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Attributable Burden, Life Expectancy and Income Loss to Non-Communicable Diseases in Ireland: From Evidence to Policy-Making

Thesis presented by

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Declaration

*"**This is to certify that the work I am submitting is my own and has not been submitted for another degree, either at University College Cork or elsewhere. All external references and sources are clearly acknowledged and identified within the contents. I have read and understood the regulations of University College Cork concerning plagiarism."***

Shelly Chakraborty

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List of Abbreviations

ARIMA	Autoregressive Integrated Moving Average
BMI	Body Mass index
BP	Blood Pressure
CODEm	Cause of Death Ensemble Model
COPD	Chronic obstructive Pulmonary Disorder
CRA	Comparative Assessment
CSO	Central Statistics Office
CVD	Cardiovascular disease
DALYs	Disability-Adjusted-Life-Years
DASH	Dietary Approach to Stop Hypertension
DOH	Department of Health
DW	Disability Weight
EU	European Union
FASD	Foetal Alcohol Spectrum Disorder
GBD	Global Burden of Disease
GC	Garbage Codes
GDP	Gross Domestic Product
GM	Geometric Mean
HALE	Healthy Life expectancy
IARC	The International Agency for Research on Cancer
ICD	International Classification of Diseases
IHF	Irish Heart Foundation
IHD	Ischemic Heart Disease
I$	International dollar
IQR	Inter-Quartile Range
LE	Life expectancy
LPA	Low physical activity
NCCP	National Cancer Control Programme
NCD	Non-Communicable Disease

PAF	Population Attributable Fraction
PPP	Purchasing Power Parity
QALY	Quality Adjusted Life Years
ROI	Republic Of Ireland
RR	Relative Risk
SDG	Sustainable Development Goals
SLAN	Survey of Lifestyle, Attitudes, and Nutrition
SMPH	Summary Measure of Population Health
SSDT	Sugar Sweetened Drinks Tax
STGPR	Spatiotemporal Gaussian Process Regression
TFR	Total Fertility Rate
TMREL	Theoretical Minimum Risk Exposure Level
UK	United Kingdom
UN	United Nations
USA	United States of America
WHO	World Health Organisation
YLDs	Years lived with disability
YLLs	Years of life lost

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Abstract

Introduction

This thesis is devoted, primarily, to the study of the burden of non-communicable diseases in the Republic of Ireland. Four major NCDs – cancer, cardiovascular disease (CVD), diabetes and Chronic Obstructive Pulmonary Disease (COPD) are chosen and their risk factors as well as socio-economic impact is analysed. Burden of disease studies utilize the evidence base and quantify the health scenario and trends over time. Such estimates are relevant for a country's policy makers to allocate the limited resources to the areas that require more attention. The Global Burden of Disease study was the most comprehensive study of its kind to draw attention to the diseases and risk factors in any country which require more attention than the others. We seek to do the same for Ireland with a special focus for NCDs.

NCDs contributed to approximately 71% of deaths worldwide in 2016 (WHO). NCDs lead to early deaths, morbidities and long-term health effects. It was observed that life expectancies have increased in Ireland. It is critically important to determine whether people are living these additional years in good health or not. NCDs also contribute to considerable economic loss. These considerations form the motivating factors for this study, whose primary objectives are as follows:

1. To estimate NCD burden and attributable burden, including LE and HALE- 1990 to 2017

2. To investigate the main drivers of NCD burden changes in 1990-2017

3. To estimate the national economic loss to NCD burden

4. To estimate the future NCD burden- 2040

5. To carry out Internal validation exercises

Methods

This work uses methods similar to that of the GBD study. The metrics used to quantify the burden are Disability Adjusted Life Years (DALYs), number of deaths, Years of Life Lost (YLLs) and Years Lived with Disability (YLDs). DALYs quantify the burden due to premature mortality and disability. They enable comparisons across nations, thus allowing benchmarking. Decomposition analysis is used to separate the effects of population ageing, population growth and changes in the risk factor scenario. We also quantified Gross Domestic Product (GDP) per capita lost to DALYs in Ireland in 2017 using the WHO model for projecting the Economic Costs of Ill-Health (WHO--EPIC model). Each DALY amounts to a loss of 1 to 3 units of GDP per capita (in international dollars). The burden of disease in 2030 was projected for Ireland using GBD's forecasting methods, and the potential and avertable YLLs were calculated. The GBD study results were also validated against some national level estimates. This is done to ascertain whether, and to what extent, the data from GBD would be an appropriate evidence base to formulate national level policy decisions. The estimates were also validated using different standard populations by checking if the results varied significantly.

Main Findings

This study analysed data from GBD as well as some national level databases, and the following are some of the main findings of the analysis.

Ireland ranks 11th best in the NCD related age-standardised DALYs, 2nd in the age-standardised deaths and 3rd in the age-standardised YLDs within the EU. This clearly shows that, while Ireland performs well in terms of number of deaths and YLDs, there is still a lot to be done when it comes to DALYs.

Life Expectancy in the ROI has increased during 1990 and 2017, however the Healthy life expectancy (HALE) has not increased at the same pace. This means that the additional years are lived in less than ideal health.

It was found that diabetes, ischemic heart disease (IHD) and stroke related death rate attributable to diets high in processed meat and sodium have increased during 1990 and 2017. Cancer and diabetes YLDs attributed to alcohol consumption have increased significantly (from 2.4 per 100,000 to 37.6 for diabetes and 15.9 per 100,000 to 25.4 for cancer). On disentangling the drivers of burden change, it was observed that except diabetes, the other three NCDs have shown more improvements in the risk factor scenario.

We also estimated that Ireland lost about 75.6 million international dollars (I$) in GDP per capita from all causes in 2017. An alarming result here is that, of the 75.6 million mention above, cancer alone contributed to 15 million I$.

A part of this study also focused on forecasting the burden in 2040. The model predicts that IHD will be the leading cause of deaths in 2040, whereas smoking is on its way to becoming the leading cause for YLLs.

In all the above-mentioned analyses, estimates based on national level data agreed with those obtained from the analysis of the GBD data. On using different standard populations the DALYs varied.

Conclusion

To the best of our knowledge, this is the first comprehensive epidemiologic and economic profile of NCD burden in Ireland. It was observed that the YLDs are on the rise and diabetes is the most neglected NCD in terms of effective population interventions. In terms of the risk factors, alcohol was found to be the leading cause of NCD morbidity. It should also be mentioned that, even though estimates obtained from GBD were in agreement with the national burden estimates, this study cannot be a replacement for a sub-national BOD study.

Overview of this Chapter

This chapter provides a brief introduction to the subject. The motivation for this work is discussed and the primary objectives of the study are laid out. Some relevant literature is discussed and the gaps in the research are identified. Finally, the main contributions of this work are reported, and a case is made for carrying out a sub-national burden of disease study for the Republic of Ireland.

Chapter 1: Introduction and Background

Non-Communicable Diseases (NCDs) are defined as those health conditions which are not transmissible from person to person. These include cancers, diabetes, cardiovascular diseases (CVDs), chronic obstructive pulmonary disease (COPD), mental health problems and musculoskeletal conditions. Most NCDs are chronic diseases and they, therefore, can have a major impact on an individual's health as well as a country's socio-economic fabric. The major challenge in studying these NCDs is that they are not the effect of one single cause. They result from a combination of many factors – genetic, environmental, physiological and behavioural factors.

The leading causes of NCD deaths in 2016 were CVDs - 17.9 million deaths (44%), cancers- 9 million deaths (22%), and respiratory diseases- 3.8 million (9%). Diabetes contributed to about 1.6 million deaths [1].

NCDs contributed to about 56.9 million global deaths in 2016 out of which 40.5 million (71%), were from NCDs [1]. The burden of these diseases were substantially high to the economy at every level (national and global) [2] [3]. A major proportion

of NCDs are modifiable and largely preventable by altering the exposure to risk factors. Examples include taking steps to lower blood pressure or increasing physical activity.

Disabilities due to NCDs are also a part and parcel of the burden and they impact not just the individual but also a country's economy. They put a strain on the resources of a nation as the health care costs of NCDs are usually very high. They also affect the ability of the affected people to carry out their work or other daily responsibilities. Thus, NCDs are a huge burden on the taxpayers' money [2] [3]. The cost of NCDs across the globe is quite significant [4]. The World Economic Forum's report on economic burden of the NCDs stated that in 2010, the cost of CVDs globally was estimated about 863 billion US dollars and the cost of diabetes alone was about 500 billion US dollars. The increasing economic burden of NCDs across the years can have severe and lasting impacts on the economy and thus appropriate quantification of this economic loss is crucial. In 2018, The Task Force on Fiscal Policy for Health, recommended that countries should increase taxes on alcohol, tobacco and sugary drinks in order to reduce the burden of NCDs [6].

NCDs can affect all ages [4] but risk significantly increases with age. However, about 15 million deaths from NCDs are in the age group 30-69 years of age [1] [4].

NCDs are a product of modifiable and non-modifiable risk factors. Modifiable risk factors are those that can be altered by the population or individuals by changing their behaviours. Examples of modifiable risk factors are tobacco use, alcohol consumption, diet and low physical activity. Non- modifiable factors are those

which cannot be altered by a population or an individual. For instance, race, ethnicity, age, sex and environmental factors [1] [5].

It has been observed that policy changes can significantly reduce burden. One such example is the minimum unit pricing of alcohol introduced in Scotland [6]. A year after this was implemented consumption went down from 7.4 litres per capita to 7.1. Also, it was observed that in Wales and England, where there was no intervention, there was an increase from 6.3 to 6.5 litres per capita. Such interventions can facilitate the reduction of NCD burden.

The Global Burden of Disease (GBD) study is the most extensive and detailed international study of health conditions. It provides estimates of morbidity, mortality, risk factors, injuries etc. at all three levels - global level, national level and regional levels [7]. The main feature of this study is the comparability across nations, effectively ranking them in terms of diseases and risk factors. The metrics commonly used in the GBD study are Disability Adjusted Life Years (DALYs), Years life with disability (YLDs), Years of Life lost (YLLs). DALYs are a combination of YLLs and YLDs.

The GBD study, since its inception in 1990, has been providing estimates of health conditions for countries around the globe. In order to understand the evolving health scenario across the world, it is important to examine trends from the year 1990 to recent years. This provides an evidence base to identify areas that require more interventions than others. This can help nations to prioritise their resource allocation to combat the growing burden of disease. For instance, GBD 2017 found that ischemic heart disease (IHD), stroke and COPD caused more than one million

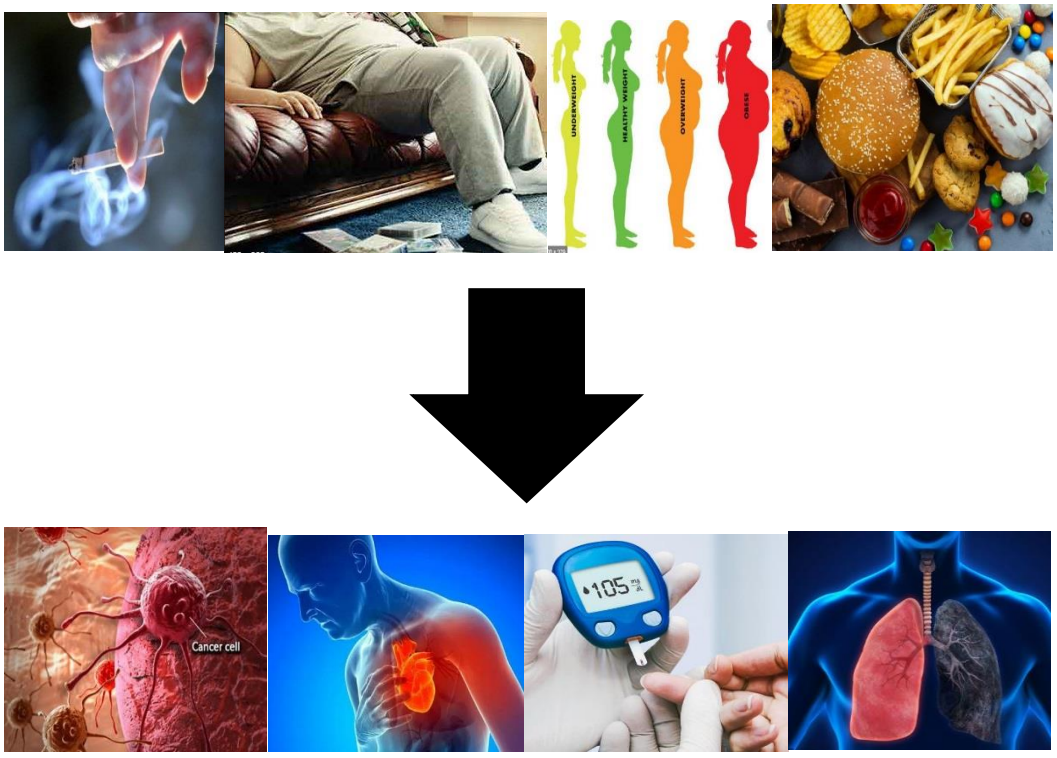
deaths and also accounted for an increased portion of global disability burden compared to 1990. The studies over the years also found that the relative contribution of individual risk factors has changed a lot. For instance, high blood pressure (BP) moved from 5th position to 1st position, smoking moved from 4th position to 2nd position, high blood sugar level from 11th to 3rd position, and high BMI from 16th to 4th position. It was also observed that males are more likely to die from an NCD as compared to females. In many countries, the overall life expectancy is on the rise, but the main question is whether these additional years of life expectancy are lived in good health or bad.

The WHO has published guidelines and targets with regards to NCDs for all nations to achieve by 2025. Meeting these targets would be seen as a huge step towards a healthier global population. A recent study in the Lancet Global Health has tracked individual progress of 150 countries with regards to these targets [8].

The WHO formulated nine targets [see appendix 1] to reduce premature mortality from the major NCDs by 25% by the year 2025 [9]. However, these nine targets can only be achieved if there is a strong commitment from governments, with engagement and support from individual citizens.

Many countries have already utilised the GBD data to infer national level trends in order to guide policy makers [10]. Countries such as the United Kingdom, China [10] and India have conducted extensive studies to quantify their health burden in collaboration with IHME using GBD data, whilst other countries have worked independently on their own burden of disease studies using the GBD framework but relying on country of origin data to calculate burden of disease estimates. E.g.

Scotland, Netherlands, South Korea. Even in the ROI, the need of the hour is to focus on the prevention of the NCDs. The Slaintecare Report [11] emphasised that although the Irish population is growing, it is also growing older and thus health care expenditure is rising. Population health approaches [12] can prevent chronic diseases, so it is important to quantify their burden in terms of modifiable risk factors, so that effective measures may be implemented [11] [12].



1.1 Rationale

There is a lot of research on NCDs and related risk factors in Ireland like the national studies on CVD, diabetes or the prevalence studies on risk factors. However, there

is no comprehensive study that has quantified the disease burden. The GBD study has detailed information on mortality, morbidity, risk factor attributions and it ensures comparability across nations. Such information can be useful to plan health policies and funding allocation on specific diseases or risk factors.

The GBD publishes its results as capstone papers. These papers, however, do not contain very detailed country level information. Although some information is published by the GBD in terms of their visualization tool, this information has not been collated or reported by any person or agency in Ireland. Moreover, it is not straightforward to draw policy related inferences from this data, they have to be analysed to answer specific questions.

Countries around the globe are using the GBD results in order to benchmark their health conditions. An example would be Belgium. The Belgian study [13] detailed the main health related issues within Belgium with the GBD dataset and laid the foundation of a future national burden of disease study. Some other nations have also used the GBD data and results to inform national policy decisions. For example, Public Health England states explicitly that their strategy is based on the findings from the GBD. GBD findings have been used at the highest levels of government in China [10] and have also been used in the prioritisation of specific policy interventions countries like Botswana [14].

Also, it is important to understand the drivers of change in the NCD burden to determine whether the changes are from population growth, ageing or changes in the risk factor scenario.

1.2 Added value of this research

Prevalence and incidence studies of NCDs and their related risk factors have been conducted previously in Ireland. However, this is the first study detailing the mortality and morbidity in terms of a universal metric i.e. DALYs. This work reports the impact of selected NCDs on the overall burden, and the most common risk factors. We have considered four NCDS- CVD, cancers, COPD and diabetes, and five relevant risk factors- dietary risks, alcohol consumption, tobacco use, low physical activity and high BMI. Furthermore, in this work we have projected the trend to predict the expected burden of disease scenario in Ireland in 2040 including the avoidable years of life lost from the most common risk factors.

There is no study in Ireland till date which quantifies the amount of national income that is lost from the burden of the NCDs in terms of the DALY metric. No study has yet analysed the driving forces behind the observed trends. Thus, this work has several novel aspects and makes many important contributions to research on burden of disease in Ireland.

This piece of work quantifies the extent to which Ireland would be able to reduce the burden of the NCDs by using effective preventive strategies. It would also help us understand where Ireland ranks in comparison to the other EU nations. This work also makes a case for a national BoD study in the ROI and some important steps are recommended.

1.3 Aims and objectives of this research

Overarching aim: To estimate the NCD epidemiologic health profile of Ireland employing the standardized GBD methodology and comparing this with other EU nations.

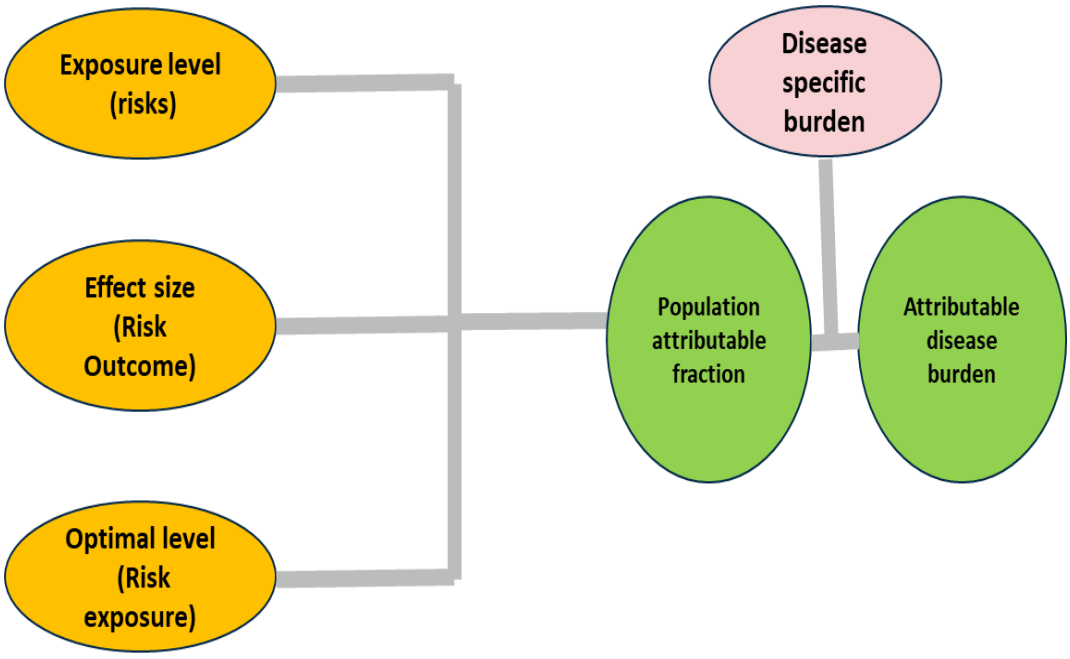
Specific Objectives:

- To estimate attributable burden (DALYs, YLDs and YLLs) of tobacco use, alcohol consumption, low physical activity, high BMI and dietary risks to four common NCDs cancer, CVD (IHD & Stroke), Diabetes and COPD in Ireland between 1990 and 2017.
- To project the future trends in NCDs and to estimate avoidable burden related to common risk factors for 2040 in Ireland.
- To estimate the main drivers (population growth, population ageing, changing risk factor patterns) of the estimated NCD burden change in Ireland.
- To quantify the loss of national income from the NCDs across the years 1990-2017.
- To interrogate key GBD estimates by validating with national-level Irish data, methods, assumptions, data inclusion (age-standardisation as a validation exercise using WSP and ESP).

1.4 Theoretical model

This work is based on the Global burden of Disease study. One of the most vital components of this study is the Comparative Risk Assessment (CRA) Framework Model [15]. It is a comparison of the level of exposure from a given risk factor to that of the risk factor at the minimum or zero level [15]. For example, the theoretical minimum level could be zero (no smoking at all) or could be non-zero (blood pressure). Below is the figure showing the theoretical model.

Figure 1.1 Theoretical Framework Model (Comparative Risk Assessment Framework Model)



There are two different components in this calculation:

The first component is the estimation of the burden of disease which can be further subdivided into two subsections- mortality and morbidity. Mortality aspect is measured in terms of YLLs and morbidity is measured in terms of YLDs.

The second component is the estimation of the contribution of risk factors to the disease burden using population attributable fractions.

Figure 1.2 Burden of disease method: diagrammatic

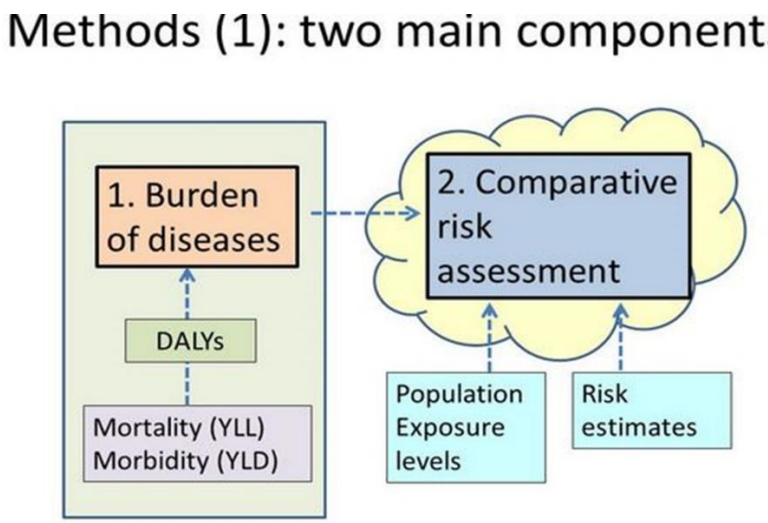


*Image taken from Public health England

1.5 Thesis outline

Chapter 1 focuses on the introduction to the thesis and this includes gap in research, aims, objectives and added value of this research. Chapter 2 focuses on a detailed literature review. Chapter 3 consists of the GBD methodology. Chapter 4 focuses on presenting the results of the EU burden of NCDs and the risk factor

attributable burden to the four major NCDs and life expectancy scenario in Ireland during 1990-2017. Chapter 5 focuses on disentangling the effects of the drivers of burden change in Ireland and also the amount of national income lost by all causes, NCDs and trends across time period 1990-2017. Chapter 6 focuses on interrogation of GBD estimates with that of the local level Irish data and cross validating some of GBD assumptions and results (like using WSP and ESP). Chapter 7 focuses on predicting the future burden of NCDs, expected LE and avoidable mortality in 2040. Chapter 8 focuses on discussion. It consists of major findings of this study in terms of both risk factors and NCDs, the reasons behind the burden, Policy implications of this study and limitations of this study.

1.6 Author's contribution

I formulated the research question of the chapters in this thesis and conducted the literature review to understand the pertinent background work. To understand the specific aspects of the data and its analysis, I attended the GBD Technical training workshop which gave me a hands-on experience of the GBD methodology, its assumptions and limitations. Utilizing all the knowledge acquired through literature review and training, I conceptualized the study and the necessary data download method from the GBD website, managed the data, and conducted the data analysis, writing out the results, interpreting the results and also editing and revising the thesis document with all my supervisors' advice. In this process, I also established contacts with other researchers in Poland and UK. I was also involved in disseminating the results of this work through oral and poster presentations.

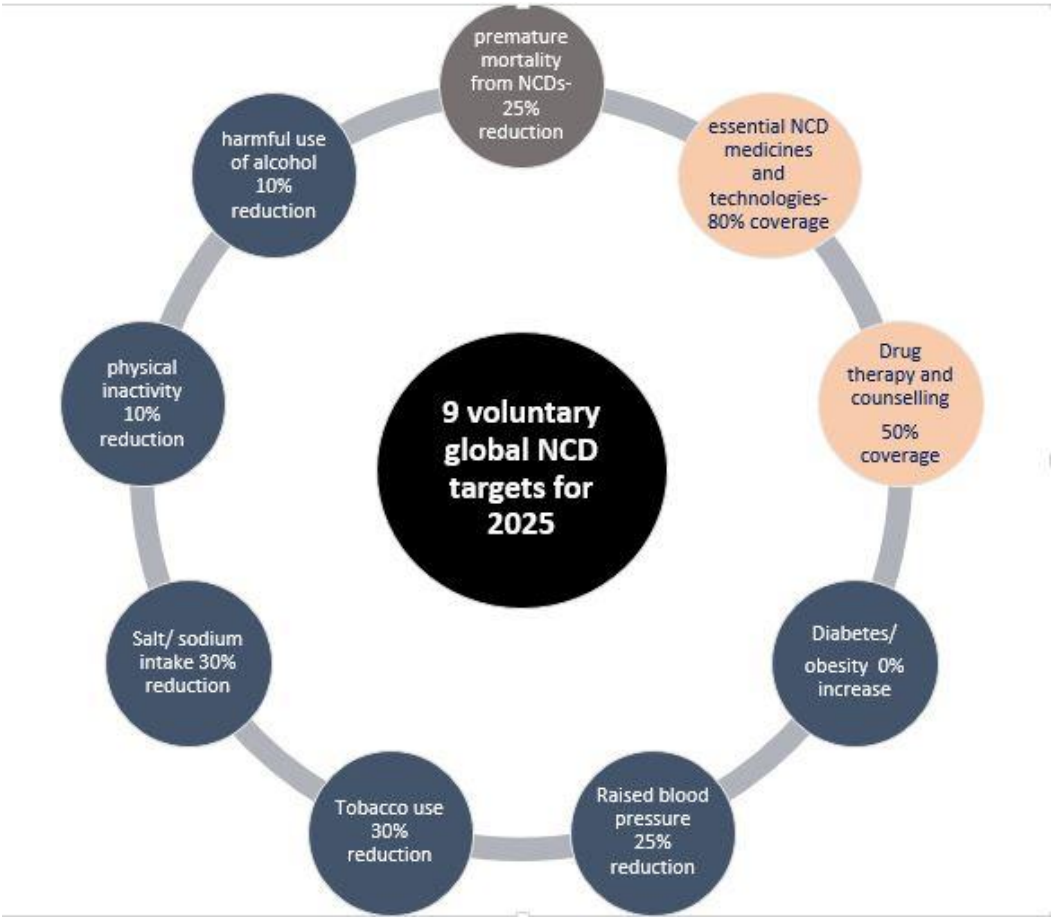
All the ideas were discussed with PhD supervisors before conducting the analysis. The supervisors have read all the drafts of the thesis and have provided their valuable feedback on the same. The author's other contribution during the course of her PhD have been detailed in the Appendix 3 of this thesis.

Chapter 2: Literature Review

This chapter focuses on the detailed literature review of existing research in the area of burden of disease at the national level and sub national level. It also describes the voluntary NCD targets for the year 2025. It also details the risk factors for selected diseases and the steps that have been put in place for tackling the risk factors for the diseases at national levels.

This chapter also includes literature review on burden of disease studies at national and subnational levels. This is also utilized so that the gap in research in burden of disease in Ireland can be elaborated and the requirement of a national burden of disease study is warranted in Ireland.

FIGURE 2.1: Schematic representation of the nine voluntary global NCD targets for 2025 [9]

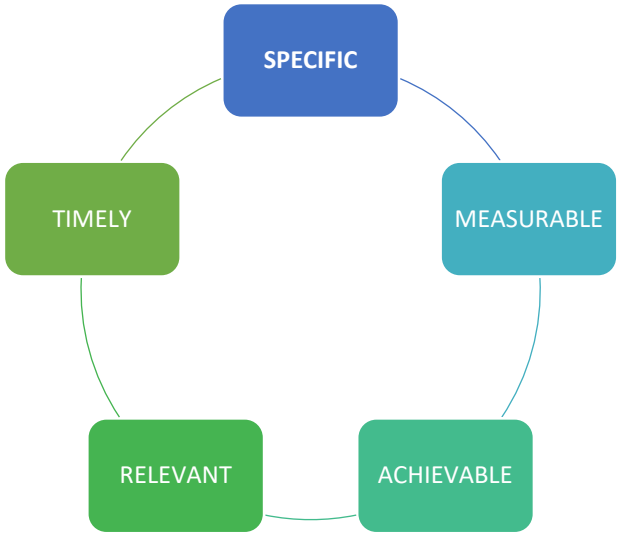


This section outlines some of the global and European level objectives outlined by the WHO. These objectives form the background for individual efforts of the various countries involved at various levels. The figure above shows the 9 targets of the WHO set for all the countries. These targets are crucial to achieve worldwide NCD reduction by the year 2025 [9].Further details of these are described in the Appendix I.

2.1 Health 2020 [16] [17]

Health 2020 was introduced and adopted in 2012 by the WHO Regional Committee for Europe. It is an evidence and value based framework that helps in taking a strategic approach towards achieving this goal. The main objective of HEALTH 2020 is to create better health conditions and overall wellbeing among the European population. This needs to be achieved with the help of the best possible evidence from the European regions. The steering committees, after careful consideration, have come up with the following considerations about targets being crucial and valuable, some qualitative as well as quantitative targets. Member states should contribute towards the Health 2020 programme to achieve Europe level objectives.

The targets must follow the **SMART** [17] goals paradigm, i.e.:



There are 6 different areas where strategic planning must be carried out in accordance with the HEALTH 2020 [16]. They are as follows:

- Governance for health and well-being
- Determinants of health inequalities and determinants of health need to be dealt with
- Investing for the people who are healthy and empowering communities
- Tackling systemic risk: The burden of disease (BOD)
- Creating supportive and overall healthy environments and assets for a healthy environment (including controlling or reducing the effects of risk factors)
- Strengthening health systems that are population centred.

2.2 Population and Mortality Statistics in the Republic of Ireland in 2016 [1]

The World Health Organisation published its country wise NCD profile for most countries. It contains basic information about the NCD scenario. The below mentioned statistics are from WHO.

Total Population: 4,726,000

Total deaths: 31,000

Total deaths from NCDs: 27,800

Total deaths of males from NCDs: 13,800

Total deaths of females from NCDs: 14,000

About 91% of the total deaths in Ireland in 2016 were from the NCDs. About 13% people died from alcohol use, 34% people from health conditions arising from physical inactivity, 23% people from tobacco use and about 8% people from obesity in Ireland during the year 2016

2.3 Cardiovascular Diseases (CVDs)

The Irish Heart Foundation (https://irishheart.ie/) defines cardiovascular disease as an umbrella term including conditions such as heart attack, angina and stroke [18]. The major risk factors which contribute to CVD are lifestyle and behavioural factors like that of high body mass index, low physical activity, high cholesterol and smoking. There are also some environmental risk factors which contribute to CVD. These are depicted in the information graphic published by the Public Health England (PHE).

Figure 2.2 Risk factors of cardiovascular disease (image by Public Health England)

Stroke is defined as the blockage of a blood vessel which carries nutrients and oxygen to the brain, by a clot. It is the third highest cause of death in Ireland and

the highest cause of disability [19]. According to the Irish Heart Foundation, there are about 10,000 incidents of stroke annually and about 2000 result in death [18]. Furthermore, it also predicts that the death rate from stroke will rise by a staggering 84% within the next 20 years. The Burden of Stroke report which was presented in Brussels in the European parliament stated that the stroke incidence in Ireland would rise by 59% by the year 2035 [18] [19].

Cardiovascular disease is not confined only to stroke, and overall, is one of the most common causes of death in the Republic of Ireland. It causes one out of three deaths and about one out of five premature deaths. In general, there has been a decline of about two thirds of all CVD related deaths over the last three decades. This can be attributed to the reduction in the prevalence of smoking, which in turn was a consequence of stricter tobacco policies implemented in the 2000's. However, there is an increased incidence of disability which increases the demand on health services.

Prevalence of smoking in the last five years in Ireland has been on a general decline according to General Population Survey (GPS). The prevalence of smoking in 2014-15 is lower than in 2010-11. However, the other risk factors like high BMI and low physical activity are on the rise and this can considerably alter the mortality rates from CVD [20]. The burden of CVD in Ireland is not only the human cost but a huge cost on health care, informal care and a loss in productivity [20]. In Ireland, however, only 6% of the national budget is directed on healthcare for CVDs, significantly lower than the average of the European Union which is 11%.

In order to manage CVD in Ireland, the Department of Health published a policy entitled 'Changing Cardiovascular Health' for the period 2010-2019 [20]. This policy aims at controlling CVD through various population level methods, with special focus towards high risk groups such as people with high BMI or additional health conditions. Tackling the challenges of rising burden necessitates not only government policies but also individual efforts. Some of the prioritised actions decided upon by this new policy for a 10 year period are as follows [20]:

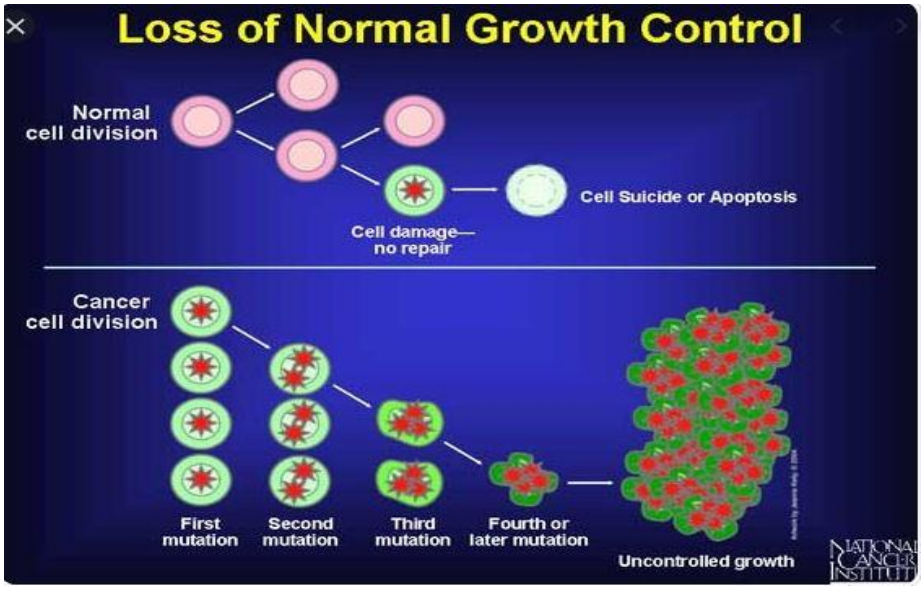
- Reducing or completely quitting smoking
- Maintaining a healthy body weight
- Regulating diet and increasing intake of healthy foods
- Increasing physical activity
- Cutting down on salt intake
- Regulating alcohol consumption

These above mentioned policies are in line with the larger Healthy Ireland strategy.

2.4 Cancer

Cancer is defined to be a group of illnesses characterised by an overgrowth of cells in the body [21]. Cancer cells multiply uncontrollably and damage tissues and organs in the body. The image below from the National Cancer Institute, USA shows the process that occurs in a cancer cell.

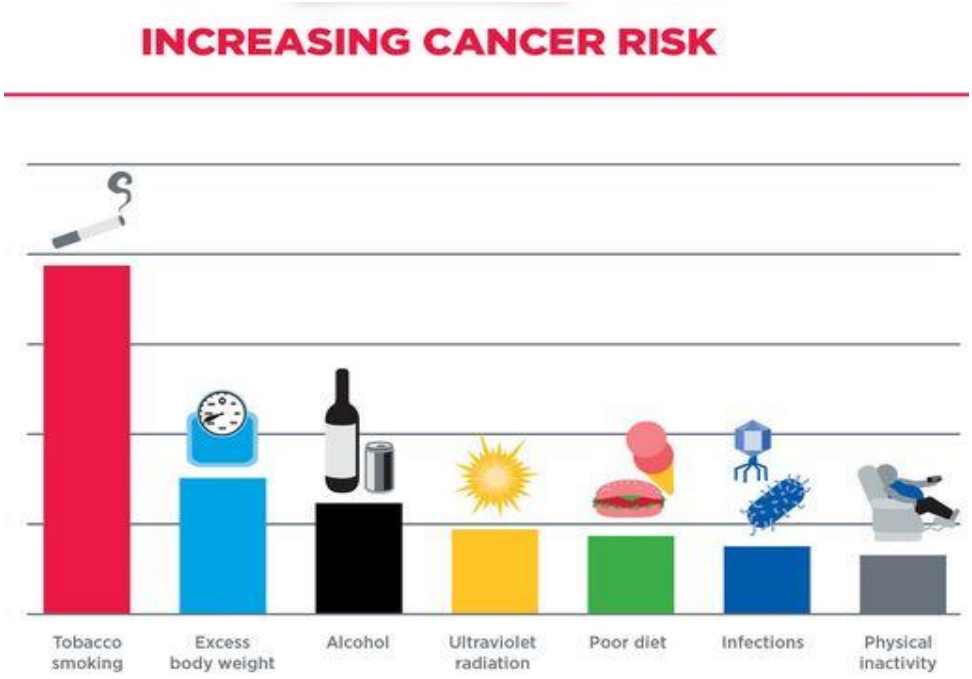
Figure 2.3: What is Cancer



∗image taken from National Cancer Institute

Cancers can occur from a wide array of causes, from genetics to external risk factors, and the causative process is complex and still remains unclear [21]. However, there is now substantial research which clearly bears out the fact that a number of risk factors increase the risk of cancer. Some of these factors are – exposure to harmful chemicals or toxic substances, alcohol consumption, smoking, dietary risks, excess sunlight exposure, radiation exposure, and high BMI. While some factors such as age and genetic factors cannot be controlled, the good news is that the other factors can be regulated in order to lower the risk. The chart below shows the risk factors closely related to cancer.

Figure 2.4: Risk factors for Cancer



∗Image taken from American Association for Cancer Research (AACR) Cancer Report 2019

The median age to be diagnosed with cancer is about 66 years according to the National Cancer Institute Surveillance, Epidemiology and End results program [22]. Alcohol is a serious cancer-causing agent and increases the risk of cancers of the throat, oesophagus, liver and breast. Also, the NCI states that the joint use of alcohol and tobacco can increase the risk of cancer [22]. Cancer is also caused by specific dietary elements. A noteworthy example is the article by the International Agency for Research on Cancer which designates processed meat as a group I carcinogen. People with high BMI (more specifically obese) have higher risk of cancer. One other major risk factor is tobacco use. Tobacco causes cancers of the mouth, lung, oesophagus, stomach, and liver. Contrary to common beliefs, there is no safe limit of using tobacco; even small amounts of tobacco are extremely

harmful. Reduction in many risk factors like leading an active lifestyle, having an appropriate diet and lowering the BMI can reduce cancer risk significantly. WHO has stated that about 33% of the cancers can be avoided by taking appropriate steps.

The cancer statistics provided by the Irish Cancer Society (ICS) are alarming [21]. There are almost 40,000 new cases of cancer are diagnosed annually. It was further predicted that, by 2020, 1 out of 2 people in Ireland would develop cancer during their lifetime. Cancers cause about 30% of the total deaths in Ireland; this is higher than the deaths caused by any other NCD. The most common cancers are lung cancer, skin cancer, breast cancer, prostate cancer and bowel cancer. Smoking is the single highest risk factor causing cancer. About one third of all cancers is caused by smoking in Ireland.

2.5 Chronic Obstructive Pulmonary Disease (COPD)

COPD is a disease which causes difficulties in breathing, particularly in exhaling due to blockages in the tracheal pathways air passageways [23]. The main risk factors are smoking and exposure to dust, fumes or other toxic gases. Such conditions are quite common in chemical factories, asbestos plants, coal mines etc., as well as polluted urban areas. The image below illustrates the common risk factors that can cause COPD.

Figure 2.5 Risk factors for COPD

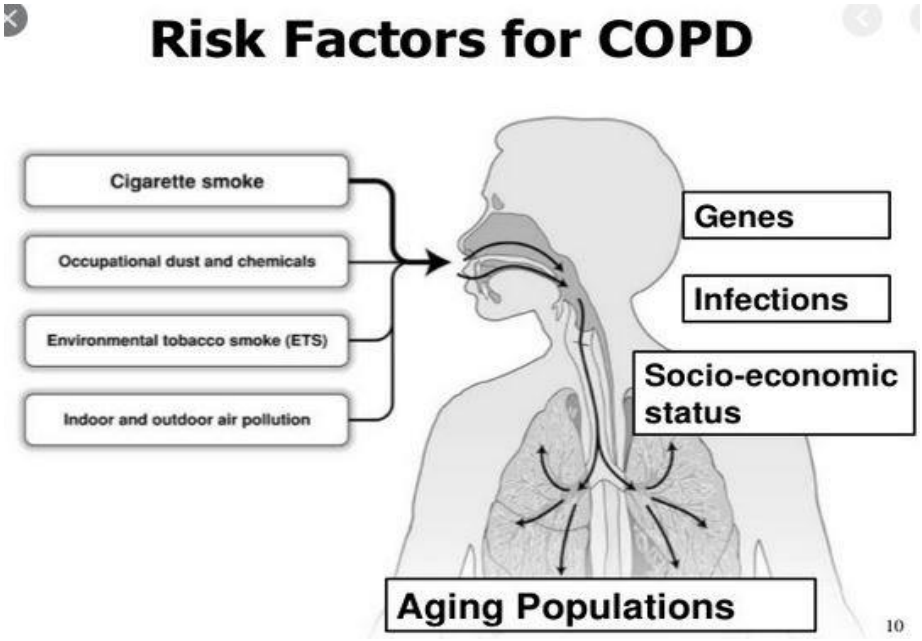


*image from Google

The HSE, Ireland states that about 110,000 persons have been diagnosed with COPD, however almost 200,000 people may actually have the disease and not been diagnosed [23]. COPD is more common in males as compared to females, however, this rate seems to be on the rise among the females now. COPD related deaths are approximately 1500 annually in Ireland. The only way to prevent COPD is complete avoidance of tobacco use.

2.6 Diabetes

Diabetes is a disease caused by the deficiency of a hormone called insulin. It is characterized by higher blood glucose levels in a person [24]. Diabetes mellitus is the most common form of diabetes and it can be subdivided into two groups - Type 1 and Type 2 diabetes. Type 1 diabetes is one in which the body is unable to

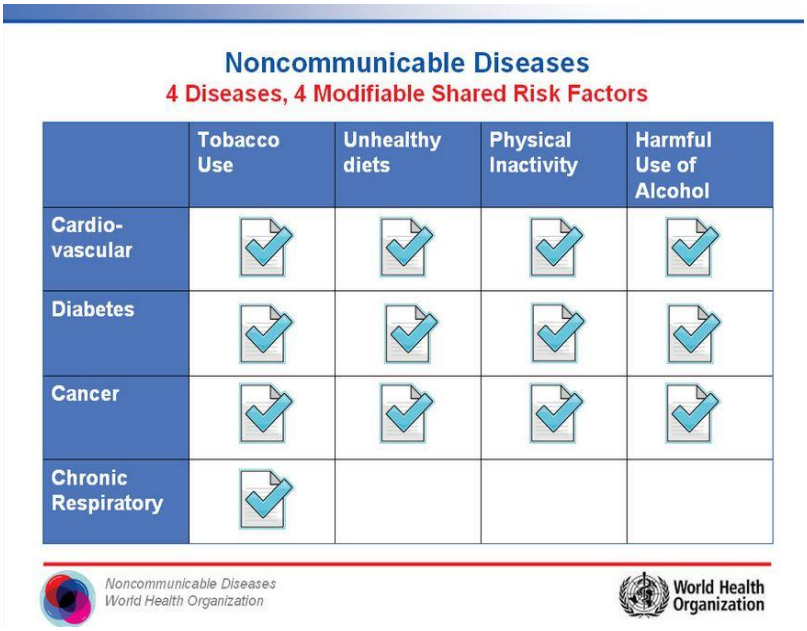
produce insulin but as a result of an autoimmune response that stops the body from making insulin. It is more common amongst young adults, children and teens. On the other hand, Type 2 diabetes condition does not allow the body to make sufficient insulin and can't keep blood sugar at normal levels. Type 2 diabetes is more common amongst adults. The rise in the prevalence of diabetes is due to an increase in the BMI as well as the ageing in the Irish population. The risk factors for Type 1 diabetes are age and family history and the risk factors for Type 2 diabetes are weight of the person, age, having a family member with diabetes and less physical active. It is important to regularly monitor the blood pressure or blood sugar levels and to promote awareness in the population. Below are the risk factors related to diabetes. Type 2 diabetes is overall more prevalent around the world as compared to Type 1 diabetes.

Figure 2.6 Risk factors for Diabetes

∗image taken from International Diabetes Federation

Diabetes Ireland stated that there are about 225,840 people in Ireland living with diabetes in 2013 and the prevalence of diabetes in the ages 20-79 years was 6.5%. The International Diabetes Federation had predicted that by the year 2020 there would be about 233,000 people in Ireland with diabetes and by the year 2030 about 278,850 people in Ireland with diabetes [25]. The economic cost of diabetes is considerably high. The annual cost of diabetes to the health service is about 2 billion euros but very little out of this amount is used in prevention or self-management of diabetes [24]. One of the studies published suggested that the government is spending almost 12-14% of the national budget on treating diabetes. However, as with the other NCDs, it is certainly possible for individuals to prevent diabetes by taking appropriate steps such as maintaining good physical activity and having a proper diet. The below figure from the WHO shows the relation between the NCDs discussed above and the most common risk factors. The following sections will go in to more details about each of the risk factors shown in the diagram.

Figure 2.7: WHO table showing the main 4 NCDs and 4 modifiable risk factors



2.7 Smoking

Smoking has been a significant risk factor around the globe and in Ireland. The Healthy Ireland survey of 2018 stated that about 17% of the population (aged 15 years and more) are current smokers, and about 3% of the population are occasional smokers. The highest prevalence of current smokers is in the age group of 25-34 years. Males smoke more than females in Ireland and they also experience more exposure to tobacco. The most popular tobacco related product in Ireland are manufactured cigarettes. It was also observed that almost all regular smokers knew about e-cigarettes, out of which 42% have also used them [26]. Smoking has a serious health impact on the physical and mental wellbeing. Smoking also contributes to many chronic diseases and this in turn affects the healthcare system as well as the entire nation, not just the affected individuals.

