DISSERTATION FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (PHD)

Inequalities, lifestyle and metabolic risk factors of non-communicable diseases across European countries, with a focus on diabetes mellitus

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DOCTORAL SCHOOL OF HEALTH SCIENCES

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Abbreviations

AIC	Akaike Information Criterion
BIC	Bayesian Information Criterion
BMI	Body mass index
CIs	Confidence intervals
CVDs	Cardiovascular diseases
DALY	Disability-adjusted life year
DM	Diabetes Mellitus
EEA	European Economic Area
EHIS	European Health Interview Survey
EHIS-PAQ	EHIS-Physical Activity Questionnaire
EU-28	European Union member states and the UK
Eurostat	Statistical Office of the European Union
GDP	Gross Domestic Product
GBD	Global Burden of Disease
GC	Gini Coefficient
HEPA	Health-enhancing physical activity
IHME	Health Metrics and Evaluation
ISCED	International Standard Classification of Education
kg/m2	Kilograms by meters squared
NCDs	Non-communicable diseases
PA	Physical activity
PRs	Prevalence ratios
SDG	Sustainable Development Goal
SEP	Socioeconomic position
SII	Slope Index of Inequality
T2D	Type 2 diabetes mellitus
95% UI	95% uncertainty intervals
YLDs	Years Lived with Disability
YLL	Years of Life Lost

1. Introduction

1.1 Burden of Type 2 Diabetes Mellitus in the European Union

Type 2 diabetes mellitus (T2D) is a complex metabolic disease with a progressively rising incidence globally, including individuals under 30–40 years old [1]. Clinically, this disorder is typified by a hyperglycemic state caused by a gradual loss or malfunction of β-cell mass. While β-cell dysfunction and loss contribute to the progression of T2D, insulin resistance in target organs such as muscle, liver, and adipose tissue represents the primary pathogenic change driving the disease. A person's age, family history, physical inactivity, poor nutrition, obesity, and even race may all play a role in the etiology and causal association of T2D [2]. Numerous chronic complications, including neuropathy, nephropathy, retinopathy, cardiovascular disease, peripheral artery disease, dental disease, and decreased resistance to infection, are more incident in people with T2D [3]. At least one-third to one-half of T2D patients worldwide are estimated to have been unaware of their condition by 2021 [4, 5].

There is an increase in the age-standardized prevalence of T2D by sex in all EU member states between 1990 and 2019. Prevention is crucial since once the disease has started, it is unlikely to be reversed [6, 7]. Because T2D is a major contributor to higher rates of mortality and morbidity, it has a substantial financial burden on health care expenditures. T2D patients are likely to suffer from a decline in productivity as a result of their disease, which impacts not just the patient but also wider society and the economy of the country [8]. Due to the high demand for healthcare resources, including the price of medications and outpatient, inpatient, and diagnostic services, T2D has a significant economic burden. A greater range of indirect costs, such as financial losses, should also be taken into account. These include opportunity costs (incapacitation, disability, and death), transportation, accommodation, dietary costs, income losses, and social productivity losses [9].

In 2019, it was estimated that over 48 million people in the EU, or 9.9% of the population, had T2D [10]. According to Article 168 of the Treaty on the Functioning of the European Union, the EU and its member states share powers and responsibilities in the health sector; however, EU member states bear primary responsibility for the health services they provide to their citizens [11]. Initiatives to concentrate on Diabetes Mellitus (DM) were attempted in the EU after the St. Vincent Declaration, but these were unsuccessful [12]. "The Blueprint for Action in the Diabetes in the European Union," an initiative from 2021, is seen as a foundational element for the efforts of DM advocacy organizations [13]. In order to reduce the burden of this disease in its member states, the EU as an organization has the authority to offer financial assistance, including financing for research and preventative measures [14]. All of the EU's member states, however, have increasing T2D prevalence rates in spite of the public health initiatives they have put in place [6]. According to Global Burden of Disease (GBD) estimates, T2D is distinct among non-communicable diseases (NCDs), as its burden is rising at a faster rate compared to other major NCDs [15].

The EU's institutions generate quantitative and qualitative metrics, such as the European Core Health Indicators or the findings of the European Health Interview Survey (EHIS), to have comparable and trustworthy data on health and health-related behavior, diseases, and national health systems [5]. Although T2D is highly significant, most data collections report overall outcomes for DM as a whole, rather than focusing specifically on T2D. Additionally, policies and initiatives frequently fail to differentiate between its types [13].

