Ireland	22.7	3	32.5
Estonia	22.8	3	33.2
Luxembourg	24.9	4	34.8
United Kingdom	25.0	4	32.6
Average	20.9		31.27

[a] The light grey indicates if the value is above average obesity prevalence or GINI-Index.
[b] The obesity prevalence have been clustered, as followed:

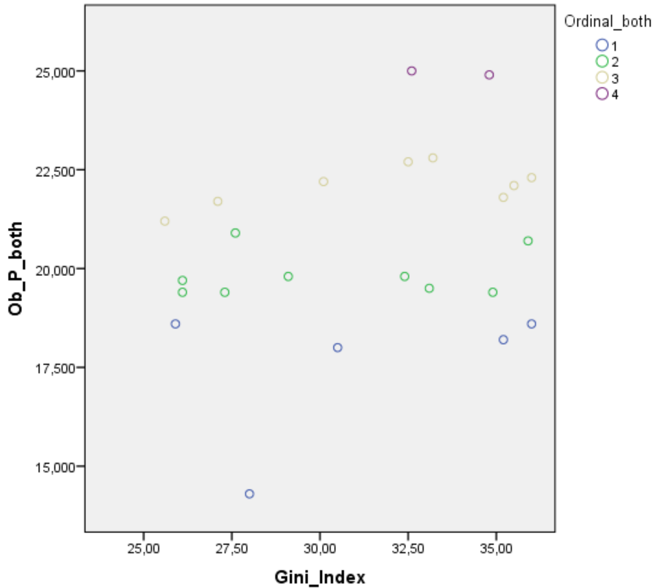
- 1: 14-18 %
- 2: 19-20 %
- 3: 21-22 %
- 4: 23-24 %

9.4.2 Scatterplots of GINI-Index

The plots below have the following axes. The x-axis GINI-Index (%). The y-axis shows the total obesity prevalence (%), Postsecondary Education (%), and gross (GDP 1000 US$/capita). The obesity prevalence has been color-coded as followed:

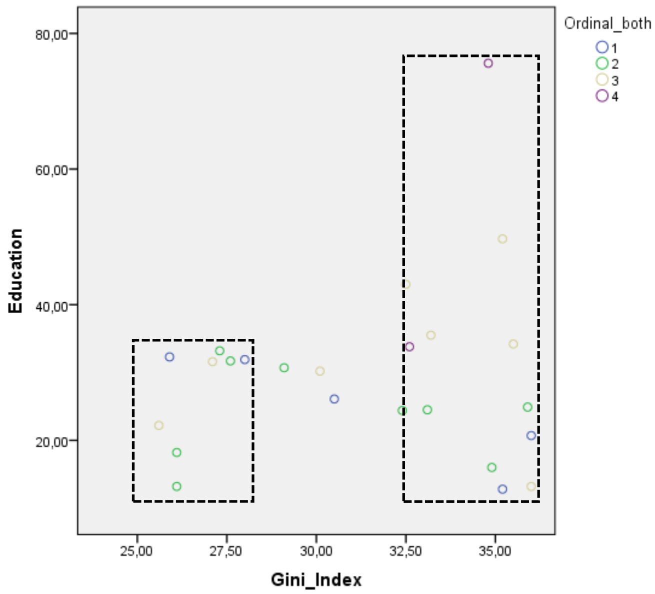
- 1: 14-18 %
- 2: 19-20 %
- 3: 21-22 %
- 4: 23-24 %

9.4.2.1 Obesity Prevalence

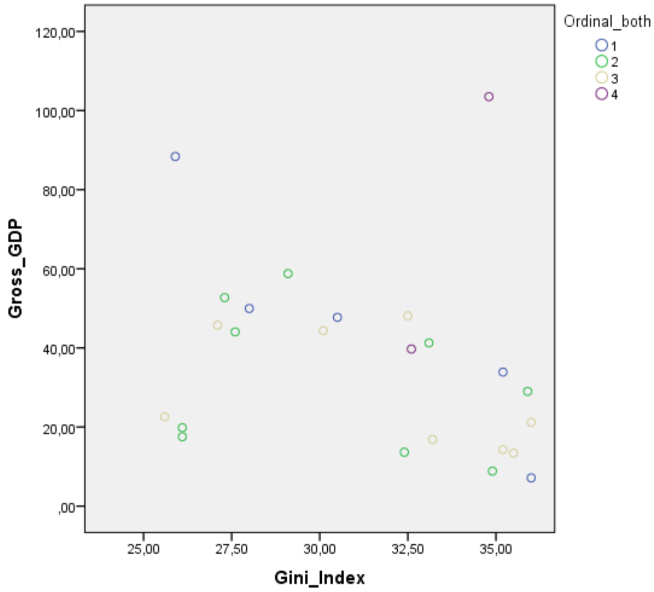


Overall, high obesity prevalence is associated with a higher GINI- index

9.4.2.2 Postsecondary Education



The variance of education level is more spread with a higher GINI-Index. Additionally, the higher GINI-Index contains most high obesity prevalence.



At the higher GINI-Index, most high obesity prevalence can be found.