In order to maintain a healthy society, it must be tobacco free. This may sound somewhat idealistic; however, it is now established that there is no level of tobacco consumption which is considered acceptable or healthy. It must be noted that a misconception about occasional smoking is widely prevalent. Ireland ranks 2nd in the tobacco control initiatives among the 34 European countries [27]. Tobacco Free Ireland has a target to make Ireland completely tobacco free by 2025. Its objective is not to control the use of tobacco but completely eliminate the use of tobacco in Ireland [28].

The main action plans based on the Tobacco Free Ireland Action Report are to protect children from smoking and to not normalize smoking in the general population. A few other tobacco control measures already in place in Ireland are as follows:

- The workplace smoking ban (2004)
- Ban on sale of tobacco and related products to children under the age of 18 (2001)
- A ban on the advertising and sale display of tobacco products (2009)
- Text, photo and graphic warning of tobacco use (2013)

One encouraging observation from the Healthy Ireland survey of 2015 is that almost 2 out of 3 people want to quit smoking.

2.8 Alcohol Consumption

Alcohol is a major risk factor in Ireland and one of the chief contributors to the NCDs. Between the years 1960-2001 the per capita consumption of alcohol increased from 4.9 litres to 14.3 litres. This decreased in the later years because of excise duties as well as the economic recession in 2007-2008 (Alcohol Action Ireland) [29]. In the year 2017, however, the alcohol per capita consumption was still about 11.15 litres. According to the WHO, Ireland is second highest binge-drinkers' country in the world just after Austria. Drinking alcohol has massive health implications to an individual and it negatively affects society too. The Health Research Board of Ireland in 2013 reported that 3 people die in Ireland every day from alcohol related issues, which is about 88 per month and approximately 1000 per year. The prevalence of drinking is higher in males as compared to females in Ireland. The Healthy Ireland survey of 2015 showed that about 76% of the Irish population consume alcohol. The systematic analysis of GBD data suggested that, for the most part, no levels of alcohol consumption is a good for health [30].

Alcohol has been classified by the IARC as a group I carcinogen. Alcohol causes a multitude of diseases and health conditions like oral cancer, laryngeal cancer, pharyngeal cancer, colorectal cancer, breast cancer, liver cancer and various others. Just like tobacco, there is not safe limit to consume alcohol. According to the NCCP, approximately 900 cases of alcohol related cancers are diagnosed every year and there are about 500 deaths annually [31]. The NCCP also pointed out that about 6.7% of male deaths and 4.6% of female deaths occur from alcohol related cancers

between the years 2001 and 2010. The risk of cancer is the same for all types of alcoholic drinks.

A joint effect of smoking and alcohol combined together on the human body is far more dangerous than consuming alcohol alone or smoking alone [32]. Alcoholic drinks also contain lots of calories which can contribute to increase in weight, thus indirectly being responsible for many other diseases. Alcohol also harms the environment, family and friends around the drinker. It can affect the safety of the family and the most vulnerable are the children. Another major issue with the alcohol is that it effects the road safety and is a major reason behind accidents on the road. The Road safety Authority (RSA) also reported that men and more likely to drink and drive as compared to women. Alcohol is also responsible for mental health issues, depression, suicidal episodes and deliberate self-harm. Alcohol is an important factor in almost 50% of suicides in Ireland and over 33% of deliberate self-harm episodes. There is ample evidence in the literature that consumption of alcohol can affect mental health and well-being of a person [33]. Alcohol is also a major contributor to criminal activities, public offences, murders, assaults and rape [34]. This is not only a problem amongst adults but in children as well [33]. Alcohol related offences are the main reason for juvenile crimes. It accounts for one fifth of the crimes from the young people. Another major issue is drinking during pregnancy. There is no safe limit for drinking alcohol during pregnancy and it increases the risk of Foetal Alcohol Spectrum Disorder (FASD) [35]. Unfortunately, the prevalence of FASD in Ireland is the third highest in the world, just after South Africa and Croatia. The prevalence of FASD in South Africa was about 111.1 per

1000 population, Croatia was about 53.3 per 1000 population and Ireland was about 47.5 per 1000 population [35].

Although Ireland has higher excise duty rates on alcohol as compared to that of other European Union nations, alcohol is still affordable in Ireland and this is a cause for concern [36]. There needs to be a minimum unit pricing of alcohol to control consumption and sales of alcohol, similar to the one introduced in the United Kingdom [6]. After introduction of the minimum unit pricing in Scotland in May 2018, the sale of alcohol decreased significantly.

2.9 High Body Mass Index (BMI)

According to the WHO, body mass index (BMI) is defined as an individual's weight in kilograms divided by the square of their height in metres (kg/m^2).

The BMI ranges are as follows:

- If BMI is lower than 18.5 the person falls in the underweight category
- If BMI is greater than but lesser than 25 the person falls in the normal category
- If BMI is greater than 25 but less than 30, the person falls in the overweight category
- If BMI is greater than 30, the person falls in the obese category

Also, the obesity category can be further subdivided into these categories:

- Class 1: BMI greater than 30 but less than 35
- Class 2: BMI greater than 35 but less than 40
- Class 3: BMI greater than 40. This category is considered as an extreme.

The BMI metric is the one of most frequently used anthropometric measure to quantify the adiposity in the body. This method has its own set of limitations – using BMI as the only method to measure adiposity in the body can be misleading. The numerator in the BMI uses the total body weight and it does not differentiate between lean mass and fat mass. This may lead to inaccurate classification of some individuals with different lean and fat mass proportions. Nevertheless, it is an important health metric as it is easy to measure – it only requires the height and weight.

The percentage of overweight and obese people have risen from 60% in 2015 to 62% in 2017 according to the Central Statistics Office [37]. While there has been a plateau in childhood obesity trends, the current prevalence is still very high and a huge cause for concern. It was found that about 1 out of 4 children are obese or overweight and 6 out of 10 adults are obese or overweight [38]. Another alarming finding from the WHO in 2015 was its forecast that Ireland could top the list of countries by obesity in the EU.

High BMI is a major contributor to chronic diseases like cancers, CVDs and diabetes. A study conducted in 2014 in Ireland reported the extent of correlation between obesity and NCDs [39]. It showed that a large portion of burden from the chronic diseases can be attributed to increasing BMI. This study also reported that High BMI is a problem that affects all age groups and both sexes. Furthermore, it has been found that healthy weight is also correlated with mental well-being.

Obesity is a very complex issue and a multitude of factors work together [40]. Some important initiatives to curb obesity could be – increasing taxes on unhealthy food

items (foods high in salt, sugar and saturated fats), spreading awareness about healthy weight, initiating programmes to monitor children's growth, promoting health benefits of proper diet and reduction of advertisement of junk foods, supporting local producers and farmers to supply fresh produce to the population, and lastly increasing physical activity.

Foresight Obesity Framework have recognised that obesity is a very complex issue and have formulated the obesity system map aimed at creating a balance in perspectives about roles played by individuals and their environment. This map helps in taking a system-wide view and facilitates a multifaceted approach to tackle obesity related challenges.

FIGURE 2.8: OBESITY MAP [40]

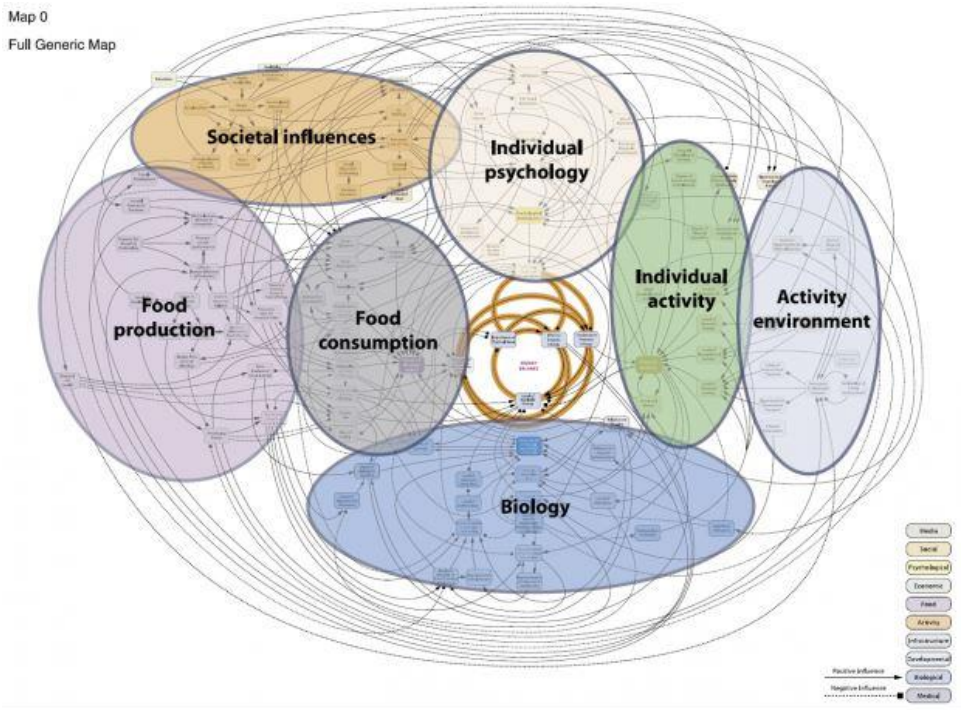


*Image from Foresight's Tackling Obesities: Future Choices Report

The solutions of obesity and overweight problems in Ireland are complex. Thus, a document like the "A Healthy Weight for Ireland-Obesity Policy and Action Plan

2016-2025" is extremely crucial [41]. It aims at reducing the levels of obesity and suggested that the solution to this problem is multiple and multidimensional and that multiple sectors can play their own roles in reducing the burden. This action plan is a major step in implementing Healthy Ireland. It is expected that this action plan will be able to reverse the epidemic of overweight and obesity in Ireland.

2.10 Dietary Risks

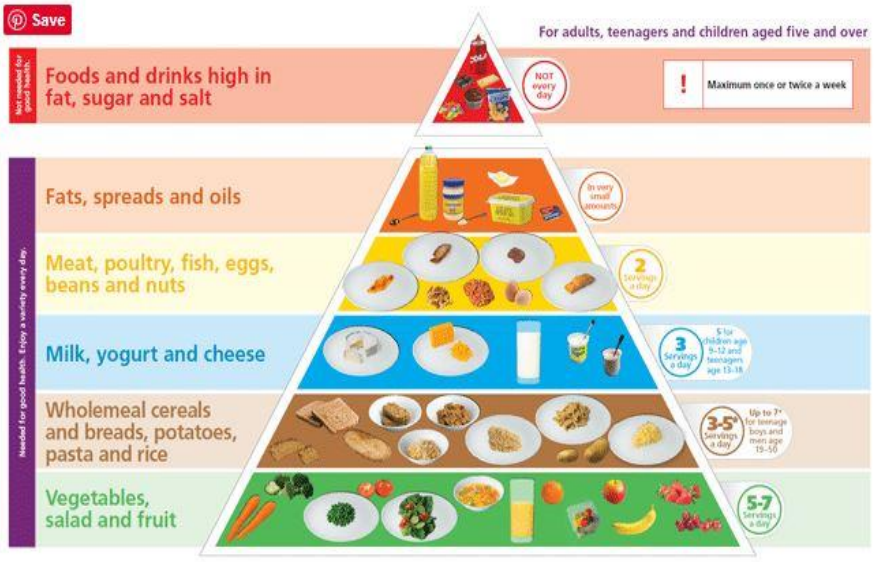
Dietary risks also contribute to cancers, CVDs and diabetes. The GBD study of 2017 on dietary risks showed that about 11 million deaths around the globe were from improper diets. Out of the 195 countries studied, Ireland was 24th in the list of number of deaths, the worst performer being Uzbekistan and the best was Israel. According to the Healthy Ireland survey of 2015, approximately 26% reported that they eat five or more portions of vegetables and fruits daily and about 22% reported that they did not consume vegetables and fruits on a daily basis. Almost 15% reported that they consume sugar sweetened beverages on a daily basis.

In order to reduce the risk of cancer or any other chronic disease a balanced and healthy diet is crucial. A balanced diet should be [42]:

- high in vegetables and fruits,
- high in fibre,
- Low in salt and sugar,
- Low in processed meat, red meat and saturated fats.

The food pyramid by the Safefood agency of Ireland shows what nutrition is required by a human being to stay healthy.

Figure 2.9 SafeFood food pyramid (image from Safefood)



There are a wide range of other diets such as the Mediterranean diet, DASH (Dietary Approaches to Stop Hypertension) diet and the Atkins Diet. Each of these diets have their own set of drawbacks and advantages. Recently in January 2020 in the U.S. News and World Report's best diet rankings for 2020, a panel of 25 experts declared the Mediterranean diet to be the best as it is rich in omega-3 fatty acids, fish, chicken, vegetables, fruits, nuts and legumes. According to these researchers, the second best diet was the DASH diet which has two drawbacks – consumption of full cream and alcoholic drinks [43].

Other important action points would be to read food labels while consuming or purchasing food items. Also, a very important way to control diet is to reduce portion size [42]. The proper dietary intake is a combination of personal interventions, social interventions and an overall country level framework.

2.11 Low Physical Activity

According to the WHO, physical inactivity has been found to be the fourth leading risk factor for mortality across the world. Regular physical activity is vital in order to have a healthy life. A lot of research has been done in this area across the world. Physical activity affects every aspect of a person's life - mental wellbeing, social wellbeing and physical wellness. Regular physical activity can reduce risk of many chronic diseases like cancers, diabetes, strokes and depression [44]. Physical activity is crucial for all age groups and both sexes. It is as vital for older people as it is for children and youth [44] [45]. It reduces the risk of injuries and falls in older population. In children too, physical activity lowers the risk of childhood obesity [45]. The SLAN study of 2007 showed that only 41% of the Irish population (adults age >=18years of age) undertook physical activity of 20 minutes or more [46]. This has improved only by 3% in a decade (38% in 1998). Comparing this with the SLAN 2002 and SLAN 1998, it was observed that the level of activity hasn't changed for the past few years - this level was about 40% in 2002 compared to about 38% in 1998.

Ireland had launched The National Guidelines on Physical Activity for Ireland [47]– 'Get Ireland Active' to highlight the benefits of physical activity, to provide information on required physical activity levels for all age groups as well as people with physical disabilities. These guidelines also call for establishing centres to provide detailed information to the general population. The guidelines recommend

30 minutes of activity daily or at least 150 minutes in a week. It is hoped that this would also help tackle obesity in the long run.

Increased physical activity in the population benefits not only individuals but also the economy. Therefore, it is important to spread the positive impact of increased physical activity as much as possible.

2.12 Cost implications of NCDs and risk factors in the Republic of Ireland

2.12.1. Costs of the NCDs

Not only do NCDs pose a significant burden on human health, they also exert a lot of pressure on the economy. This section reports the economic losses incurred due to different NCDs at different points of time.

CVD costs the European economy approximately 210 billion euros a year. Out of this, 111 billion euros is towards health care costs, 45 billion for the informal care of CVD patients and 54 billion euros due to productivity losses [48] [49]. The table below shows the healthcare costs in Ireland from CVD and IHD from above papers.

FIGURE 2.10 Cost of CVD and IHD in Ireland in 2015

	Total health care costs	**Percentage of total health care expenditure**
Costs of CVD in Ireland in 2015	€ 856,876	3%
Costs of IHD in Ireland in 2015	€ 157,830	1%

The cost of stroke to the Irish economy is about 557 million euros annually as reported by the 'Cost of Stroke in Ireland' study which was conducted by the IHF.

The total expenditure from hospitalisations from COPD was about 70 million euros in 2014. In the year 2016, among those with General Medical Service eligibility, medications costs for COPD was approximately 67.6 million euros.

Below is the table published in *Diabetic Medicine* which showed the direct costs of the various aspects of Diabetes [50].

FIGURE 2.11 Direct costs of diabetes in Ireland annually

	Direct costs (95% CI)
Health service	Euro
GP visits	8,886,425 (6,560,448–11,212,403)
Outpatient department visits	18,512,617 (13,932,175–23,093,058)
Hospital admissions	60,002,517 (18,000,755–96,004,027)
A&E attendances	1,492,862 (213,266–2,985,725)
Total	88,894,421 (38,706,645–133,295,212)

A report by the National Cancer Registry estimated the total losses due to cancer at 143 billion euros during 2011-2030 [51]. This study also stated that a 1% annual decrease in mortality could result in a saving of 8.5 billion euros over the same period.

2.12.2. Cost of the risk factors

It was estimated in 2013 that the economic cost due to smoking related disorders to the health service was about 460 million euros and the estimated loss in productivity amounted to just over a billion euros [52].

On an average, weekly expenses on tobacco and alcohol in a household is about 28 euros as stated by the Household Budget Survey in 2015.

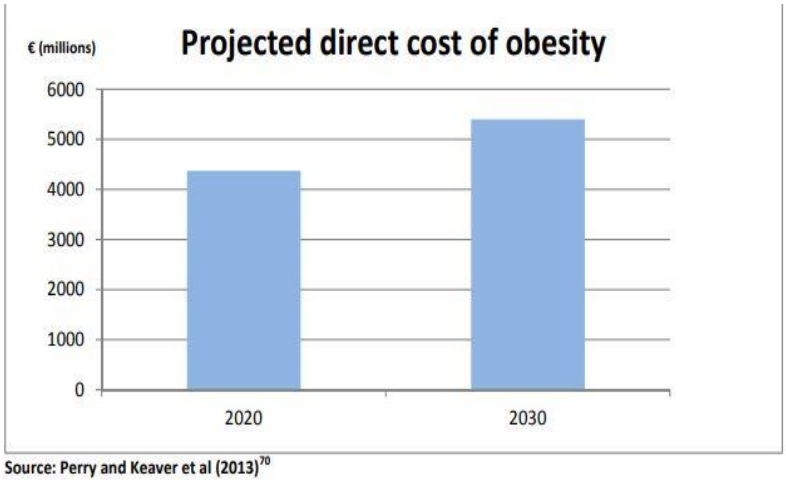
The Health Research Board of Ireland has studied the costs arising from alcohol consumption and its concomitant health conditions. The approximate cost of alcohol related hospitalisations was found to be about 1.5 billion euros. The Department of Health in 2013 stated that the cost of alcohol related illnesses on the healthcare system is a huge 800 million euros. Below is the table in this report which showed the approximate amount of expenditure on different issues arising from alcohol. The table is taken from the document titled "Costs to Society of Problem Alcohol Use in Ireland" as a report for the HSE [53].

FIGURE 2.12: Costs of alcohol

Category of Cost	**€Million**	**% of total**
Cost to the health care system	800	34
Cost of alcohol related crime	686	29
Cost of alcohol related road accidents	258	11
Cost of lost output due to alcohol related absenteeism	195	8
Cost of alcohol related accidents at work	185	8
Cost of alcohol related suicides	169	7
Cost of alcohol related premature mortality	65	3
Total costs	2358	100

The direct costs of obesity and high BMI in 2014 was estimated at 400 million euros and there were also indirect costs of about 728 million euros [54]. Costs that are incurred by the healthcare system are known as direct costs. Costs due to factors such as premature deaths, absenteeism, and reduced productivity comprise the indirect costs. The study used the UK's obesity framework model [55], to project future trends and determined that , without interventions, the cost will rise to over 4.3 billion euros in 2020 and 5.4 billion euros in 2030 (see fig. below).

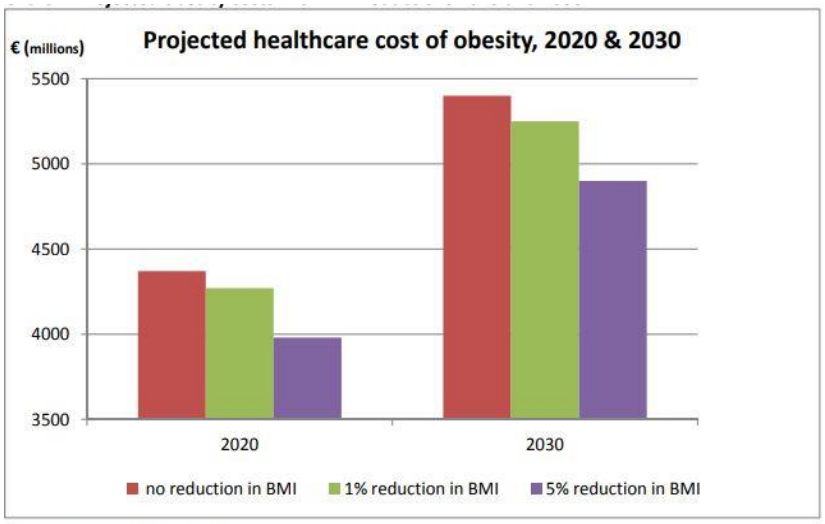
FIGURE 2.13: Projected cost of obesity



Source: Perry and Keaver et al (2013)[70]

The study further went on to estimate the benefits of reduction in the levels of overweight and obesity shown in the figure below.

FIGURE 2.14: Projected healthcare costs of obesity in 2020 and 2030



Source: Perry and Keaver et al (2013)

The economic costs of low physical activity around the world was estimated at 67.5 billion dollars in 2013. It was 1.7 billion pounds in the UK and 150 million euros in Ireland. Although this is small in comparison to the other risk factors, it is nevertheless a major issue that needs to be addressed urgently.

2.13 Global Burden of Disease (GBD)

The Global Burden of Disease of study was commissioned in the 1990s by the World Bank to provide a detailed assessment of the burden for about 100 diseases, injuries, sequelae and ten risk factors for the eight World Bank regions [56]. In the 1990s it was expected that the next few years would face dramatic changes in the health scenario. It had become evident that NCDs were going to become a larger cause for concern owing to the rise of ageing population across the world. This meant that there would be long-term health challenges not only to individuals, but also to governments. There was a glaring lack of proper information and an evidence base upon which policies could be formulated. Most of the research effort was devoted to descriptive epidemiology. It was also scattered, incomplete, and not comparable across nations. It was thus important to develop a standardized methodology to enable an appropriate comparison across different regions, diseases and risk factors [57].

This gap was for the first time filled by the GBD studies. These landmark studies further provided opportunities for individual country level disease burden studies. One of the main objectives was to make the worldwide data comparable. A mathematical model called the DISMOD was developed to calculate the estimates of mortality, cause of death, prevalence or incidence. A metric called DALY (Disability Adjusted Life Years) was introduced to estimate the burden of disease. This was a time-based metric which was a summation of two components:

- Years of life lost (YLLs) and

- Years of life lived with a disability (YLDs)

DALY thus measures the healthy life lived by a person considering the years of life lost and years lived with a certain disability. The fatal cases of any injury or a disease is measured by the YLLs and the not fatal conditions are measured by the YLDs. This was not the first study to have used the DALY metric. DALYs are more generalised form of the QALYs (Quality Adjusted Life Years) which was proposed in 1976 by Zeckhauser and Shepar. However, it is important to understand why DALYs are more preferred in Burden of disease studies as compared to the QALYs. QALYs are easy to calculate. It is a measure of the time a person is going to spend in a health condition. A score of 1 shows perfect health and 0 shows death. Below is a table which describes how calculation of DALY and QALY is done, their limitations and an example.

Figure 2.15 Comparison of DALYs and QALYs

DALYs	QALYs
Calculation DALYs= YLLs +YLDs	**Calculation** QALY=product of LE combined with one other measure of the quality of life-years that remains
Limitation Can be overestimated as the standard Life expectancy figures as actual LE is much shorter	**Limitation** QALYs may be difficult to implement in cases of chronic diseases and may lack sensitivity in the results.
Example A man has LE=80 years and is about to die at the age of 50 would suffer 30 years of life lost (YLL). Also, if he turned deaf at the age of 40, this would add 10 years of his life to be spent amidst disabilities with a weight of 0.40 which results in 0.40 x 10 = 4 YLDs. So, in this case the total number of DALYs=34	**Example** An intervention is given to a patient and this gives the patient an extra two years of life at a health status of 0.5 would give rise to one QALY

A few other important concepts used in the GBD [58] study is the LE, CRA, SDG and SDI.

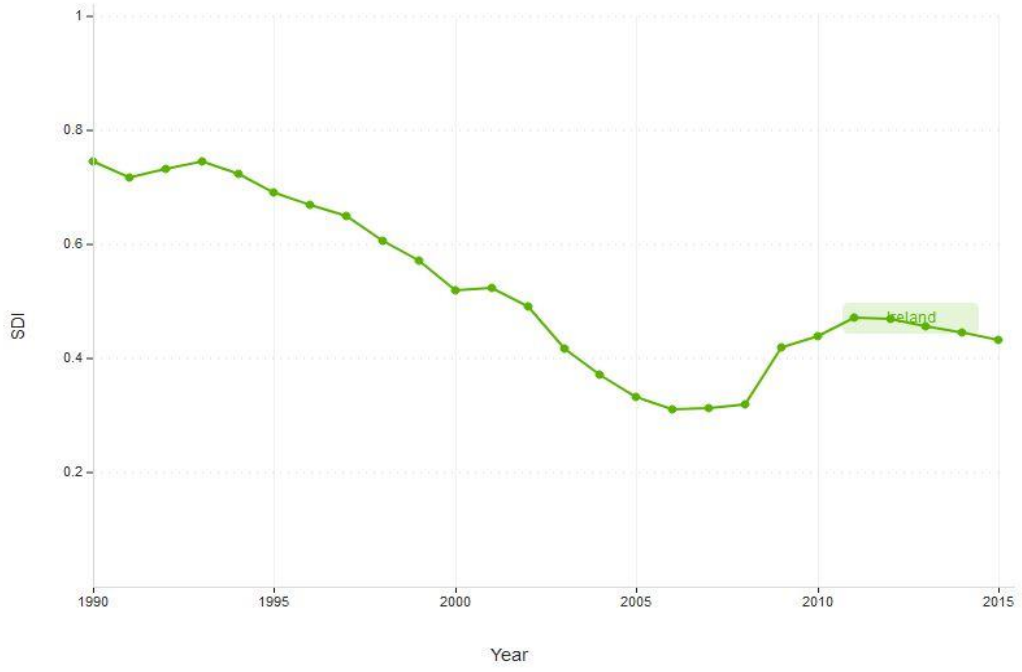
LE: life expectancy is the number of years a person is expected to live at a given age.

CRA: the comparative risk assessment framework enables a systematic comparison of population health when the distribution, or exposure to one or more risk factors changes. In the GBD study, the baseline or counterfactual distribution is used.

SDI: Sustainable Development Index computes the ecological efficiency of human advancement, realizing that advancement must be within planetary limits. SDI is measured using the Human development score (that uses LE, Income and education) divided by the carbon dioxide emissions from consumption and material footprint per person.

Figure 2.16 shows the change in Ireland SDI over the years

(https://irelandsdg.geohive.ie/)



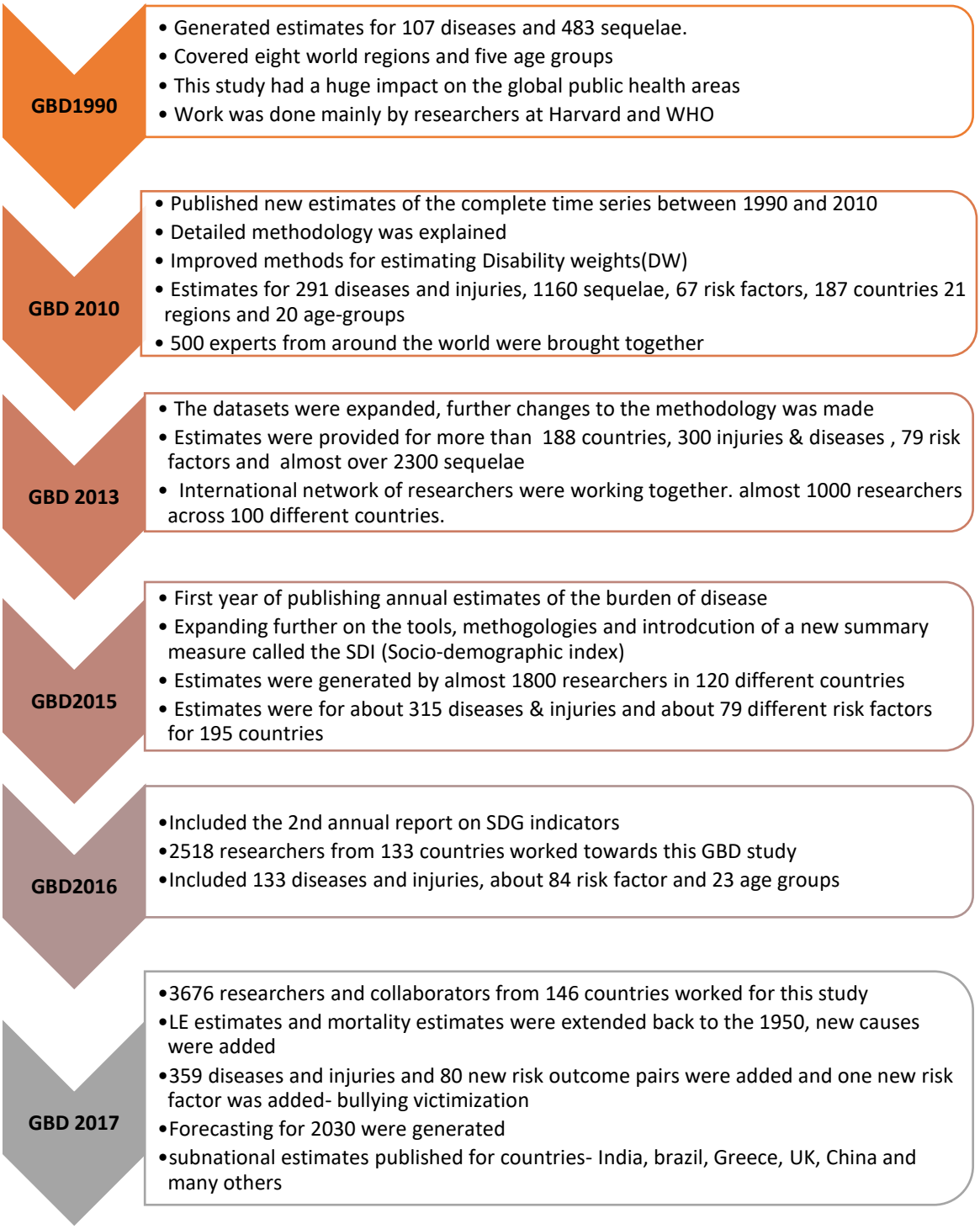
	Rank	Country	SDI	Life Expectancy (years)	Expected Years of Schooling	Mean Years of Schooling	Income (GNI per capita constant 2011$ PPP)	CO2 emissions per capita (tonnes)	Material Footprint per capita (tonnes)
	129	Ireland	0.432	81.3	19.6	12.3	48,551	9.91	21.08

The GBD study has evolved over the years. With each new GBD iterations, there are new datasets added, more advancements in the methodologies, and more collaborators across the world.

Below is the pictorial representation of the GBD study over the years from its origin in 1990 to the year i.e. 2017. It also displays methodological changes, inclusion and exclusion of any new diseases, injuries and risk factors, as well as the addition of research teams.

It contains all the GBD waves- GBD 1990, 2010, 2013, 2015, 2016, and 2017. It gives an overall understanding of how the GBD study has evolved across the time.

FIGURE 2.17 GBD study across the years



We conducted a literature review of the existing research in the area of burden of disease to understand the main focus of these papers, the types of comparative

results that they produce and also the policies or decisions which could be based on such studies. We have focussed one section on global or national studies whilst the other on subnational studies. The subnational and national studies were brought to attention as we wanted to understand the gap in research in Ireland in the area of burden of disease and how the vast amount of data published by the GBD could be utilized to draw conclusions and also to become the framework for a subnational estimation with local level datasets. The GBD 2017 study provided extensive estimates of the burden of diseases, risk factors and the trends over time during 1990 and 2017.

Authors	Study design	Global or National study	Year of study/GBD wave	Population	Main topic of the paper
BURDEN OF DISEASE STUDIES (GLOBAL)					
Roth et al.	GBD study	Global (195countries)	2017	All age groups	Cause of specific deaths
James et al.	GBD study	Global (195countries)	2017	All age groups	incidence, prevalence and YLDs
Kyu et al.	GBD study	Global (195countries)	2017	All age groups	DALYs and HALE

GBD 2017 Risk Factor Collaborators	GBD study	Global (195countries)	2017	All age groups	Comparative risk assessment of risk factors
Lozano et al.	GBD study	Global (195countries)	2017	All age groups	Sustainable Development Goals
Foreman et al.	GBD study	Global (195countries)	2017	All age groups	Forecasting LE, YLLs, all cause and cause specific mortality
Abubakar et al.	GBD study	Global (188 countries)	2013	All age groups	All-cause and cause-specific mortality
Kassebaum et al	GBD study	Global(188 countries)	2013	Women of reproductive age	Maternal Mortality Rate
GBD 2016 Stroke Collaborators	GBD study	Global(195 countries)	2016	All age groups	YLLs, YLDs and DALYs
Charlson et al	GBD study	Global(195 countries)	2016	All age groups	YLLs, YLDs and DALYs

Whiteford et al	GBD study	Global(187 countries)	2010	All age groups	YLLs, YLDs and DALYs
Feigin et al	GBD study	Global(187 countries)	2010	All age groups	YLLs, YLDs and DALYs
NATIONAL BURDEN OF DISEASE STUDIES					
Murray et al	National Burden study	United Kingdom	2010	All age groups	Deaths, DALYs, YLDs
Steel et al	National and sub national Burden study	United Kingdom and 150 local English local authority areas	2016	All age groups	Deaths, DALYs, YLDs
Marinho et al	Subnational BOD study	Brazil	2016	All age groups	Deaths, DALYs, YLDs
Dandona et al	Subnational BOD study	India	2016	All age groups	Deaths, DALYs, YLDs
Wyk et al	Subnational BOD study	South Africa	2010	All age groups	Mortality trends
Bosetti et al	National BOD study	Italy	2017	All age groups	Burden of cancer

Yoon et al	National BOD study	Korea	2007	All age groups	Burden of disease (DALYs)
Ciobanu et al	Results from GBD	New Zealand	2015	All age groups	YLDs, DALYs
Melaku et al	Findings from GBD 2013	Ethiopia	2013	All age groups	YLDs, deaths and DALYs
Haro et al	Findings from GBD 2010	Spain	2010	All age groups	YLDs, deaths and DALYs

The above literature review summarizes the global level burden of disease studies and the kind of health and risk factor information that it provides researchers with, thus highlighting the importance of such kind of studies. The second section of the literature review focusses on the national and sub national estimation and why they are crucial to any nation. This also points out the gap in a burden of disease report for Ireland and we aim to fill in that gap in this work.

The above studies clearly explain the information that they can provide to a researcher. On one hand, the global studies provide primary or comparable health information for many countries together, there exists a lack of detailed information required to take any national level decisions. On the other hand, the national or subnational estimations(both using the publicly available data or in collaboration

with GBD group) provides much detailed information on health conditions, risk factors and trends over time. This kind of granular information would be appropriate for any national level policy decisions or frameworks. Also, the main difference between the publicly available data and the collaboration with the GBD group lies in the sharing of national level data, accuracy of standard populations, selection of disability weights, socio economic differences and many other factors. Thus, ideally, a study based on the openly accessible data is a baseline output for any country whereas a collaborative effort for a subnational estimation of the Burden of disease study would be the step forward. In the next section we describe a few subnational studies to understand how these have helped determine national level policies or frameworks in different countries.

Although, the GBD studies have provided a plethora of information not only about current global level health metrics, but also projections for the future burden of disease, national level studies are also crucial in determining appropriate health policies. Some of the countries which conducted sub-national estimation include United Kingdom, United States of America, South Africa, India, Brazil, China, Japan, Greece and a few others. Earlier in the literature review in this chapter, we found some of the national and sub national studies interesting and we wanted to enquire how they influenced the nation's policy and decision making. For this particular aim, we shall detail the subnational estimation for UK, Brazil and India to point out why a subnational estimation is important.

2.14 Subnational Estimation of Burden of Disease

2.14.1 United Kingdom-[59] [60]

The United Kingdom conducted subnational estimation working in collaboration with the GBD team. There have been a lot of changes in the health system and policy initiative in the last few years. This study used data from GBD 2010 to compare health metrics for the UK with several other countries. The metrics considered were - overall causes of death, YLLs, DALYs, YLDs, mortality rates, as well as HALEs. This was a detailed study which considered 259 diseases and 67 risk factors. This study showed that the performance of United Kingdom in terms of health is lower than many of the compared countries. It pointed out that concerted efforts are needed to reduce premature mortality from cancer and cardiovascular diseases. It also found an increase in substance use disorders as well as mental health disorders which require immediate attention. Drugs and alcohol have contributed to the decline in health conditions. Moreover, it found alarming levels of prevalence in younger age groups. Based on this result the UK government was considering a public consultation to levy a minimum pricing for alcohol. One of the striking findings from this paper was how chronic disability was getting increasingly

common. As the population is living longer than before and many factors steadily increase with age, living longer could mean living more years with disability. The study also brought dietary risks in focus.

The United Kingdom introduced the National Health Service Long Term Plan which is a 10-year blueprint for health services. This plan relies heavily on the GBD study as an evidence base.

2.14.2 Brazil [61]

The health system in Brazil has been affected by economic, political and epidemiological changes over the last five decades. Several health promotion reforms were implemented over the years, and they have had significant results. The GBD 2016 study was used as a basis in the more detailed analysis on the changing health patterns in Brazil. It was found that there were large disparities in health across the population, and specific recommendations were made to address these issues. The studies on the Burden of disease in Brazil focussed on bringing out the inequalities in the access to healthcare services, quantified the burden of neglected tropical diseases in Brazil and also brought about more attention areas where there was not much attention prior to the GBD study like leading causes of

death in children, variations in mortality from cardiovascular outcomes, morbidities from some leading risk factors etc.

2.14.3 India [62] [63] [64] [65] [66]

India is a very diverse country which has population very similar to that of many large countries around the world. About 18% of the world's population lives in India. To improve the overall health of the population of India, comprehensive estimation of state-level data is crucial.

- Until this study, there had been no such comprehensive estimation of the burden for all the major diseases and risk factors in India. The study was carried out in collaboration with the global burden of disease study group.
- In early 2018 the Indian government announced the national health protection mission known as the Ayushman Bharat. This scheme provides health insurance to more than about 500 million people from the poor and the vulnerable sections of the Indian Society. With an increase in NCD incidence, there is an increased economic pressure building up on individuals and families. Such national level initiatives for a large country such as India, are only possible when there is appropriate population-level information.

- Cardiovascular diseases are on the rise in India. The studies have recommended dietary risks related policies such as the ‘fat tax’ and a ban on advertising foods high in sugar, salt and fat to the Food Safety Authority of India in 2017.

Such sub-national estimation of burden of disease is crucial for effective implementation of policies, appropriate allocation of resources. Developing robust monitoring systems is an urgent requirement in India.

2.15 Gap in Research

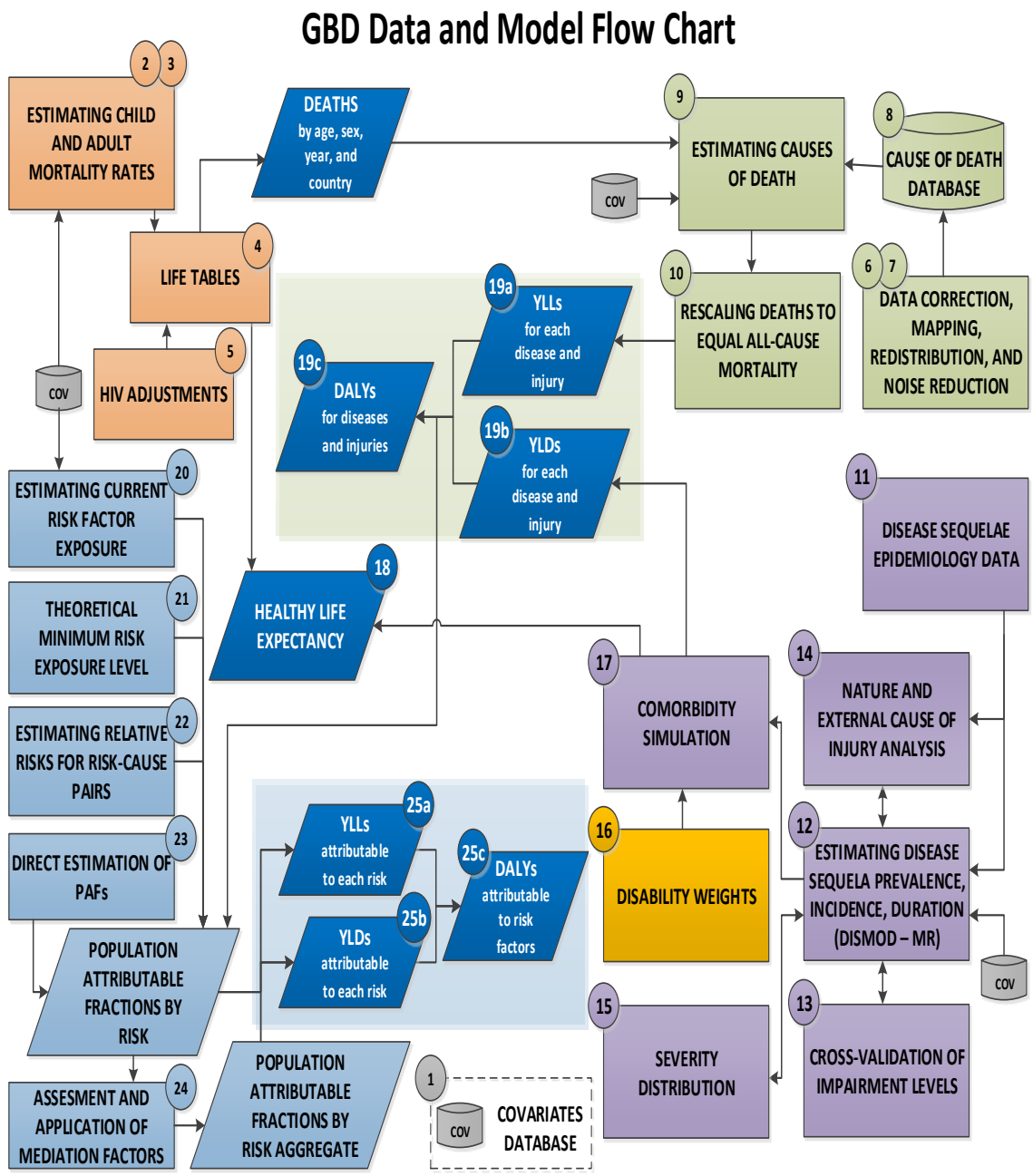
The GBD study is the most comprehensive global endeavour making meaningful comparisons of health metrics between countries, ranking them by diseases and risk factors employing a standardized methodology. Nevertheless, national Burden of Disease (BoD) Studies are becoming increasingly important for national policy-makers. Monitoring and benchmarking health performance of Ireland against comparable nations is clearly important. To the best of our knowledge there is no comprehensive, systematic analysis for NCDs and comparative risk assessment of risk factors for Ireland. Future projections of NCD burden and leading risk factors are currently not available in Ireland. The same is the case for drivers of the burden metrics for the NCDs. It is also important to quantify the loss of GDP per capita from the NCDs in Ireland. It is also vital to understand how reliable and valid the GBD estimates are from the Irish perspective.

Chapter 3: Methods [67]

This chapter describes the methods developed and used by the GBD group. Different chapters required different kinds of analysis and those have been detailed in the respective chapters.

The GBD study uses various methods at the different stages of calculations of the health metrics. Below is a flowchart that describes the data model flow in the GBD study (Figure 3.1). Some of the important methods used by the GBD group are the cause of death (COD) modelling, Space time Gaussian process regression (STGPR), calculations of years of life lost, years of life lived with disability, and disability-adjusted-life-years. Also, in the estimations of risk factor attribution, concepts of the TMREL were utilized. Also, the forecasting modelling used by the GBD to predict the health and disease conditions in Ireland in 2040 were used. For the chapter on the drivers of burden change, decomposition analysis was used and for the chapter on the loss of national income we used the Centre for Macroeconomics and Health measure. The methods for these chapters and the forecasting model have been described in the respective chapters.

Figure 3.1: The GBD data and model flow chart [68]

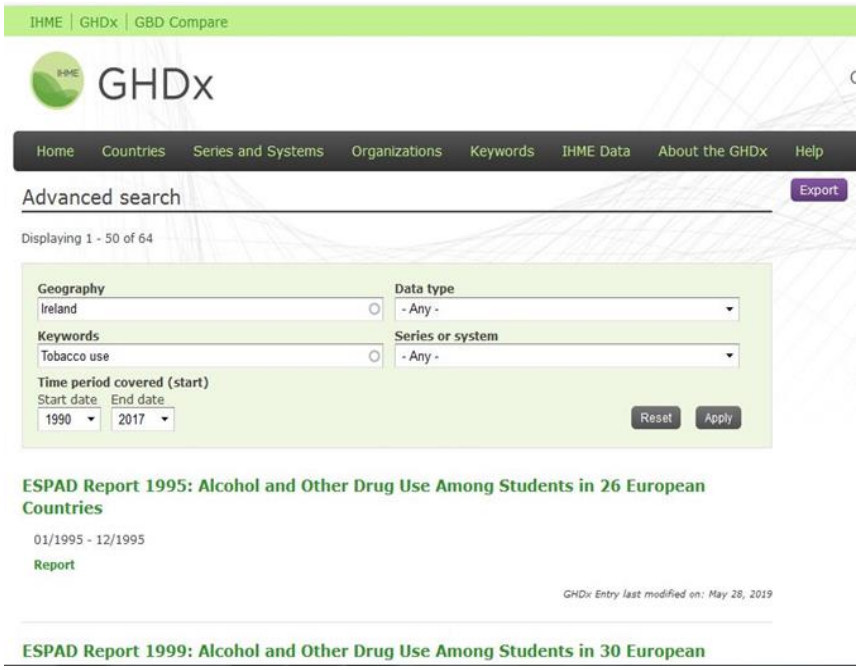


GBD uses a variety of data sources like censuses, surveys, vital registration, police reports, mortuary, verbal autopsy, population based cancer registries, surveillance systems and hospital records. The Institute of Health Metrics and Evaluation (IHME) stores and shares the data in the GBD to the public using their platform GHDx-

Global Health Data Exchange. This increases the transparency of the datasets that have been used in the process of calculation of the burden metrics.

Data used in this study: The deaths, DALYs and YLDs data was extracted from www.healthdata.org. This data downloaded comprised of yearly information on burden metrics (namely deaths, DALYs, YLDs and YLLs) of the NCDs of this study and sex wise information. Also additional information on the contribution of the specific risk factor towards the NCD was extracted and using the risk attribution formulae the attributable burden of the NCD from the risk factor was calculated and trends across time periods were observed.