This broad categorization of DM complicates the collection of epidemiological, economic, health, and policy data specific to the T2D population. Moreover, most existing data are restricted to mortality and morbidity, failing to provide comprehensive insights into T2D, particularly at the subnational level, where data are rarely gathered. Usually, effective health policies rely on data collection and analysis at the subnational level rather than solely at the national level [16]. Systematic reviews of economic analysis and epidemiological metrics, including prevalence, incidence, and mortality, related to T2D in all EU member states and the UK (EU-28) are still lacking. It is implied by the absence of evidence that data from various countries and regions cannot be compared. This makes it more difficult to identify the best preventive practices and create efficient, nationally or regionally specific health programs [17].

1.2 Inequalities in the Burden of NCDs across European countries

Numerous chronic diseases, including DM, cancer, respiratory diseases, and cardiovascular diseases (CVDs), fall under the definition of NCDs. Each year, NCDs account for 41 million deaths worldwide, representing 74% of all deaths in 2019. Individuals under 70 years old make up 42% of NCD-related mortality, although higher morbidity and mortality rates are found in older age groups [10, 18]. Four major behavioral risk factors are linked to the majority of NCDs: smoking, excessive alcohol consumption, unhealthy diet, and physical inactivity. Four key metabolic and physiological abnormalities can be caused by these habits: high blood pressure, overweight/obesity, high blood sugar, and raised cholesterol [19, 20].

In addition to these medical disorders and behavioral risk factors, a low-socioeconomic position (SEP) is directly linked to the prevalence of NCDs [21]. SEP is also associated with a number of NCD risk factors, including smoking and sedentary lifestyles [22]. At the population level, where the prevalence of CVDs, including stroke and coronary heart disease, is significantly linked to lower GDP per capita and health spending per capita, the relationship between NCD prevalence and SEP is also evident [23].

NCDs are the cause of substantial health inequalities, even though the general state of health has improved in many European countries [24]. Socioeconomic disparities and a social gradient contribute to the inequalities in NCD prevalence rates in Europe, with the majority of diseases having a higher prevalence among lower classes [25]. It has long been acknowledged that reducing these inequities is a significant public health challenge [26].

Health inequalities are unfair and preventable disparities in health status that exist both within and across different population groups [27]. The magnitude of the financial expenses associated with health inequalities serves as a clear example of how those disparities affect society. Health inequalities result in 33 million cases of disease and over 700,000 deaths yearly within the EU [28]. They bear 15% of the cost of social security and 20% of all healthcare expenditures [28]. Evidence also shows that the financial cost of inequality-related welfare losses is estimated at €980 billion annually, or 9.4% of GDP in the EU. Health losses associated with inequality also reduce labor productivity and GDP by 1.4% annually [28].

Many studies have investigated health inequalities in Europe, primarily concentrating on differences in prevalence and mortality across the eastern, western, and central Europe [29–32]. Most research highlights significant health inequalities across Europe, particularly between countries in the western and eastern parts of the region, with nearly all health indicators consistently lower in eastern European countries compared to those in the west [33, 34]. Compared to Western region, Eastern region has greater prevalence rates of DM, high blood pressure, obesity, and tobacco usage [35]. Differences in health literacy, access to healthcare services, a countries' economic status, and actual national health policies can affect or influence these inequalities [36–38]. Eastern and Western Europe continue to have major health inequalities, with post-socialist countries showing larger differences compared to Western countries [35]. For mental disorders and cancers in particular, inequalities seem to be larger in Eastern European countries than in Western ones. According to research, several southern European countries had reduced health inequalities in mortality, whereas the eastern and Baltic areas had significant inequalities [31]. Geographical health inequalities frequently reflect underlying socioeconomic level differences, with wealthier nations typically demonstrating superior health outcomes [37]. Addressing these disparities may involve improving educational opportunities, ensuring fair income distribution, promoting healthier lifestyles, and expanding access to healthcare services [39].

Differences between males and females should be considered when assessing health inequalities [40]. Even though NCDs account for the highest disease burden in both men and women in Europe, there are variations in risk factor exposure, social determinants of health, and access to health care services [40]. Alcohol consumption and smoking are more common among males than women, but these substances cause harm at lower levels in females, especially postmenopausal, with less favorable improvement trends in women. Women also consume more fruits and vegetables and are more likely to practice preventative behavior [41–43]. To combat sex inequality, several national and EU-level policies are being developed, including ones that target women's unpaid care work and promote equality in public services [44–46].