9.5 APPENDIX V | DETAILED RESULTS REGRESSION

9.5.1 Total Population

Table 9: Detailed Summary of Regression Analysis – Total Population

	R-Squared	Included Countries	Total	Significance
	R^2		B (95% CI)	p-value
Economic variables				
GDP	0.007	24	0.008 (-0.035-0.051)	0.705
Postsecondary Education	0.103	25	0.067 (-0.018-0.152)	0.117
Unemployment	<0.001	25	-0.001(-0.255-0.252)	0.992
GINI-Index	0.090	24	0.185 (-0.076-0.445)	0.155
Food variables				
Available Calories	0.021	25	0.002 (-0.003-0.006)	0.492
Available Fat	0.012	25	-0.014(-0.068-0.040)	0.599
Available Fruit/Vegetables	0.087	25	0.016 (-0.006-0.038)	0.153
Alcohol Consumption	0.020	25	0.207 (-0.424-0.838)	0.504
Physical variables				
Passenger Cars	0.061	24	0.069 (-0.050-0.189)	0.243
Urbanization	0.001	24	-0.005 (-0.087-0.077)	0.901
Socio-Cultural variables				
Single-Member Households	0.080	22	-0.228 (-0.589-0.134)	0.203

9.5.2 Female Population

Table 10: Detailed Summary of Regression Analysis – Female Population

	R-Squared	**Included countries**	**Total**	**Significance**
	R^2		B (95% CI)	p-value
Economic variables				
GDP	0.017	24	-0.015 (-0.064-0.035)	0.542
Postsecondary Education	0.131	25	0.079 (-0.009-0.167)	0.075
Unemployment	0.006	25	0.049 (-0.217-0.315)	0.708
GINI-Index	0.121	24	0.248 (-0.047-0.544)	0.096
Food variables				
Available Calories	0.005	25	-0.001 (-0.006-0.004)	0.745
Available Fat	0.095	25	-0.041 (-0.096-0.014)	0.135
Available Fruit/Vegetables	0.008	25	0.005 (-0.019-0.030)	0.666
Alcohol Consumption	0.092	25	0.473 (-0.166-1.113)	0.139
Physical variables				
Passenger Cars	0.020	24	0.041 (-0.087-0.169)	0.169
Urbanization	0.011	24	-0.022 (-0.117-0.072)	0.627
Socio-Cultural variables				
Single-Member Households	0.056	22	-0.197 (-0.577-0.182)	0.291

9.5.3 Male Population

Table 11: Detailed Summary of Regression Analysis – Male Population

	R-Squared	**Included countries**	**Total**	**Significance**
	R^2		B (95% CI)	p-value
Economic variables				
GDP	0.134	24	0.037 (-0.005-0.079)	0.078
Postsecondary Education	0.050	25	0.052 (-0.046-0.149)	0.149
Unemployment	0.010	25	-0.067 (-0.348-0.214)	0.284
GINI-Index	0.018	24	0.086 (-0.198-0.370)	0.155
Food variables				
Available Calories	0.133	25	0.004 (-0.000-0.009)	0.073
Available Fat	0.022	25	0.021 (-0.039-0.081)	0.477
Available Fruit/Vegetables	0.230	25	0.029 (0.006-0.058)*	0.015*
Alcohol Consumption	0.006	25	-0.127 (-0.836-0.582)	0.715
Physical variables				
Passenger Cars	0.111	24	0.104 (-0.026-0.234)	0.111
Urbanization	0.012	24	0.021 (-0.064-0.107)	0.613
Socio-Cultural variables				
Single-Member Households	0.083	22	-0.263 (-0.671-0.145)	0.194

* The asterisks indicate if an association is significant

9.6 APPENDIX VI | TABLE PREDICTIVE MODEL

Table 12: Summary of Predictive Models Results

Country	Female Obesity Prevalence		Male Obesity Prevalence	
	Known	Predicted	Known	Predicted
Austria	17,40	21,01	18,40	19,96
Belgium	21,70	21,60	20,10	21,50
Bulgaria	20,30	17,34	16,60	21,36
Czech Republic	20,80	19,33	17,80	20,42
Denmark	19,90		19,60	19,55
Estonia	25,60	17,48	19,00	23,52
Finland	22,30	18,00	20,90	21,35
France	19,70		19,30	20,41
Germany	22,50	19,69	21,90	20,89
Ireland	22,50	22,65	22,90	23,07
Italy	18,60	18,86	17,70	19,55
Latvia	25,70	18,75	17,40	24,72
Lithuania	24,40	20,29	18,30	26,49
Luxembourg	26,00	24,68	23,70	24,50
Malta	27,50		29,00	
Netherlands	15,90	18,20	12,70	20,70
Norway	18,00	19,63	19,10	17,65
Poland	20,90	19,94	18,30	22,04
Portugal	23,40	20,20	20,90	19,97
Romania	19,80	19,33	18,70	21,06
Slovakia	21,50	18,15	17,60	19,36
Slovenia	22,40	20,07	19,90	21,51
Spain	20,90	20,93	20,20	22,08
Sweden	19,80		18,90	21,28

[a] The light grey indicates a difference of 0-1% between the known and predicted obesity prevalence
[b] The grey indicates a difference of 1-2% between the known and predicted obesity prevalence
[c] The dark grey indicates a difference of 2-3% between the known and predicted obesity prevalence