Figure 3.2: Global health Data Exchange: A snapshot



3.1 Causes of Death (COD)

One of the most important and fundamental metrics of population health is cause-specific mortality. Trends in major causes of death can be important to a nation's appropriate policy planning and fund allocation. Majority of these causes are related to age and sex and can be rare or more prevalent in the population.

The COD was based on the international classification of diseases (ICDs).

3.1.1 Cause of death Ensemble model (CODEm)

Ensemble models are the standard methods used for prediction in many fields including soil chemistry, meteorology, consumer choice, etc. Ensembles are weighted averages of individual models. The CODEm model is based on two important steps-covariate selection and model specification [69].

Covariate selection is done by first identifying all possible covariates based on biological factors, socioeconomic factors and then based on literature a positive or negative relationship is established. In the next step the covariates are classified into levels like strong relationship, strong relationship but no biological link and weak relationship. In the next step the covariates are tested for all possible combination and only the ones which are statistically significant are retained ($p<0.05$). This process is performed in level 1, level 2 and level 3 of the hierarchical levels.

Model specification is done by the model selection methods- mixed effects linear models and the ST-GPR model. For the mixed effects linear model, there are fixed

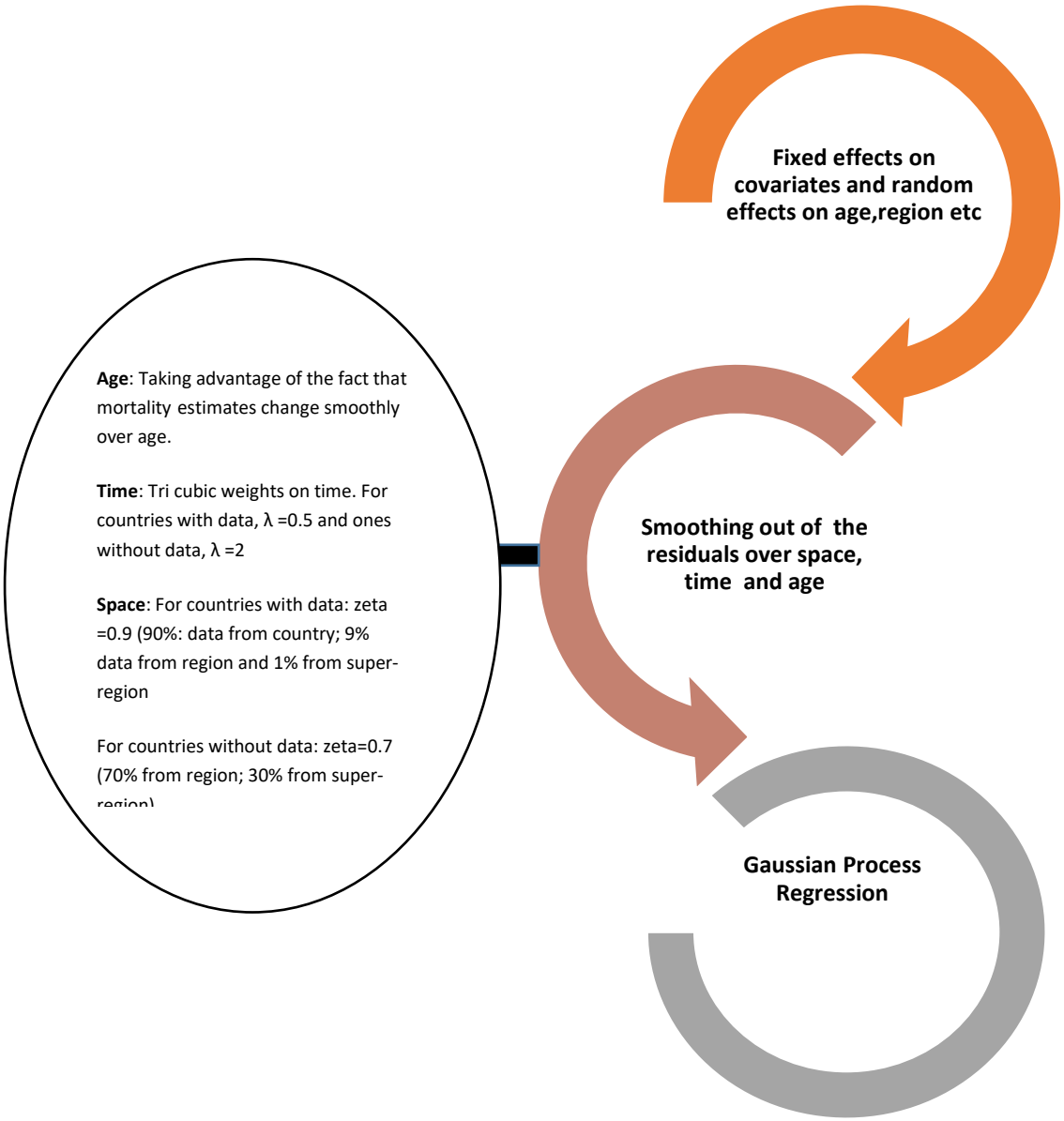
effects on the age groups and covariates, there are nested random effects on age, region, super region and country:

$$\ln\left(rate_{s,r,c,y,a}\right) = \beta_i X_{i_{s,r,c,y,a}} + \beta_a d + \pi_s + \pi_{s,r} + \pi_{s,r,a} + \pi_{s,r,a,c} + \varepsilon_{s,r,c,y,a}$$

$$\text{logit}\left(cause\ fraction_{s,r,c,y,a}\right) = \beta_i X_{i_{s,r,c,y,a}} + \beta_a d + \pi_s + \pi_{s,r} + \pi_{s,r,a} + \pi_{s,r,a,c} + \varepsilon_{s,r,c,y,a}$$

Space-time and Gaussian process regression models: The flowchart below shows the method used in ST and GPR models.

FIGURE 3.3: Methods used in the ST and GPR models



3.1.2 Cause of death Correction (CODCORRECT)

There are several situations where the sum of the predicted deaths from a specific year, age group, sex, country etc. doesn't equal to the number of deaths from all causes on all the mortality envelopes. In such a situation, CODCORRECT is used. It ensures that the results from cause specific factors is line with the results from the

cause of death (COD) estimation method. Below is the algorithm used for CODCORRECT.

$$CD_{cyadsj} = D_{cyadsj} \frac{ACD_{cyadsj}}{\sum_{j=1}^{k} D_{cyadsj}}$$

where CD_{cyadsj} represents the corrected number of deaths in a country c, in the year y, at age a, draw d, sex s and cause j, $Dcyadsj$ represents the corrected number of deaths from a particular cause j in a country c, in the year y, at age a, draw d and sex s, ACD_{cyadsj} represents all cause death rate in a country c, in the year y, at age a, draw d, sex s and cause.

3.2 Calculation of the Years of life lost (YLLS) –premature mortality

Years of life lost is defined as the number of years lost to premature mortality. It is measured as the difference between the age at death and the life expectancy at that age for an individual. Also this approach gives more importance to the death of young people as compared to the death of old people.

$$\mathbf{YLL}_{a,s,c,y} = \mathbf{D}_{a,s,c,y} * \mathbf{E}_{a};$$

where $YLL_{a,s,c,y}$ is the years of life lost at age a, sex s, in a country c and in the year y. $D_{a,s,c,y}$ is the number of deaths at age a, country c, sex s and year y. E_a is the life expectancy at age a. This method can have its own set of limitations. GBD's use of life table and WSP can provide estimates which are not accurate representation of metrics from countries with good quality data. YLLs are largely dependent on the choice of life table. Ranks of non-fatal causes can be significantly impacted by the choice of the life table. Also, GBD uses the WSP in most of its calculations, however the age group distribution in the GBD WSP is widely different from ESP (which is more relevant for ROI) and hence results can vary significantly while using ESP. This has been done in this thesis in the chapter on validation of the GBD methods and estimates. The detailed method of YLL has been explained in a pictorial representation further in this chapter.

3.3 Calculation of Years of Life lived with Disability (YLDs) [70]

YLD is defined as years lived with disability. YLD is calculated as follows:

$$\textbf{YLD sequela} = \textbf{Prevalence}_{\textbf{sequela}} \times \textbf{Disability weight}_{\textbf{health state}}$$

YLDs of all sequelae are calculated independently.

$$\textbf{YLD adjusted sequela} = \frac{\sum_{p=i}^{n} \textbf{Attributable DW}_{\textbf{seq}_i}}{\textbf{size simulated population}} \; ; \quad \text{where n is the size of the}$$

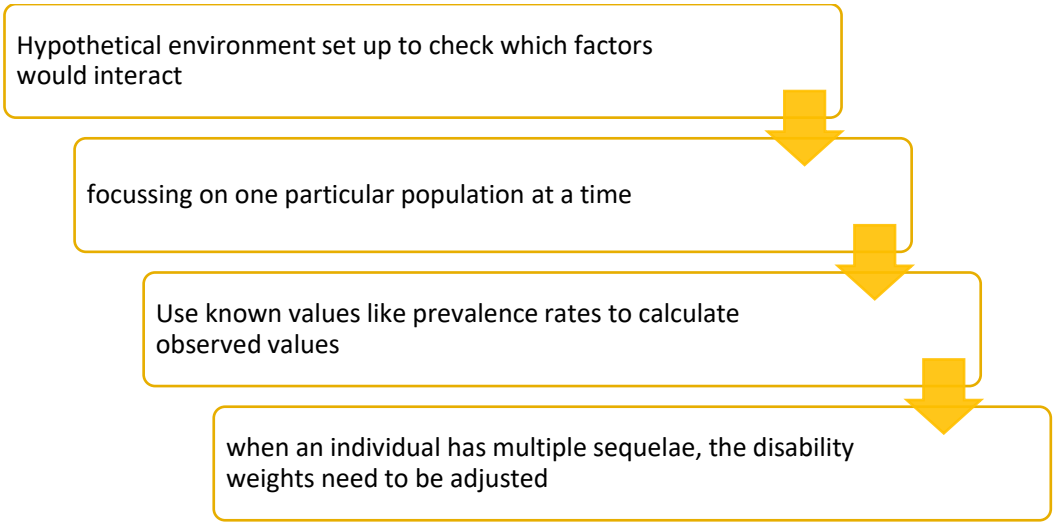
population and i is the individual.

$$\boldsymbol{YLD_{disease} = YLD_{sequela1} + YLD_{sequela2} + YLD_{sequela3}} \\ \boldsymbol{+ \cdots \qquad YLD_n}$$

Each of the diseases can have many sequelae but each of these sequelae are mutually exclusive but collectively exhaustive. For example: Headache, anxiety, aggression, dizziness, depression could be various sequelae of traumatic brain injury.

Comorbidity is important to understand in a health state of disease condition. If comorbidity is ignored, there will be an overestimation of YLDs. When the effects of comorbidity was estimated in the GBD study, it was assumed that the diseases or sequelae were independent. The method used was called the COMO simulation (comorbidity simulation). A simple flowchart of how COMO simulation works is shown below:

Figure 3.4 COMO simulation [70] [71]



Furthermore, the method of calculation of YLD is explained in the form of a pictorial representation further in the chapter.

3.4 Disability-Adjusted-Life-Years (DALYs)

DALY is the metric which measures burden. It is the total number of years lost due to risk factors or causes. DALY=YLL+YLD where YLL is years of life lost to premature mortality and YLD is years lived with disability. One DALY would be one healthy year of life lost.

The DALYs, YLDs and YLLs are a concept which seems rather complicated however below is an easy example of how a DALY, YLL or YLD is calculated in a set of apartments where few of the residents have health conditions and others are fully healthy at a specific time point.

Figure 3.5 Pictorial representation of how DALYs are calculated from the population

3.5 Risk factor measurements

Below is the flow chart from the GBD study which shows how the GBD study estimates the risk factors.

Figure 3.6: Risk factor attribution

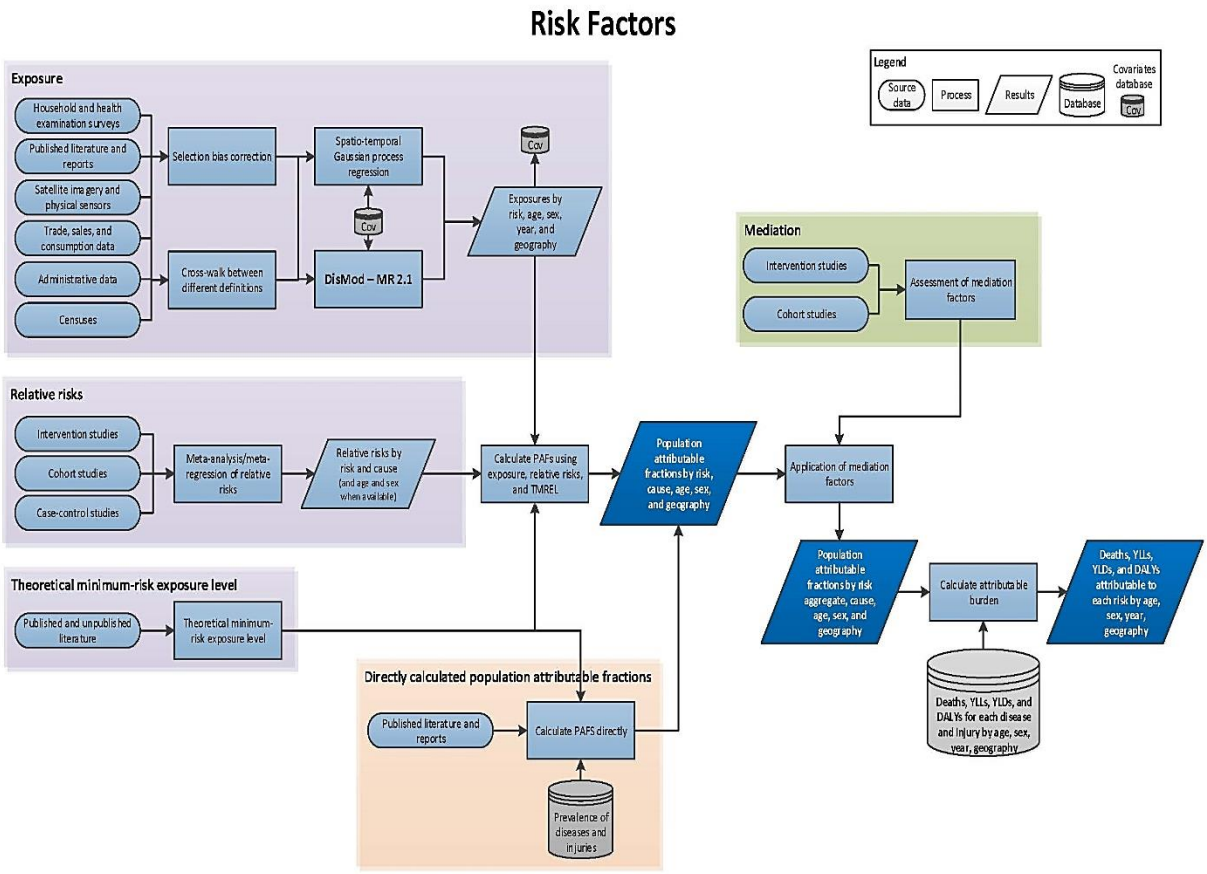


*image taken from IHME website for risk factor attribution

3.6 Comparative risk assessment (CRA) framework [72]

The GBD study used the CRA framework for measuring the risks. It is an important and useful tool in quantifying and synthesizing the risk-outcome information.

There are two different types of causal attribution of health outcomes with the risk factors- counterfactual analysis and categorical attribution. In a categorical attribution, each death is attributed to a single cause or a group of causes. In counterfactual analysis, the effect of one or more group of diseases or health states to the Summary Measure of Population health (SMPH) is measured by comparing

the current or future levels of the SMPH with a baseline or reference scenario (where the levels are under some hypothetical scenario like reduction or complete absence of the risk factor). This hypothetical scenario is called the counterfactual. Although both the above methods could be used to quantify the SMPH to the risk factors, however, the categorical attribution method ignores the fact that diseases can have multiple causes. Thus, a vast amount of literature has used the counterfactual approach. The main counterfactual exposure distribution used in studies is the zero exposure for the entire population or a fixed non-zero level where zero is clearly impossible- like level of blood plasma glucose or level of blood pressure. The statistic obtained in this approach is the population attributable fraction (PAF) which is defined as the proportional reduction in the death or disease condition if the risk factor is reduced to zero.

The attributable burden of disease, mortality etc. due to the risk factor, AB, is calculated as follows AB = PAF × B where B is the total burden of disease from a specific cause or group of causes affected by the risk factor with a relative risk of RR.

$$\boldsymbol{PAF = \frac{P(RR-1)}{P(RR-1)+1}}$$

If the exposed population is divided in several categories based on the respective levels of exposure with their own RR. The PAF formula with multiple (n) exposure categories can then be generalized to this form:

$$\boldsymbol{PAF = \frac{\sum_{i=1}^{n} P(RR-1)}{\sum_{i=1}^{n} P(RR-1)+1}}$$

It may be useful to choose zero as baseline for a few cases however it can be a problem in other cases as previously mentioned. In that case, we can do it by comparing the burden from an observed exposure distribution with that of another distribution instead of comparing it with an unexposed level and this is defined as the Potential Impact fraction and it is represented as:

$$\boldsymbol{PIF = \frac{\int_{x=0}^{m} RR(x)P(x)dx - \int_{x=0}^{m} RR(x)P'(x)dx}{\int_{x=0}^{m} RR(x)P(x)dx}}$$

Where RR(x) is relative risk at the level of exposure x

P(x): population distribution of exposure

P'(x): counterfactual distribution of exposure

m is the maximum level of exposure

The term $\int_{x=o}^{m} RR(x)P(x)dx$ measures the total exposure-weighted risk of mortality or disease in the population under current exposure distribution.

The term $\int_{x=o}^{m} RR(x)P'(x)dx$ represent the total exposure-weighted risk of mortality or disease in the population under counterfactual exposure distribution.

Also in case the exposure variable is a discrete variable with n levels the formula

changes to $\boldsymbol{PIF = \frac{\sum_{i=1}^{n} PiRRi - \sum_{i=1}^{n} Pi'RRi}{\sum_{i=1}^{n} PiRRi}}$

The above formulas can be further generalized to counterfactual risks. For an example: traffic accidental related injuries from drug abuse may also depend on traffic enforcement and on the road conditions. Thus, the formula becomes:

$$PIF = \frac{\int_{x=0}^{m} RR(x)P(x)dx - \int_{x=0}^{m} RR'(x)P'(x)dx}{\int_{x=0}^{m} RR(x)P(x)dx}$$

The attributable fraction of mortality of a disease due to a single risk factor in the causal-web obtained by integrating the outcome (O) over the current- P(x) and counterfactual P' (x) population distributions of exposure.

$$AF = \frac{\int_{P(x)} O(x) - \int_{P\prime(x)} O(x)}{\int_{P(x)} O(x)}$$

The attributable fraction relationships mentioned earlier was from individual risk factors. However, mostly disease conditions or mortality are often affected by multiple risk factors and sometimes even correlated. It is thus important that the joint effects of these factors are considered as many factors work with one another and some work as intermediates too. Also, any change in any of the risk factors could also vary the disease burden.

3.7 Estimation of the attributable burden for a risk-outcome pair

The concept of a risk outcome pair came was used in the GBD study. A risk outcome pair is a pair of risk and outcome which have a convincing or probable evidence of causation. Example of risk outcome pairs used in this study would be high BMI and CVD, tobacco use and COPD, alcohol consumption and cancers and so on.

There are four important components of attributable burden which are as follows

1. The burden metric which is being used (deaths, YLLs, DALYs or YLDs)

2. Levels of exposure of the risk factor

3. Counterfactual levels of exposure of the risk factor/TMREL

4. RR (Relative Risk) in relation to the TMREL

For example, to calculate the attributable DALYs= Total DALYs x PAF for age, sex, location and year.

Spatiotemporal Gaussian process regression (STGPR) has been used in many of the GBD studies to estimate the exposure value. It borrows strength across time, age, space to provide appropriate estimates of the trends of a given risk factor. STGPR is especially useful for a fast modelling strategy. In GBD 2015, however, a separate DisMod model- DisMod-MR2.1 (Bayesian meta-regression tool) was run for age and sex to estimate exposure instead of using the STGPR model.

3.8 Distribution of the exposure for the theoretical minimum risk

Risk factors that are used in the GBD study can be classified into four different categories:

3.8.1. Physiological risk factors

This group of risk factors includes physiological attributes of humans like blood plasma glucose level, high blood pressure etc. The relationship between the exposure and response is usually J or U shaped as these are factors which sustain life. The theoretical minimum risk for these factors are determined from empirical evidence from various disciplines. An example of U shaped graph would be like that between alcohol and mortality.

3.8.2. Behavioural risk factors

The relationship between the exposure and response is usually J shaped or monotonically increasing. For the majority part, the theoretical minimum in this group of risk factors would be zero until the attainment of zero seems to be impossible in any case. If there is a J shaped curve like that of the physiological group, the theoretical minimum can be based on empirical evidence.

3.8.3 Environmental risk factors

The relationship between the exposure and the response is usually monotonically increasing as the toxicity of majority of the environmental factors keep increasing. The theoretical minimum exposure would be the lowest achievable level of exposure of the risk factor.

3.8.4 Socioeconomic risk factors

These factors are factors like poverty, education, income, socio-economic status etc. The effects of these risk factors on one another is quite significant and they depend on one another too. The theoretical minimum exposure even if specified, would keep varying over time and space. Thus, these variables are best measured with respect to counterfactual distribution based on interventions and policies.

Theoretical minimum risk exposure level (TMREL) [72] for the risk factors used in this study are specified. The table below shows the definition of the exposure of the risk factor and the TMREL for each of the risk factors used in this study based on the GBD. GBD calculates the DALYs- a universal metric [73].

FIGURE 3.7: TMREL of the risk factors used in the GBD study

Risk Factor	*Exposure definition*	*TMREL*
1. Smoking	**Prevalence of past use of any tobacco product and of current use of any smoked tobacco product, cigarette equivalents smoked per smoker per day and cumulative pack-years of exposure; among former smokers, number of years since quitting**	All individuals are non-smokers throughout their life.
2. Alcohol use	**Average daily intake of pure alcohol (measured in grams per day) in current drinkers who had consumed alcohol during the previous 12 months.**	Estimated quantity of 0–10 grams per day
3. Dietary risks		
3.a. Diet low in fruits	**Average daily consumption of fruits (fresh, cooked, frozen, canned, or dried, excluding fruit juices and salted or pickled fruits).**	Consumption of about 200-300grams of fruits daily
3.b. Diet low in vegetables	**Average daily consumption of vegetables (fresh, cooked, frozen, dried or canned excluding legumes and salted or pickled vegetables, nuts and seeds, juices and starchy vegetables such as potatoes or corn)**	Consumption of about 290-430 grams of vegetables daily
3.c. Diet low in whole grains	**Average daily consumption of whole grains from bread, breakfast cereals, biscuits, rice, pasta, muffins, pancakes, tortillas and other sources**	Consumption of 100-150grams per day

3.d. Diet low in seeds and nuts	**Average daily consumption of seeds and nuts in diet**	Consumption of 16-25 grams per day
3.e. Diet high in red meat	**Average daily consumption of red meat like pork, lamb, beef and goat**	Consumption of 18-27grams per day
3.f. Diet high in processed meat	**Average daily consumption of meat which have been preserved by smoking, curing, salting, or addition of chemical preservatives**	Consumption of processed meat 0-4grams per day
3.g. Diet high in sugar-sweetened beverages	**Average daily consumption of beverages with ≥50 kcal per 226·8 g serving which includes sodas, carbonated beverages, energy drinks, fruit drinks, but excludes almost 100% vegetable and fruit juices**	Consumption of sugar-sweetened beverages 0-5 grams per day
3.f. Diet low in fibre	**Average daily intake of fibre from all sources including vegetables, fruits, grains, legumes, and pulses.**	Consumption of 19-28 grams of fibre daily
3.g. Diet high in trans-fatty acids	**Average daily intake of trans fat from all sources, mainly partially hydrogenated vegetable oils**	Consumption of trans-fatty acids as 0-1% of total energy per day
3.f. Diet high in sodium	**24-hour urinary sodium measured in grams per day**	24-hour urinary sodium 1-5grams per day
4. Low physical activity (LPA)	**Average physical activity in a week at home, at work, transport related and recreational activities measure in terms of MET min per week**	adults should experience about 3000-4500 MET min per week
5. High Body Mass Index(BMI)	**Body Mass Index (BMI) measured in kg/m^2**	BMI=20-25kg/m^2

Below is a comparison between the GBD TMREL and the EAT-Lancet Commission recommended levels of diet to ensure the assumptions by GBD are line with what other institutes conducting diet research suggest. These are to make sure that the GBD TMREL and EAT Lancet commission are quite similar and thus can be used for calculation or measurement of dietary risks.

Figure 3.8 Comparison between the GBD TMREL and EAT Lancet commission on required food intake [74]

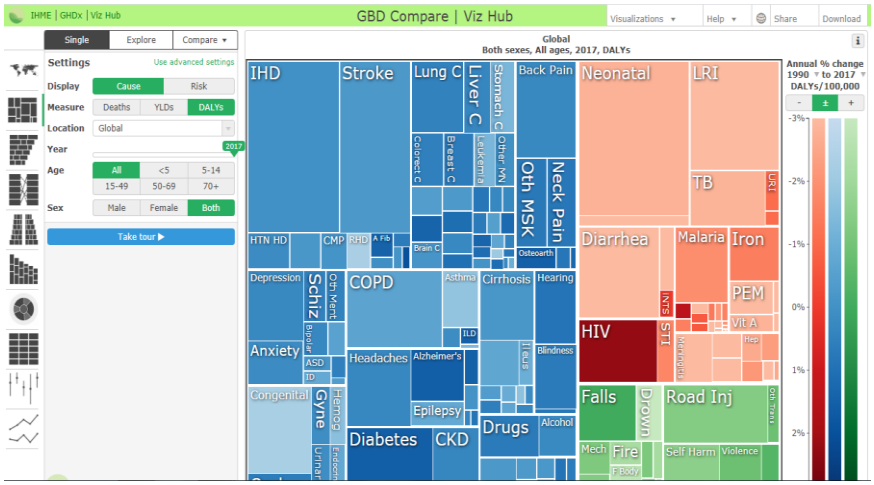
	GBD TMREL	**EAT lancet Commission**
Whole grain	100-150gms	232gms
Vegetables	290-430gms	300gms (200-600)
Fruits	200-300gms	200gms (100-300)
Nuts	16-25gms	50gms (0-75)
Red meat	18-27gms	14gms (0-28)
Sugar/ SSB	SSB=0-5gms	Added sugar 31gms (0-31)

3.9 Risk factor hierarchy

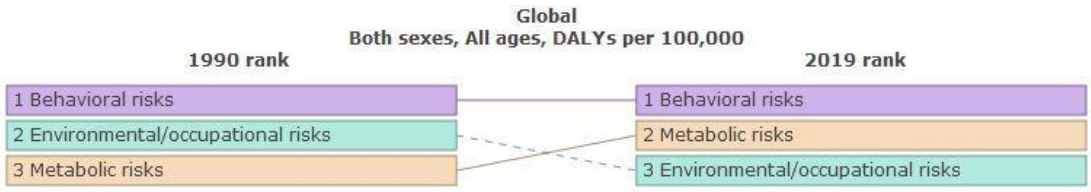
The GBD study had divided Risk Factors into four levels of hierarchy. The link to that can be found here https://vizhub.healthdata.org/gbd-compare/

The home page of the GBD compare looks like this below;

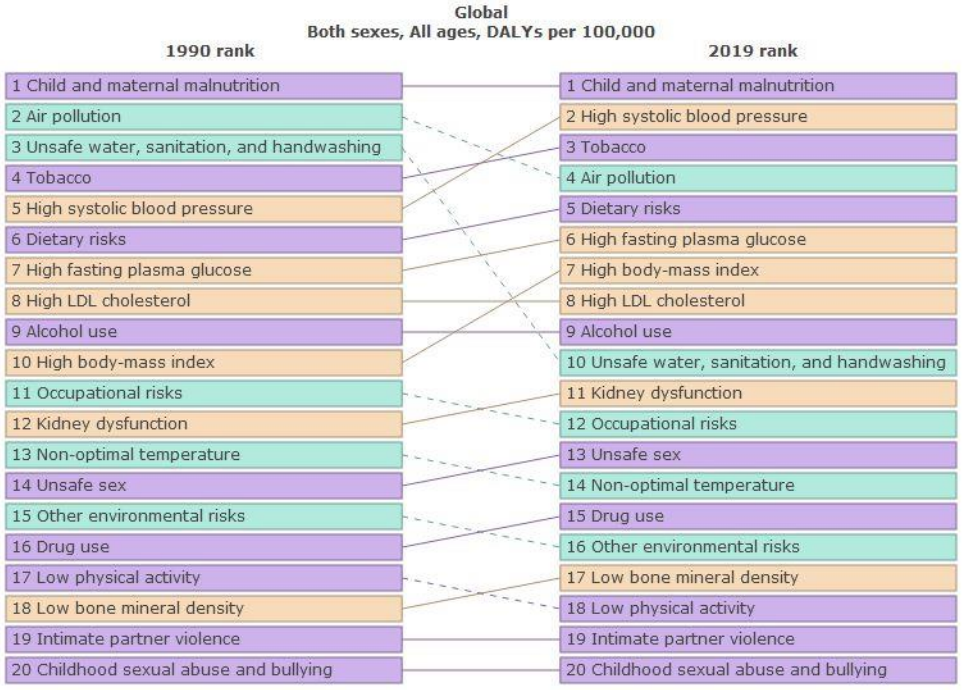
FIGURE 3.9: GBD compare homepage [75]



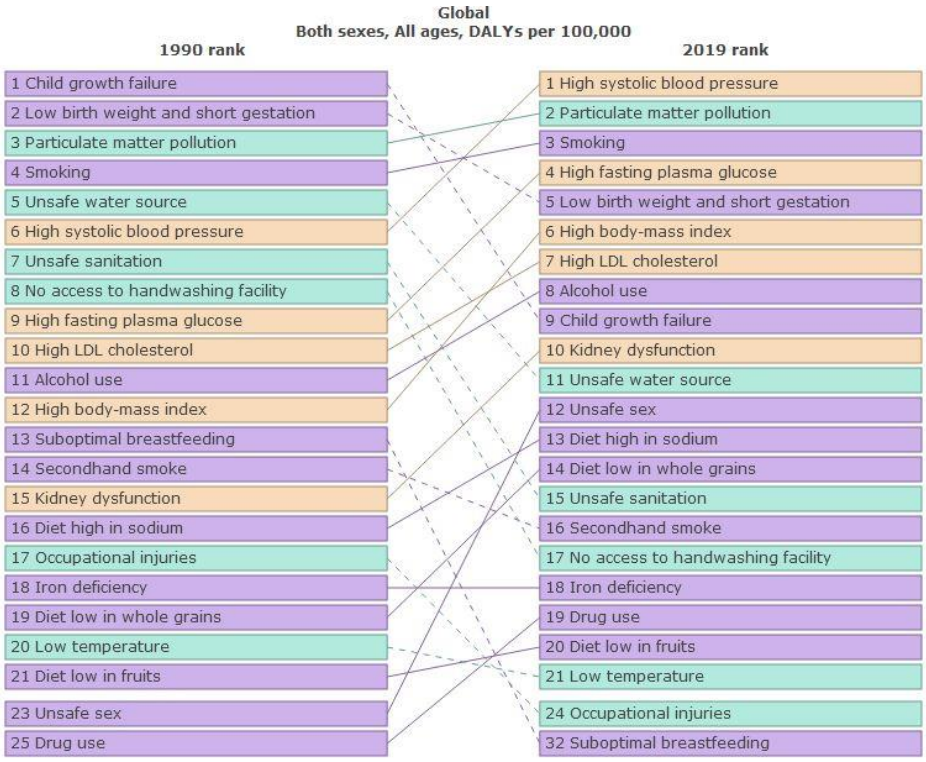
- Level 1: This level is mainly divided into three main risk factor categories namely- behavioural, occupational or environmental and metabolic risk factors



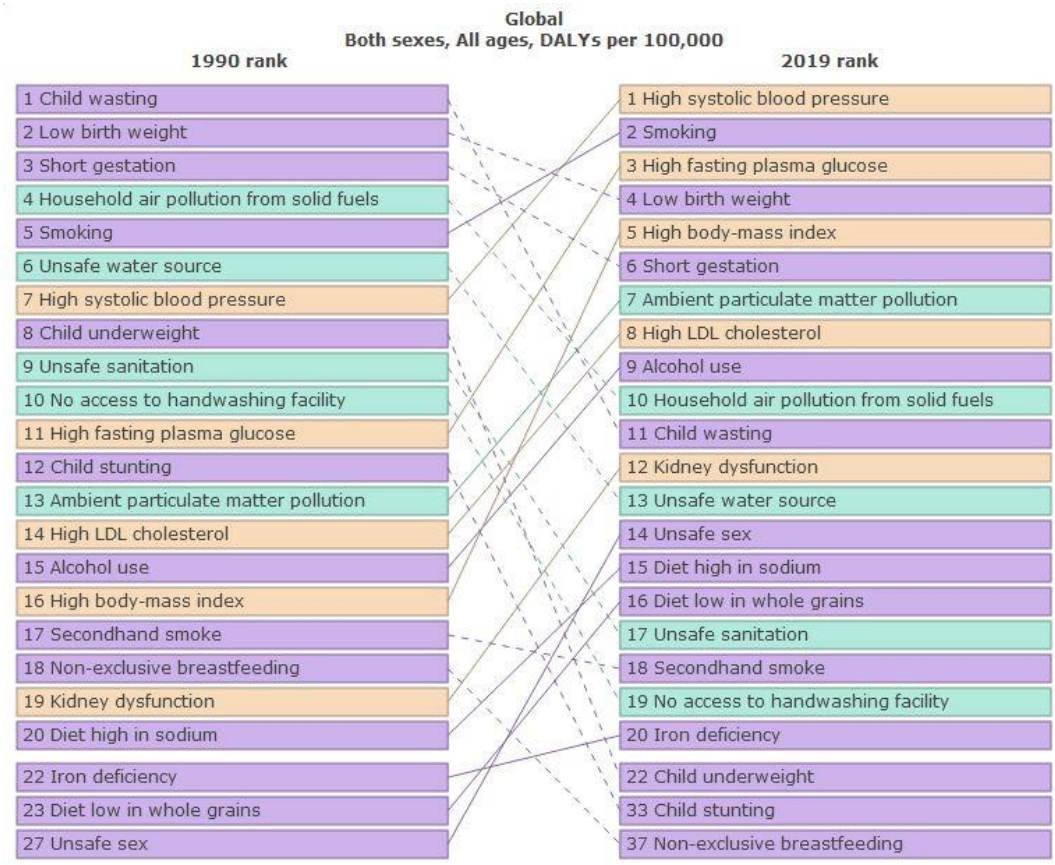
- Level 2: this group contains larger grouping of risks like that of tobacco, alcohol, dietary risks



- Level 3: more detailed components subgroups of risk factors- secondhand smoke, chewing tobacco as subsections of tobacco and diet low in fruits, vegetables nuts, seeds as a subsection of dietary risks.



- Level 4: individual occupational carcinogens like that of the two types of sub-optimal breastfeeding



This study is primarily based on the GBD study methodology. The GBD data on disease, risk factors for all years were accessible from open accessible GBD compare. Absolute numbers, rates per 100,000 and risk factor data were extracted from the GBD compare tool. The NCD burden attributable to these risk factors were calculated. Trends across time periods were measured and reported. Also, avoidable deaths were calculated as a difference between the 2040_reference and 2040 _better [76].

A decomposition method was used to disentangle the effects of the drivers of burden change, forecasting the burden of these NCDs have been explained in detail

in the respective chapter. The validation of some of local Irish results with that of the GBD results were done in different procedure as explained in the respective sections.

Chapter 4: Results of European Union (EU) Burden of NCDs and NCD burden in Ireland attributable to selected risk factors during the time periods 1990-2017

This chapter focuses on two major sections 4A and 4B. The first part 4A focuses on the European Union Burden of NCDs during the years 1990 and 2017. The second part of this chapter 4B focuses NCD burden attributable to the most common risk factors in Ireland during the same years 1990 and 2017.

Chapter 4A: European Union (EU) Burden of NCDs during time periods 1990-2017

For this chapter on the EU burden of NCDs, the data was extracted from the GBD website (www.healthdata.org). The risk factor percentages were extracted from the GBD compare and some of the visualizations comparing between the different EU nations were done on the GBD website itself.

Our analysis of the GBD 2017 study show that almost 91% of deaths and about 87% of DALYs in the EU are from NCDs, out of which approximately 61% and 46% can be attributed to the risk factors. The largest burden in terms of DALYs and deaths is from CVDs and cancers. The NCDs contributed to 4,750,862 deaths and 129,240,554 DALYs in the EU in 2017.The two-top ranking NCDs- CVDs contributed to 1,893,003 deaths and 27,331,667 DALYs, cancers contributed to 1,434,987 deaths and 27,707,323 DALYs.

The table below shows the absolute number of deaths from NCDs during the five time periods. All the values are in millions. For deaths, the percentage of the deaths from the NCDs out of the total deaths in the respective year are mentioned within

brackets and for the DALYs the 95% uncertainty interval is mentioned in brackets for the NCD DALYs.

FIGURE 4.1: NCD deaths and DALYs in the EU across the years 1990-2017

	1990	2000	2005	2010	2017
NCD deaths	4.43 (89.7%)	4.38 (90.2%)	4.36 (90.7%)	4.45 (91%)	4.75(91.3%)
NCD DALYs	130.1(95%UI= 117-145)	127.1(113.7-142.5)	126.7(112.9-142.6)	127.2(112.9-143.7)	129.2(114-146.7)

*All values are in millions, UI-Uncertainty Interval

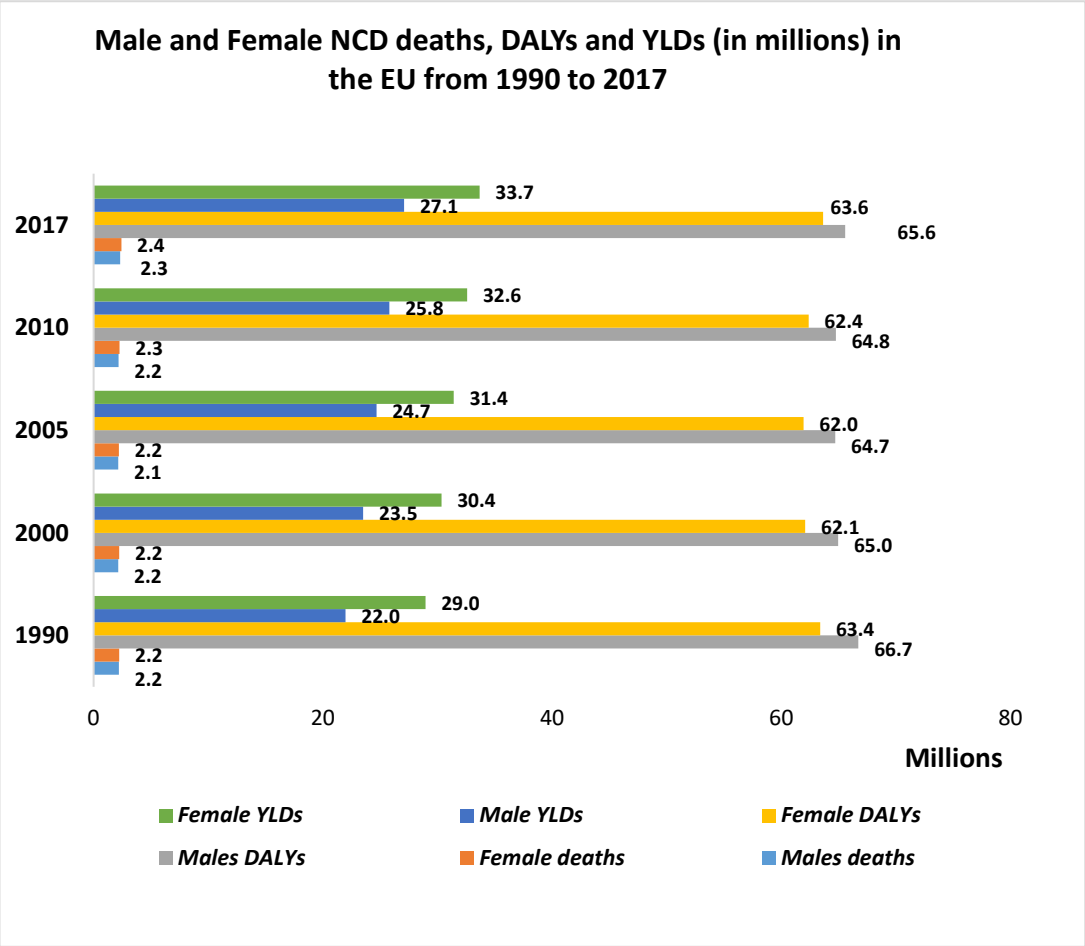
The table below shows the percentage of total YLLs and YLDs from the NCDs in the EU for the five years.

FIGURE 4.2: NCDs YLDs and YLLs in the EU across the years 1990-2017

GBD Metric	1990	2000	2005	2010	2017
NCD YLDs	81.7%	83.9%	85.1%	86.2%	87.6%
NCD YLLs	84.1%	85.3%	85.4%	85.42%	85.5%

Figure 4.3 below shows the male and female NCD deaths, DALYs and YLDs in the European Union for the five calendar years 1990, 2000, 2005, 2010 and 2017

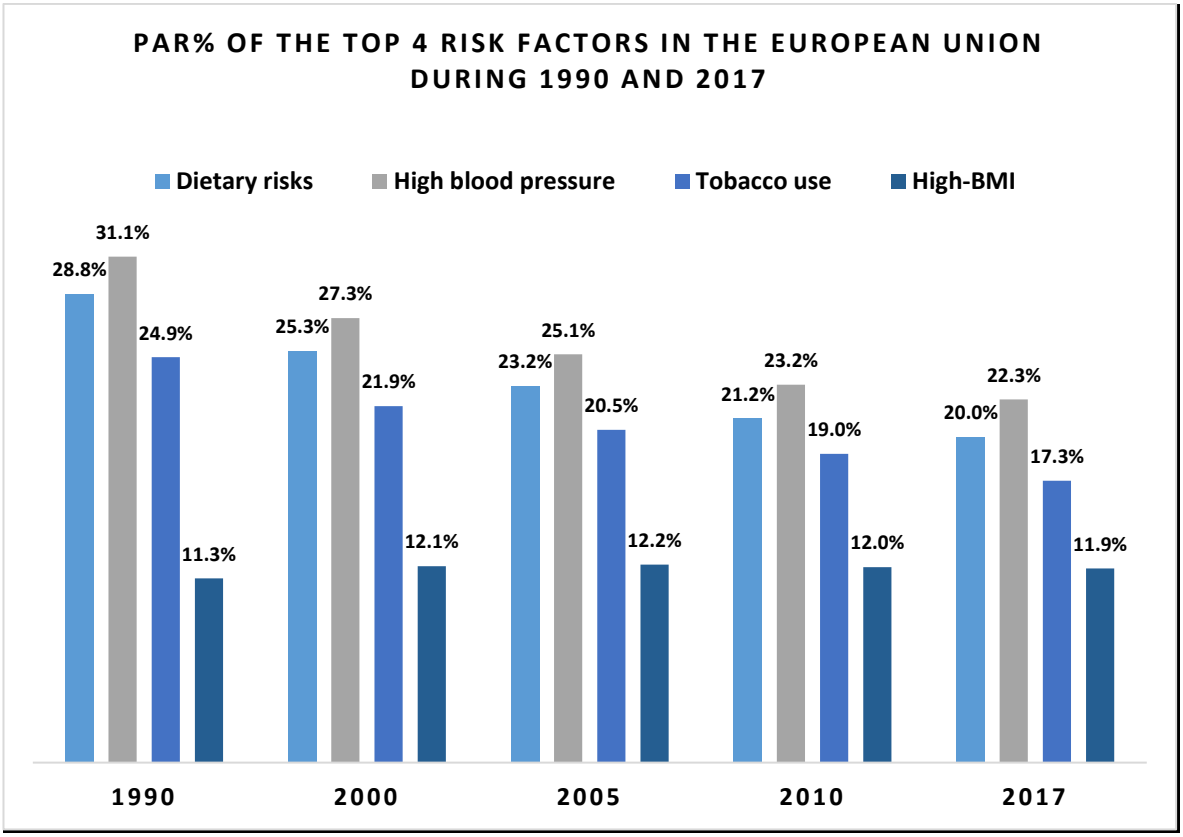
Figure 4.3 Sex wise distribution of deaths, DALYs and YLDs in EU from 1990-2017



Females had higher NCD deaths for all five time periods compared to males. Females also had higher YLDs for all the five time periods compared to males whereas males had higher DALYs for all the five time periods as compared to females in the EU.

The top four risk factors which contributed to NCD deaths in the EU during 1990 and 2017 are dietary risks, high blood pressure, and tobacco and high body mass index. Figure 4.4 below shows the PAR% of the top four risk factors causing NCD deaths in the EU during 1990 and 2017.

FIGURE 4.4



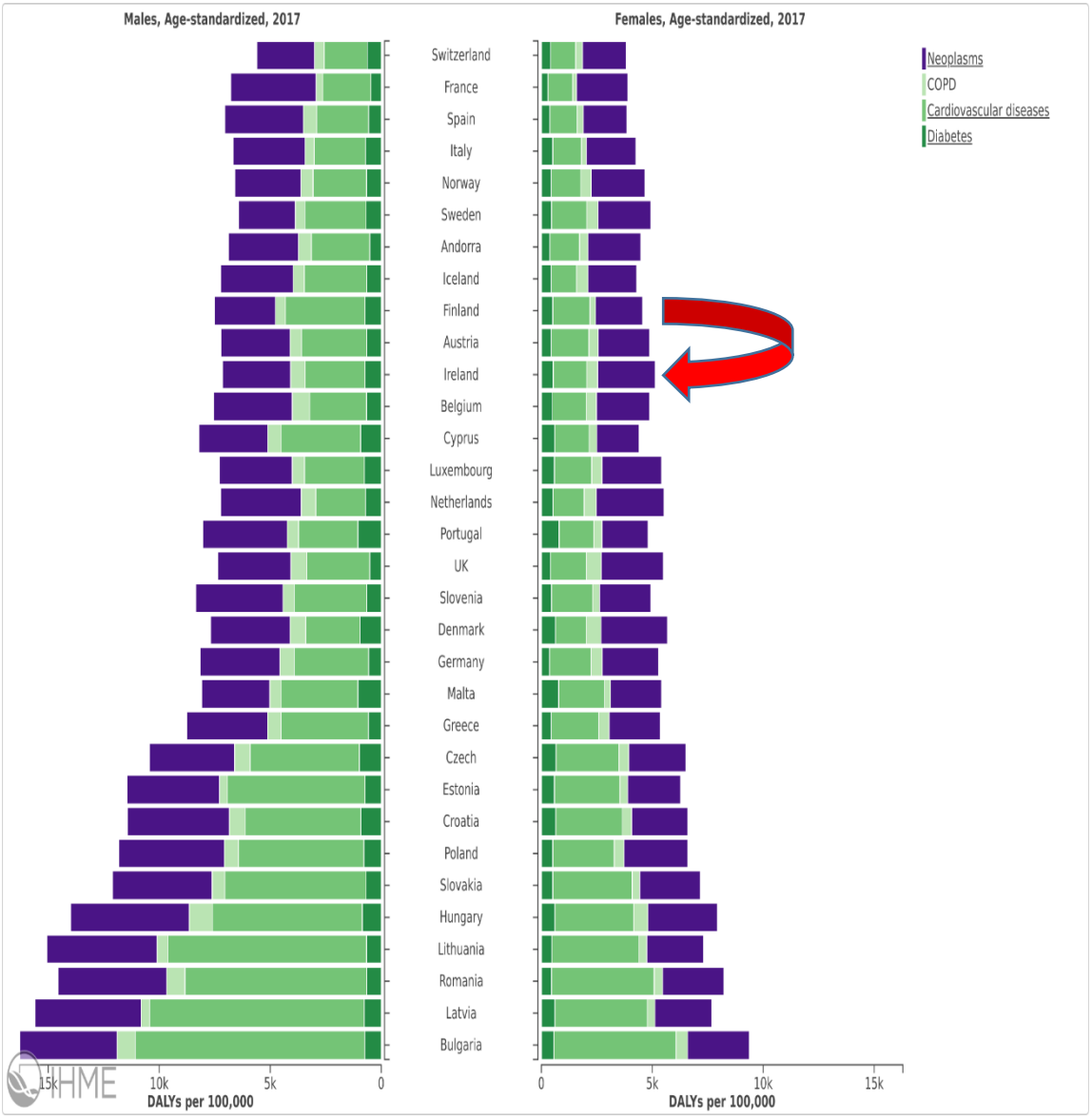
Of all the NCDs, CVDs contributed largest to overall deaths, DALYs and YLLs for all the years 1990, 2000, 2005, 2010 and 2017 followed by cancers.

The percentage contribution of the risk factors have also changed during 1990 and 2017. The percentage contribution have decreased for all the risk factors except for high BMI.

The NCD burden in the EU is still significant (~4.75 million deaths and ~129.2 million DALYs) in 2017. In terms of the above EU burden of NCDs it is crucial that a detailed national and subnational level analysis is conducted to have complete information on the health scenarios in the ROI in the NCD context. The pyramid graph below

shows the DALYs per 100,000 in the EU for males and females. Ireland ranks at 11th from the top.

Figure 4.5 Age standardised DALYs per 100,000 in EU nations during 2017

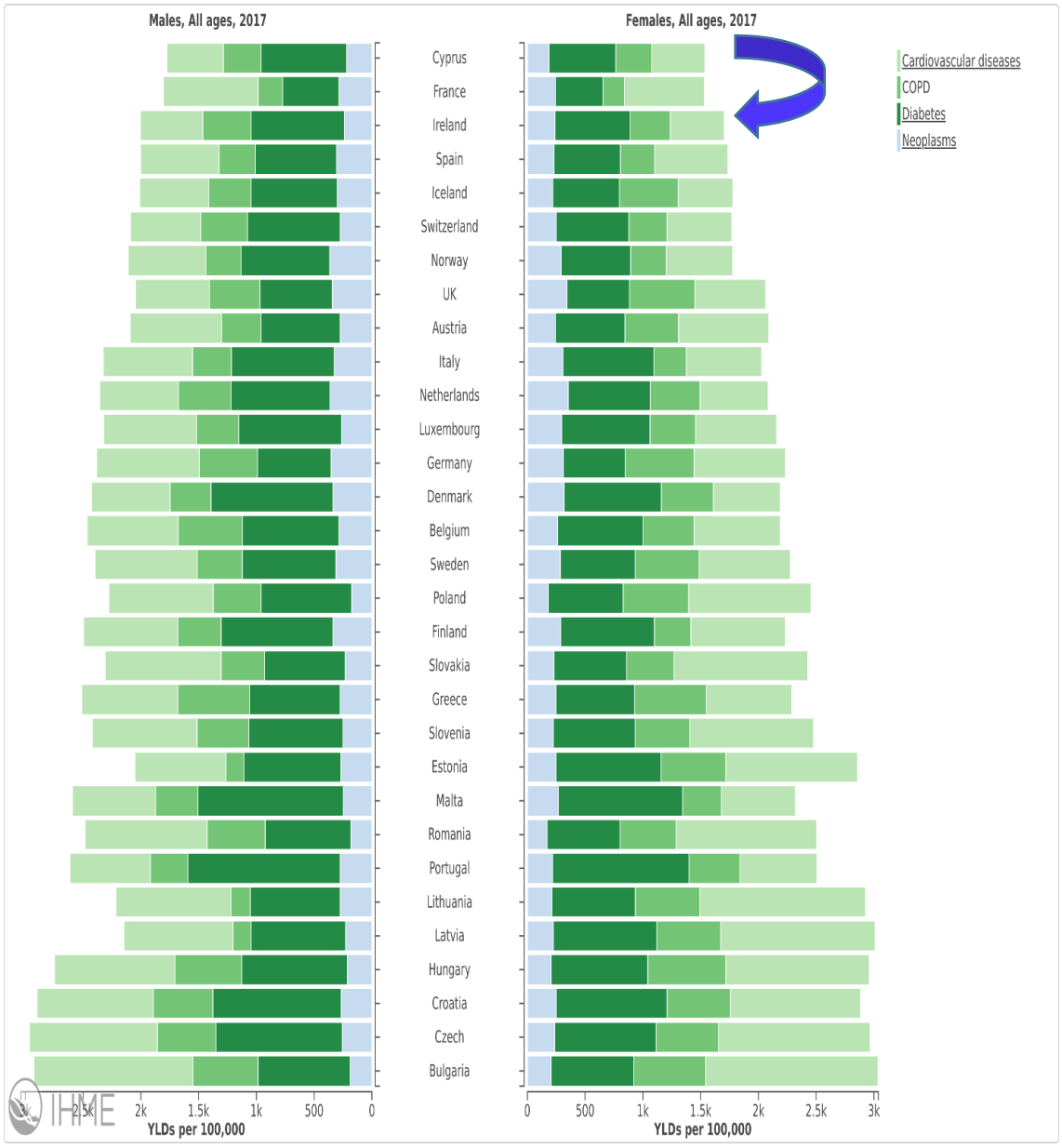


The above figure shows the age-standardised DALYs in the EU countries in 2017. Ireland ranks 11th from the top where the countries at the top like Switzerland, France, Spain have lower DALYs per 100,000 as compared to Ireland. The arrow just shows the position where Ireland stands.

Figure 4.6 Age standardised deaths per 100,000 in the EU nations during 2017

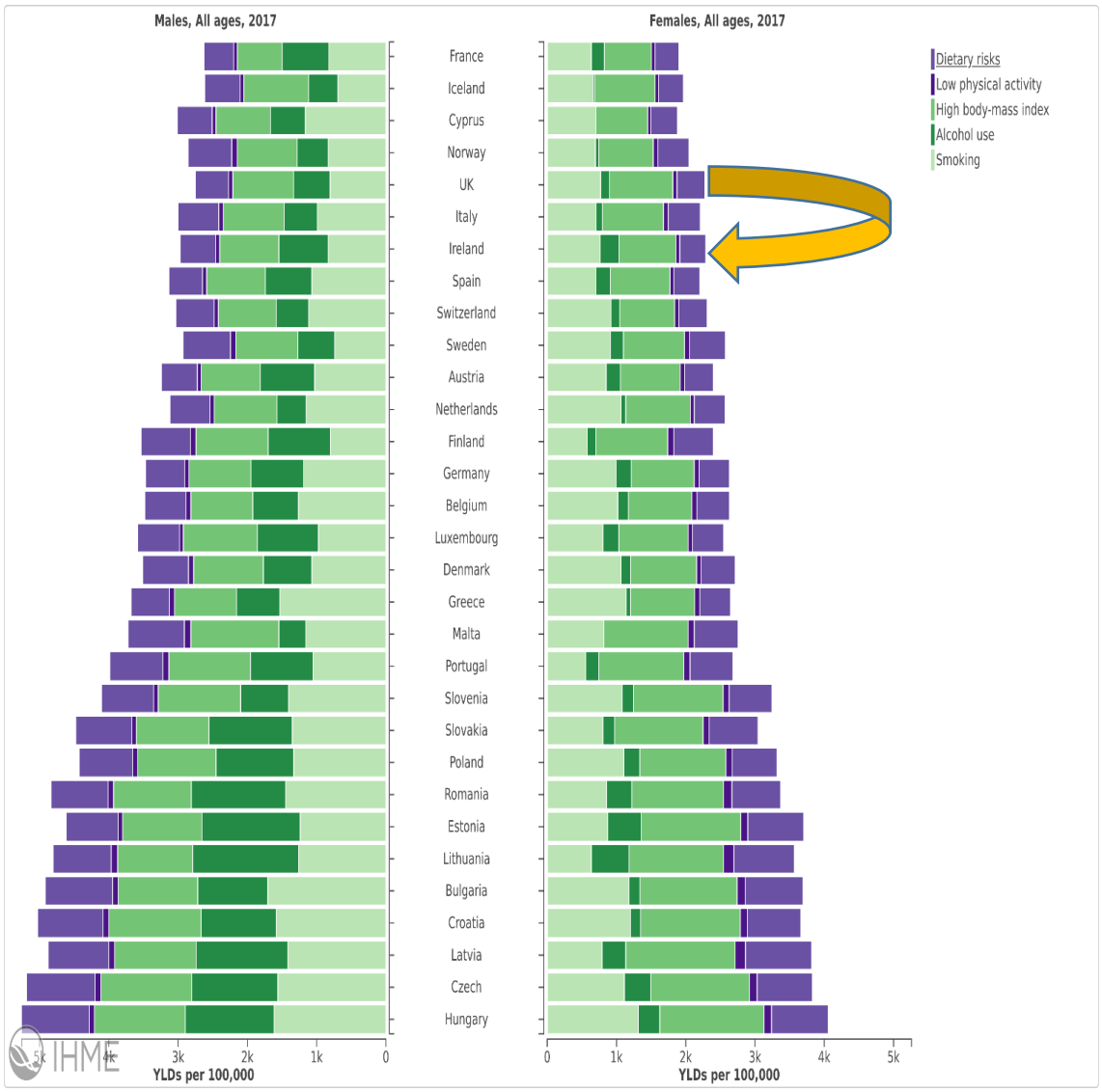
The above figure shows the age-standardised deaths in the EU countries in 2017. Ireland ranks 2nd from the top where the country at the top Cyprus have lower death per 100,000 as compared to Ireland. Ireland is performing well in terms of most of the other EU nations in term of deaths per 100,000.

Figure 4.7 Age standardized YLDs per 100,000 in the EU nations during 2017



The above figure shows the age-standardised YLDs in the EU countries in 2017. Ireland ranks 3rd from the top where the countries at the top are Cyprus and France which have lower YLDs per 100,000 as compared to Ireland. Ireland is performing well in terms of most of the other EU nations in term of YLDs per 100,000.

Figure 4.8 Age standardised YLDs per 100,000 from the five most common risk factors in the EU in 2017



Chapter 4B: Risk factor Attributable Burden and Life Expectancy in Ireland 1990-2017

This chapter focuses on the life expectancy patterns in Ireland during the time period 1990-2017, followed by the attributable burden of the NCDs from the most common risk factors. The reason we have firstly focussed on the life expectancy changes is that we wanted to look into the patterns of LE and HALE and how widely different they are. In case the HALE is significantly different from LE, it becomes pertinent to quantify where these healthy years of life are lost and whether they are from morbidities.

The data in this section has been extracted from the GBD website according to sex, years, and age groups. The percentage contribution of a specific risk factor towards the burden of the NCDs were also extracted from the GBD compare section and then the attributable burden for the years have been calculated. Further analysis to manage the data was conducted in Excel.

Also for the risk factor related attributions we have included all cancers, or all CVD cases and not only those causally linked to the NCD. Thus some of the figures in the results section may contain zero values where the contribution of the risk factor towards the NCD death/DALY or YLD are not present. For example: contribution of high BMI towards COPD shows zero contribution in the table.

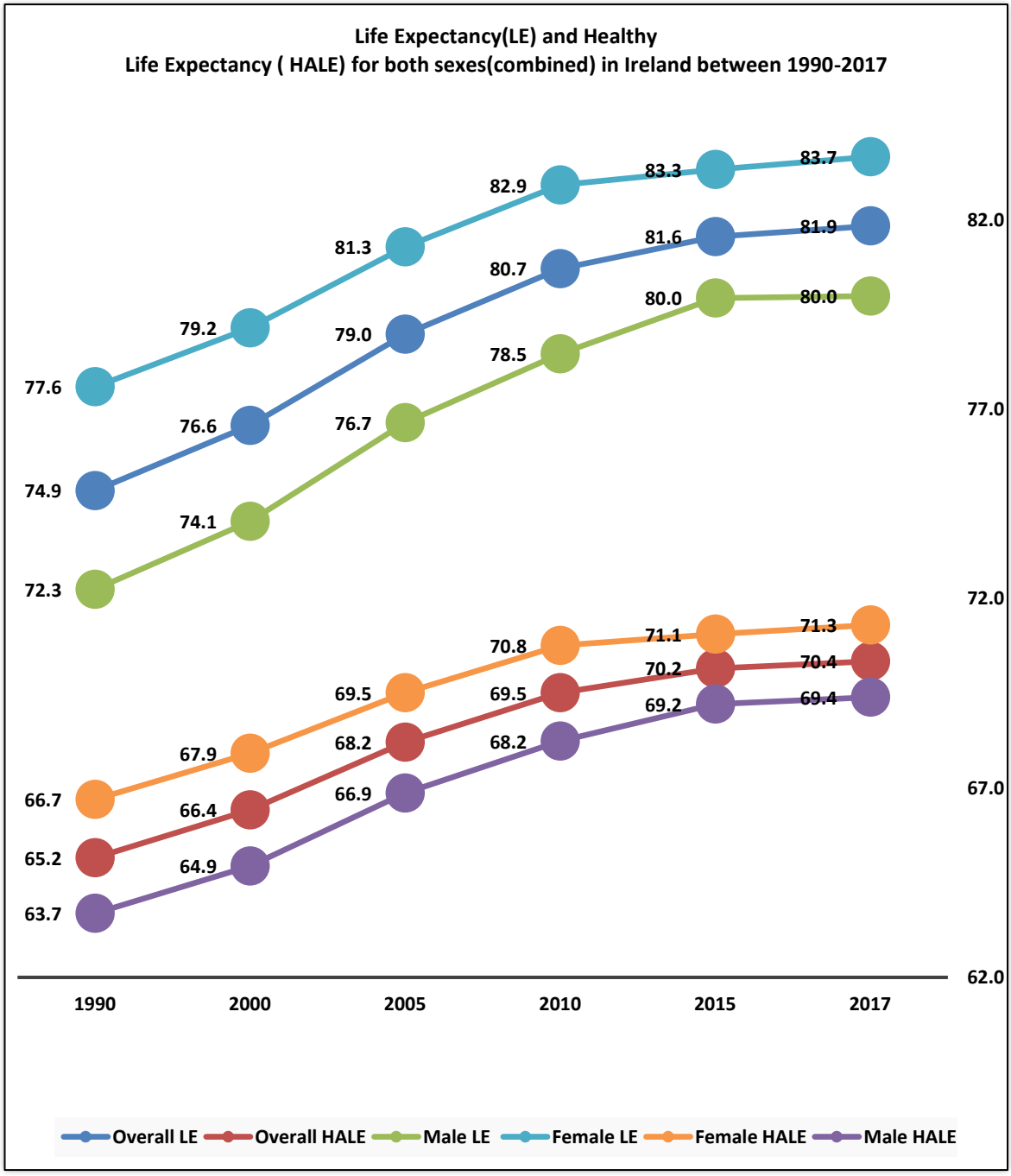
4.B.1. Life Expectancy Changes in Ireland during 1990-2017

The life expectancy in the ROI changed during the years 1990 and 2017. Figure 5.1 below shows the LE and HALE for 1990, 2000, 2005, 2010, 2015 and 2017.

LE (at birth) increased and also showed a similar trend for both males and females separately. Females had a higher LE as compared to males throughout the 1990-2015 time period and we observed a constant gap in male-female LE for all the years.

Figure 4.B1 shows the LE and the HALE for males and females across the time period 1990 to 2017. It is observed that the overall LE and HALE have increased during 1990 and 2017, however HALE <LE (for both males and females). In 2017, males lived for 80 years, however the HALE was 69.4, hence the 80-69.4=10.6 extra years were lived in less than full health, and similarly females lived for 12.4 years in less than ideal health. This implies that though males and females are living longer, a large part of those extra years lived are in less than ideal health and thus it is crucial to understand the underlying factors that are contributing to these extra years of ill health. It is also observed that life expectancy has almost plateaued in the last few years.

Figure 4.B1


Life Expectancy(LE) and Healthy
Life Expectancy (HALE) for both sexes(combined) in Ireland between 1990-2017
77.6
79.2
81.3
82.9
83.3
83.7
74.9
76.6
79.0
80.7
81.6
81.9
72.3
74.1
76.7
78.5
80.0
80.0
66.7
67.9
69.5
70.8
71.1
71.3
65.2
66.4
68.2
69.5
70.2
70.4
63.7
64.9
66.9
68.2
69.2
69.4
82.0
77.0
72.0
67.0
62.0
1990
2000
2005
2010
2015
2017
Overall LE
Overall HALE
Male LE
Female LE
Female HALE
Male HALE

4.B.2 Risk factor attributable burden to NCDs in Ireland during 1990-2017

NCD deaths per 100,000 was 773.5 in 1990 decreased to 711.1 in 2000 to 594.4 in 2005 to 538.8 in 2010 to 575.4 in 2017.

NCD-related DALYs showed a similar declining trend between 1990 and 2010 but an increase from 2010 to 2017. NCD related DALYs in the ROI per 100,000 declined from 23750.3 in 1990, 22700.6 in 2000, 20613.5 in 2005, and 19590.8 in 2010 and increased to 19908.3 in 2017.

CVD contributed to 44.7% of deaths in 1990 out of which 29.5% were ischemic heart disease (IHD) related deaths and 9.57% were stroke related deaths. Cancers contributed to 23.4% of the total deaths in 1990 and COPD to 6.6%. Deaths from CVD (IHD and stroke) showed declines during 1990 to 2017 whereas cancers showed an increasing trend between 23.4% in 1990 to 31.1% in 2017. DALYs from cancer also showed an increase from 15.7% in 1990 to 17.5% in 2017. YLDs only from one NCD namely COPD showed a rising trend 2.5% in 1990 to 3.1% in 2017.

The overall risk factor contribution across the years during 1990 and 2017 were as shown in the table below TABLE 4.B2. It shows the percentage of deaths in the years from the risk factors and per 100,000 deaths from these risk factors for the five time periods 1990, 2000, 2005, 2010 and 2017.

FIGURE 4.B2: NCD Mortality attributable to risk factors from 1990-2017 in Ireland

Risk factors	*Year 1990*		*Year 2000*		*Year 2005*		*Year 2010*		*Year 2017*	
	% of total deaths From the risk factor	No. of deaths Per 100,000	% of total deaths From the risk factor	No. of deaths Per 100,000	% of total deaths From the risk factor	No. of deaths Per 100,000	% of total deaths From the risk factor	No. of deaths Per 100,000	% of total deaths From the risk factor	No. of deaths Per 100,000
Tobacco use	31.1%	270.8	26.8%	217.6	24.1%	161.8	22.5%	134.5	19.3%	122.4
Dietary risks	25.9%	225.1	21.6%	175.8	19%	127.3	16.9%	101.2	15.9%	101
Alcohol Consumption	3.7%	32	9.1%	74.1	9.1%	60.9	7.9%	47	6.9%	43.9
Low Physical Activity	4.4%	38.7	3.9%	31.1	3.4%	22.8	3%	18.1	2.9%	18.5
High BMI	9.1%	79.2	9.2%	75.1	9.3%	62.5	9.2%	55	9.1%	57.8

In the figure above, the number of deaths from the NCDs attributable to all the risk factors showed declines between 1990 and 2017 except for alcohol consumption in which the deaths per 100,000 showed an increase during the same time period.

4B.2.1 High BMI -attributable NCD Burden in Ireland

DEATHS: The percentage of IHD deaths from high-BMI showed an increasing trend during 1990 and 2017 from 17.1% in 1990 to 18.5% in 2000 to 18.9% to 19.1% in 2005 to 18.6% in 2017. Similar increasing trends were observed in cancer deaths from high-BMI during the period 1990 and 2017. High-BMI contributed to

significant rise in deaths from diabetes which showed a steady rise from 29.9% in 1990 to 35.1%, in 2000 to 35.5%, in 2005 to 34.5% in 2010 and to 34.5% in 2017.

Figure 4.B3: High BMI attributable NCD deaths in Ireland in the year 1990 and 2017

High BMI attributable NCD deaths in Ireland in the year 1990 and 2017 (all values are per 100,000		
	1990	2017
Deaths from IHD attributable to high BMI	43.9	20.7
Deaths from stroke attributable to high BMI	12.1	6.2
Deaths from cancer attributable to high BMI	8.3	11.3
Deaths from diabetes attributable to high BMI	3.4	3.0
Deaths from COPD attributable to high BMI	0	0

DALYs: DALYs per 100,000 from IHD declined for IHD and stroke from 1990 to 2017. However the DALYs per 100,000 from cancer attributable to high-BMI increased from 1990 to 2017. YLDs from IHD showed a decrease from 1990 to 2017, whereas all the other NCDs showed a rise in the YLDs per 100,000. Cancer is the only NCD which showed an increase in all the burden metrics (deaths, DALYs and YLDs) during 1990 to 2017. The table below shows the DALYs, YLDs and the deaths from the NCDs attributable to high BMI for 1990 and 2017.

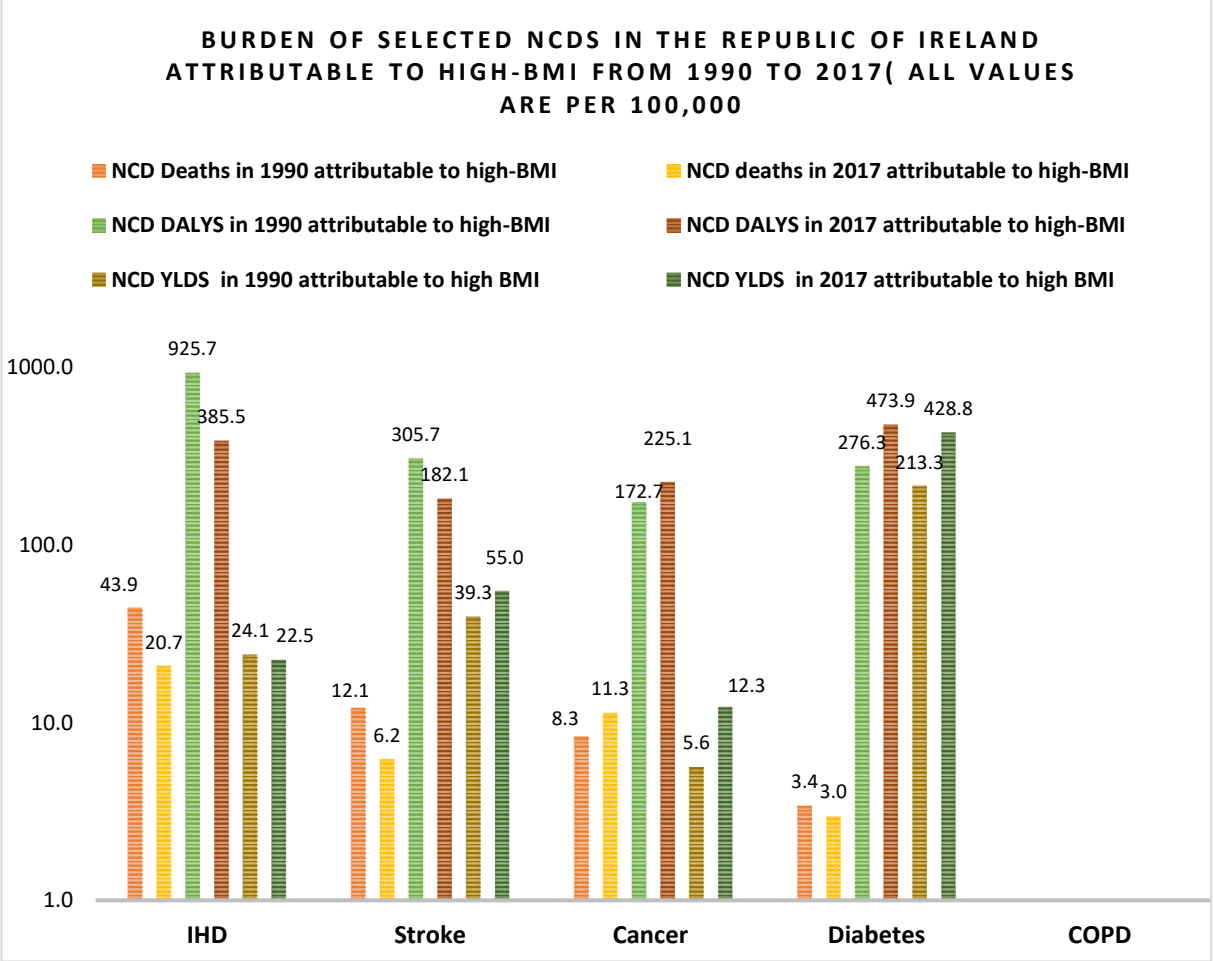
YLDs: YLD of the NCDs attributable to high BMI per 100,000 have increased for all the selected NCDS except for IHD.

YLLs: The YLLs of the NCD attributable to high BMI are shown in the table below (all values are per 100,000)

Figure 4.B4: YLLS of the NCDS from high BMI

1990		2017	
YLLs from IHD attributable to high BMI	901.4	YLLs from IHD attributable to high BMI	363.2
YLLs from stroke attributable to high BMI	266.3	YLLs from stroke attributable to high BMI	127.1
YLLs from cancer attributable to high BMI	167.2	YLLs from cancer attributable to high BMI	212.6
YLLs from diabetes attributable to high BMI	63.4	YLLs from diabetes attributable to high BMI	45.7
YLLs from COPD attributable to high BMI	0.0	YLLs from COPD attributable to high BMI	0.0

FIGURE 4.B5: Burden of NCDs attributable to high-BMI



4B.2.2 Tobacco attributable NCD Burden in Ireland

DEATHS: NCD burden from tobacco use declined during 1990 to 2017. Deaths per 100,000 from all five NCDs attributable to tobacco use declined during 1990 and 2017. The largest decline in deaths was for IHD from 96.1 in 1990 to 21.7 in 2017.

DALYS: A decrease in the DALYs attributable to tobacco use was observed from 1963.8 in 1990 to 435.6 in 2017.DALYs per 100,000 from all the NCDs attributable to tobacco use declined during 1990 and 2017.

YLDs: YLDs per 100,000, increased for cancer (30.7 in 1990 to 32.5 in 2017), diabetes (110.9 in 1990 to 121 in 2017) and COPD (173.2 in 1990 to 194.9 in 2017).

FIGURE 4.B6: NCD metrics attributable to tobacco use during 1990-2017

	1990			2017		
	Deaths (per100,000)	**DALYs (per 100,000)**	**YLDs (per 100,000)**	**Deaths (per100,000)**	**DALYs (per 100,000)**	**YLDs (per 100,000)**
RISK FACTOR- Tobacco use						
IHD	96.1	1963.8	48.7	21.7	435.6	24.4
Stroke	21.7	448.7	55.4	5.5	136.3	40.8
Cancer	71.3	1458.0	30.7	53.6	1030.8	32.5
Diabetes	2.2	149.7	110.9	1	135.7	121.0
COPD	39.9	774.3	173.2	20.5	444.6	194.9

YLLs: The tables below show the YLLs from the NCD attributable to tobacco use

FIGURE 4.B7: YLLs from the NCDs attributable to tobacco use

YLLs from the NCDs attributable to tobacco use (all values are per 100,000)		
	1990	**2017**
YLLs from IHD in 1990 attributable to tobacco use	**1914.7**	**411.3**
YLLs from stroke in 1990 attributable to tobacco use	**393.2**	**95.4**
YLLs from cancer in 1990 attributable to tobacco use	**1427.3**	**998.5**
YLLs from diabetes in 1990 attributable to tobacco use	**38.9**	**14.7**
YLLs from COPD in 1990 attributable to tobacco use	**601.1**	**249.5**

4B.2.3 Alcohol use contribution to NCD burden in Ireland during 1990-2017

Deaths (per 100,000) from the five selected NCDs attributable to alcohol consumption increased from 13.8 in 1990 to 24.5 in 2017. DALYS and YLDs also increased during 1990 and 2017. Deaths and DALYs per 100,000 from cancer attributable to alcohol consumption showed an increase during the time periods 1990 to 2017

Figure 4.B8 NCD burden metrics attributable to alcohol consumption during 1990-2017

RISK FACTOR-Alcohol consumption						
	1990			*2017*		
NCD	**Deaths (per100,000)**	**DALYs (per 100,000)**	**YLDs (per 100,000)**	**Deaths (per100,000)**	**DALYs (per 100,000)**	**YLDs (per 100,000)**
IHD	-11.7	-129.2	-4.8	-0.5	38.6	1.6
Stroke	8.6	175.2	15.9	6.6	118.8	27.4
Cancer	17	398.6	16	18.3	404.2	25.4
Diabetes	0.1	2.7	2.4	0.2	42.3	37.6

FIGURE 4.B9: YLLS FROM THE NCDS ATTRIBUTABLE TO ALCOHOL

YLLS FROM THE NCDS ATTRIBUTABLE TO ALCOHOL (ALL VALUES ARE PER 100,000)		
	1990	**2017**
YLLS FROM IHD IN 1990 ATTRIBUTABLE TO ALCOHOL	**-124.5**	**36.9**
YLLS FROM STROKE IN 1990 ATTRIBUTABLE TO ALCOHOL	**159.4**	**91.4**
YLLS FROM CANCER IN 1990 ATTRIBUTABLE TO ALCOHOL	**382.9**	**379.0**
YLLS FROM DIABETES IN 1990 ATTRIBUTABLE TO ALCOHOL	**0.3**	**4.7**
YLLS FROM COPD IN 1990 ATTRIBUTABLE TO ALCOHOL	**0.0**	**0.0**

4B.2.4 Low Physical Activity Attributable NCD Burden in Ireland

Deaths: Total deaths (per 100,000) from selected NCDs attributable to low physical activity (LPA) levels declined during 1990 and 2017. Deaths (per 100,000) from IHD (changed from 36.1 in 1990 to 15.9 in 2017) and stroke (5.2 in 1990 to 2.7 in 2017) attributable to LPA levels showed a significant decline.

DALYs: DALYs (per 100,000) from IHD reduced by more than 400 deaths per 100,000 from 671.8 in 1990 to 251.7 in 2017.DALYs per 100,000 from stroke and cancer also showed similar declining trends, however diabetes-related DALYs attributable to LPA levels increased from 23.4 in 1990 to 34.1 in 2017.

YLDs: YLDs (per 100,000) from selected NCDs attributable to LPA levels showed an overall increase between 47.9 in 1990 to 62.1 in 2017. This shows that the Irish population is living longer but with disabilities from low physical activity levels. YLDs per 100,000 from all the selected NCDs increased between the years 1990 to 2017 except that from Ischemic Heart disease.

Figure 5.10 shows the selected NCD burden (deaths, DALYs and YLDs) from the risk factor low physical activity levels in Ireland during 1990 and 2017. All the values in Figure 4.B10 are combined aggregate values of burden metrics from the five selected NCDs in our study.

FIGURE 4.B10

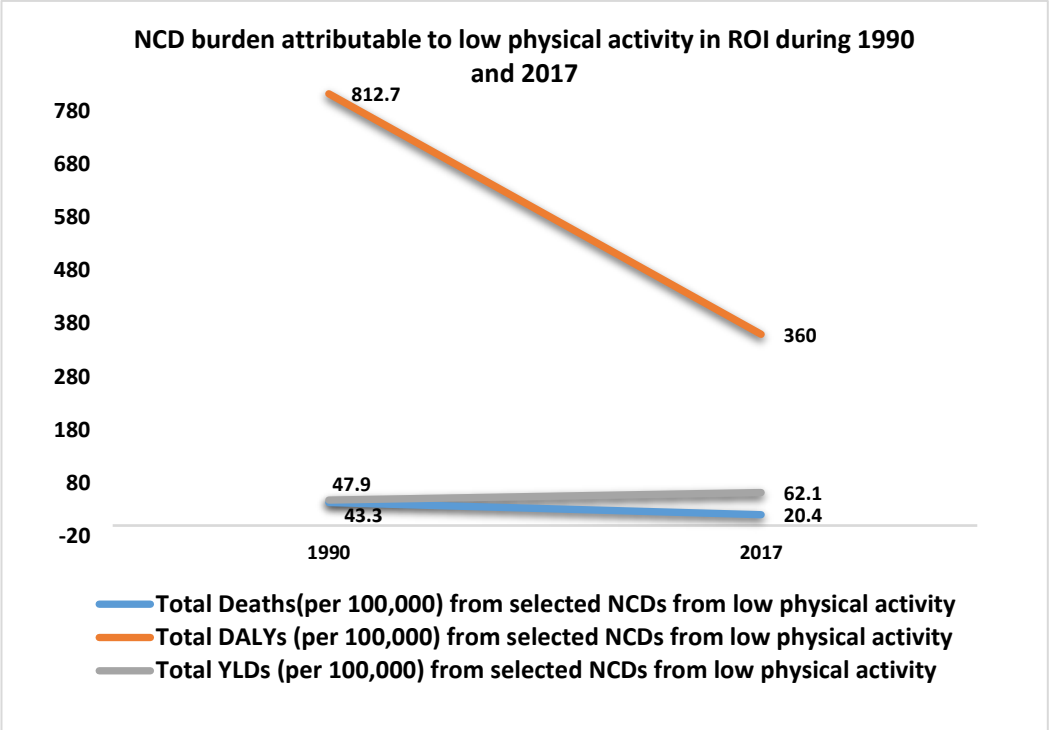


FIGURE 4.B11: YLLS from NCDs attributable to low physical activity (LPA) in Ireland during 1990-2017

YLLS from the NCDs attributable to low physical activity (all values are per 100,000)		
	1990	2017
YLLs from IHD attributable to LPA	501.1	176.1
YLLs from stroke attributable to LPA	72.3	28.3
YLLs from cancer attributable to LPA	29.8	23.5
YLLs from diabetes attributable to LPA	5.9	3.9
YLLs from COPD attributable to LPA	0.0	0.0

4B.2.5 Dietary risks Attributable NCD Burden in Ireland

Overall, deaths from NCDs attributable to dietary risks have shown a decline between the years 1990 and 2017.

FIGURE 4.B12: Deaths from NCDs attributable to dietary risks in Ireland during 1990-2017

Deaths are per 100,000		
	1990	2017
IHD attributable to dietary risks	173.3	70.8
Stroke attributable to dietary risks	30.0	12.6
Cancer attributable to dietary risks	16.0	11.9
Diabetes attributable to dietary risks	3.0	2.1
COPD attributable to dietary risks	0.0	0.0

FIGURE 4.B13: DALYs from NCDs attributable to dietary risk factors in Ireland during 1990-2017

DALYs are per 100,000		
	1990	2017
IHD attributable to dietary risks	3129.2	1047.7
Stroke attributable to dietary risks	608.7	259.9
Cancer attributable to dietary risks	317.3	217.6
Diabetes attributable to dietary risks	229.6	317.9
COPD attributable to dietary risks	0.0	0.0

FIGURE 4.B14: YLDs from NCDs attributable to dietary risks in Ireland during 1990-2017

YLDS PER 100,000

	1990	2017
IHD ATTRIBUTABLE TO DIETARY RISKS	75.1	53.4
STROKE ATTRIBUTABLE TO DIETARY RISKS	77.4	76.4
CANCER ATTRIBUTABLE TO DIETARY RISKS	7.4	10.2
DIABETES ATTRIBUTABLE TO DIETARY RISKS	176.2	286.6
COPD ATTRIBUTABLE TO DIETARY RISKS	0.0	0.0

FIGURE 4.B15: YLLs from NCDs attributable to dietary risks

YLLs are per 100,000		
	1990	2017
IHD attributable to dietary risks	3054.3	994.3
Stroke attributable to dietary risks	531.2	183.4
Cancer attributable to dietary risks	310.1	207.7
Diabetes attributable to dietary risks	53.8	31.6
COPD attributable to dietary risks	0	0

The next section details the dietary risk attribution to the NCDs. We have sub categorised the dietary risks into groups like- a diet high in red meat, diet high in sugar sweetened beverages, diet high in sodium etc. and estimated the burden of diabetes and CVD attributable to the dietary risk factors. This was done to be able

to understand in more detail the effects of the different kind of dietary risk factors better.

4B.2.5.1. Dietary risk attributable CVD burden in Ireland for 1990 and 2017

For this section: we had selected only one NCD- i.e. CVD and dietary risks. We selected only one NCD as it has been observed that CVD is largely attributed to dietary risks and thus we wanted to understand the main dietary risks which contributed to the burden of CVD in Ireland. CVD is subdivided into 3 groups-

1. Ischemic Heart Disease (IHD)

2. Stroke

3. Other cardiovascular and circulatory disease

The dietary risks group was also subdivided into 5 different groups:

1. Diet high in processed meat

2. Diet high in sodium

3. Diet high in trans-fatty acids

4. Diet low in fruits

5. Diet low in vegetables

Absolute deaths and DALYs from stroke, IHD and the other cardiovascular and circulatory diseases showed a decline during 1990 to 2017 but YLDs showed an increase during 1990 to 2017 for all three sub-groups of CVD. The five dietary risks were found to be causative factors of CVD from previously surveyed literature. In

this section, we shall quantify the burden of CVD (IHD, stroke and other circulatory and cardiovascular disease) attributable to the selected risk factors in the Republic of Ireland during 1990 and 2017. All rates will be per 100,000 for deaths, DALYs and YLDs. Figure 4.B16 shows the deaths from cardiovascular disease from the selected risk factors in Ireland in 1990 and 2017.

FIGURE 4.B16: Death rate from CVD attributable to dietary risks in ROI during 1990 and 2017 (all deaths are per 100,000)

	IHD deaths Attributable to risk factor in 1990	IHD deaths Attributable to risk factor in 2017	Stroke deaths attributable to risk factors in 1990	Stroke deaths attributable to risk factors in 2017	Other Cardiovascular and circulatory disease attributable to risk factors in 1990	Other Cardiovascular and circulatory disease attributable to risk factors in 2017
Diet High in processed meat	2.3	2	0	0	0	0
Diet high in sodium	17.3	10.8	5.1	3.9	0.3	0.3
Diet high in trans-fatty acid	3.3	0.7	0	0	0	0
Diet low in fruits	26.8	6.4	13.1	3.4	0	0
Diet low in vegetables	37.7	13.5	6.5	2.5	0	0

CVD deaths from all the selected risk factors have declined during 1990 and 2017. 230.1 deaths per 100,000 have been attributed to the selected six risk factors in 1990 which decreased to 70.7 deaths per 100,000 in 2017. A diet high in processed meat (0.9% in 1990 to 1.8% in 2017) and a diet high in sodium (6.8% in 1990 to 9.7% in 2017).

Figure 4.B17

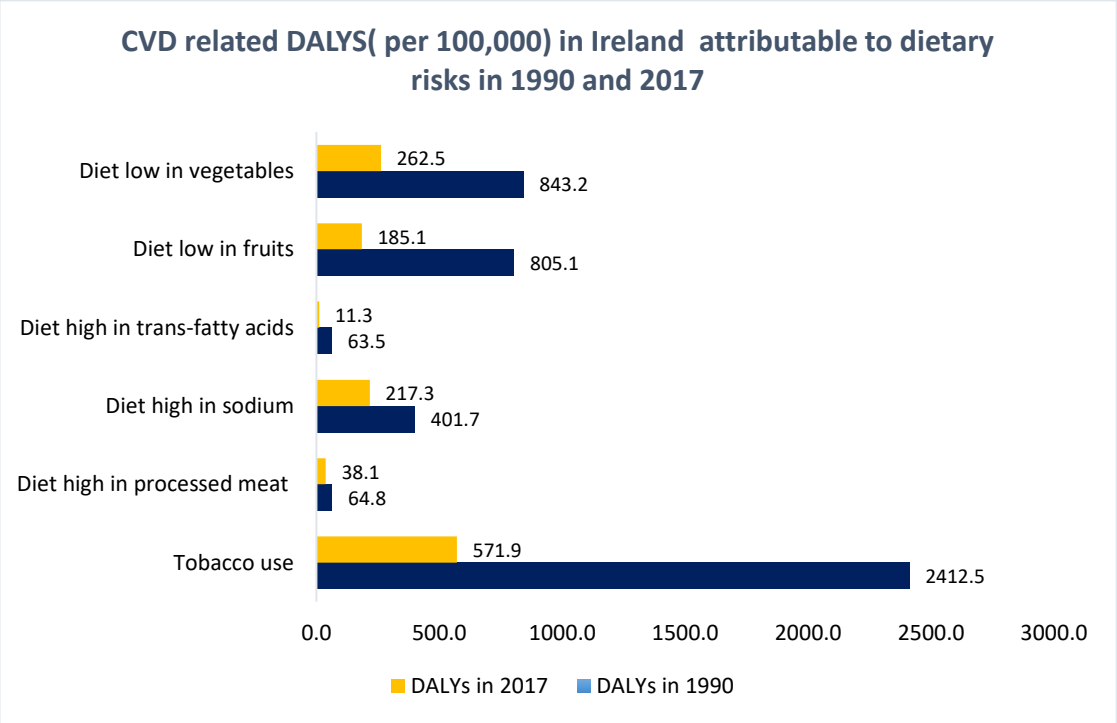
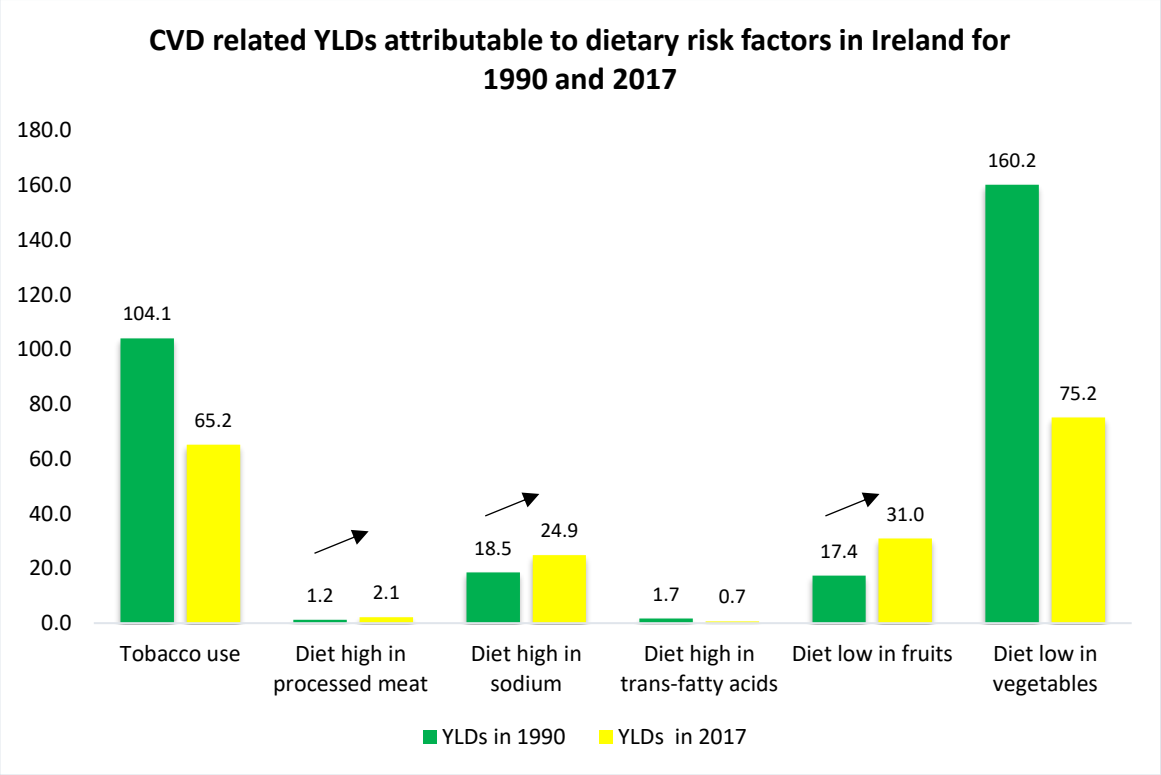


Figure 4.B18



4B.2.5.2 Dietary risk attributable Diabetes burden in Ireland for 1990 and 2017

We have selected some important dietary risk factors which are known to be related to diabetes from previously reviewed literature and estimated their attribution to the burden of diabetes in Ireland for 1990 and 2017. For this section, dietary risks group were subdivided in to six groups which are as follows:

1. Diet low in fruits

2. Diet low in whole grains

3. Diet low in nuts and seeds

4. Diet high in red meat

5. Diet high in processed meat

6. Diet high in sugar sweetened beverages.

The burden of diabetes attributable to dietary risks (six subgroups) for 1990 and 2017 were calculated. All values would be per 100,000. Deaths per 100,000 is shown in figure below for 1990 and 2017 separately for DALYs and YLDs. Deaths per 100,000 only for a diet high in sugar sweetened beverages showed an increase during 1990 and 2017.

Figure 4.B19

Deaths from diabetes attributable to dietary risks in Ireland in 1990 and 2017

	Deaths in 1990 (per100,000)	Deaths in 2017 (per 100,000)
Diet low in fruits	0.7	0.3
Diet low in whole grains	1.4	0.9
Diet low in nuts and seeds	0.9	0.6
Diet high in red meat	0.2	0.2
Diet high in processed meat	0.1	0.1
Diet high in sugar- sweetened beverages	0.1	0.2

Figure 4.B20

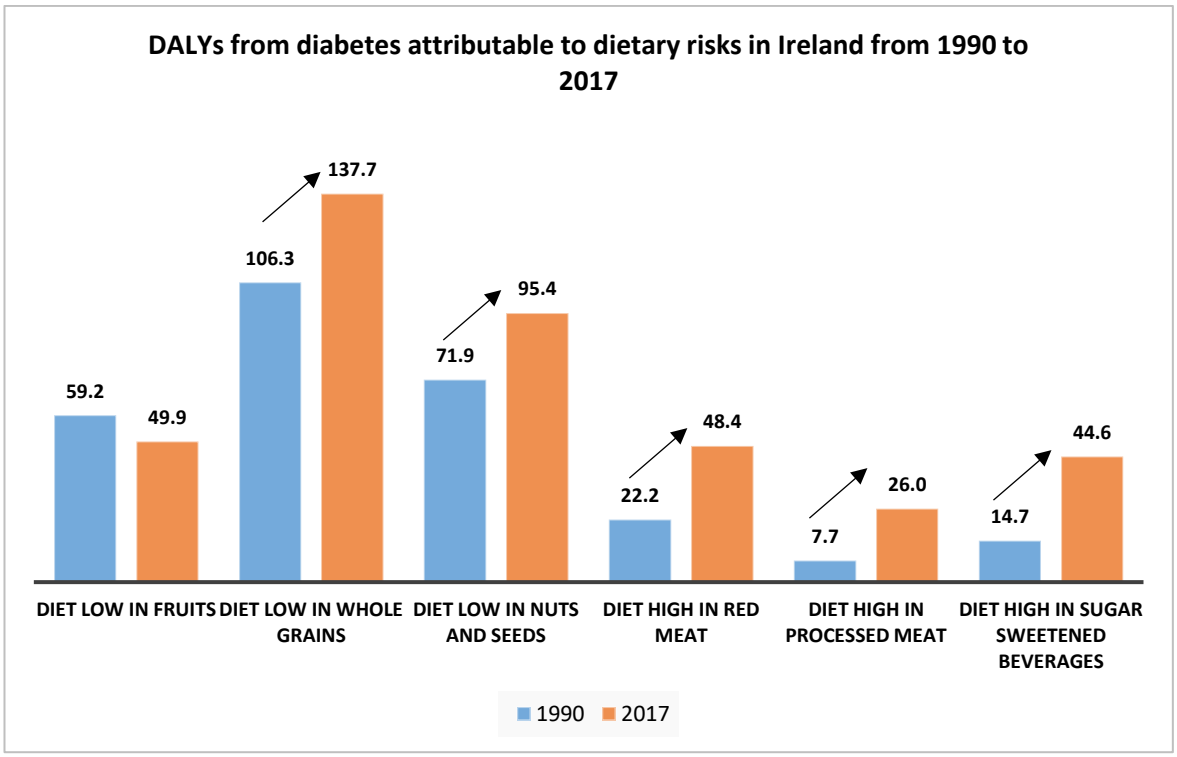


Figure 4.B21

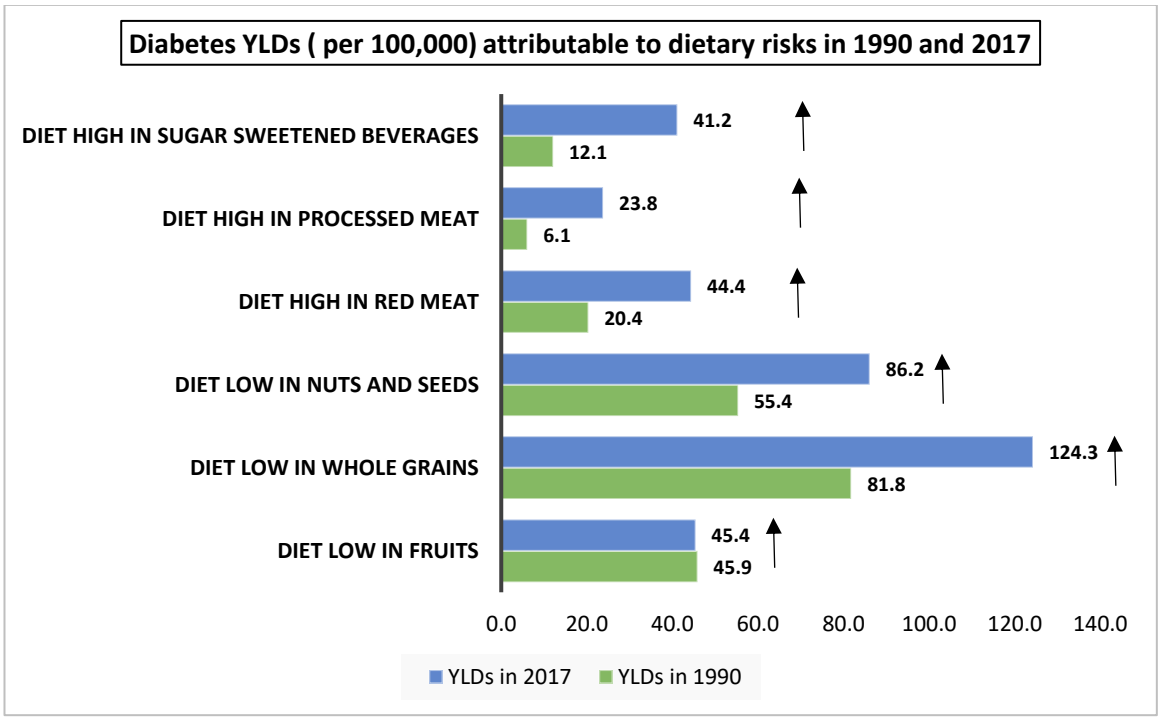
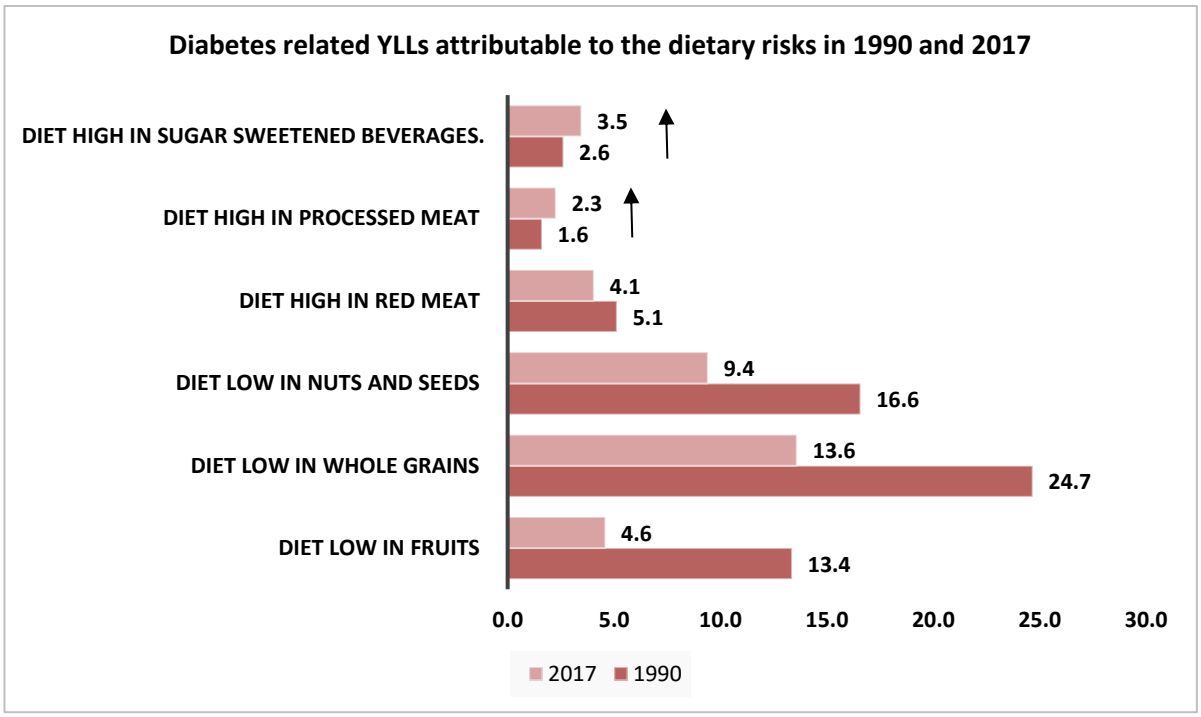


FIGURE 4.B22



Diabetes related DALYs and YLDs showed significant change from 1990 to 2017. YLDs from diabetes attributable to all the dietary risk factors except for a diet low in fruits showed an increase during the time period 1990 -2017.DALYs per 100,000 from diabetes attributable to a diet low in grains changed from 106.3 in 1990 to 137.7 in 2017, a diet low in nuts and seeds changed from 71.9 in 1990 to 95.4 in 2017, a diet high in red meat from 22.2 in 1990 to 48.4 in 2017, a diet high in processed meat from 7.7 in 1990 to 26 in 2017, a diet high in sugar sweetened beverages from 14.7 in 1990 to 44.6 in 2017. Observations in relation to the context of a diet low in grains and a diet low in nuts and seeds was also observed at the global level in the Lancet paper on dietary risks published by the GBD study group.

YLDs from diabetes attributable to the selected group of dietary risk factors also showed an increasing trend just like the DALYs. Except a diet low in fruits all other dietary risk factors showed an increase in the YLDs from diabetes.

CHAPTER 5A: Decomposing the main drivers of disease burden change for the Republic of Ireland in 2017 [77]

5A.1 Background

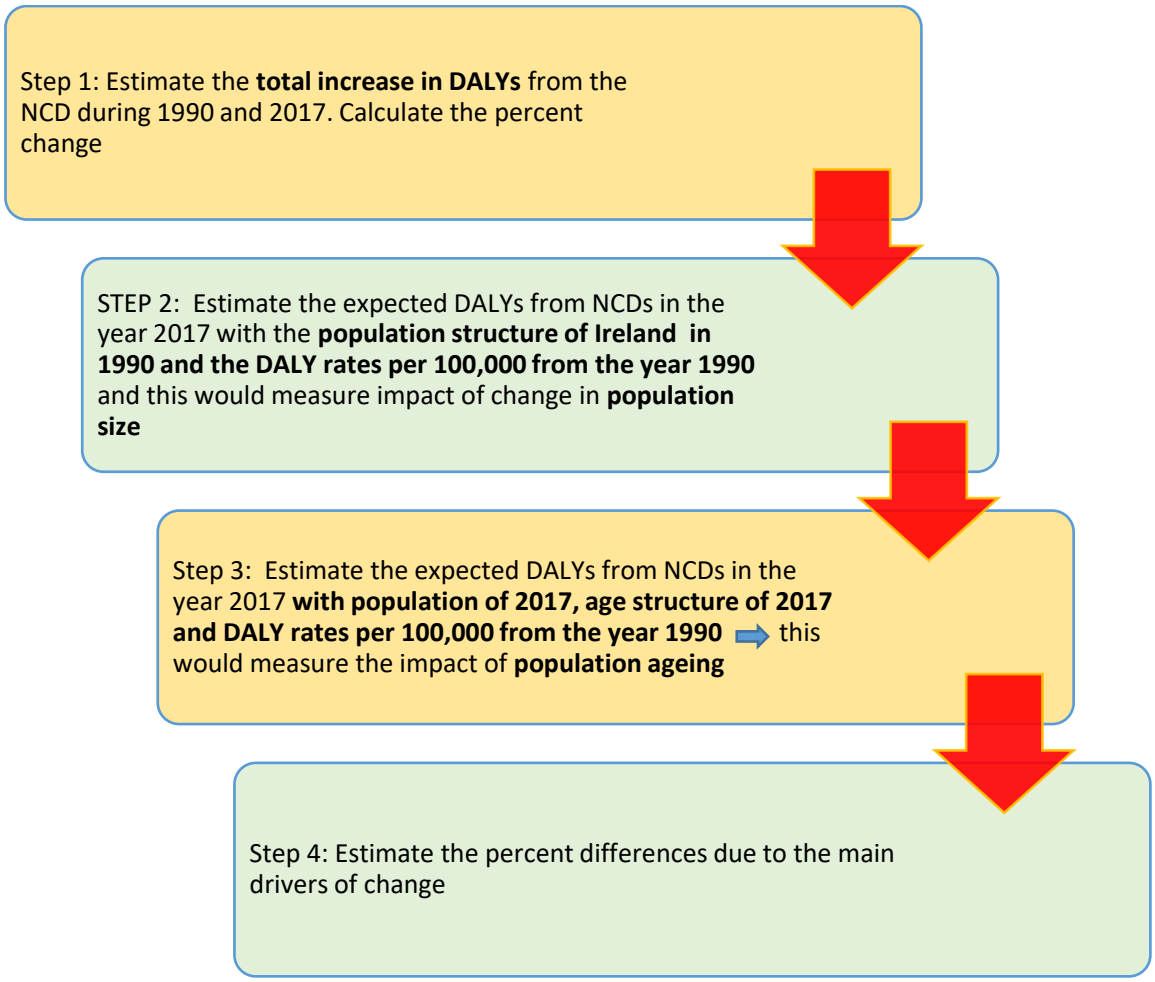
It is a challenging exercise for a country to be able to understand whether its population is living longer and healthier or not in full health. However, this needs to be looked into. Metrics like deaths, DALYs, YLDs showed rise across time periods 1990 to 2017 and it is valuable to understand whether these rises or falls are from an overall increase in population or is it attributed to an ageing population or whether more population level interventions need to be implemented. It is crucial that the effects of ageing, population growth and the effects of the population level interventions are teased out. Studies conducted in other parts of the developed world have found that an ageing population, growth in population and the outcomes of different population level interventions have considerable effects on the burden of the disease especially NCDs. Thus we aim to understand whether the same pattern is observed in Ireland or not. This study looks at disentangling the drivers of burden change over the years.

5A.2 Methods [71] [77]

In order to understand whether the change in metrics (DALYs) is a result of ageing, changing risk factor scenario or population growth, a decomposition method was used to attribute changes in total DALYs to population ageing, population growth, and change in risk factor scenario during 1990 and 2017. The DALY data used for this process were extracted from the GBD website (www.gbdhealthdata.org). Also

the age structures were also available from the GBD website. All calculations were done in Excel. The flow chart below shows the detailed method that was used in the decomposition analysis.

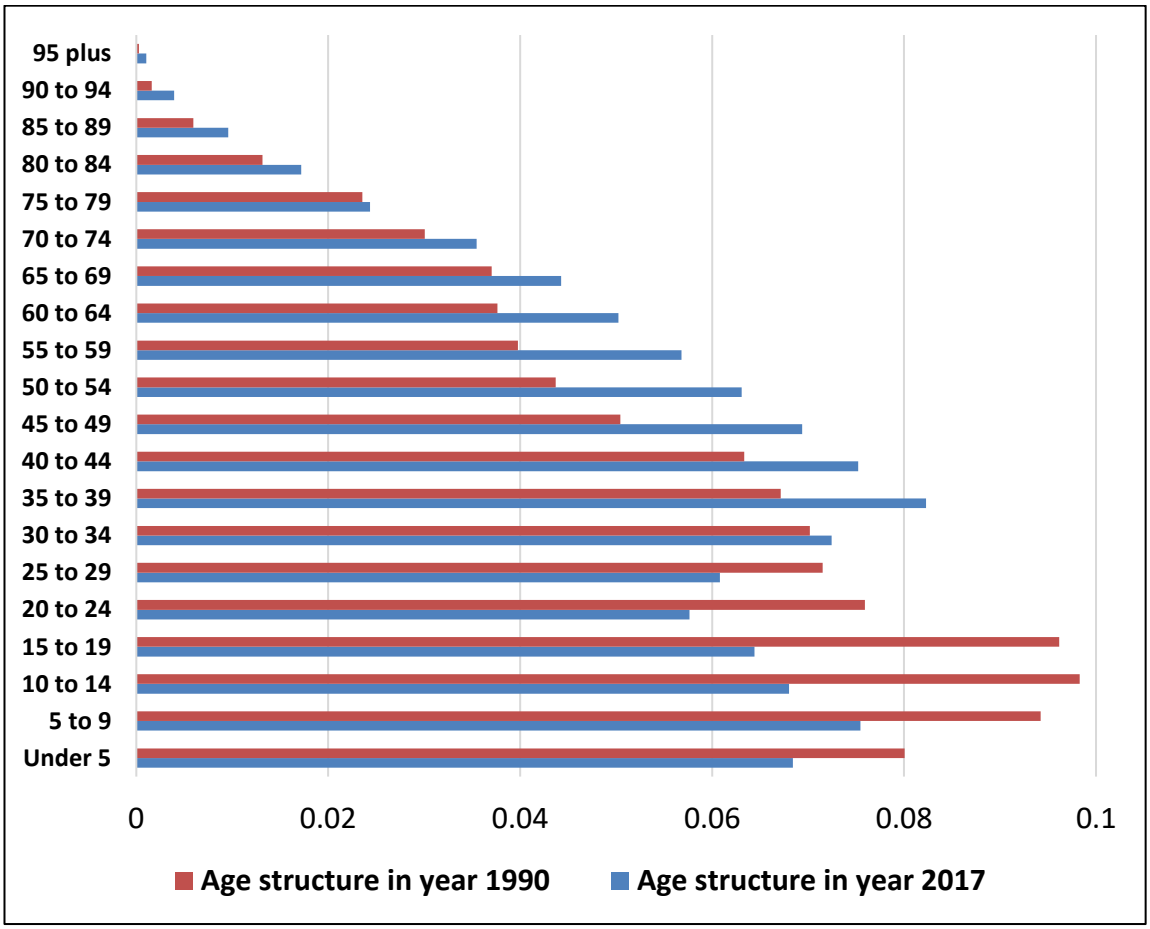
Flowchart showing the methods of calculation of the drivers of burden change



5A.3 Results

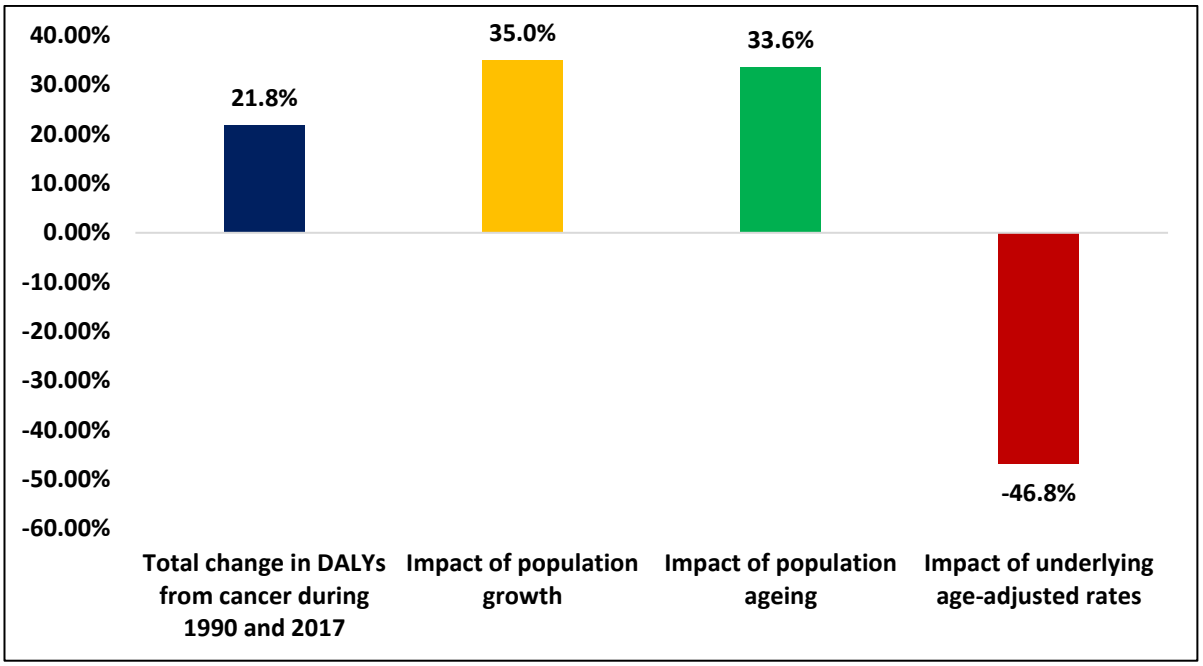
Figure 5.A1 below shows the distribution of population in different age groups (age pyramid).

Figure 5.A1: Demographic transition in Ireland during the period 1990-2017



The graph above shows that 2017 has a larger ageing population as compared to that of 1990.The red bar charts above shows the age structure in 1990 and the blue bar charts show the age structure in 2017. In 2017, higher number of people were observed in the ageing groups like 40-44, 45-49, 50-54 and the higher age groups as compared to 1990. The graph below shows the main drivers of cancer burden change in Ireland during 2017.

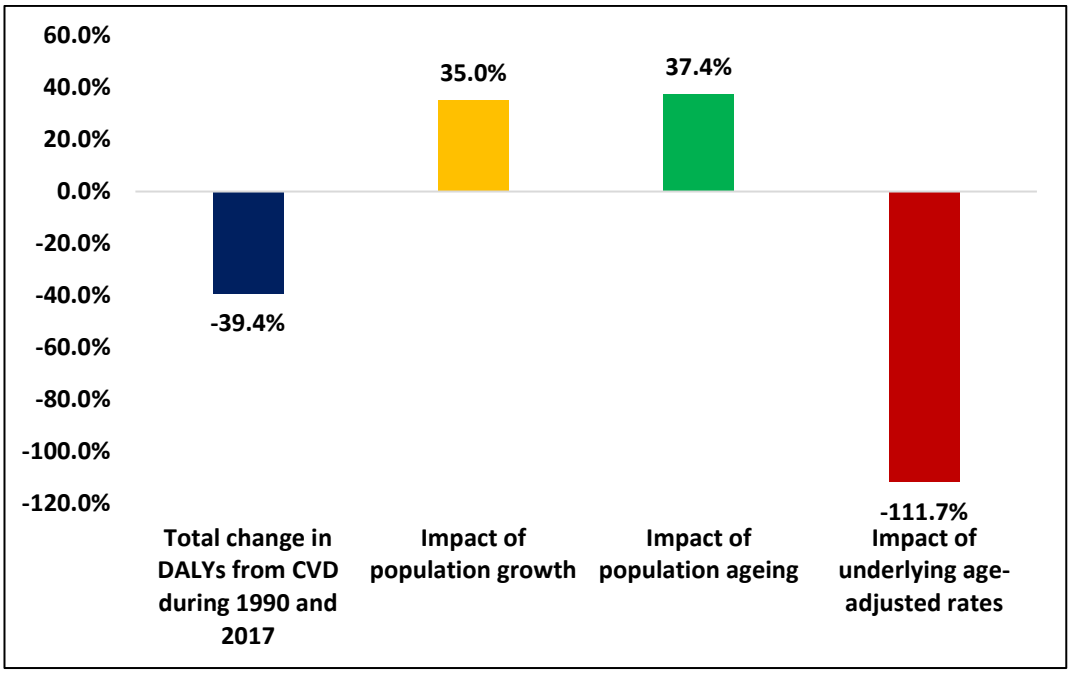
Figure 5.A2 Main drivers of cancer burden change in Ireland in 2017



The change in cancer DALYs attributed to population growth is 35%, from population ageing is 33.6%. Although the observed change in total cancer DALYs is 21.8%, the real change in drivers after eliminating the effects of ageing and population growth is a decrease by –approximately 47%. This implies Ireland is doing well in terms of its health system performance like preventive strategies, population level interventions etc.

The graph below show drivers of burden from CVD in Ireland in 2017.

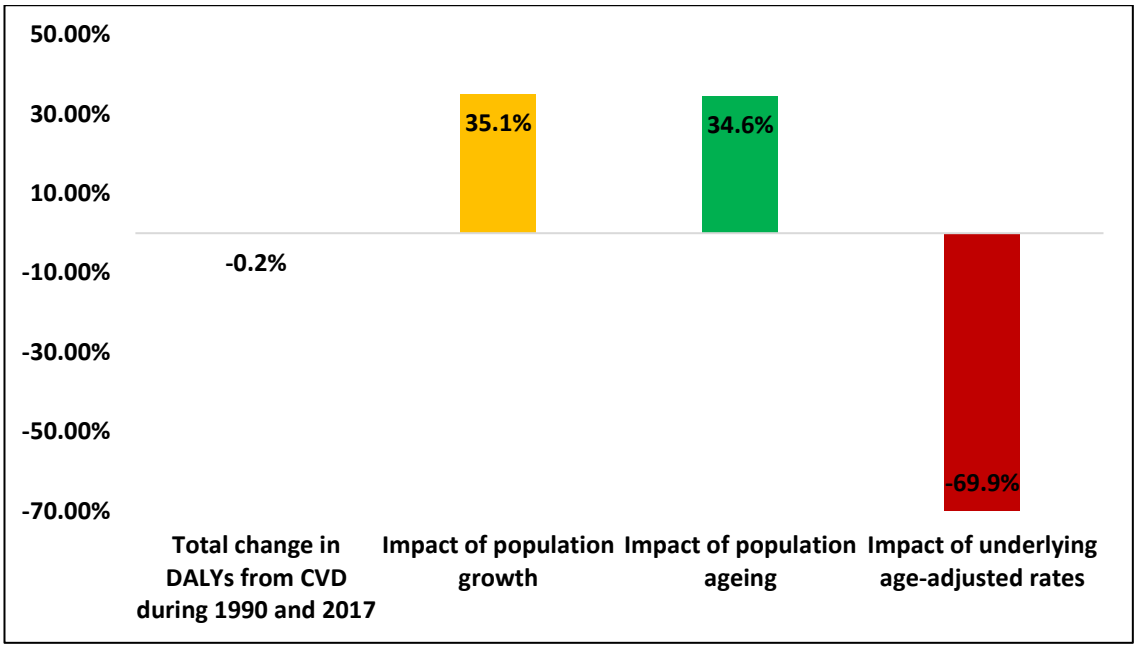
Figure 5.A3 Main drivers of CVD burden change in Ireland in 2017



The change in CVD DALYs attributed to population growth is 35% from Population ageing is 37.4%.Although the observed change in total CVD DALYs is a decline of 39.4%, the real change in the drivers after eliminating the effects of ageing and population growth is by almost -112%. This implies Ireland is doing well in terms of its health system performance like preventive strategies, population level interventions etc. from CVD even more than cancer. This could be a result of a decline in levels of smoking and strict workplace smoking bans etc.

The next graph shows the drivers of change of burden of COPD in Ireland in 2017.

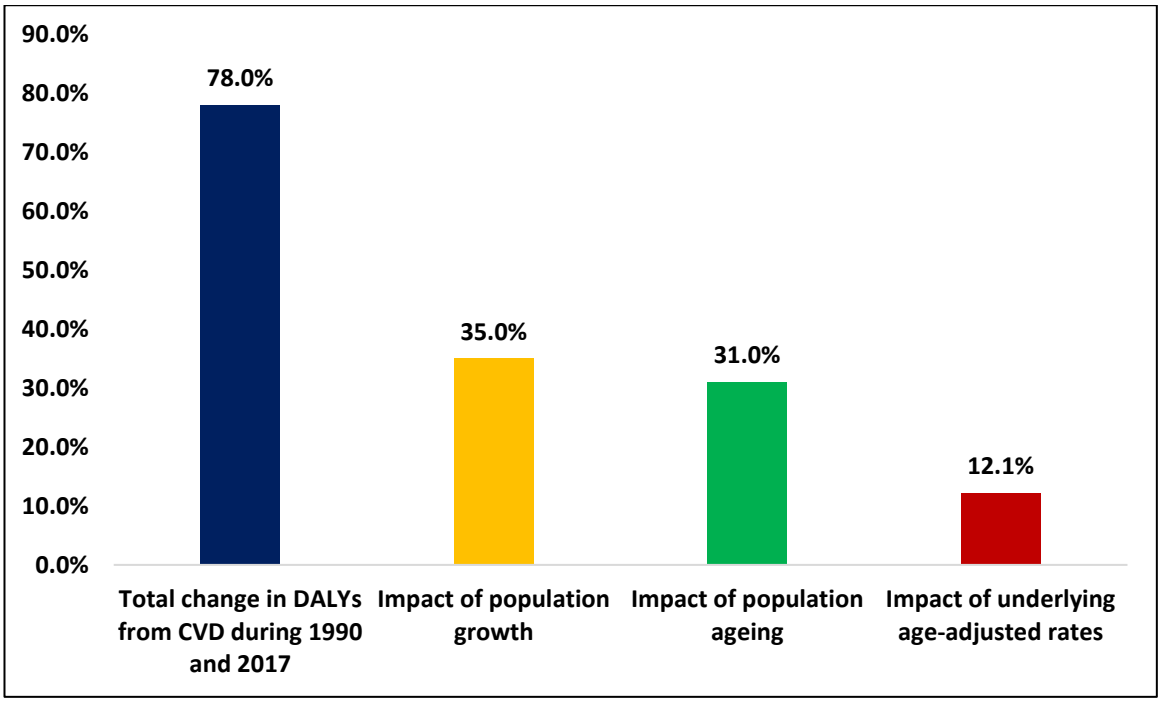
Figure 5.A4 Main drivers of COPD burden change in Ireland in 2017



The change in COPD DALYs can be attributed to population growth (35%), from population ageing is 34.6%. The total observed change in total COPD related DALYs is a decline of 0.2%, the real change in drivers after eliminating the effects of ageing and population growth is by almost -69% which implies Ireland is doing well in terms of its health system performance like preventive strategies, population level interventions etc. for COPD. Some of the decline could be attributed to that of the declining levels of tobacco use and workplace smoking ban.

The next graph depicts the impact of the population growth and ageing from diabetes in Ireland in 2017.

Figure 5.A5: Main drivers of diabetes burden change in Ireland in 2017



The change in diabetes DALYs that can be attributed to population growth is 35%, from population ageing is 31%. The total observed change of Diabetes DALYs is about 78% but the real change in drivers after eliminating the effect of ageing and population growth is about 12.1% which implies that more steps in order to tackle modifiable risk factors for diabetes need to be implemented.

On the whole, the effect of population ageing in Ireland has been between 30%-38%, and the effect of population growth in Ireland on an average has been 35%. After eliminating the effects of these factors there has been a varying range of impact of the underlying rates for the different diseases.

5A.4 Conclusion

There is a considerable effect of population ageing on the DALYs from the four most common NCDs in Ireland during the time period 1990 to 2017. Population growth also contributed to the drivers of burden change but the major contribution was from the impact of the age adjusted rates. Despite population ageing and population growth, diabetes still seems to be requiring more effective intervention strategies or risk factor control measures (as evident from the breakdown of drivers of burden change). There has been significant good impacts of population level interventions on CVD and COPD. Stricter population level intervention need to put in place for diabetes. COPD and CVD showed improvements as risk factors interventions like smoking bans. Similar population level interventions should be implemented more strictly for diabetes- like taxes on red meat and processed meat, taxes on alcohol.

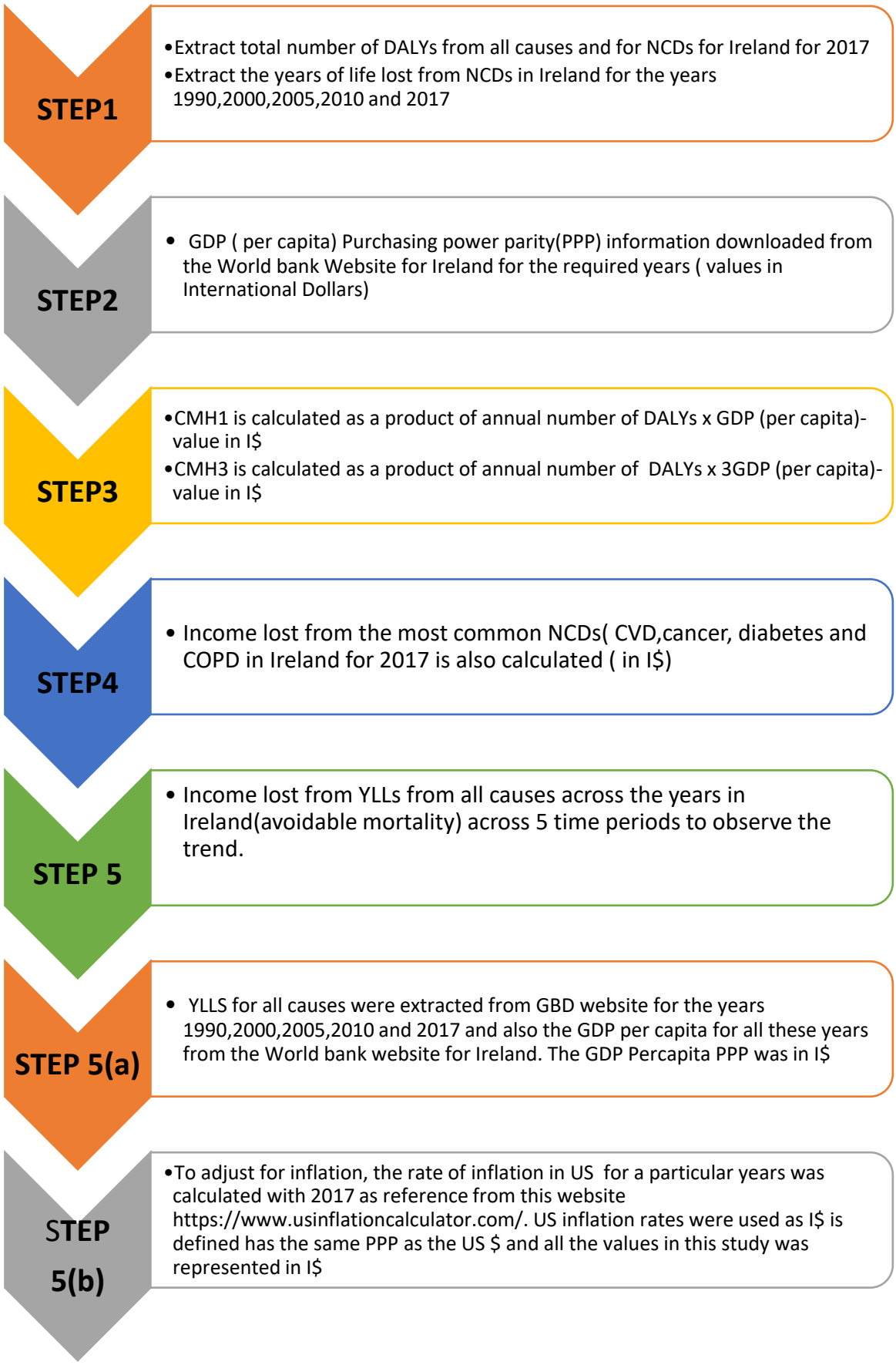
CHAPTER 5B: National Income lost from burden of disease in the Republic of Ireland: 1990-2017

5B.1 Introduction

Burden of NCDs and related risk factors are not only a health issue for a country but also contributes to significant amount of economic loss as shown by many studies across the world. It is thus important to understand the patterns in the overall loss of income (GDP) in a particular year and also look at its trends across time periods. GDP or Gross Domestic Product of a country is defined as the total monetary value of all goods and services produced and sold in a specific country in a specific year. This measure is a prognostic one as it measures the impact of a disease on the overall country's GDP [78]. This method allows us to account for the impact of disease by reducing production factors like that of capital and labour in a country. This method was originally applied by an expert group based in Harvard University and led by Professor D. Bloom [79]. It was collected by the World Economic Forum to assess the economic burden of NCDs worldwide across the years 2011-2030. This approach used the WHO tool for projecting the Economic Costs of Ill-Health (WHO--EPIC model) which was constructed in the year 2006.

5B.2 Methods

The methods of calculating the loss of national income is based on the WHO Commission on Macroeconomics and Health, which values one unit of DALY at about one or three times GDP per capita. The flowchart below shows the methods of calculation of loss of national income in terms of GDP in more detail.


STEP1
•Extract total number of DALYs from all causes and for NCDs for Ireland for 2017
•Extract the years of life lost from NCDs in Ireland for the years 1990,2000,2005,2010 and 2017
STEP2
• GDP (per capita) Purchasing power parity(PPP) information downloaded from the World bank Website for Ireland for the required years (values in International Dollars)
STEP3
•CMH1 is calculated as a product of annual number of DALYs x GDP (per capita)-value in I$
•CMH3 is calculated as a product of annual number of DALYs x 3GDP (per capita)-value in I$
STEP4
• Income lost from the most common NCDs(CVD,cancer, diabetes and COPD in Ireland for 2017 is also calculated (in I$)
STEP 5
• Income lost from YLLs from all causes across the years in Ireland(avoidable mortality) across 5 time periods to observe the trend.
STEP 5(a)
• YLLS for all causes were extracted from GBD website for the years 1990,2000,2005,2010 and 2017 and also the GDP per capita for all these years from the World bank website for Ireland. The GDP Percapita PPP was in I$
STEP 5(b)
•To adjust for inflation, the rate of inflation in US for a particular years was calculated with 2017 as reference from this website https://www.usinflationcalculator.com/. US inflation rates were used as I$ is defined has the same PPP as the US $ and all the values in this study was represented in I$

5B.3 Results

The graph below shows the total income lost from all causes in Ireland in 2017. The values are in billion and represented in International dollars (I$).

Figure 5.B1

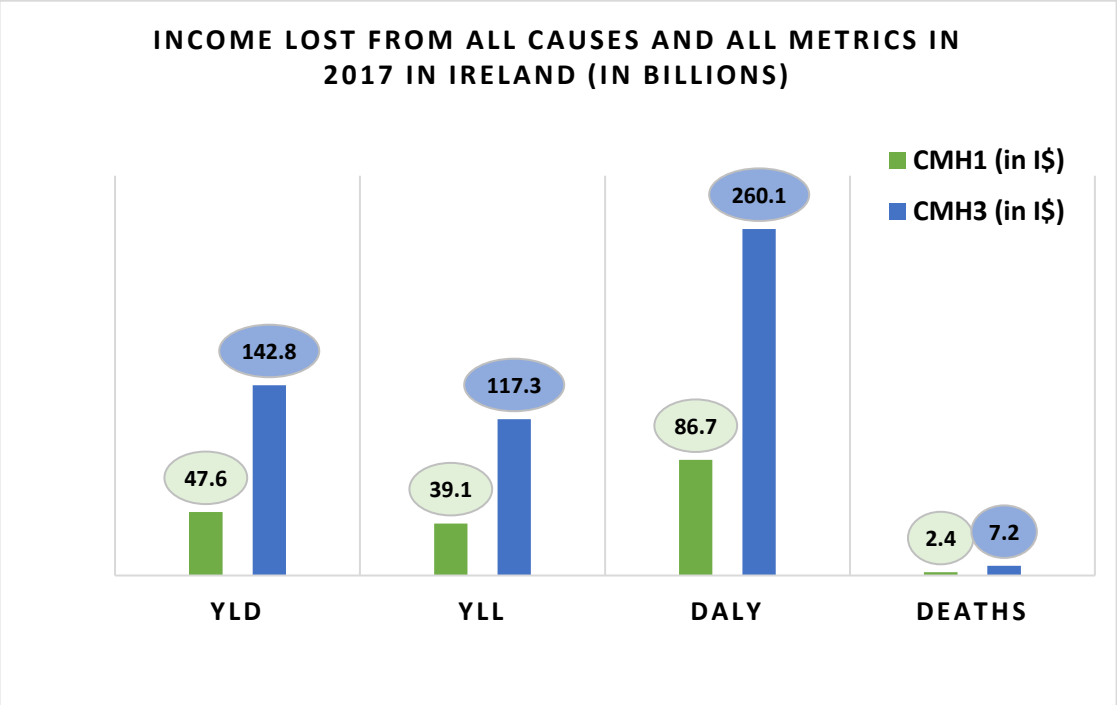
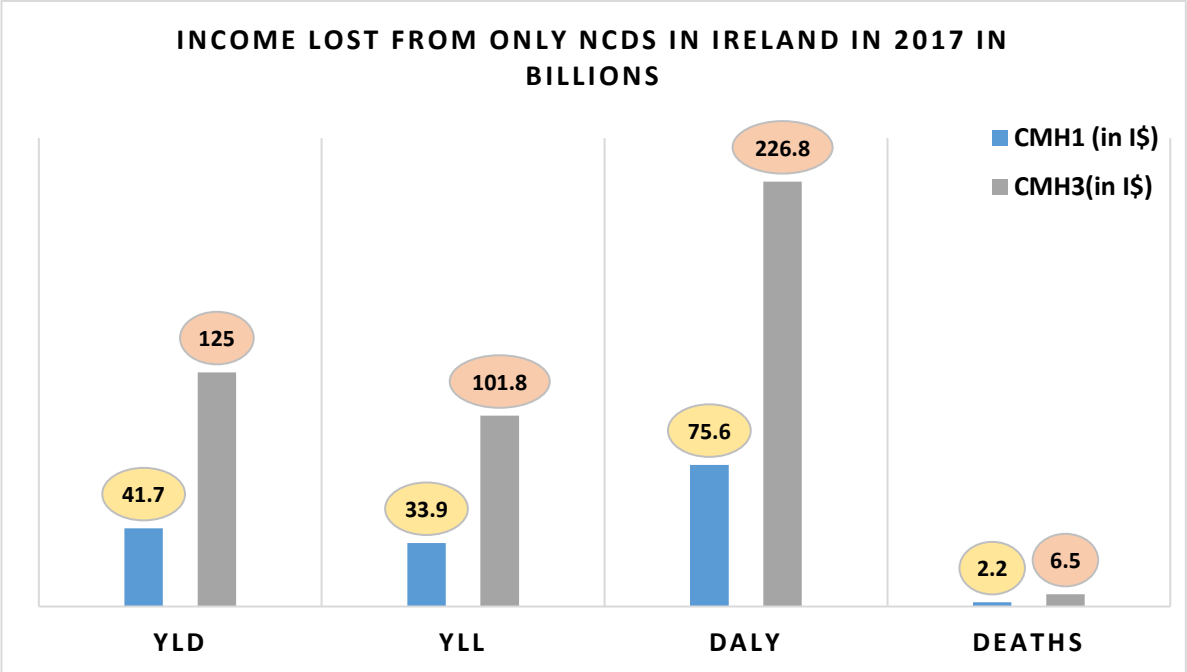


Figure 5.B2



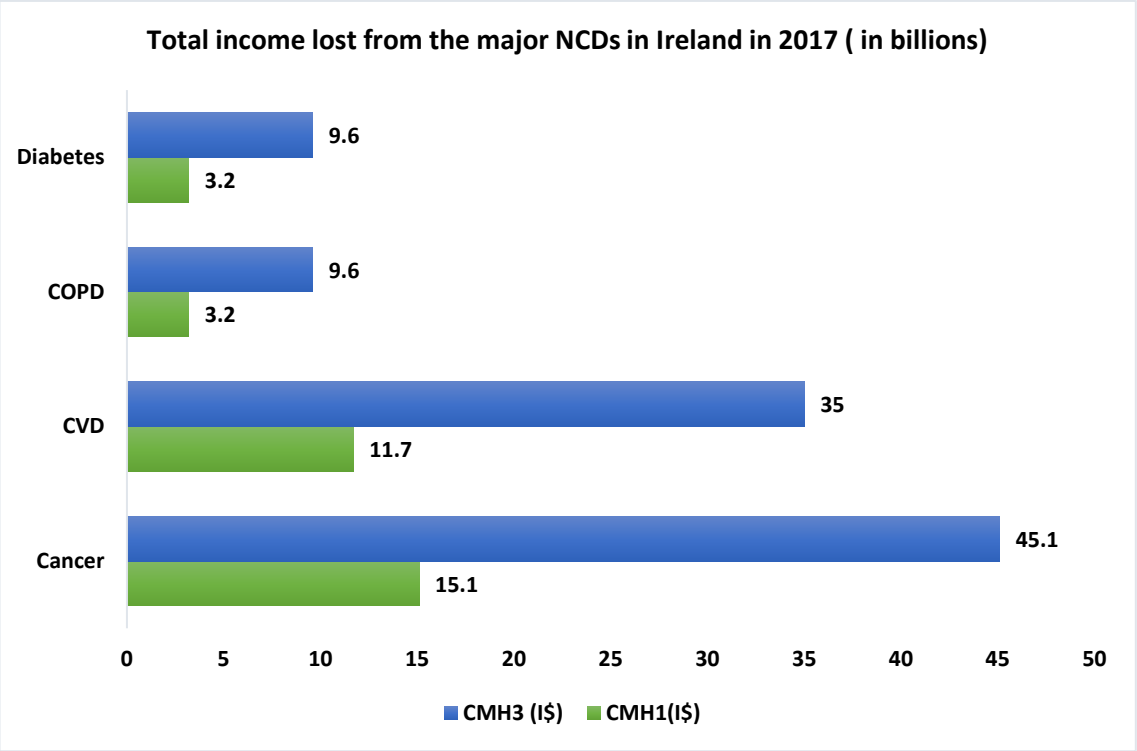
The table 5.B3 below shows the sex wise distribution of the loss of income in Ireland in 2017 in international dollars.

Table 5.B3

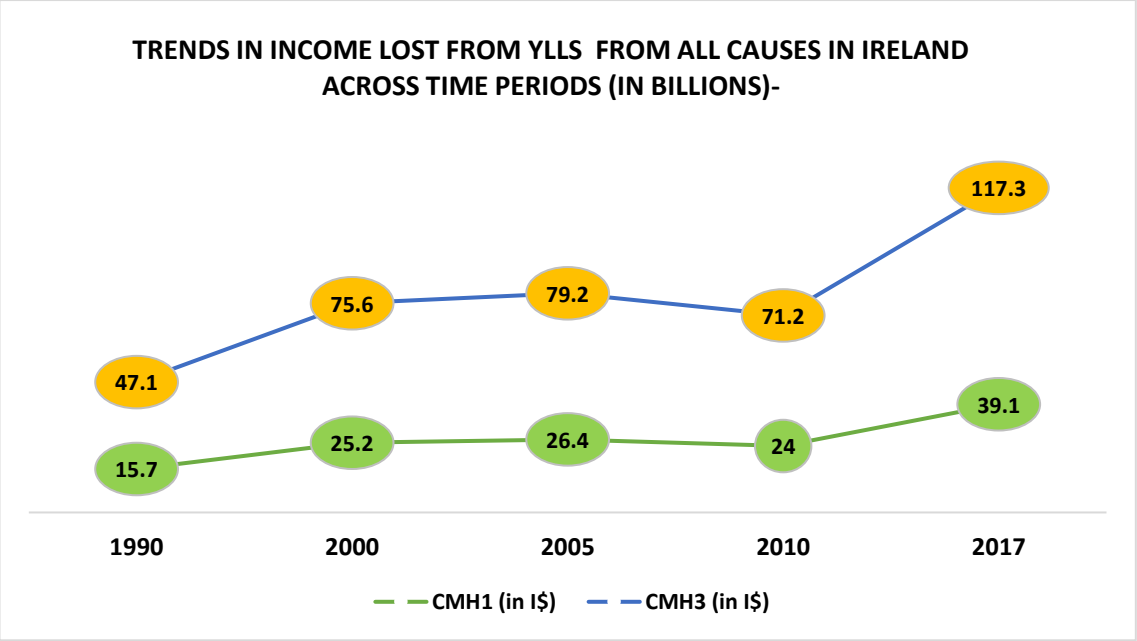
	FEMALES (CMH1)	MALES (CMH1)	FEMALES (CMH3)	MALES (CMH3)
YLDs	**22.7 billion I$**	**19 billion I$**	**67.9 billion I$**	**57.1 billion I$**
YLLs	**15.1 billion I$**	**18.8 billion I$**	**45.4 billion I$**	**56.4 billion I$**
DALYs	**37.8 billion I$**	**37.8 billion I$**	**113.3 billion I$**	**113.4 billion I$**

The graph below shows the total income lost from the four major NCDs in Ireland in 2017 in International dollars (I$)

Figure 5.B4



The figure 5.B5 below shows the trends in the income lost from years of life lost from all causes across the years in Ireland (avoidable mortality)



5B.4 Conclusion

The total amount of income lost from all diseases in Ireland is almost 86.7 billion I$ (CMH1) to 260.1 billion I$ (CMH3) respectively in 2017. The total income lost to NCDs in Ireland is about 75.6 billion I$ (CMH1) to 226.6 billion I$ (CMH3) in 2017. About 87% from the total income lost is attributed to the NCDs. (75.6 out of 86.7 billion I$).There were no major differences between the two sexes in terms of income lost from NCDs in 2017.

The income lost (CMH1) from the major NCDs are about 15.1 billion I$ for Cancer, 11.7 billion I$ for CVD, 3.2 billion I$ for COPD and 3.2 billion I$ for Diabetes in 2017. Cancer alone contributes to 19.1% of the income loss amongst the NCD related income loss.

Despite adjusting for the rates of inflation between the years 1990 and 2017, there was an overall increasing trend in the amount of income lost during this time period (Both the CMH1 and CMH3 showed an increase over the years). The most probable scenario in future is usually CMH1 but could be anywhere up to CMH3 (worst case scenario).

This study shows that NCDs are contributing to a large financial burden on the economy and a huge impact on the GDP. In order to reduce this economic burden, appropriate population level interventions need to be introduced. Diseases like cancer need stricter interventions as it is observed that a large portion of the GDP loss is attributable to cancer.

Chapter 6: Interrogation of results from the GBD study with national datasets

There is a lot of publicly available data and data visualization tools from GBD on NCDs, life expectancies, risk factors contributions, forecasting the future burden etc. however, there is no comprehensive report for the NCDs and the related risk factors for the Republic of Ireland for any year till date. There are many national level prevalence and incidence studies conducted within Ireland with focus on the selected NCDs and risk factors but utilization of the large amount of data from GBD to draw any conclusions or policy related outcomes are not available. This piece of work is aimed to fill in that gap. It is thus important that some of the results from the GBD data are validated by the national level data to verify if these results are in line with the local level estimates. Also, it is critical to understand whether the GBD data can be used to drive local level policies.

FIGURE 6.1: Deaths in Ireland in 2017 (comparison of CSO and GBD) [37]

	Central Statistics office(CSO),Ireland results (rates are per 1000)	GBD study results (rates are per 100,000)
Males	~650	655.1
Females	~620	613.1
Total	~630	633.9

Some figures can be validated against the results from the GBD data like the deaths from cancers, disease of the circulatory system, diseases of the Respiratory system (Figure 6.2).

FIGURE 6.2 Deaths from circulatory diseases and respiratory systems (CSO vs. GBD)

2017	**Diseases of circulatory systems**	**GBD (CVD) 9,681.5(9124.5-10258.9)**	**CSO 8,938**
2017	Diseases of respiratory system	GBD (chronic respiratory diseases) 2,225.9(2077.4-2394.4)	CSO 4,165

We also validated some results related to cancers from the GBD data comparing the results from CSO data.

FIGURE 6.3 Cancer deaths (CSO vs. GBD)

	Malignant cancer deaths in 2007	**Malignant cancer deaths in 2017**
CSO data	7917	9141
IHME data (all cancers)	8397 (8193-8549)	9580 (9016-10170)

- ✓ The above figures 6.1 to 6.3 shows that the national level estimates from CSO and are compared to that of the GBD study and the results for all-cause mortality, cancers and circulatory diseases show that they are close to one another.
- ✓ The state of tobacco control in Ireland report of 2018 stated that the prevalence of smoking in adults in 2017 = 22% and the prevalence of smoking in adults in 2015 =21.3% (19%-23.8%) (GBD data results)

- ✓ Based on the Healthy Ireland 2015 report the prevalence of smoking in males is 24% and in females is 21% in 2015.
- ✓ Based on the GBD data, the prevalence of smoking in males in Ireland in 2015 was 21 % (18.8%-23.3%) and for females is 22.2% (19.7%-25%).
- ✓ Total number of deaths from second-hand smoking and smoking in 2017 =5899 (Healthy Ireland report)
- ✓ Total number of deaths from second-hand smoke and smoking is about 5947.9 (5487.1-6424.7) in 2017. (GBD data)

On closer analysis of the GHDx (Global Health Data exchange)- the storehouse for all GBD information, it was observed that some of the data from Irish data sources were not used in the GBD analysis- for example, the Healthy Ireland dataset. Some of the datasets included are SLAN, TILDA. This would mean some of the estimates for Ireland would be based on data from some of the past years or from other nations and even from non-European nations (whose demographics and population distribution would be widely different from Ireland).

This is one of the first comprehensive analysis of the GBD results to obtain mortality, morbidity and future burden of disease estimates for Ireland. These results need to be examined and interpreted with caution and can definitely not replace a need for a national BOD study in Ireland.

6.1 Validating GBD results using different populations (World Standard population and European Standard population) [80]

The GBD study estimates DALYs which describe is used by the GBD as universal metric for population health. DALYs are comparable across countries and it helps in understanding the overall health scenario of the country and helps in effective allocation of resources. GBD estimates aims to warrant comparability across nations by utilizing ASR (age-standardised rates) to account for different age-structures of populations. It is important to understand that the choice of a standard population can change the rates of DALYs and thus depict a very different health scenario. In this study, we tried to estimate the same for the Republic of Ireland. Generally, the most common approach used in the BoD studies is to directly standardise population by using rates per 100,000. This is done by applying a reference age structure of a population to a population which it is being compared to. This results in modelling by forming a hypothetical scenario which would occur if both the populations were similarly distributed across age groups. In this study, we have used two different standard populations- GBD World Standard population (WSP)-2017 and European Standard population (ESP) of 2013.

Methods:

The number of DALYs in Ireland were derived from the burden of disease study. They were extracted according to five year age groups and sex. The age groups were as follows; under 0-1, 1-4, 5-9… 80-84, and 85 years and over.

The age group 85 years and over was created to ensure comparability across the population data from the Central Statistics office and from the GBD study. The 85 years and over age group consisted of the groups 85-89 and 90-94 merged together. The population of the Ireland were resourced from the Central Statistics Office and a three year annual average across 2015 to 2017 were calculated (by sex and five year age groups similar to that from the GBD study).Then two different standard populations were used for calculation- GBD WSP 2017 and ESP 2013. The crude rate was calculated by dividing the total number of DALYs by the Irish three year annual average 2015-17. This crude rate was then further standardised using the GBD WSP and ESP to validate the changes in the DALY rates in the age groups.

RESULTS

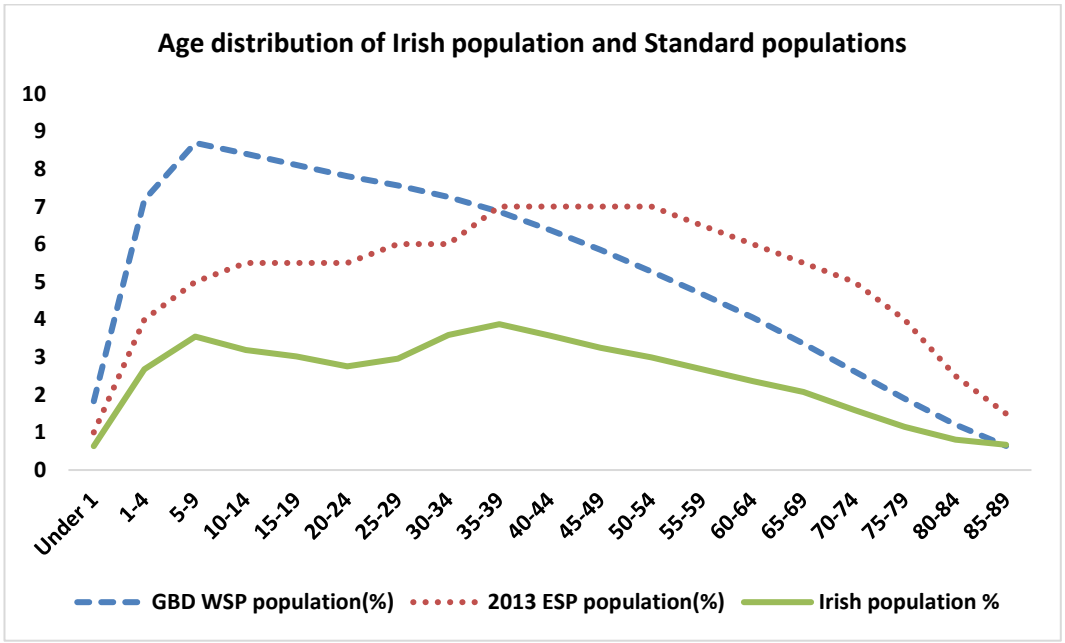
The graph below shows the overall general distribution of the population that have been selected for this study- namely the Irish population average across three years from the Central Statistics office, the GBD WSP 2017 and the ESP 2013.

Below is the figure 6.4 showing the distribution of the ESP and GBD WSP.

AGE GROUP	GBD WSP POPULATION (%)	2013 ESP POPULATION (%)
UNDER 1 YEAR	1.83	1
1-4 YEARS	7.18	4
5-9 YEARS	8.69	5
10-14 YEARS	8.4	5.5
15-19 YEARS	8.1	5.5
20-24 YEARS	7.81	5.5
25-29 YEARS	7.56	6

30-34 YEARS	7.25	6
35-39 YEARS	6.86	7
40-44 YEARS	6.38	7
45-49 YEARS	5.85	7
50-54 YEARS	5.27	7
55-59 YEARS	4.68	6.5
60-64 YEARS	4.06	6
65-69 YEARS	3.36	5.5
70-74 YEARS	2.63	5
75-79 YEARS	1.9	4
80-84 YEARS	1.21	2.5
85 YEARS AND OVER	0.98	2.5

Figure 6.5



The four graphs below show the comparison of DALYs from selected NCDs from GBD and age adjusted DALYs using WSP and ESP. *DALYs used in the figures are crude unadjusted DALYs.

Figure 6.6

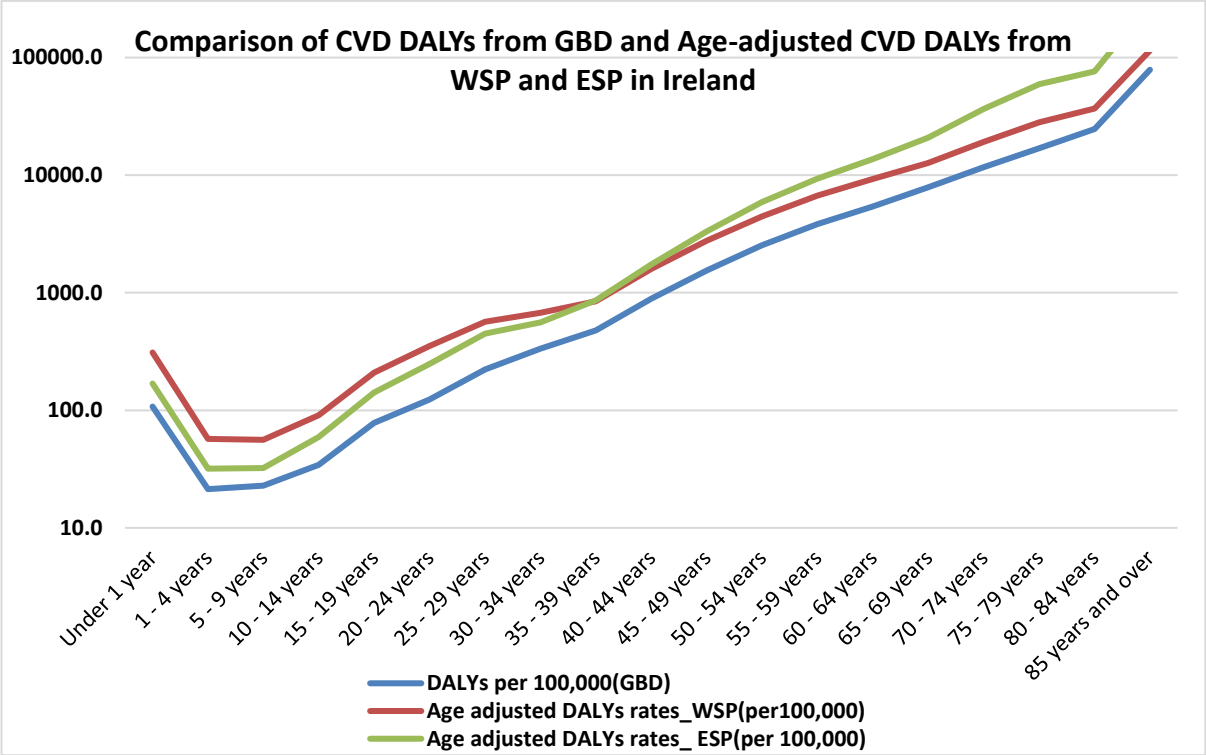


Figure 6.7

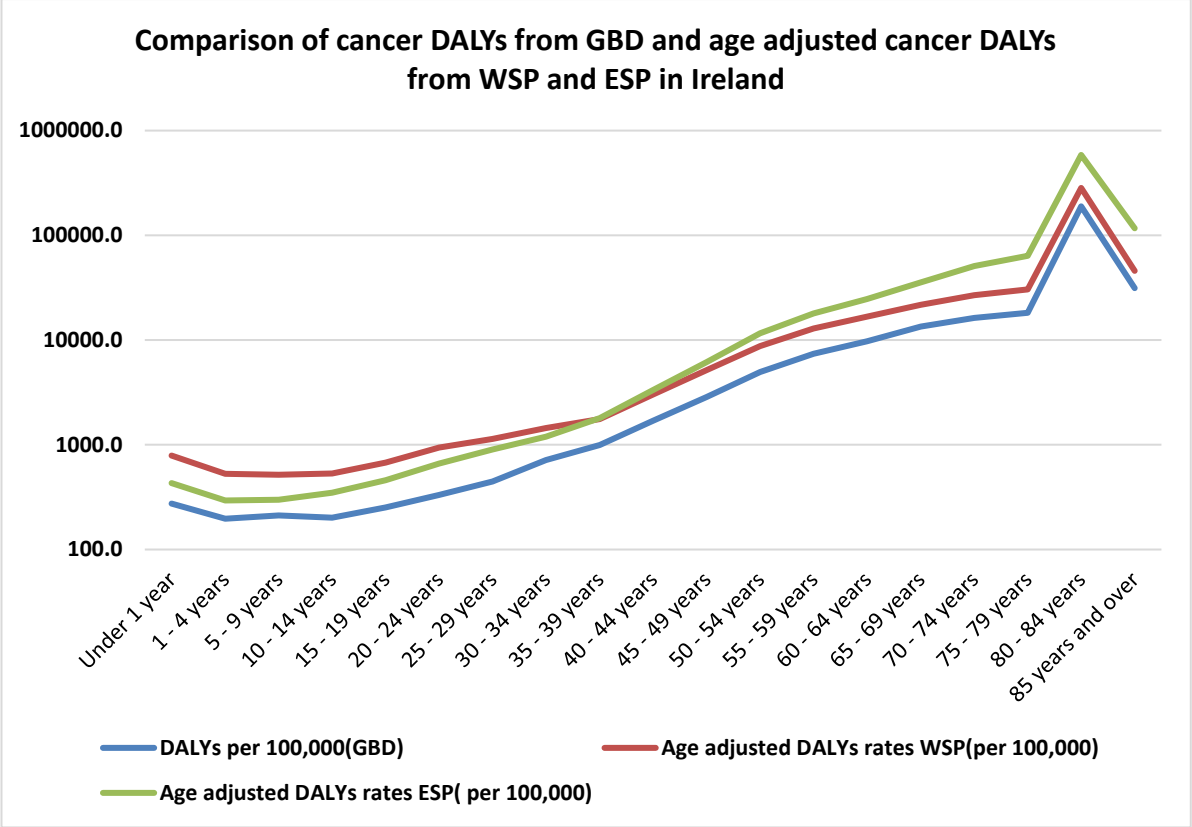


Figure 6.8

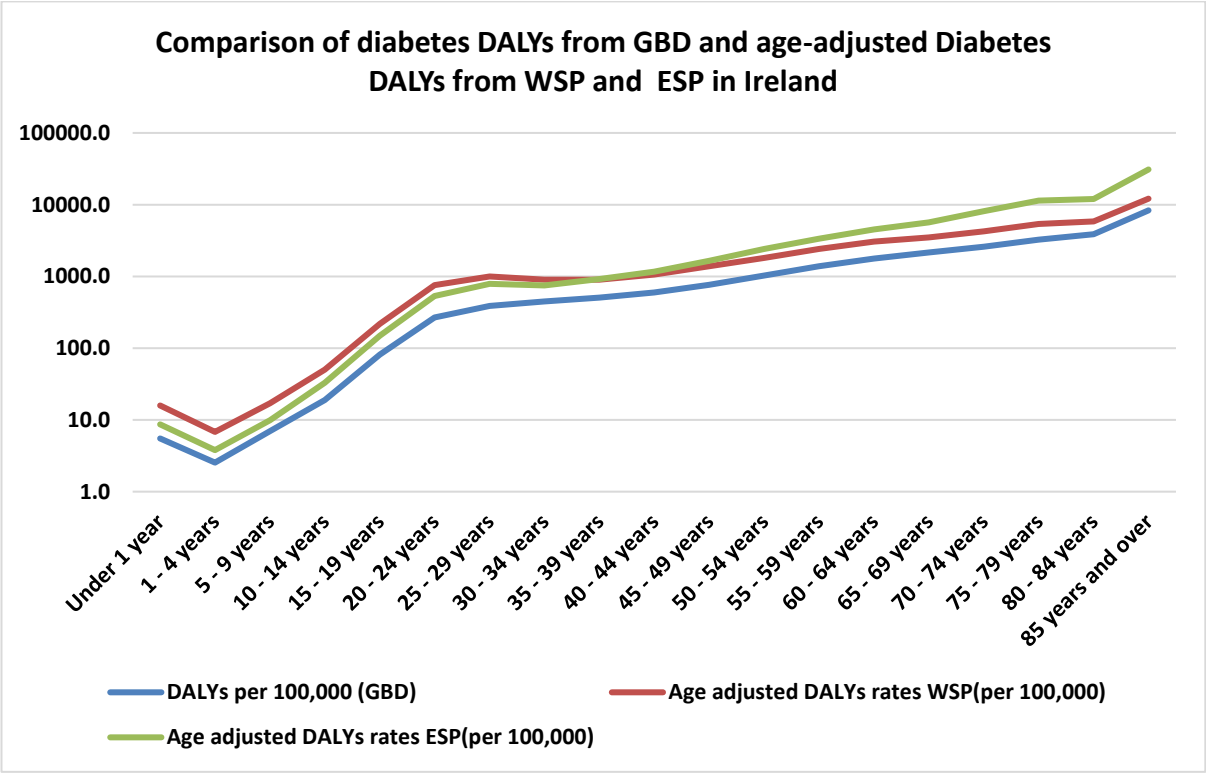
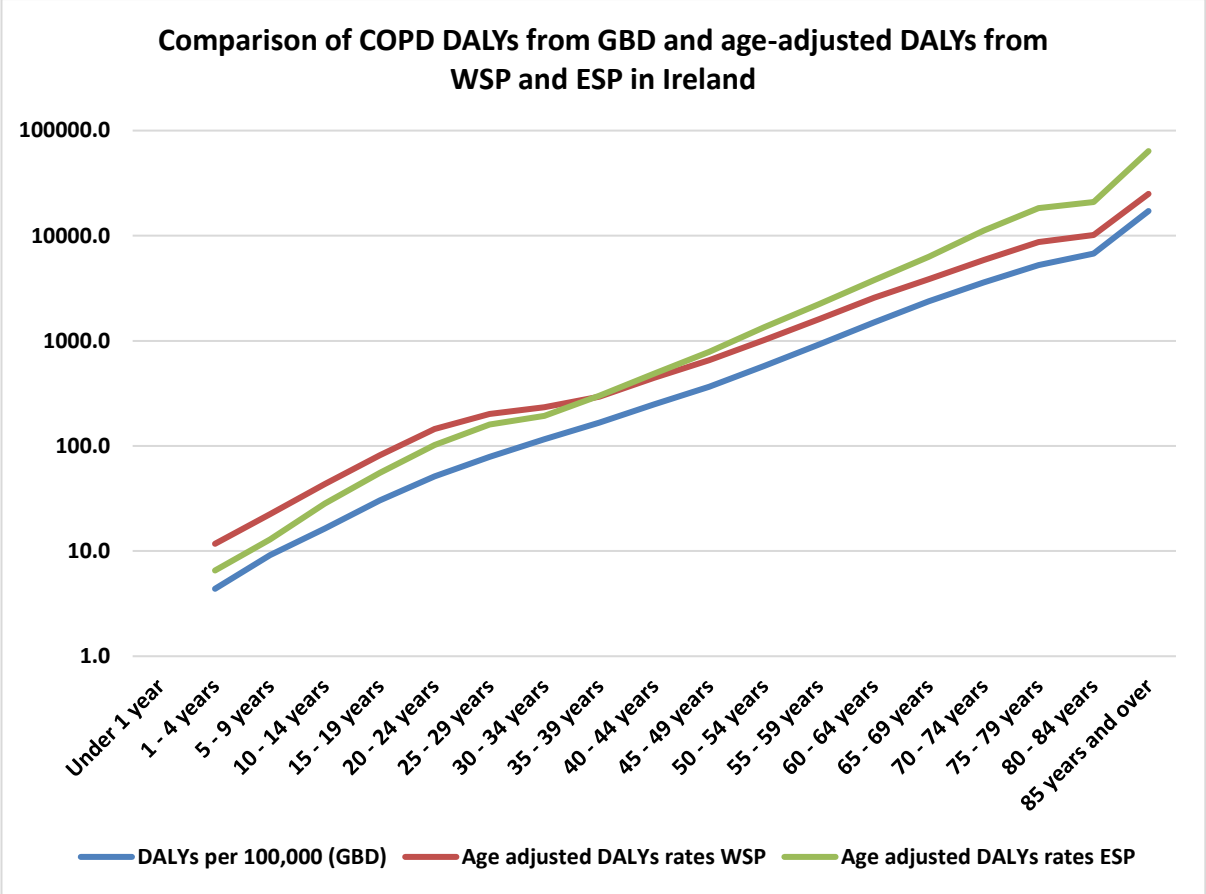


Figure 6.9



Conclusion

Choice of standard population can alter the values of DALYs per 100,000 in a nation. This can also affect the way the DALYs are ranked in a particular country. Although GBD had used WSP as a standard population, ESP is a better choice in terms of standard population for Ireland. The graphs above showed that for all the NCDS, the DALYs per 100,000 varied significantly and depended on the choice of standard population.

On most of the occasions, it is observed that the GBD results are close to the Irish national estimates in terms of deaths, risk factor prevalence etc. It is observed that although some results correspond well to the GBD study, significant differences are

observed in the DALYs per 100,000 and largely dependent on the choice of standard population. In this study we focussed only on the four NCDs, however if we estimate the variation from the choice of standard population for all NCDs, the ranks of the diseases could changes. This difference in the ranking could be misleading. It is thus important to have a national burden of disease in Ireland where these important factors can be taken into account in the calculations.

CHAPTER 7: Future burden of NCDs in Ireland [81] [76]

7.1 Introduction

In the earlier chapters we have quantified the past burden of NCDs and related risk factors during the time period 1990-2017, however it is important to also understand the future trends. These trends can help in introduction of effective preventive strategies for risk factors and diseases. This section will focus mainly on the forecasted health scenarios of the selected NCDs and the related risk factors and the life expectancies for 2040.

For this part of the research, the GBD foresight tool was used to estimate life expectancy, years of life lost (YLLs), overall cause specific mortality and all-cause mortality. It also used reference and alternative scenarios to quantify the changes. These scenarios were reference, better and worse. The predictions were made for 2040. Such health-related forecasts contribute to effective planning, prevention strategies at a national level and allocation of investments in the high priority areas. The health conditions and overall health scenario in a country can improve but such improvements are only possible when there is appropriate action, resources and attention to health drivers.

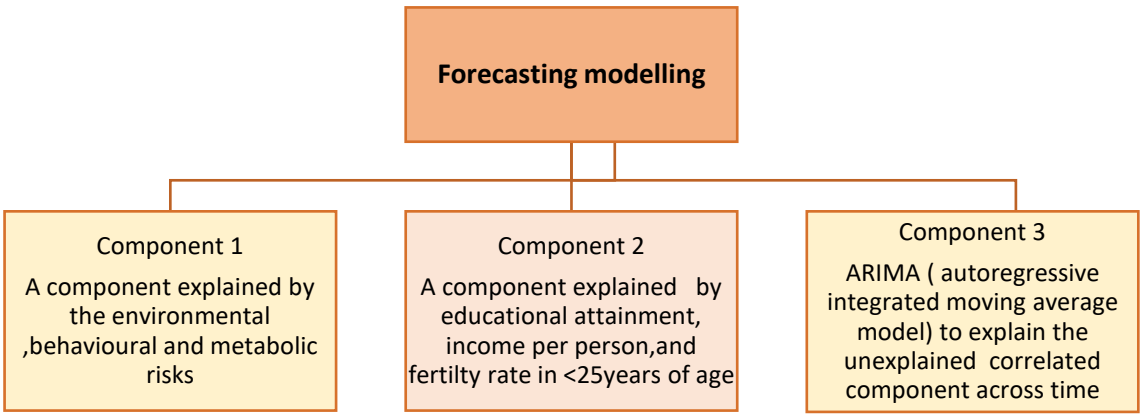
7.2 Methods

GBD forecasting model

The GBD forecasting methodology allows for robust modelling for the future trajectories in health, life expectancies, and years of life lost and cause of death

forecasting. They also considered alternative scenarios (worse future scenario, better future scenario and current reference scenario).

The GBD study group modelled 250 causes and groups using the GBD hierarchical structure from the years 1990 to 2016 to predict the future scenarios from 2017 to 2040. A three-factor model of cause specific mortality was used in the forecasting modelling. Below is the flowchart showing the three-factor model. This was the kind of prediction study which was used to forecast a set of all-cause mortality and cause-specific mortality and some related indicators which used a framework that allowed exploring a wide range of scenarios for many risk factors.



Component 1 is the main component of the modelling process and it considers the prevalence of the risk factors used in GBD 2016 and the relative risks between the levels of exposure to the risk factor and the related outcome. It also considered different intervention strategies used in the GBD study.

Component 2 focussed on the relationships between variations in the different causes of death which could not be explained by intervention and strategies to three variables which measures overall development. These 3 variables are

- ✓ income per person
- ✓ level of education in age groups ≥ 15 years
- ✓ Total fertility rate(TFR) in age ≤ 25years

These three factors are highly collinear and thus a combined measure called the SDI was used. For the two above mentioned components, the following relationship was considered by the GBD group. The log of the total cause specific mortality was modelled as a sum of mortality captured by a secular trend, the SDI, and a scalar component which includes the effects of different interventions.

The third component was the ARIMA model. This model was used to capture variation across time periods where the first two components couldn't. The trends were forecasted using an ARIMA model. The forecasting method had three different conditions- reference scenario, better scenario and worse scenario.

Reference scenario represents the most probable future trajectory that is based on the past trends of the health conditions in a country. This is the most likely situation that would occur in a nation if the past trends and patterns continue. There were also a better and worse scenario in the trajectories. In the better scenario, pace of change for each of the independent drivers was changed to the 85th percentile of rates of change observed in the past across different locations and years. This is not a very feasible situation, instead a very hypothetical scenario but it does

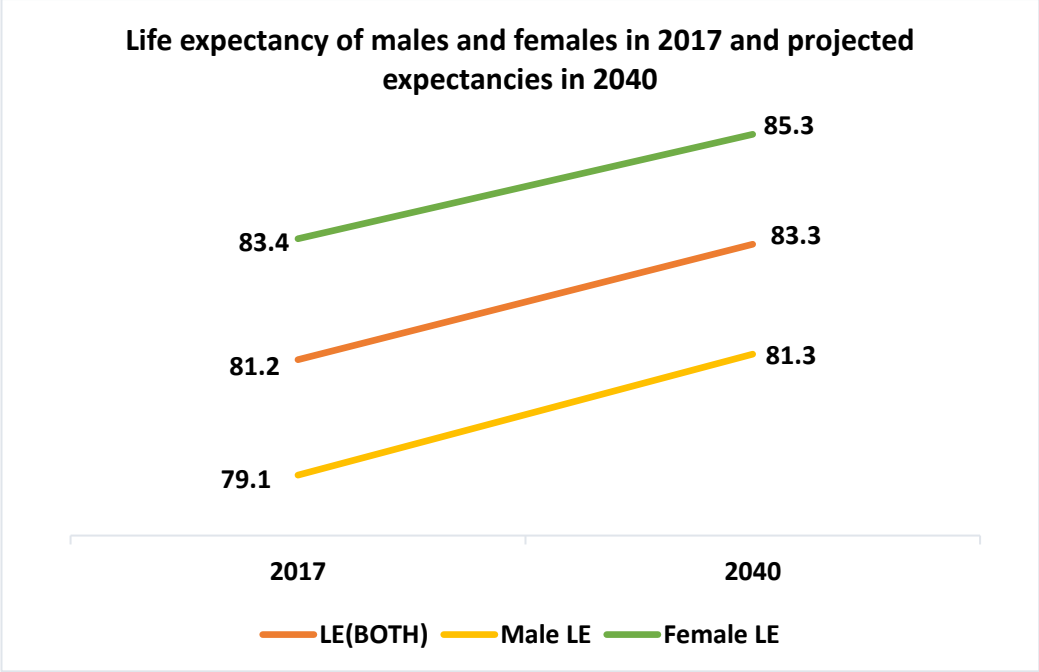
provide an upper bound as to what can be achieved by a country. A worse scenario is constructed using 15th percentile of the rate of change.

In order to measure the future burden of the top ranking risk factors in Ireland, the potential years of life lost averted by reduction in the exposure to the risk factors was calculated. This was done by finding the difference between the *2040_reference* and *2040 _better* where *2040_reference* is the future trend based on the previous health scenario and *2040_better* was based on the future trend based on improvements in the health scenarios.

7.3 Results

The annual percentage change in the life expectancy is 0.21%. In Ireland, life expectancy is expected to increase by 2.07 years between 2017 and 2040, but in case lesser progress occurs, LE will decrease by 0.7 years for males and by 0.4 for females and in case more progress occurs, LE will increase by 3.5 years for males and by 3 years for females.

Figure 7.1



*LE is expected to ⬆ by **2.07 years** between 2017 and 2040*

*In case lesser progress occurs, LE is expected to ⬆ by **0.7 years for males and** by **0.4 for females** and*

*In case more progress occurs, LE is expected to ⬆ by **3.5 years for males** and by **3 years for females.***

Similar to LE, the deaths and YLLs would differ in 2040. The tables below will show the forecasted change in health scenarios in Ireland. Figures 10.2 and 10.3 below shows the leading causes of death rates (per 100,000) and leading causes of early deaths (YLLs) in the ROI in 2017 and 2040. The deaths from the selected NCDs attributed to selected risk factors would have also changed during the time period 2017 and 2040. These figures are based on the reference scenario. The total deaths from the NCDs is expected to show declines in 2040 (365 per 100,000) when compare to 2017 (445 per 100,000).

Figure 7.2 shows the leading causes of death in 2017 and 2040

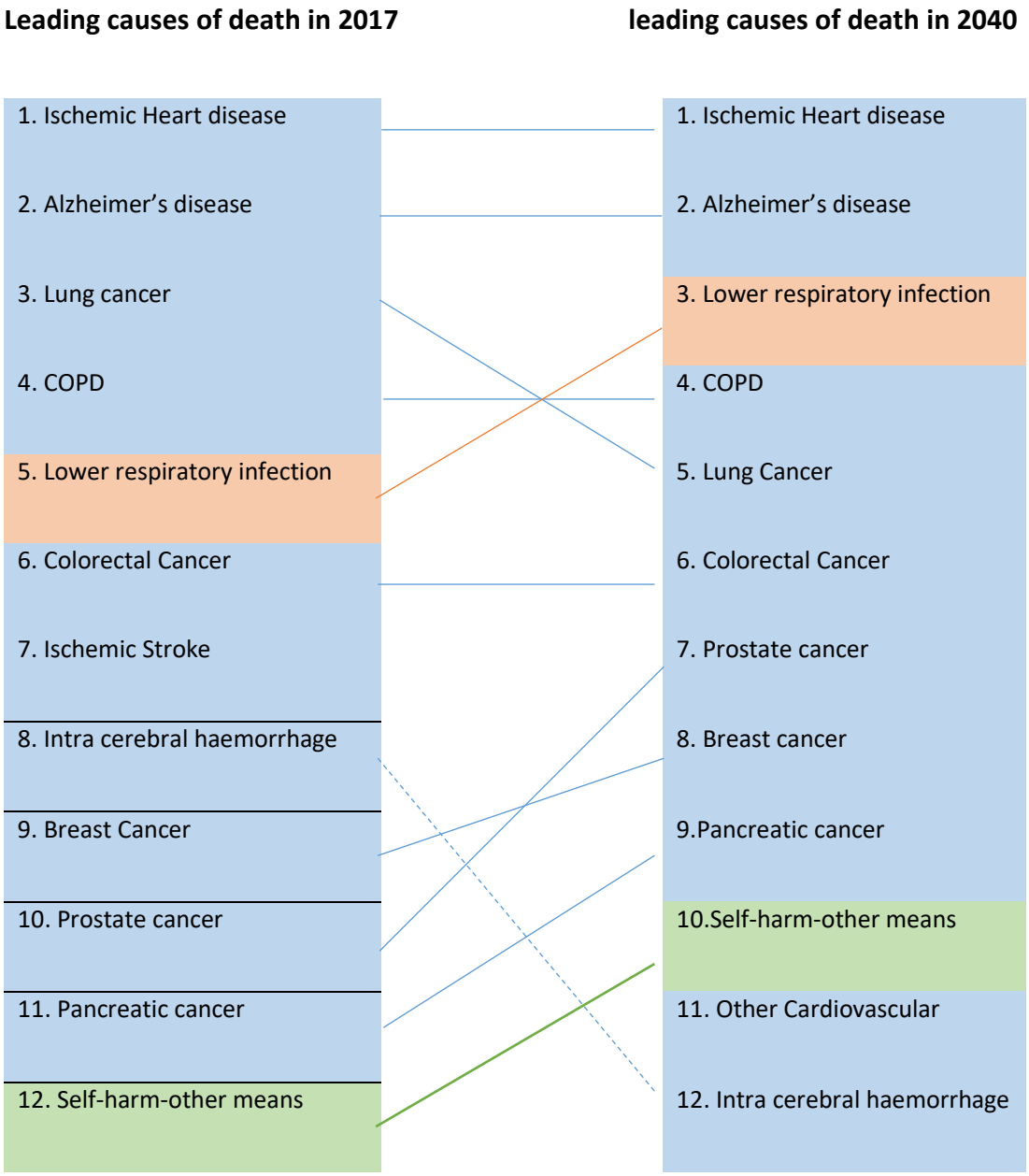


Figure 7.3 shows the leading causes of early deaths (years of life lost) in 2017 and expected YLLs in 2040 for both sexes combined.

Figure 7.3

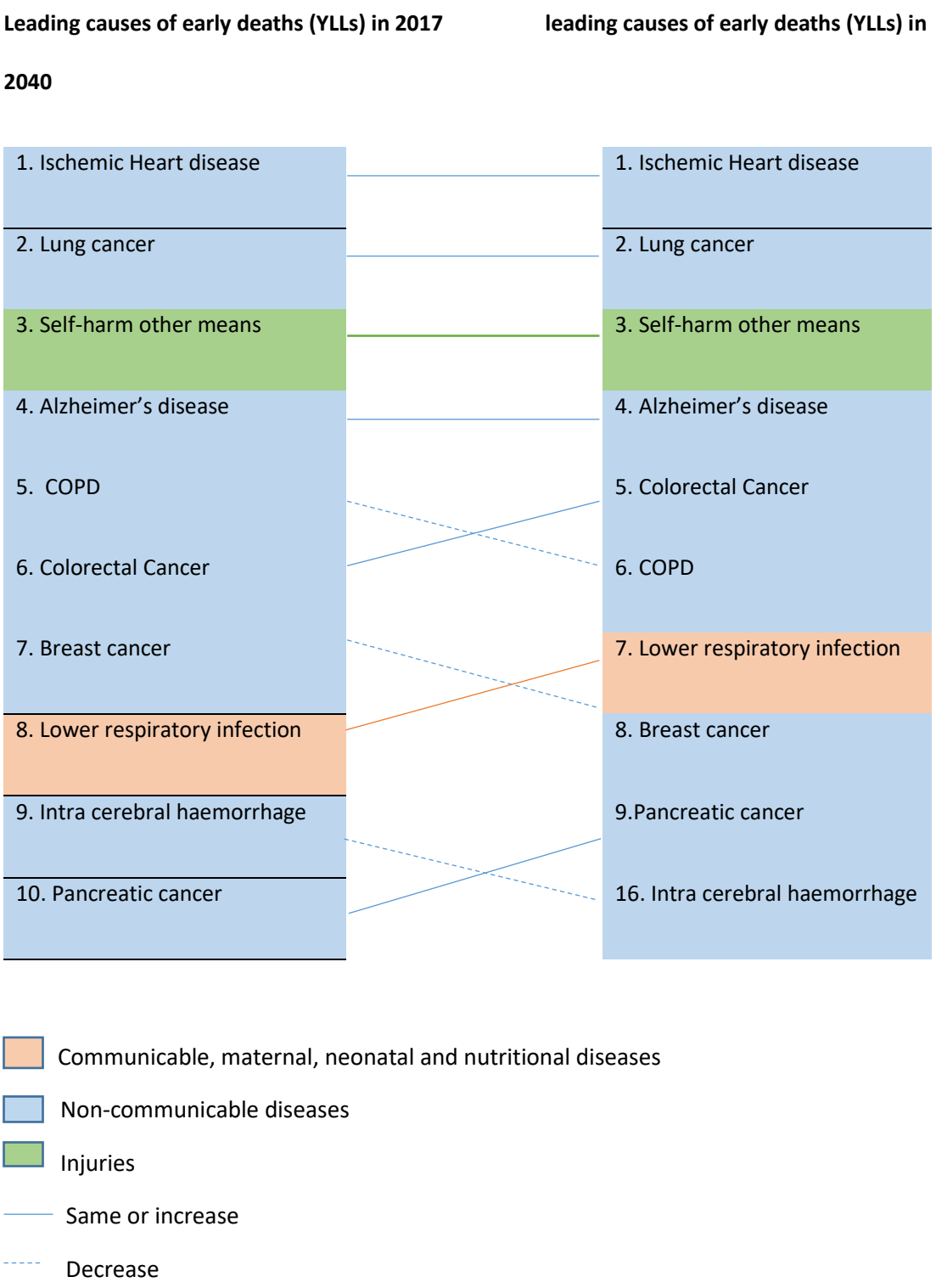


Figure 7.4 and 7.5 shows the top ten leading causes of deaths from risk factors and leading causes of early deaths (YLLs) from risk factors in Ireland in 2017 and 2040.

Figure 7.4

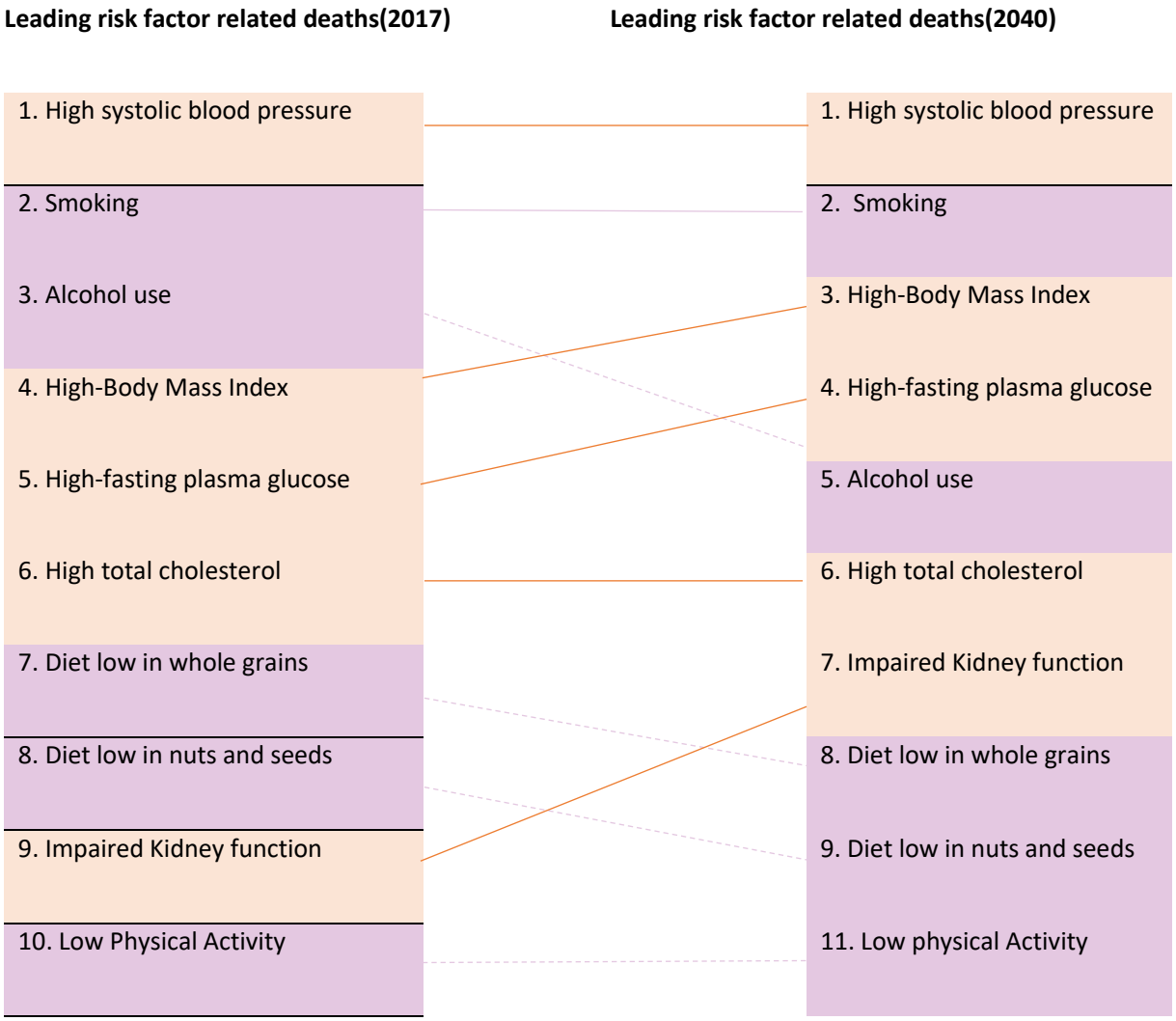

Leading risk factor related deaths(2017)
Leading risk factor related deaths(2040)
1. High systolic blood pressure
2. Smoking
3. Alcohol use
4. High-Body Mass Index
5. High-fasting plasma glucose
6. High total cholesterol
7. Diet low in whole grains
8. Diet low in nuts and seeds
9. Impaired Kidney function
10. Low Physical Activity
1. High systolic blood pressure
2. Smoking
3. High-Body Mass Index
4. High-fasting plasma glucose
5. Alcohol use
6. High total cholesterol
7. Impaired Kidney function
8. Diet low in whole grains
9. Diet low in nuts and seeds
11. Low physical Activity

Figure 7.5

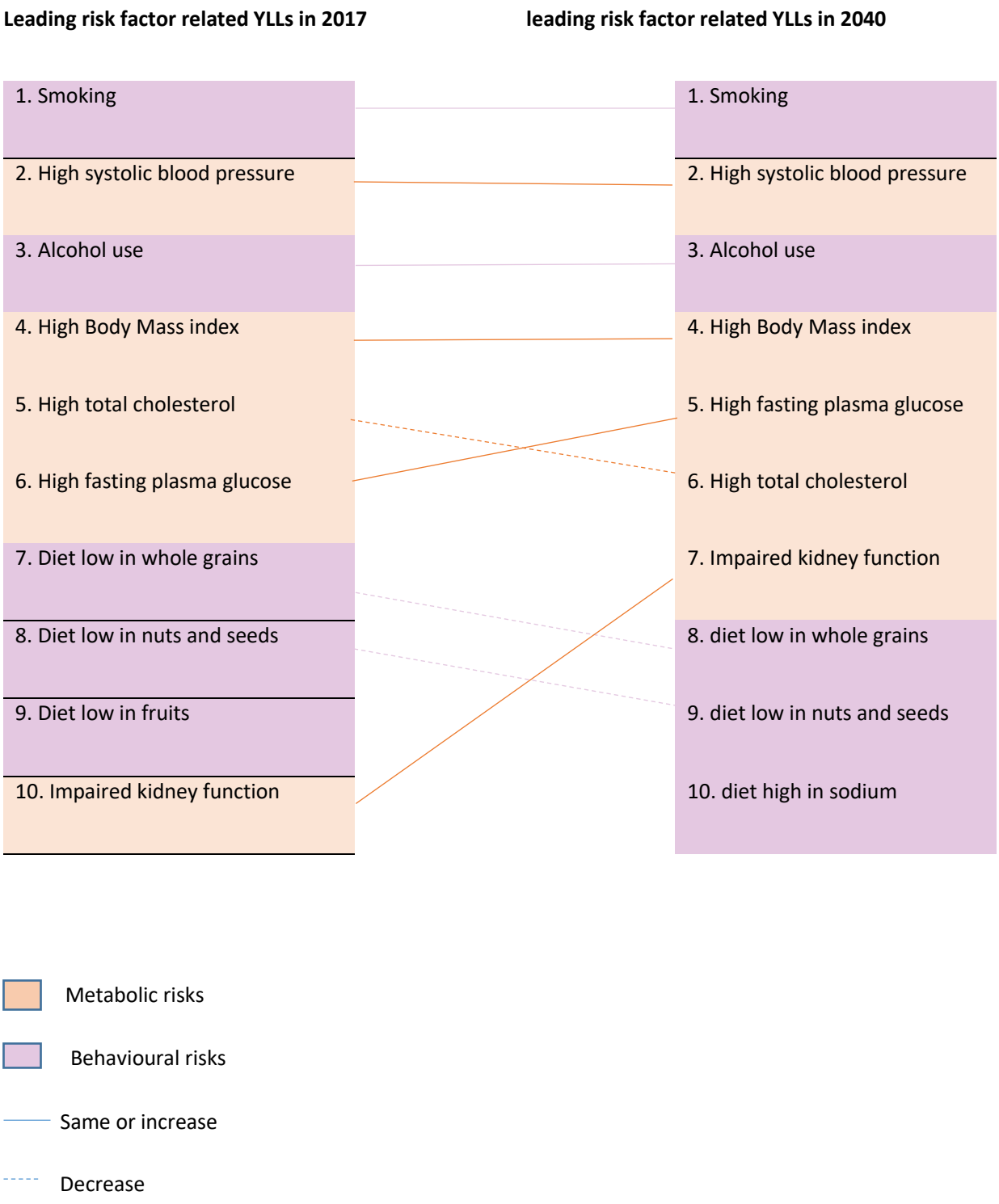
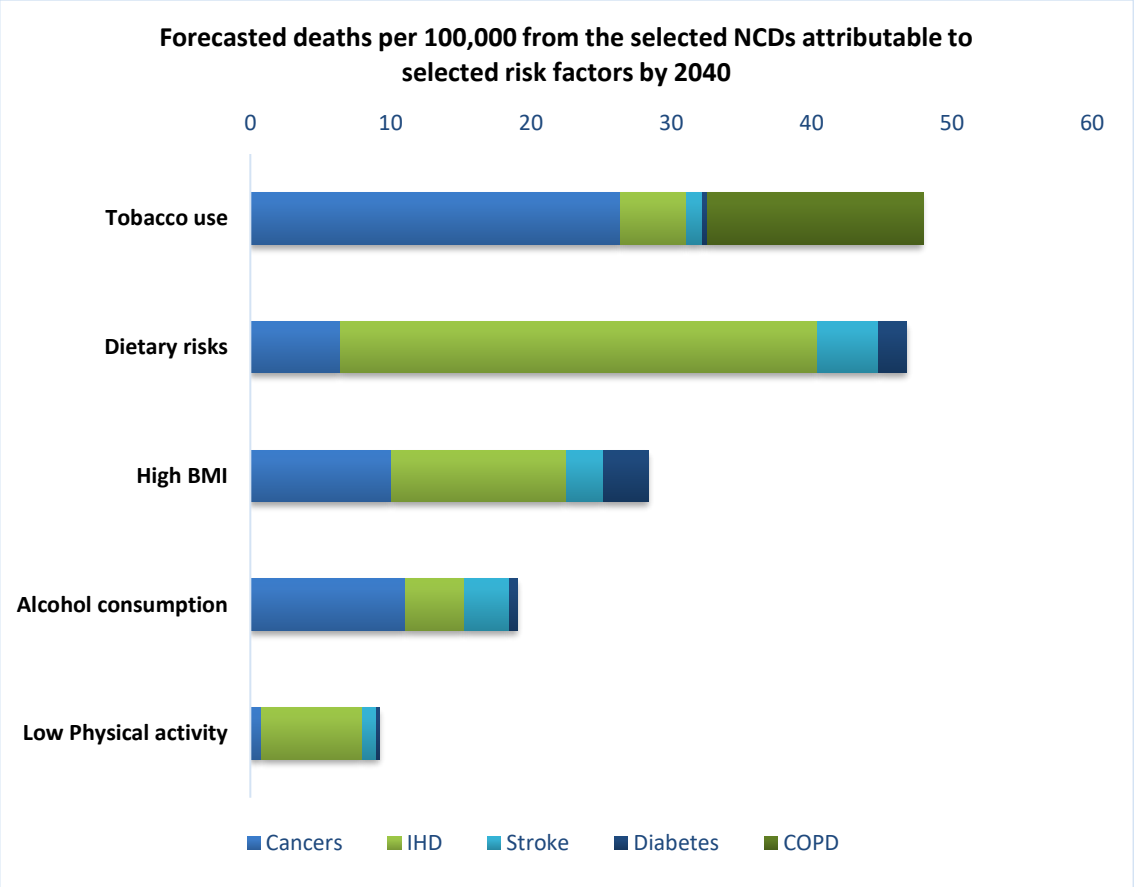
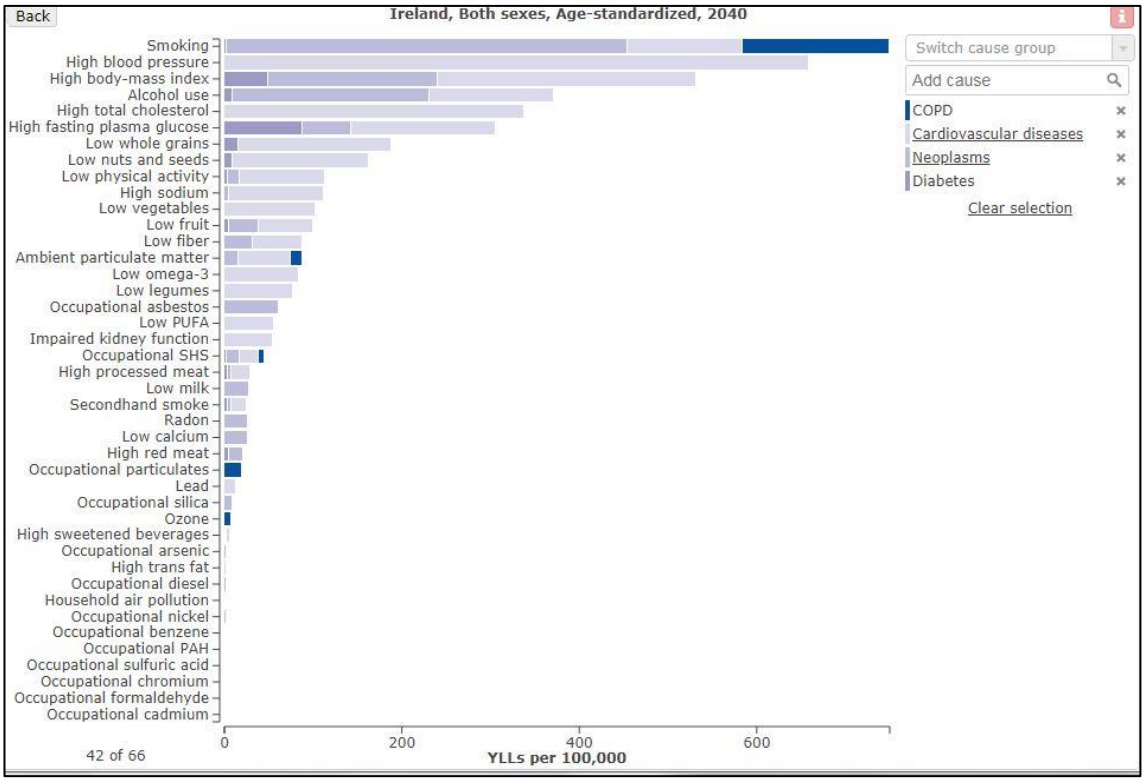

Leading risk factor related YLLs in 2017
leading risk factor related YLLs in 2040
1. Smoking
2. High systolic blood pressure
3. Alcohol use
4. High Body Mass index
5. High total cholesterol
6. High fasting plasma glucose
7. Diet low in whole grains
8. Diet low in nuts and seeds
9. Diet low in fruits
10. Impaired kidney function
1. Smoking
2. High systolic blood pressure
3. Alcohol use
4. High Body Mass index
5. High fasting plasma glucose
6. High total cholesterol
7. Impaired kidney function
8. diet low in whole grains
9. diet low in nuts and seeds
10. diet high in sodium
Metabolic risks
Behavioural risks
Same or increase
Decrease

Figure 7.6



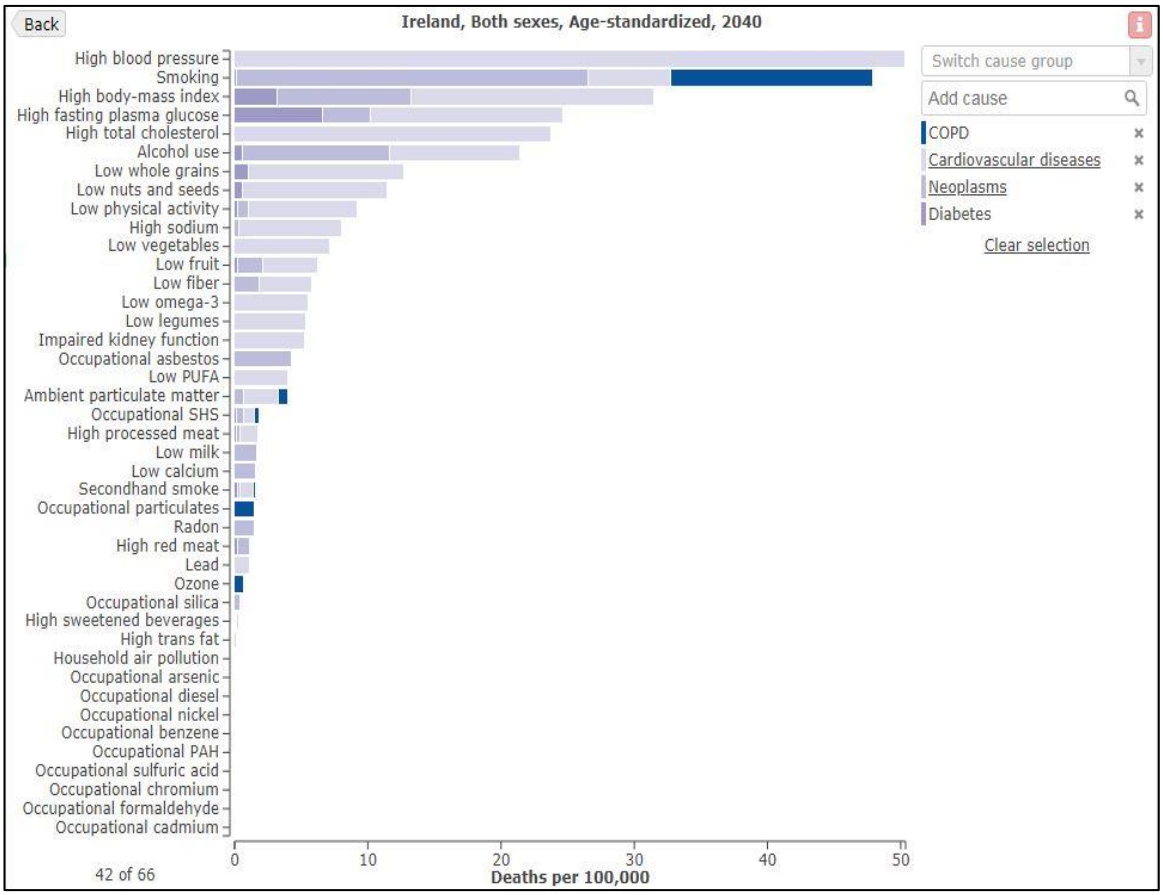
The figure above shows forecasted deaths attributable to risk factors by 2040. Deaths per 100,000 from cancer was highest from tobacco use. Deaths per 100,000 from IHD were highest from dietary risks. Below are the two graphs show the forecasted YLLs and deaths from the NCDs and the common risk factors.

FIGURE 7.7: Forecasted YLLs in 2040 (GBD website)



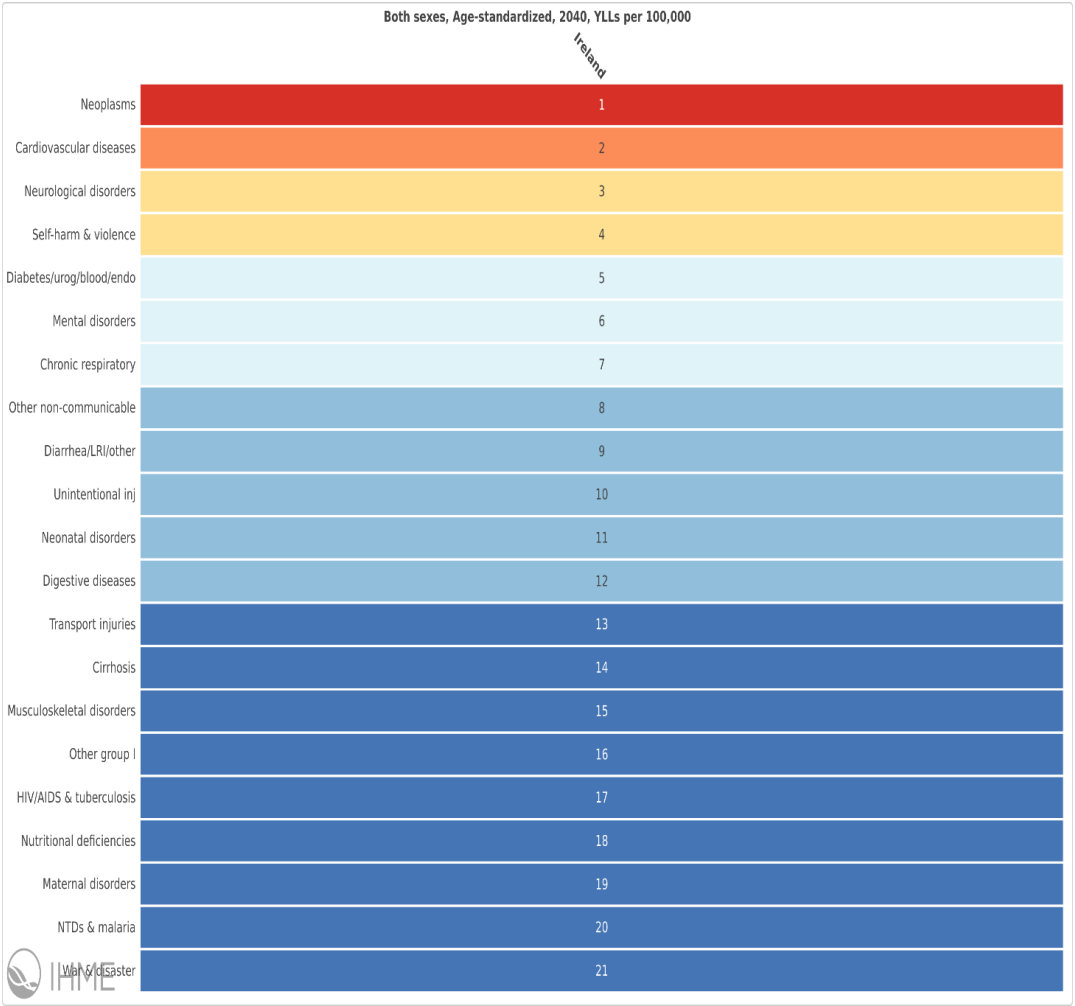
The forecasted YLLs from smoking contributed highest to cancers, followed by high blood pressure contributing to CVDs (Figure 10.7).

Figure 7.8 Forecasted deaths in 2040 (GBD website)



The forecasted deaths in Ireland were highest from high blood pressure causing CVDs and smoking causing cancers (Figure 7.8).

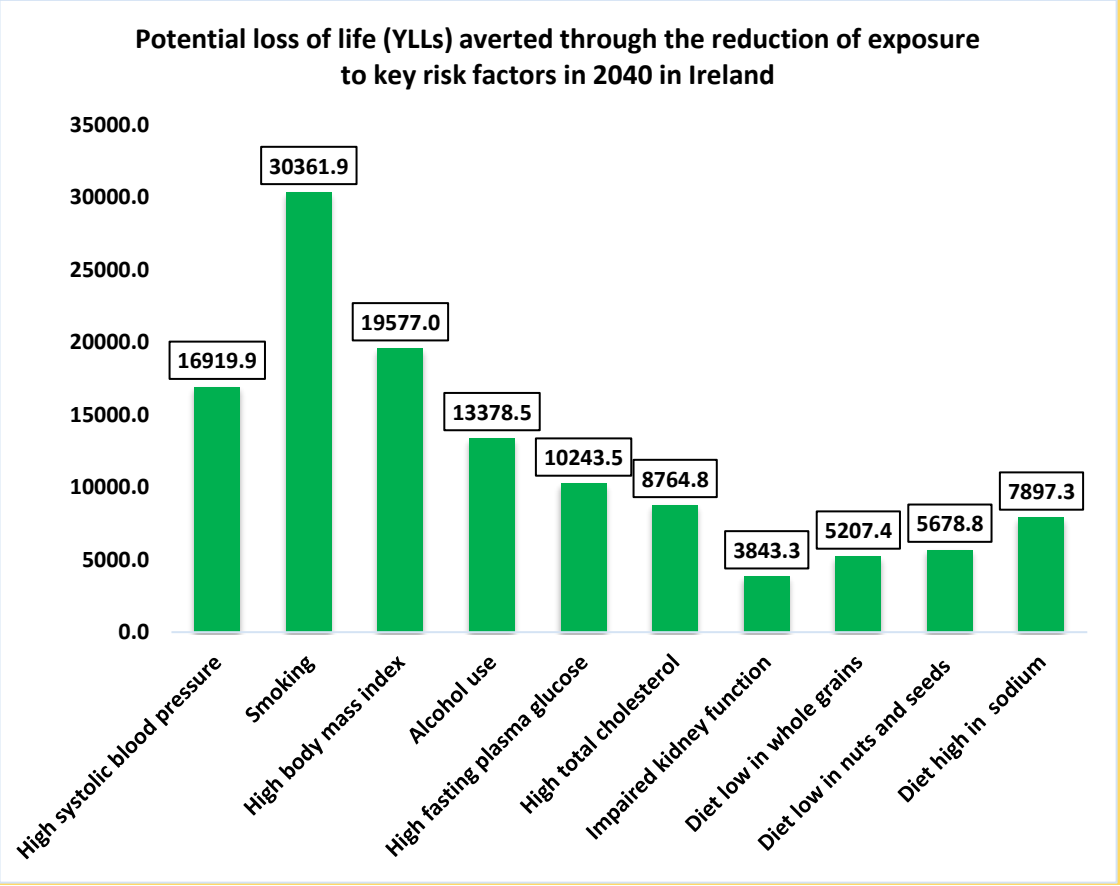
7.9 Ranks of diseases expected in 2040 in Ireland



Cancers contribute to highest YLLs followed by CVDs and then by neurological disorders. The graph below shows the potential years of life lost that could be averted by reducing the exposure to the important risk factors in 2040. This table below compares Ireland with that of the Western European countries in terms of NCD deaths in 2040. Ireland is expected to have higher deaths from NCDs as compared to the average of the Western European nations.

The graph below (Figure 10.10) shows the potential years of life lost that could be averted by reducing the exposure to the important risk factors in 2040

Figure 7.10



7.4 Conclusion

There is substantial scope for improvement in risk factors (reduction) and years of life lost especially for risk factors like smoking, high BMI, alcohol use and high BP. Cancer and CVD is expected to be the top diseases for YLLs and thus risk factor intervention for those that are known to be associated with these diseases should be monitored more closely. This work can be particularly relevant for policy makers

for future planning of the Irish health services. This can contribute to the appropriate allocation of resources and funding. It is observed that NCDs are on the path to top the list of diseases and would be the highest burden causing disease in Ireland in 2040. These kinds of future predictions or projections of health care scenario-disease related or risk factor related are crucial for the initiation for long term preventive strategies, implementation of population level interventions of stricter regulations on the consumption of any of the common risk factors like tobacco, alcohol etc.

CHAPTER 8 Discussion

It is crucial for any nation to quantity its national burden of disease and injury and the contribution of risk factors to this disease burden. This could contribute to formulating its policies and preventive strategies. Most of the preventive measures are based on an appropriate evidence base which is derived from appropriate health outcomes arising from population level studies. The GBD study was the first of its kind to bring global attention to diseases, health outcomes, risk factors which required more attention than the others. Appropriate allocation of limited health resources towards the more alarming health concerns is necessary. A number of countries have utilized the publicly available data from GBD to produce national level estimates of population level health metrics. Furthermore some nations like the UK, India, Brazil, and Mexico have also conducted sub-national estimations of the burden of diseases, injuries and risk factors in collaboration with GBD group. It is thus critical to understand the methodology, assumptions and interpretations of the data that are used, visualization tools and the estimates that are published.

The United Kingdom (more specifically Public Health England) along with IHME assessed their health conditions, diseases and risk factors in comparison to other countries. This study gave UK the insights it needed to check its performance and its rank in terms of health and disease conditions in comparison to other countries.

Similar studies in Greece also brought national attention to areas of concern like areas with increase in deaths and a rapid rise in the YLDs. Such estimates not only provide information about the current health scenarios in a country but also help in understanding future health conditions.

Ireland has had different population level studies focussing on different diseases and risk factors. However, the GBD study is unique in its own terms- it not only provides information on diseases and risk factor burden for different time periods but also provides them in terms of a universal metric DALY which helps in comparison of health conditions and benchmarking of the Irish estimates with other nations. There is no such study in Ireland which has collated the evidence from the GBD data on the burden metrics of NCDs and their related common risk factors till date. This work also projected the expected health conditions in Ireland, LE in 2040, disentangled the effects of potential drivers of change, the annual income in terms GDP per capita that was lost from the burden and also cross validated some of the GBD results with that of the national datasets. These results could play a vital role in spurring further research on the health challenges of the Irish population in the current years and the future.

EU burden of the NCDs

The burden of NCDs across the globe is still significantly high and the same is the case with the EU. In fact, the EU has shown an increase in the overall deaths with an excess of 0.32 million deaths during the time period 1990-2017.

There are approximately 4.75 million deaths and about 129.2 million DALYs from the NCDs in the EU. Ireland ranks 11th best in the NCD related age-standardised DALYs, 2nd in the age-standardised deaths and 3rd in the age-standardised YLDs within the EU. This clearly shows that, while Ireland performs well in terms of number of deaths and YLDs, there is still a lot to be done when it comes to DALYs.

The overall LE has increased in the EU, however the increase in the HALE was lower than the LE which would imply that the additional number of years lived were not lived in full health. There was a constant gap in the male female life expectancy in the EU and the life expectancy of females was generally higher than the males. Understanding of such gender differences is very important from a policy perspective.

Except for high-BMI, NCD deaths in the EU showed declines during 1990 and 2017. This major observation about the risk factor- high BMI would be very relevant in terms of formulating health strategies to tackle obesity related problems in the ROI. Eurostat had reported that about 51.6% of the EU population (aged 18 years and above) were overweight in the year 2014. These results also help in setting obesity as an urgent priority of the government. It is important to recognise obesity as a chronic disease; however, Portugal is the only country in the EU which has done so. As a result of such detailed reporting, the European commission has been very active in raising awareness and promoting healthy and active lifestyle. Several initiatives and policies like EU Action Plan on Childhood Obesity 2014-2020 [82] and the Conclusions on Nutrition and Physical Activity, 2014 [83] have been adopted.

A part of the burden of the NCDs in the EU could be from an ageing population [84] and a growing population. However, different factors like socioeconomic status, education and demographic differences, could be responsible for the difference in the metrics in different countries. It is relevant to have a decomposition analysis to disentangle the drivers behind the burden scenario. This could increase the

effectiveness of national level efforts and improve their prospects of meeting the WHO-NCD targets.

8.1 Main findings of this study

- IHD, diabetes and stroke related death rates per 100,000 attributable to *a diet high in processed meat* and *diet high in sodium* showed increases during 1990 and 2017.
- *Alcohol* seems to be the most prominent issue currently and in the future. It is the number one killer and also the largest contributor of morbidity in Ireland
- Despite considerable effects of population growth and ageing, *diabetes* still needs stricter population level interventions and is the most neglected NCD. The risk factors predominantly responsible for increasing burden of diabetes are *high-BMI and alcohol consumption.*
- *Loss of national income* in Ireland for NCDs was (75.6 million I$) 87% of the loss in national income from all causes (86.7 million I$). The NCD that contributed to the highest loss of national income is cancer (15 billion I$).
- LE has plateaued over the years in Ireland and the future burden of NCDs. Females had a higher life expectancy and there was a constant gap in male and female HALE and LE similar to that which were observed in the EU. The overall LE has increased during 1990 to 2017 in the EU however the increase in the HALE was lower than the LE which would imply that the additional number of years lived were not lived in full health. We have observed

reversing of mortality rates in some specific age-groups, slowing down and the overall plateauing of life expectancy like that observed in the United Kingdom.

- ❖ IHD is topping the list in terms of highest number of deaths in 2040 and smoking is expected to cause the highest number of YLLs in 2040.

Some of the other important findings of this study are stated below:

1. The largest decline in deaths was from IHD attributable to *tobacco use* during the time period 1990 and 2017.
2. The overall deaths per 100,000 from the selected risk factors showed lower values in 2017 as compared to 1990 except for deaths from alcohol consumption. A closer look at the data shows that the trend had a point of change in 2010. This could be as a result of the economic recession which occurred during 2007-2008.
3. Absolute YLDs from CVD increased during 1990 and 2017.
4. In 1990, females had higher number of deaths per 100,000 from diabetes as compared to men but this trend was completely reversed in 2017.
5. YLLs from all four NCDs attributable to tobacco decreased with larger decreases for IHD and stroke.
6. Deaths from diet high in sugar sweetened beverages showed an increase per 100,000 during 1990 and 2017

8.2 Disease related main findings

1. CANCER

An effective management of cancer burden and the understanding of the pattern of underlying risk factor contributions are very relevant and useful. Cancers in Ireland contributed to 23.4% of deaths in 1990 and 31.1% of deaths in 2017. The cancers with highest deaths were lung cancer and colorectal cancer. The highest cancer deaths in males in 2017 was from lung cancer and prostate cancer and for females it was from lung cancer and breast cancer. Death and DALYs per 100,000 from cancer attributable to high-BMI and alcohol consumption showed an increase during 1990 and 2017. However cancer DALYs from all the risk factors showed an increase, which meant even though the person is living longer, he /she is living with disability from cancer. For effective control of cancer in Ireland, the function of NCCP is crucial. NCCP is the National Cancer Control Programme which was formed as a response to the second National cancer strategy which had suggested that there was a need for a comprehensive cancer control programme in the Republic of Ireland. The NCCP was set up so that cancer care could be delivered in an appropriate manner to the general population. The NCCP provided other information like the ways to reduce the chance of occurrence of cancer like reducing alcohol intake, abstinence from smoking, enjoying a healthy diet with lots of fruits and vegetables, maintaining a healthy weight, being as active as possible, breastfeeding a baby by mothers, protecting skin from sun which are also a part of the European Code against cancer [85]. Programmes like the NCCP also provide information on screening of cancers like Breastcheck [86], Cervicalcheck [87] and

Bowelscreen [88] in Ireland conducted by the National screening service to the Irish population. Cancer also caused the highest income loss out of all the NCDs (15million I$).

2. Cardiovascular Diseases

More people around the world die annually from CVD than any other disease. Thus, quantifying the burden of CVD from the related risk factors in Ireland over the years was important. The CVD related DALYs per 100,000 from tobacco use showed declines during 1990 and 2017. CVD related YLDs from a diet high in sodium and a diet high in processed meat contributed to increase in YLDs. Thus it is important to have stricter policing on processed meat and sodium. National Cardiovascular Health Policy 2010-2019 by the Ministry for Health and Children provided a policy framework for preventing, detecting and also treatment of CVD in Ireland.

3. Diabetes

Diabetes is known to be a major cause of heart disease, stroke etc. and was the seventh leading cause of death in 2016 around the world. The death rates per 100,000 from diabetes declined during 1990 and 2017. However, in 1990, women had higher number of diabetes deaths per 100,000 as compared to men but this trend was completely reversed in 2017. Policies such as Diabetes Ireland: 5 year strategy 2016-2020 are useful for tackling diabetes in the island of Ireland.

4. COPD

A majority of the COPD related deaths, DALYs and YLDs are attributable to smoking. Smoking has been established to be a major causative factor for COPD. In Ireland

the death rates and DALYs from COPD attributable to tobacco use declined during 1990 and 2017, however the years lived with disabilities increased. National Clinical guidelines on COPD are also crucial to tackle COPD in Ireland.

8.3 Risk factor related main findings in Ireland

1. Tobacco use

Tobacco use is one of the major risk factors around the globe. The death rates, YLDs and DALYs from the selected NCDs attributable to tobacco use showed a declining trend during 1990 and 2017. The largest decline in deaths was from IHD attributable to tobacco use. This decline in burden metrics from tobacco use could be attributed to the strict tobacco policies in Ireland like the Tobacco Free Ireland policy which had set a target to make Ireland to reduce the prevalence of smoking to 5% by 2025. Furthermore work place smoking ban, reduction in advertising the smoking products etc. accelerated the decline in the tobacco related metrics in ROI between 1990 and 2017.

2. Alcohol consumption

Alcohol consumption is one of the significant risk factors which has affected Ireland throughout the 37 year period .The death rates, YLDs and DALYs from most of the selected NCDs attributable to alcohol consumption showed increasing trend during 1990 and 2017. It is thus important that strict laws and policies be implemented for alcohol consumption in ROI just like the strict policies on tobacco smoking. It is important to develop a policy to reduce alcohol consumption and related harms.

The National Substance Misuse Strategy introduced by the National Substance Misuse Steering Group which suggests comprehensive and wide range of policy measures in order to reduce the consumption of alcohol in Ireland to 9.1 litres per person per year (the OECD average) by 2020. The current high level of consumption of alcohol which is 11.46 litres per person per year. Another major development in controlling the consumption of alcohol in Ireland is the Public health (Alcohol) Act, 2016 which contain some evidence based measures like minimum unit pricing to be introduced at about 10cent per gram of alcohol, control the style of advertisement of alcohol products, labelling methods and other measures. It is necessary for Ireland to have a minimum unit pricing of alcohol like that of Scotland which also analysed the post effects of introducing this legislation and found that the consumption of alcohol went down by 3.6% in 2018.

3. Low physical activity

Apart from the other risk factors, low physical activity has been a silent risk factor. Higher physical activity levels is linked to a reduction in chronic diseases like cancer, IHD, stroke etc. The World Cancer Research fund has stated that there is substantial evidence to show that an increase in physical activity lowers the risk of colon cancer. Almost about 3% of colon cancers can be attributed to physical inactivity (NCRI risk factors report).

DALYs attributable to low physical activity showed declines during 1990 and 2017 except for diabetes related DALYs. By increasing physical activity, it is possible to improve the overall nutrition, reduce alcohol use, drug use and tobacco use, and increase social interaction. The National Guidelines on Physical Activity for Ireland

formed basic action points to increase the overall physical activity levels by emphasizing the importance of physical activity on health and providing the recommended physical activity levels for different ages. The recommended amount of physical activity for an adult (aged 18-64 years) is 30 minutes of moderate activity for 5 days a week (150 minutes in a week).

4. High BMI

High BMI has been a significant health risk to individuals. In Ireland, death rates per 100,000 from IHD and diabetes declined but increased for cancers during 1990 and 2017. High BMI continues to be a serious risk factor especially in its contribution to cancer. Effective BMI control or preventive strategies need to be in place to tackle the cancer burden from high-BMI. In order to control the rising issues with high BMI, in particular obesity, a new action plan to tackle obesity was introduced by the Department of Health in 2016- A Healthy Weight for Ireland - Obesity Policy and Action Plan 2016- 2025. This action plan has about 60 actions to control and reduce the burden of obesity and improve the overall health of the people of Ireland. A few of the important directives of this action plan is to develop a nutrition policy, support the SSDT, calorie posting legislation. The burden of diabetes and cancer has been on the rise (attributable to BMI). This is a cause for concern as cancers accounts for a large amount of income loss in Ireland. It is also interesting that on disentangling the drivers of burden change, it was observed that diabetes needed for effective management and intervention, which could only be possible by appropriate management or these risk factors –mainly high BMI and alcohol consumption.

5. Dietary Risks

1. ***Diet high in processed and red meat***: According to the IARC, processed meat is declared to be a definite cause of cancer (i.e. a group I carcinogen). A study at the University of Oxford suggested that a price hiking meat tax was the only way out to bring about an overall control in processed and red meat intake. According to NANS data, males and females consume about 42.7grams and about 23.9 grams of processed meat per day in Ireland.
   A recent publication by World Cancer Research Fund stated that there is an almost 13% increased chance of developing colorectal cancer with a 50grams per day increase in the consumption of processed meat in Europe.
   A tax like that of the sugar sweetened beverages needed to be put in place for processed meat in Ireland too. The tax levels for the processed meat and red meat was suggested by this study for different countries- an effective tax in Sweden would be 185% for processed meat and 27% for red meat, an effective tax in the UK would be 79% for processed meat and 14% for red meat and an effective tax in the Republic of Ireland would be 80% for processed meat and 12% for red meat [89]. Such strict regulation or taxations by the government is the only way to bring the consumption of processed meat under control. This type of high consumption of red or processed meat not only affects personal health but also the healthcare systems which are many times funded by the taxpayers in some countries. Higher taxes on these meats would definitely mean switching to healthier alternatives and

thus indirectly reducing the burden on the economy, health care system and improving one's own health.

2. ***Diet high in sodium***: In terms of understanding the health threats, a diet high in sodium poses serious health consequences. One major drawback in understanding the sodium intake is the labelling done by the companies or stores for consumers and they should be simplified. Most manufacturers measure the level of sodium in the food item and not the salt for the labelling purposes as these figures are much lower. For example: sea water contains 1gram of sodium but 2.5grams of salt per 100 grams. In comparison to this, cornflakes and cream crackers have 1.1grams of sodium but 2.7grams of salt per 100grams. Lower salt intake would reduce blood pressure which would in turn reduce the risk of stroke or heart attack. A public health expert from Cork, Ireland had stated that a salt tax is the way forward to reduce salt intake in processed foods and snacks.

3. ***Diet high in sugar-sweetened beverages***: Deaths per 100,000 from diet high in sugar sweetened beverages increased during 1990 and 2017.Except for a diet low in fruits, all the other dietary risks showed an increase in the DALYs and YLDs per 100,000 from diabetes during 1990 and 2017. Thus strict dietary intervention strategies need to be introduced in Ireland as the burden metrics seem to be on a rise for diabetes deaths and pose a considerable amount of DALYs and YLDs. Also a diet high in sugar sweetened beverages need strict policing just like the Sugar Sweetened Drinks Tax

(SSDT) came into effect on 1 May 2018 [90]. Such government levied taxes is the need of the hour. The SSDT is applied to water and juice based drinks which have added sugar in them and a total exceeding 5 grams per 100ml of liquid. Since January 2019, the SSDT was also expanded to drinks containing milk fats and certain categories of plant protein drinks. Drinks which have an added sugar content of more than 5grams but less than 8grams per 100ml would be levied with a tax of 16% per litre(20cent including VAT). Drinks which have an added sugar content of more than 8grams of added sugar per 100ml would be levied a tax of 24% per litre (30cent including VAT).

8.4 Driving forces behind the observed findings

The driving forces behind the observed findings can be attributed to few important factors- ageing of the population, growth of population, risk control measures implemented and access to health care services.

1. **Population Ageing**: It is observed in Ireland that majority of metrics- deaths and DALYs have declined over the years, however the YLDs have shown increases. This increase in the YLD metric can be attributed to the longer years of life lived in old age. With an increase in age there is an increased risk of a number of diseases and health conditions. Although, the Irish population is living for longer (increased life expectancy), the net increase the healthy life expectancy is still considerably lower than the LE.

In an ideal scenario, the population would be expected to live in full health and the years lived must be quality years lived and not in less than full health. Ageing adults live with certain health conditions for years from diagnosis (longer duration). The BoD study helps in identifying the health conditions, disease conditions and risk factors which contribute to the highest number of healthy years lost for the ageing adults. This is critical in terms of guiding interventions, health policies, increasing the quality of life of the ageing adults and increasing the longevity of these adults. DALYs, YLDS, YLLs can thus guide the overall health policy to enhance the quality of life by continuously evolving the preventive strategies for the diseases.

Also, some of the diseases like hypertension, diabetes, CVD etc. have higher prevalence in ageing adults as compared to younger adults. Age seems to accelerate and actively contribute to increased burden metrics specially the YLLs and the YLDs. People who have experienced stroke (usually in middle aged or older adults) during their lifetime live with considerable amount of disability and this costs the government some amount of expenditure. Heart disease in general shows an increase in ageing population. On decomposing the drivers of burden change, it was observed that an approximate 30% of the burden was from population ageing for the four main NCDs.

It is crucial to quantify the non-fatal health outcomes in order to effectively understand and respond to more important and crucial health challenges. Globally, more affordable and effective strategies are required to deal with the increasing burden arising from an ageing population. The below picture shows the distribution of the NCD burden according to age in Ireland across the years 1990 to 2017.

2. **Population growth:** Population is growing everywhere. In a recent report ***Population and Migration Estimates April 2019*** by the Central Statistics office, Ireland has reached a record high in its population in the last 170 years and it was predicted that Ireland will possibly reach its 5 million mark early 2020 (which it has approximately). This report showed that the total population increased to almost about 4.92million in April 2019 [91]. The number of births recorded were much higher than that of the deaths and thus resulting in a natural growth in population.

An increase in population would mean an increase in the detected and recorded number of NCD cases overall. The absolute number of deaths, DALYs, YLDs etc. would always show a higher value when compared to burden metrics from the previous years or past years. In order to maintain uniformity of the results and correct interpretation of the results, rates per 100,000 have been used.

The changing faces of demography can be an influencer in terms of burden change. Factors like population growth and ageing can thus have significant effects on the changing burden. On disentangling the drivers of burden change, it was observed that some portion of the burden change was attributable to change in population size as well for all the NCDs.

3. Risk factor control measures

The measures to control risk factor attribution are most important preventive measures. In Ireland there are several important measures that have been undertaken to control the NCDs and the risk factors. Most of the risk factors like high BMI, alcohol consumption, tobacco use have significantly affected the overall

quality of life. They contributed to a large number of DALYs and deaths. Thus the overall burden of the NCDs can definitely be reduced substantially if these risk factors are controlled.

There has been a decrease in the burden of tobacco over the years in Ireland and that improvement can be attributed to the strict tobacco policies introduced in Ireland. Also, there is a strict ban on smoking in public places, workplace smoking ban and different other preventive measure put in place by the government like reducing the advertisements of tobacco or smoking related products. Such strict risk factor control measures is crucial to control the increasing burden of the NCDs in any country.

Alcohol consumption still seems to be a major issue in Ireland. Just like the tobacco use there needs to be a strict policy in order to reduce consumption of alcohol and alcohol related self-harm. Some of the other important measures would be the introduction of the minimum unit of pricing of alcohol, and control of advertisement of alcohol products, no sale of alcohol to people below the age of 18.

It is important to realise that population-level interventions are more effective as compared to individual-level interventions. Also, population level interventions are more cost-effective than that of the individual level interventions.

When a food provider reduces the amount of salt in his bread, there is a decreased salt intake without the population even knowing. Such population level

interventions are much cheaper and easier to execute. Another example is substituting healthier food options at a university cafeteria.

On disentangling the drivers of burden change for the four NCDs, it was observed that after removing the effects of population ageing and growth, diabetes still needs stricter interventions.

8.5 Loss of National income from NCDs

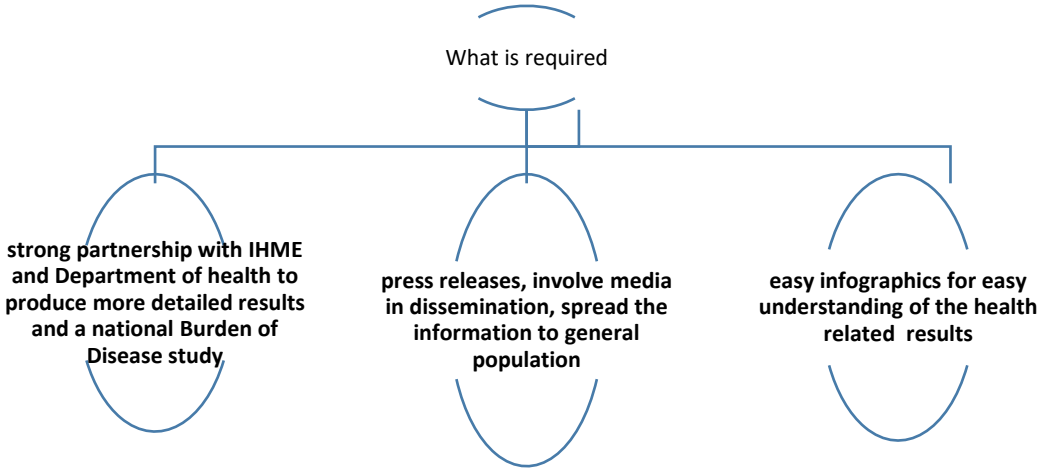
The total income lost to NCDs in Ireland is about 75.6 billion I$ (CMH1) to 226.6 billion I$ (CMH3) in 2017. About 87% from the total income lost is attributed to the NCDs. Cancer alone contributes to 19.1% of the income loss amongst the NCD related income loss.

Despite adjusting for the rates of inflation between the years 1990 and 2017, there was an overall increasing trend in the amount of income lost during this time period (Both the CMH1 and CMH3 showed an increase over the years).

Thus, this study based on the GBD data laid out the health metric scenario in Ireland. This study determined drivers of change, loss of income, future burden and provides the ROI with burden of disease metrics which need to be tackled and are brings to attention the areas that need immediate priority of the policy makers.

8.6 Future direction of our study

FIGURE 8.1: Requirements for Ireland to conduct a national Burden of disease study



Although the estimates of past, current and future burden metrics can be derived from the publicly available data, collaboration with the GBD team at the national level would definitely provide Ireland would more detailed estimates, give GBD the access to many more national datasets, using national data for prevalence and incidence. The current or future metrics which are based on the STGPR to calculate the prevalence can be derived from the national data instead of drawing strength across space and time from neighbouring countries or areas and that in turn can also help in identifying the areas of lack of national data. IHME will have access to many more national datasets, which will contribute to the increasing accuracy of the estimation process. Countries like UK, India, China ,Greece, Brazil that have collaborated directly with the GBD group have more information, more accurate results and expert guidance on interpretation of these results.

One main aim of the GBD study is to ensure comparability of the results across different nations and geographic regions. However, the methodology used to calculate the burden metrics is the same across all countries irrespective of their levels of development, demographic diversities and economic differences, differences in methods of collection of data. For example: a country In Europe which has high quality vital registration data has same method being used in that of a country from the Sub- Saharan Africa which has very poor quality data. This scenario can sometimes lead to overestimation or underestimation of the burden metrics and wrong interpretation of the health scenario. If there was a harmonised methodology across the European Union (where the demographics, levels of development, population, availability of data, completeness of the data), it would ensure more comparable results and depict the true nature of the health condition in the nation. Good estimates will be based on stronger evidences and proper data. In order to conduct a national level study in collaboration with IHME, there needs to be more data which can be used in the GBD modelling especially in areas of disability weights etc. in Ireland. There is no local data on disabilities in Ireland and disability weights in Ireland.

A national level BOD study is definitely warranted. Also, sub national analysis is required as Ireland. Ireland has different socio-economic groups with different rates of alcohol consumption, tobacco use and high BMI in different communities. While it is important to exercise stricter preventive strategies, government should definitely be mindful of the different socio-economic groups in our society which poses greater burden from the different types of cancer. There are also disparities

between urban and rural areas. The need of the hour is an effective and long term collaboration with the Global Burden of Disease team with that of the Health Research Board of Ireland and Department of Health. More accurate and specific estimates of mortality, morbidity in collaboration with IHME will lead to proper quantification of the health scenario and also effective allocation of the limited financial resources that are available to a country.

8.7 Policy implications of this study

In the 1990s there was no detailed comprehensive understanding of the world's health scenario and no documentation relating to the most important challenges faced by the nations or at the global level. The Global Burden of Disease was the first of its kind to collate all available resources and information from different nations and make these large amount of information into meaningful results giving rise to systematic and comparable results across the world and between nations.

The results of the GBD study forms the basis of benchmarking of the progress of the countries, comparison across the countries, also observing the trends over time. The GBD publishes their results annually, keep adding new datasets and thus improving upon their estimations. Such studies at a national level is the way forward as it provides substantial input about health conditions to researchers, policy makers, government, health professionals and decision makers.

This study details the Irish burden of NCDs and the related risk factors and thus would be crucial in terms of policy planning and reporting to the government about

the current health scenario. Some of the results like the increase in YLDS from alcohol over the years, a rise in the number of deaths from sugar sweetened beverages, an increased number of YLDs from a diet high in sodium and diet high in processed meat [92] sends important and alarming messages to the policy makers. These outputs can be used to inform the nationwide policy and many of these can be converted to action points by the policy makers, researchers and governing bodies.

Some of the important policy recommendation are:

- Despite the population ageing effect, ***diabetes*** still seems to be requiring more effective intervention strategies or risk factor control measures (as evident from the breakdown of drivers of burden change)

- Strict policies to reduce consumption of alcohol. Important measures would be the introduction of the ***minimum unit of pricing of alcohol*** like that of the UK.

- Tax like that of the sugar sweetened beverages tax (SSDT) need to be put in place for ***processed meat and salt*** in Ireland too.

- The ***tax*** levels for Ireland would *be* ***80% for processed meat and 12% for red meat.***

- An overall decline in burden metrics from tobacco use have been observed during 1990 to 2017 and further targets of the Tobacco free Ireland is to reduce the prevalence of ***smoking to 5% by 2025*** would be the way forward

- New action plan to tackle obesity was introduced by the Department of Health in 2016- ***A Healthy Weight for Ireland - Obesity Policy and Action Plan 2016- 2025.*** Some directives of this action plan is to develop a nutrition policy, support the SSDT, calorie posting legislation

The GBD data on health of Ireland helps in achieving the required information which can be put into action by relevant authorities, however a national level study in collaboration with the GBD study group would be crucial.

It is observed that a large amount of GDP per capita has been lost to the NCDs in Ireland in 2017 and a major portion of it is from cancer.

This research can be made available to the policy makers in terms of a comprehensive report of the NCD burden and related risk factors in Ireland. Also of special relevance are the predictions of the burden of NCDs in 2040 which could be of special interest to the policy makers, stakeholders and the government in order to plan the allocation of resources or introduction of preventive strategies.

This study forms the first Burden of disease report for Ireland. It details out that Ireland needs to be able to make a move from focusing on mortality issues to morbidity issues and respond actively to this changing health scenario in Ireland.

The results from this study show that there is still need to implement more strict prevention strategies at the primary levels by reducing levels of high BMI, increasing physical activity, lowering the alcohol consumption levels. The allocation of resources from the health services need to be redirected towards areas of comorbidities.

8.8 Limitations

The GBD study has many limitations-one of which is that data has not been continuously available to the researchers and only freely accessible data or published data, vital registries etc. from Ireland has been made available to the GBD. Data which need special access are not available to these researchers. Hence, some diseases might have larger uncertainty intervals (UI) which could be attributed to limited amount of data available or poor quality of data available. When comparisons are made between different countries, it is essential to bear in mind the variations in the UI. The GBD team and all other participating nations need to ensure validity of the results for effective international comparisons.

The main drawback of the GBD study is that the choice a standard population could be crucial in terms of having appropriate country based analysis of DALYs. The ranks of the diseases that are based on the age standardised DALYs are largely influenced by the choice of standard population. In order to produce estimates that can be compared worldwide, the WSP is used as a standard, but in case of within the country analysis (especially in the EU), ESP is deemed to be more ideal. Also, countries like Ireland whose population structure aligns more with the ESP rather than WSP would have more appropriate estimates using ESP as the standard population. This has been shown in the Scottish Burden of disease study paper too [80].

GBD modelled estimates from other locations and various other covariates in the event of unavailability of data for a particular country. This is the STGPR modelling technique and sometimes this method may give rise to results which are not close

to the real value. Disability weights (DW) [93] contribute in a large way in the calculations of the DALY metric. DW have been criticized at times, more particularly in regard to certain limitations in the methodologies or the application of the global disability weight. One example could be the assignment of low disability weight for blindness/severe visual impairment so as to make it easy for an ordinary person to comprehend. There have been other instances where these weights have shown some really surprising choices. IHME has used survey tools to generate their own data to determine how a person feels about the impact on life quality from different diseases. Due to this, sometimes there have been misleading inferences too. One striking example would be: the years of life lost to disability from acne was greater than from Chronic Kidney Disease was less than Human Immunodeficiency Virus (HIV) and autism in the developed nations.

Data quality and availability is definitely still a concern for the IHME team for different nations which do not have appropriate data available. For the ROI, there is some high quality data available but many of these datasets are not accessible from researchers outside Ireland and thus a country level collaboration with the IHME team is required to establish a National burden of disease study in Ireland.

One important issue with the GBD estimates is that the annual estimates of the GBD can be complicated to interpret by the policy makers and the general population. There is additional amount of data added to existing datasets in the GBD health data exchange and with every wave of the GBD, comes new estimates of the burden (revising all the current year estimates and the previous year estimates). Although such improvements in the estimates is important, however

interpretation can be complicated for the policy makers and for the government (how to change priorities and allocation of resources so quickly).

Another important drawback of the GBD study is using Dismod MR [94] to estimate the prevalence. Ireland has very good quality prevalence data and it does not seem important to use such a measure to estimate prevalence. Such assumptions do not hold valid for countries whose prevalence data is of high quality.

The Central statistics office (CSO), Ireland website has extensive data on life tables and calculations of Life expectancy in Ireland. In the presence of such a good quality data, it is not very relevant to use other methods used by GBD to calculate LE for Ireland.

Some of the other limitations of this study are: the study was completely based on the data that was publicly available and not individual level data which could definitely vary the results. In case of all-cause cancer estimates there might be an overestimation of the attributable burden to various risk factors but ultimately that would not make a lot of difference to the findings as these NCDS drive much of developed countries' burden of disease. The validation exercise of this thesis was also restricted to the data that was publicly available from GBD and thus too many estimates could not be validated against the national level estimates from Ireland.

8.9 Conclusion

This study is the first burden of disease study in Ireland which quantified the burden of four NCDs and the related common risk factors in Ireland during the years 1990 and 2017, predicted the future burden scenario in 2040, disentangled the drivers of burden change, calculated the loss of national income form the NCDs and also validated some assumptions and results based on the GBD with that of the national datasets. Such studies are important as they can guide some of the major health policy decisions, facilitate resource and funding allocation and intervention measures in high priority areas. While this GBD study can be used to draw some important conclusions in this direction, it is hardly adequate as the basis of a nation's entire health policy. An Irish National Burden of Disease study is crucial in this regard and its importance cannot be overstated.

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Appendix I

WHO NCD targets [9]

NCD Target 1: A 25% relative reduction in the overall mortality from CVDs, cancer, diabetes, or chronic respiratory diseases.

The WHO Global NCD Action Plan 2013-2020 provide a roadmap of policies and interventions to realise this vision of the NCD targets. Some priority actions are: setting national NCD targets that are in line with the nine NCD targets of the WHO, creating and strengthening the surveillance of NCDs.

NCD Target 2: At least 10% relative reduction in the harmful use of alcohol in the national context

Immediate actions need to be taken like enforcing strict and raised taxation which could control the consumption of alcohol, restricting the availability of the alcoholic beverages, and careful advertising or complete banning of the advertisement of alcoholic beverages.

NCD Target 3: A 10% relative reduction in prevalence of insufficient physical activity.

A change in physical activity in population like walking to work or using more active modes of transportation to work (like cycling) can bring up the physical activities. Some action points would be: implementing national guidelines on physical activity on health, campaigning through social media.

NCD Target 4: A 30% relative reduction in mean population intake of salt/sodium.

It is crucial to control salt consumption at a global level .Some important action points may include reduction in the overall salt or sodium intake, collaboration with restaurants, catering services, campaigning the side effects of excess salt in the food through social and mass media.

NCD Target 5: A 30% relative reduction in prevalence of current tobacco use in persons aged 15+ years.

Some priority action points would include increasing the taxation for all tobacco products, enforce laws to create tobacco and smoke free areas, warning by social and mass media through legible health warnings, banning advertisement of tobacco products.

NCD Target 6: A 25% relative reduction in the prevalence of raised blood pressure

Some action points are: to implement public health policies to aid in reduction of the incidence of hypertension in the general population, educating the general population about the ways and means to reduce other risk factors which affect high BP like reducing the intake of alcohol, cutting down smoking completely or having a balanced proper diet.

NCD Target 7: Halt the rise in diabetes and obesity

In order to tackle the problem of obesity, nations would need a dynamic approach. Changing physical activity levels and diet could definitely help in reducing the rise in obesity levels. Other action points would be- construct fiscal policies like that of the tax on sugar sweetened beverages in Ireland, having healthy food options at workplaces and schools, marketing through social media, ensuring easily comprehensible food labels for general population, increase the availability of healthy food options and at cheaper prices.

NCD Target 8: At least 50% of people receive drug therapy and counselling to prevent heart attacks and strokes.

The main action points would be providing proper health care services, making improvements in the primary healthcare services, strengthening the healthcare workforce for the control and prevention of the NCDs.

NCD Target 9: 80% availability of essential medicines and affordable basic technologies and treating major NCDs both in public and private facilities.

Some of the action plans are: improving and introducing cost effective NCD related interventions at the primary care levels, to detect risk factors early and introduce cost- effective interventions to address these risk factors, to make NCD related basic technologies and medicines readily available to the population.

Global Burden of Disease study 2019 Report (published in October 2020)-Summary from GBD website

GBD 2019 was recently published in October 2020. There were more advancements in the methods of quantifying the burden in 12 ways- some of which are new sources have been introduced to calculations based on location, sex and age, the TMREL for dietary risks was revised based on new systematic reviews, for many of the risk outcome pairs new sets of systematic reviews have been added too.

There is no country level information in GBD 2019 for Ireland. Most of the outcomes are represented as a comparison among different geographic regions and are based on SDI. Below are reported some of the preliminary findings of the GBD 2019 using the GBD compare for Ireland.

Figure 8.2 Burden metrics of Ireland in 2019

	Deaths	DALYs	YLDs	YLLs
Ireland 2019 (absolute number)	32354.4	1186357	629570.7	556786.3
Ireland 2019 (rates per 100,000)	658.9	24160.3	12821.3	11339

Below are the three heat maps to show the ranks of the different diseases causing the highest number of deaths, DALYs and YLDs in Ireland in 2019. All the values are rates per 100,000.

Figure 8.3 Heatmap for deaths per 100,000 in Ireland in 2019(from GBD website)

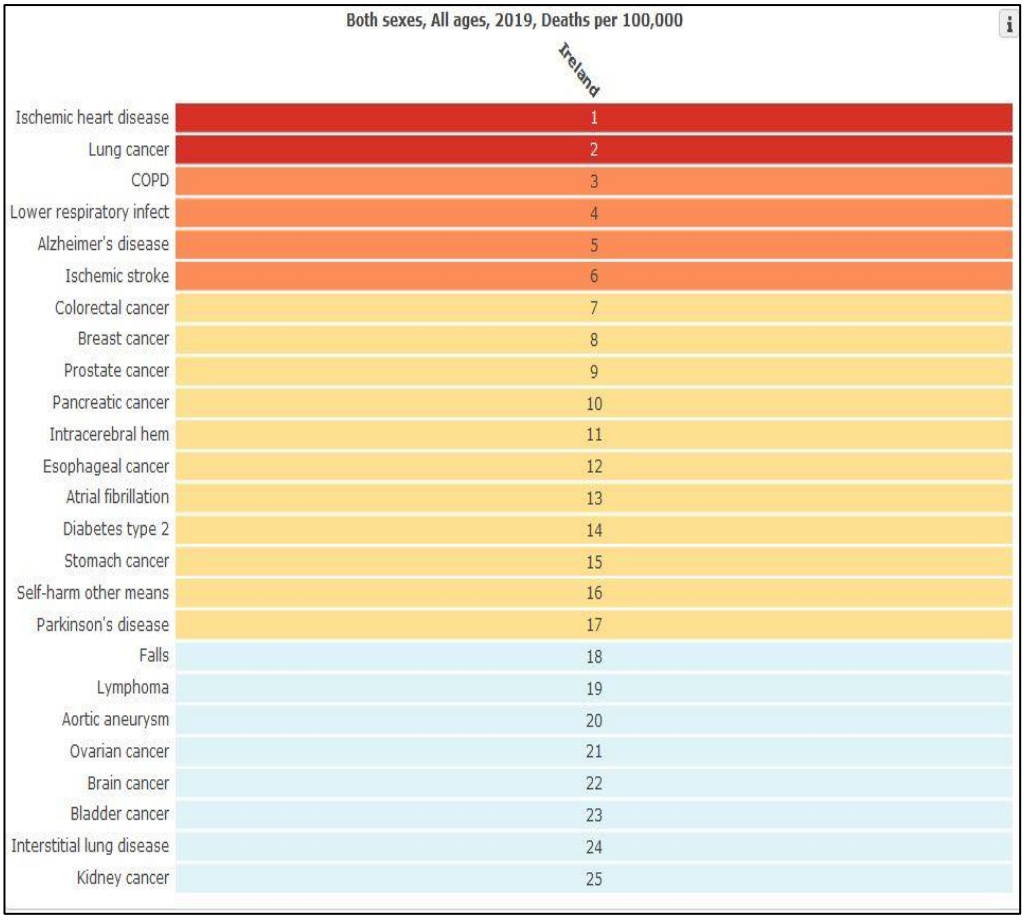


Figure 8.4 Heatmap for DALYs per 100,000 in Ireland in 2019 (from GBD website)

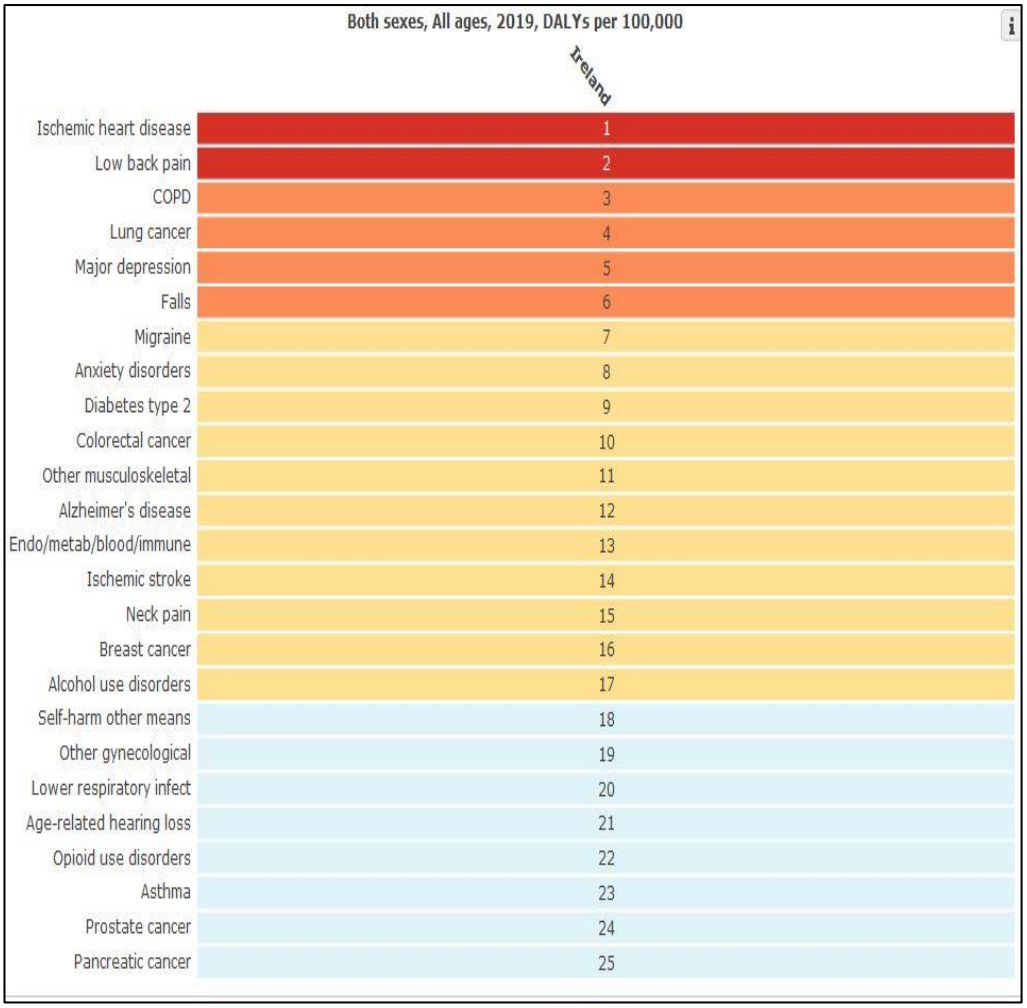
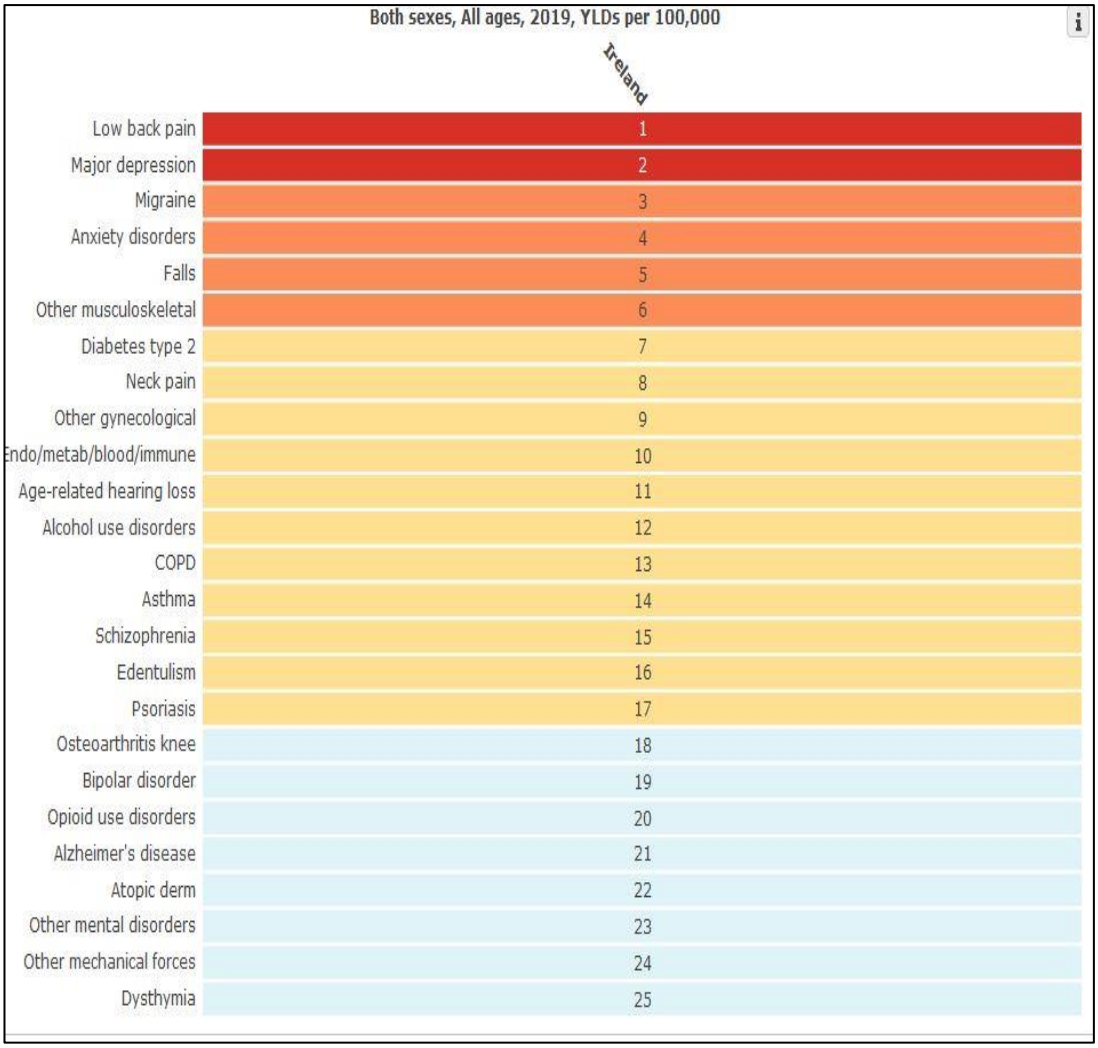


Figure 8.5 Heatmap for YLDs per 100,000 in Ireland in 2019 (from GBD website)



Below are also the comparative tables of the top ranking risk factors of 2017 and 2019 to effectively understand if there is any significant difference observed in the metrics during this short period of time of 2 years.

Figure 8.6 Death rates from the risk factors in Ireland in 2017 and 2019 (rank wise)

(from GBD website)

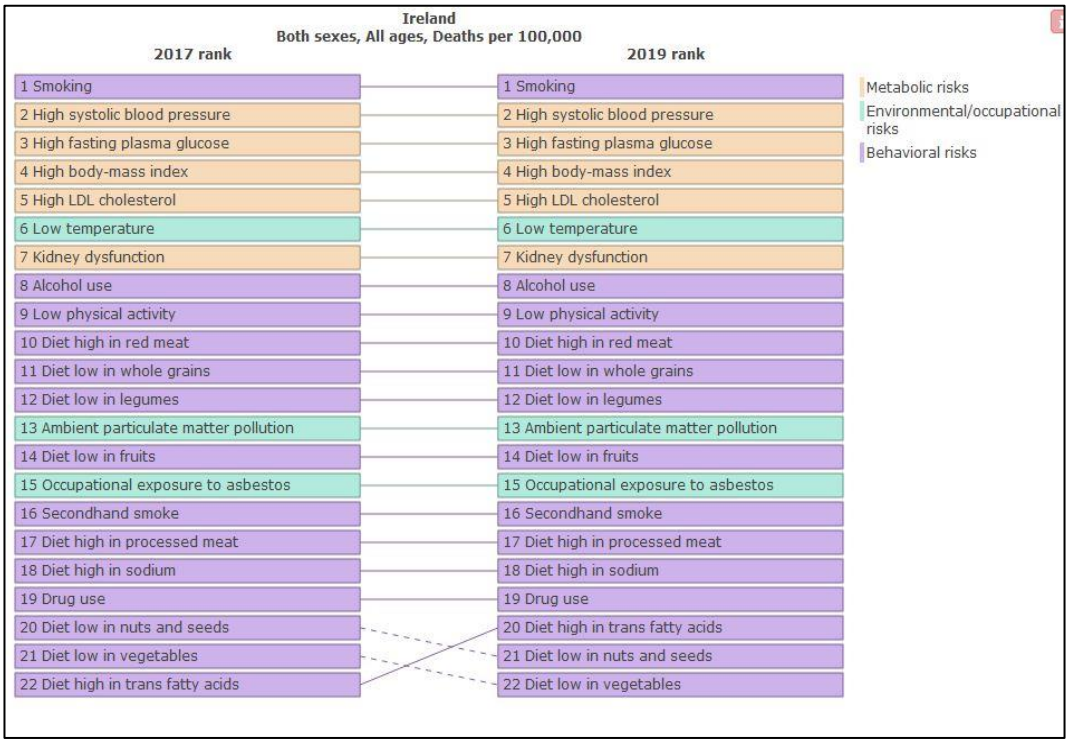


Figure 8.7 YLDS per 100,000 from the risk factors in Ireland in 2017 and 2019 (rank wise) (from GBD website)

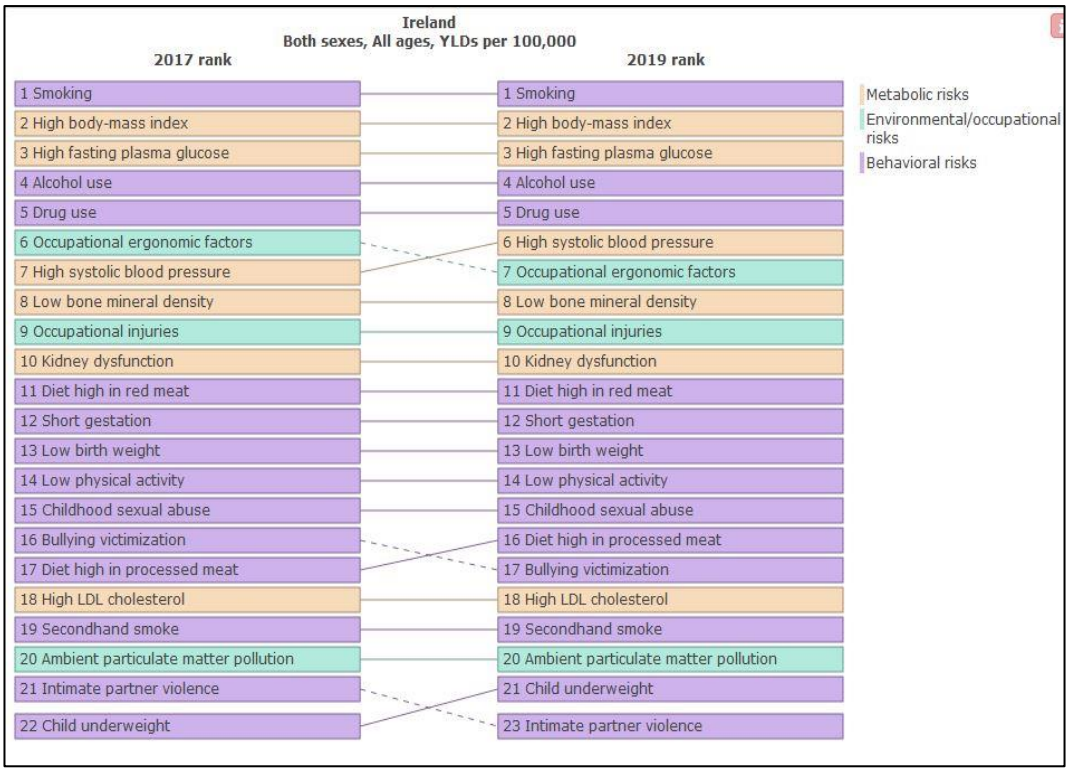
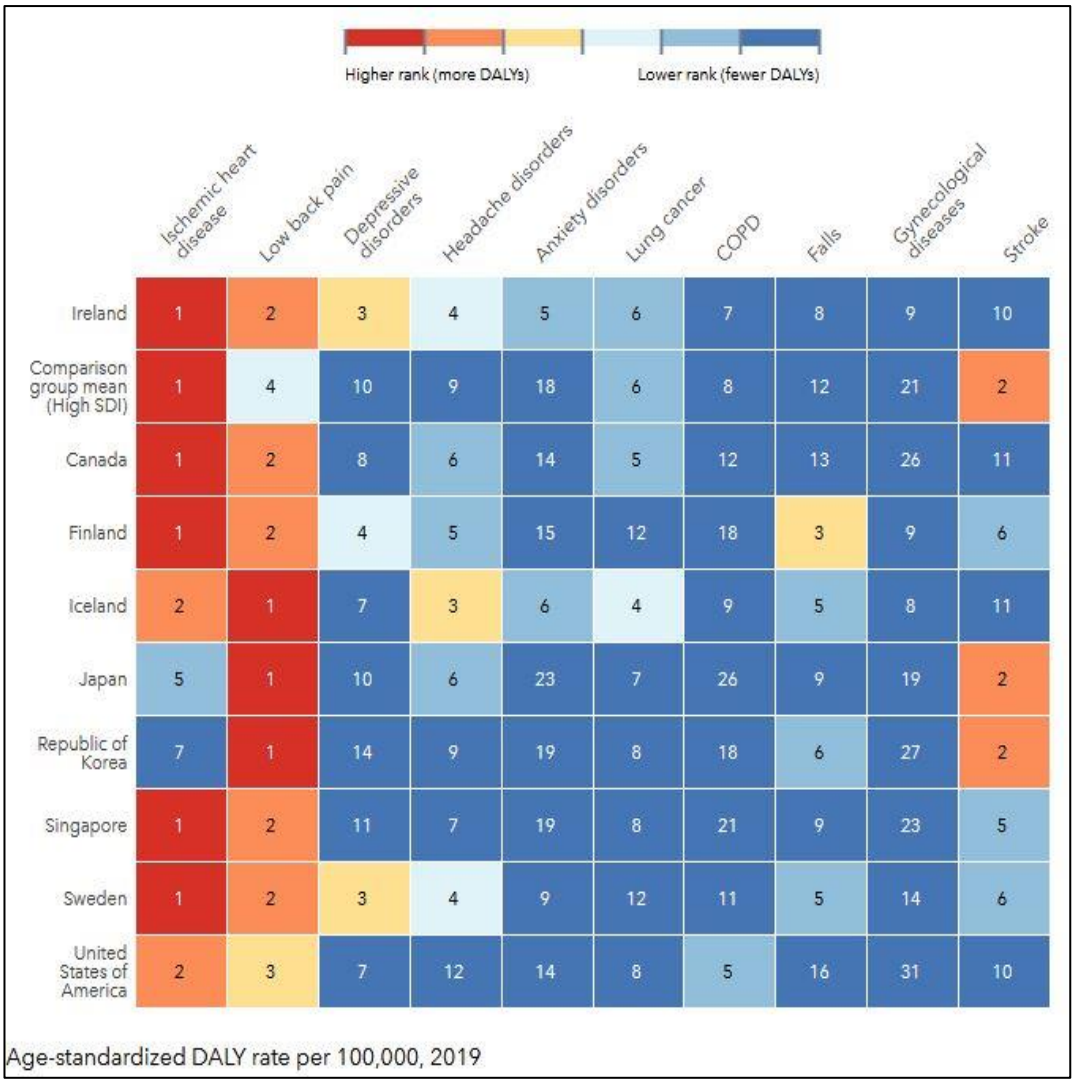


Figure 8.8 DALYs per 100,000 from the risk factors in Ireland in 2017 and 2019 (rank wise) (from GBD website)

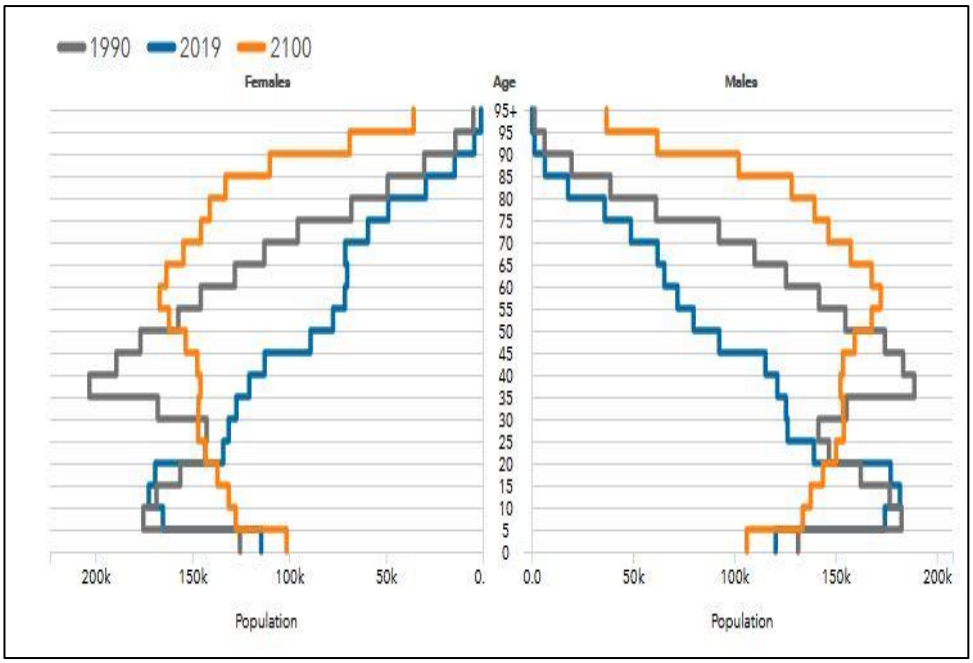
Below is an interesting comparison of countries with top 10 causes of death and DALYs (disability). It ensures that a comparison can be made with the countries and also the countries in this list were chosen based on the socio-demographic indicators.

Figure 8.9 Comparison between countries on top 10 causes of death and DALYs (countries based on socio-demographic indicators) (from GBD website)



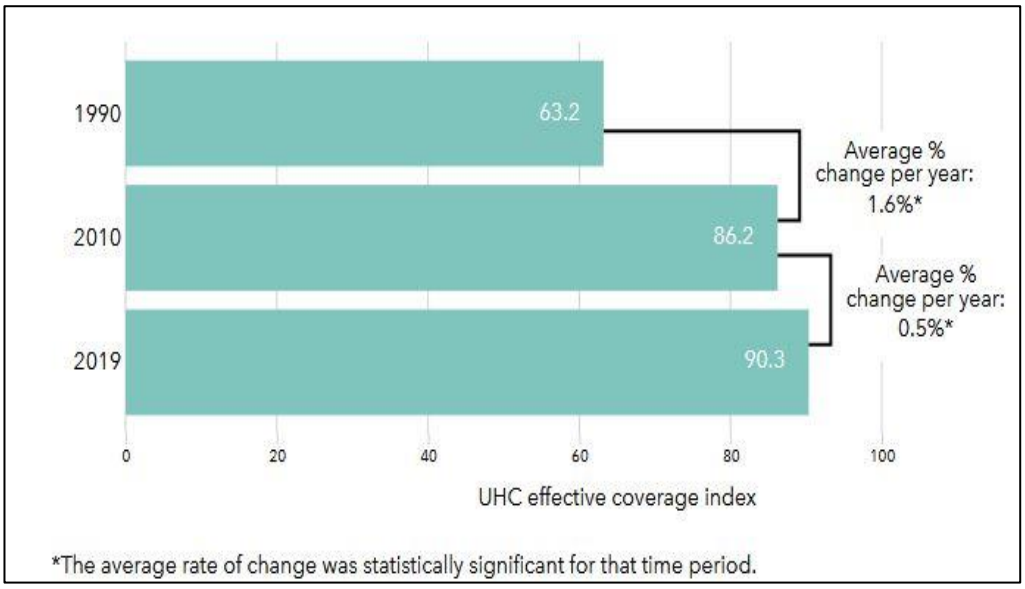
Another important aspect of health metrics is dependent on what the structure of the population will be in future as compared to current scenario. Below is the graph published by GBD to describe the age structure of the population in 1990, 2019 and 2100 where 2019 is considered to be the reference scenario.

Figure 8.10 Age structure of the population in 1990, 2019 and 2100 (from GBD website)



Another interesting result from GBD 2019 is how well Ireland's health care services are being provided over the years during 1990-2019. The graph below shows UHC (Universal Health Coverage) index. UHC is defined as a coverage index which represents how good is the service of the health services and how much would be useful in improving people's lives in a country or territory. Below is the graph showing the same.

Figure 8.11 UHC effective coverage index (from GBD website)



Appendix 2

EXTENDED SUMMARY

Background: Non-Communicable Diseases (NCD) constitute approximately 86% of deaths and about 77% of disease burden in the European Region of the World Health Organisation (WHO). The WHO stated that the leading causes of NCD deaths in 2016 were cardiovascular diseases (44% of all NCD deaths), cancers (22% of all NCD deaths), and respiratory diseases (9% of all NCD deaths). Diabetes contributed to about 1.6 million deaths. NCDs are attributable to both modifiable and non-modifiable risk factors. NCDs pose a substantial burden in terms of economic loss and health loss. The World Economic Forum's report on economic burden of NCDs stated that in 2010, the cost of CVD (overall costs including productivity costs, per capita costs) globally was estimated 863 billion US dollars and diabetes 500 billion US dollars.

Global Burden of Disease (GBD) study is the most comprehensive global study of health conditions of people employing a standardized methodology. It provides estimates of morbidity, mortality, risk factors and injuries at all three levels- global level, national level and regional levels. The main advantage of this kind of study is the comparability across nations, effectively ranking them in terms of diseases, risk factors etc. In order to understand the evolving health scenario across the world, it is valuable to examine trends from 1990 to the recent years. Many countries have utilized the publicly available data from the GBD studies across different time periods to produce national estimates to guide policy makers to prioritize funding and attention in specific areas.

The GBD study has detailed information on mortality, morbidity, risk factor contributions and it ensures comparing and benchmarking the health performance of Ireland. Till date, there has been no comprehensive study quantifying the NCD mortality and NCD morbidity trends in Ireland over time. We set out to quantify the burden of the four common NCDs (CVD, cancer, Diabetes and COPD) and their related risk factors (tobacco use, alcohol consumption, dietary risks, high-BMI and low physical activity) in Ireland and rank Ireland in terms of the burden metrics – DALYs, YLDs and YLLs with other EU nations.

The main objectives of this study are

•To estimate a comprehensive NCD epidemiologic health profile of Ireland employing the standardized GBD methodology and comparing this with other EU nations

•To estimate attributable burden (DALYs, YLDs and YLLs) of tobacco use, alcohol consumption, low physical activity, high BMI and dietary risks to five common NCDs both in Ireland and in EU during 1990 and 2017

•To decompose main drivers (population growth, population ageing, changing risk factor patterns) of the estimated NCD burden in Ireland

•To calculate the loss of national income from the NCDs across the years 1990-2017

•To internally validate some key GBD outputs and specific estimation methods.

•To project future trends in NCDs and to estimate avoidable burden related to common risk factors for 2040 in Ireland.

Methods

1. This thesis work is based primarily on the GBD methodology. In GBD 2017, there were 282 causes of death, 84 risk factors, 354 diseases and injuries, 3484 sequelae. The GBD study uses CODem (cause of death Ensemble model) for the cause of death modelling. The risk factor analysis is based on the TMREL (theoretical minimum risk exposure level).

The metrics of GBD are measured as follows:

- **Years of life lost**

$YLL_{a,\,s,\,c,y} = D_{a,s,c,y} * E_{\,a}$; where $YLL_{a,\,s,c,y}$ is the years of life lost at age a, sex s, country c and year y. $D_{a,s,c,y}$ is the number of deaths at age a, country c, sex s and year y. E_a is the life expectancy at age a.

- **Years lived with disability**

$$\text{YLD sequela} = \text{Prevalence}_{\text{sequela}\times}\ \text{Disability weight}_{\text{health state}}$$

- **Disability-Adjusted-Life-Years (DALYs)**

DALY=YLL+YLD

Attributable burden from the risk factor, AB, is calculated as follows AB = PAF × B where B is the total burden of disease from a specific cause or group of causes affected by the risk factor with a relative risk of RR.

$$PAF = \frac{P(RR-1)}{P(RR-1)+1}$$

2. After we have quantified the burden of NCDs and the attributable burden we aim to disentangle the drivers of burden change. We used a decomposition method was used to attribute changes in total DALYs to population ageing, population growth, and change in risk factor scenario during 1990 and 2017.

3. We also aimed to understand the patterns in the overall loss of income (GDP) in a particular year from DALYs and also look at trends in Ireland across time periods. This approach used the WHO tool for projecting the Economic Costs of Ill-Health (WHO--EPIC model) which was constructed in the year 2006. This method values one unit of DALY at about one or three times GDP per capita in the country.

4. Also, we compared national level estimates from the national datasets and resources like the National Cancer Registry, Central Statistics Office (CSO), Healthy Ireland, SLAN surveys with that of the results from GBD study to check the validity of the results. We also tried to understand how the results change based on the choice of standard population like the World standard population and European Standard population.

5. We also quantified the burden of the NCDs expected in 2030. We used the GBD foresight tool and methodology for the results. We also calculated the potential YLLs averted by reducing the exposure of a risk factor to a theoretical minimum in 2040.

The GBD 2019 was recently published in October 2020. The preliminary results of GBD 2019 was also reported from www.healthdata.org.

Results: NCD deaths increased during time periods 1990 and 2017 in the EU from 4.43million (89.7%) to 4.75 million (91.3%). Females had a higher life expectancy as compared to males throughout the 1990-2015 time period and we observed a constant gap in male-female life expectancy for all the years. There was almost a five year gap in male-female life expectancy in ROI during the years 1990 -2015. It was observed that the overall LE and HALE had increased during 1990 and 2017, however HALE <LE (for both males and females).In 2017, Males lived for 80 years (LE), however the HALE was 69.4, hence 80-69.4=10.6 extra years were lived in less than full health, similarly females lived for 12.4 years in less than ideal health. Le has plateaued over the years in Ireland. The burden of the NCDs attributable to the risk factors are as follows. Cancer deaths, DALYs, YLDs and YLLs per 100,000 attributable to high BMI during the time period 1990-2017. NCD burden from tobacco use declined during 1990-2017. YLDs per 100,000 from cancer, diabetes and COPD attributable to tobacco use increased during 1990-2017. DALYs and YLDs from cancer and diabetes attributable to alcohol consumption increased during the years 1990-2017. Alcohol CVD deaths attributable to a diet high in processed meat (0.9% in 1990 to 1.8% in 2017) and a diet high in sodium (6.8% in 1990 to 9.7% in 2017.Diabetes related DALYs and YLDs attributable to diet high in diet high in processed meat and a diet high in red meat showed an increase during 1990-2017.

The change in cancer DALYs that can be attributed to population growth is 35%, from population ageing is 33.6%. Although the observed change in total cancer DALYs is 21.8%, the real change in drivers after eliminating the effects of ageing and population growth is by almost -47% (which implies Ireland is doing well in terms of

its health system performance like preventive strategies, population level interventions etc. The change in diabetes DALYs that can be attributed to population growth is 35%, from population ageing is 31%. The total observed change in diabetes DALYs is about 78% but the real change in drivers after eliminating the effect of ageing and population growth is about 12.1% which implies that more steps in order to tackle modifiable risk factors for diabetes need to be implemented.

The total income lost to NCDs in Ireland is about 75.6 billion I$ (CMH1) and 226.6 billion I$ (CMH3) in 2017. About 87% of the total income lost is attributed to the NCDs. (75.6 out of 86.7 billion I$).

LE is expected to increase by 2.07 years during 2017 and 2040. In case lesser progress occurs, LE is expected to increase by 0.7 years for males and by 0.4 for females and if more progress occurs, LE is expected to increase by 3.5 years for males and by 3 years for females. IHD is expected to be the leading cause of death and early death (YLL) in 2040.

Results based on the GBD data were quiet similar to the estimates from the national data. The prevalence of smoking, overweight and obesity, deaths from NCDs from the GBD data have been validated against the national data and the estimates were close. On using different standard populations like the ESP and WSP, the DALYs from the NCDs differed from the estimates from the GBD data. Thus, the choice of standard population significantly changes the estimates from the GBD.

Discussion and Conclusion

Quantification of national burden estimates are crucial for any country in order to formulate national policies and preventive strategies. A large number of countries have utilized the publicly available data provided by GBD to draw up national level estimates of population level health metrics. Furthermore some nations like the UK, India, Brazil, Mexico and many other countries have also conducted national and sub-national estimates of the burden of diseases, injuries and risk factors. In Ireland ,despite the ageing of population, diabetes still seems to be requiring more effective intervention strategies or risk factor control measures (as evident from the breakdown of drivers of burden change). Alcohol attributed to higher DALYs, YLDs to cancer, CVD etc., thus stricter policies to reduce consumption of alcohol need to be in place.

Some important policy recommendations are related to alcohol, high-BMI and a tax on processed meat. Alcohol attributed to higher DALYs, YLDs to cancer, CVD etc., thus stricter policies to reduce consumption of alcohol need to be in place. Important measures could be introduction of the minimum unit of pricing of alcohol like that of the UK. An overall decline in burden metrics from tobacco use have been observed during 1990 to 2017 and further targets of the Tobacco free Ireland is to reduce the prevalence of smoking to 5% by 2025 would be the way forward. New action plan to tackle obesity was introduced by the Department of Health in 2016- A Healthy Weight for Ireland - Obesity Policy and Action Plan 2016- 2025.The predictions of the burden of NCDs in 2040 which could be of special interest to the

policy makers, stakeholders and the government in order to plan the allocation of resources or introduction of preventive strategies.

GBD methodology has its own set of limitations. One of the most important is the choice of the standard population which can alter the estimates of the burden metrics. One other limitation is related to new iterations of the GBD, there is additional amount of data added to existing datasets in the GBD health data exchange and with every iteration of the GBD estimates, comes new estimates of the burden (revising all the current year estimates and the previous year estimates.

Some of the major health policy decisions are resource and funding allocation and intervention measures in high priority areas. These decisions need to be informed by burden of disease studies. While the GBD study can be used to draw some important conclusions in this direction, an Irish National Burden of Disease study is crucial in this regard.

Appendix 3

Courses and Training completed during PhD

1. Completed the Advanced Epidemiology (25 credits) pathway of the Masters in Public health course in UCC

- ST 6011 (Advanced Biostatistics)- 5 credits
- ST 6012 (Survival Analysis)- 5 credits
- ST 6031 (Advanced Epidemiology)- 10 credits
- ST 6044 (Meta-Analysis)- 5 credits
- The Graduate information literacy skills (PG6009)- 5 credits

2. ASOI 2016 Conference Implementing Obesity Policy into Practice: 5hours CPD accreditation approved by RCPI

3. Completed the 11 day GBD Technical training workshop by the Institute of Health Metrics and Evaluation (IHME), University of Washington, Seattle.

Awarded partial funding for attending the workshop by Centre for Health trends and forecasts and Global burden of disease, Melbourne School of Population and global health for partial funding of the GBD technical training Workshop.

4. Awarded the Health Research Board Knowledge Exchange and Dissemination Scheme (KEDs) for placement at Institute of Public health at Dublin and Belfast

5. Presented at the Young Researcher' forum (ASPHER) at the European Public health conference, Vienna, 2016

6. Awarded a free place at Society for social medicine annual scientific meeting in Dublin in 2015.

Contributions to the School of Public Health

1. Tutor for thesis: 2 student (MPH) (campus based) and co-supervised 1 MPH student (campus based)
2. Statistical advisor to online MPH students.
3. Represented the Department at the ASOI conference on behalf of the Centre for Health Diet Research.
4. Lectured undergraduates of BSc Public Health (4th year) on the Global Burden of Disease.
5. Lectured students of Higher Diploma in Health, Safety and Welfare at Work course on study designs and biostatistics at UCC for two consecutive years.
6. Lectured students of Masters in Occupational Health at UCC
7. Lectured on academic writing and study designs in the School of Nursing and Midwifery.

Oral & Poster Presentations

1. Burden of selected non-communicable diseases and related risk factors in the Republic of Ireland, 1990-2010 Annual Scientific Meeting, Society of Social Medicine, Dublin, September, 2015, **Oral Presentation**
2. Prevalence of overweight and obesity and its contribution to Disease Burden in the Republic of Ireland: 1990–2010 8TH European Public Health Conference, Milan, October, 2015 , **Poster presentation.**

3. Selected non-communicable disease (NCD) burden attributable to dietary risks and low physical activity for the Republic of Ireland: 1990-2013 ,European Obesity Summit, Gothenburg June 2016, **Oral Presentation**
4. Burden of cancer attributable to high body mass index (BMI) in the Republic of Ireland between 1990 and 2013, European Obesity Summit, Gothenburg June 2016, **Poster Presentation**
5. Cancers in the Republic of Ireland between 1990 and 2013: A Burden of Disease Study, Annual Scientific Meeting, Society of Social Medicine, York, September 2016, **Poster presentation**.
6. Cancer and Cardiovascular Disease (CVD) burden attributable to tobacco smoking and alcohol-use in the Republic of Ireland, Annual Scientific Meeting, Society of Social Medicine, York, September 2016**, Poster presentation**.
7. Contribution of Tobacco use and Dietary risks to Cardio Vascular deaths in Ireland between 1990 and 2013, 9TH European Public Health Conference, Vienna, Nov 2016 **Pitch Presentation**
8. EU burden of Non-Communicable Diseases (NCDs): 1990-2015,Young Researchers Forum, ASPHER, Vienna, November 2016 **Poster presentation**
9. Impact of high-BMI (Body Mass index) on Non-Communicable Diseases in the European Union, 24th European Congress on Obesity in Porto, May 2017 **Poster presentation**
10. The past, present and future burden of non-communicable diseases in Ireland, European Burden of Disease Network Meeting ,Copenhagen, February 2020 **Poster presentation**

11. Main drivers of change to the Non-Communicable Disease (NCD) Burden in Ireland, 1990 – 2017, New Horizon Research Conference, December 2020 ,**Poster Presentation**
12. Estimated National Income Lost from Non-Communicable Disease (NCD) Burden in Ireland in 2017, New Horizon Research Conference, December 2020, **Poster Presentation**

Manuscripts in preparation

1. Tobacco use and its related burden in the Republic of Ireland- Past, present and future scenarios
2. Disentangling the drivers of NCD burden change in Ireland during 1990-2017
3. Loss of national income from NCD burden in Ireland-1990-2017