The high disease burden of NCDs has been on the political agenda of EU for more than 30 years [47]. Interestingly, the EU is primarily made up of high-income countries, except for Bulgaria, which is upper medium income [48]. Although the EU has significant competence in health context, it lacks legislative authority over member states' healthcare systems [49, 50]. National organizations are essentially responsible for the prevention and early detection of diseases. However, there are a few EU programs, such the "Healthier together – EU non-communicable diseases initiative," that seek to find and apply efficient strategies to address NCDs [45].

The European Commission is determined to support EU Member States in their efforts to achieve the target of reducing NCD mortality under the Sustainable Development Goal (SDG) 3.4: "By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being" [51]. Though, only a modest decrease in NCD mortality was attained by 2020, as stated in the UN's 2030 Agenda for Sustainable Development, and efforts to combat NCDs need to be doubled [52]. The very high COVID-19 mortality rate among people with certain NCDs severely underlined the lack of progress [53, 54].

A method for measuring health losses from hundreds of diseases, injuries, and risk factors is the GBD study, which is led by the Institute for Health Metrics and Evaluation (IHME). GBD estimates assist policymakers in comprehending the level of health inequalities and the nature of their nation's health issues, particularly in countries where subnational GBD estimates are achievable [55, 56]. In order to assess the health effects while combining data on mortality, morbidity, and disability [57], the disability-adjusted life year (DALY) metric was developed and initially reported in the GBD 1990 study [55]. According to earlier GBD studies, 87% of the disease burden in EU member states was caused by NCDs. The significant increase in years lived with conditions such ischemic heart disease, stroke, and depressive disorder is highlighted by the high disease burden [45, 58]. Additionally, smoking (11.54%), high fasting plasma glucose (10.4%), high body-mass index (9.91%), and high systolic blood pressure (14.57%) are the top four risk factors linked to DALY of NCDs [59]. For the top four risk factors in the EU, the age-standardized DALY rate changed from 2007 to 2017 as follows: -22.6, -18.3, -5.7, and -9.7 [15].

1.3 Lifestyle, metabolic risk factors, and diabetes mellitus prevalence in Europe

Currently, DM constitutes an important health concern in both developing and developed countries [60]. It is estimated that 61 million people in Europe between the ages of 20 and 79 have DM, and by 2045, that prevalence number is expected to rise to 69 million (from 9.2 to 10.4%). About 1.1 million deaths among individuals aged 20 to 79 were accounted to DM or its complications in 2021 [5]. Diabetes has a significant economic burden as well, with a broad impact on society and healthcare systems [17]. The International Diabetes Federation reported that the expected cost of DM in Europe in 2021 was USD 189 billion [5].

Type 1 DM, T2D, and gestational diabetes are the most often used categories for the broad category of metabolic disorders that is DM [61]. 90% of all cases of DM are T2D [62], which is mainly avoidable because of its modifiable risk factors, which include body mass index (BMI), food, physical activity (PA), alcohol and tobacco use [63, 64]. Given the strong evidence that a healthy lifestyle can lower the burden of T2D, identifying and tracking lifestyle-related risk variables is essential to implementing successful management and prevention plans [63, 65].

The EU has an extensive record of measures for combatting DM. The EU can take meaningful action, such as in the field of DM prevention, even though it cannot directly enforce health legislation and member states govern healthcare services [66]. Regardless of the aetiology, the EU often does not differentiate between different forms of DM in its efforts. The St Vincent Declaration, which was released in 1989 following an international conference, was one of the first DM initiatives. It established goals and targets for the next five years to enhance the quality of life and life expectancy of those with DM and to lower the severe consequences linked to the condition [67].

The ability to reduce uncertainty on the course of action in policy design may be feasible by having enough evidence-based data on policy development. Although the significant epidemiological burden of DM and the lifestyle risk factors linked to it are acknowledged in all member states, the lack of adequate data makes it difficult to establish effective policies at the EU level. Existing studies have emphasized regional and national differences in the prevalence and trends of DM, as well as the varying impact of individual risk factors across EU countries [17, 68, 69].

The EHIS conducted in average every five years, helps to address data scarcity by enabling periodic comparative assessments. EHIS focuses on key aspects of population health, providing standardized data across Europe to evaluate the prevalence of DM and its associated risk factors [70]. The use of large, population-based representative samples and standardized data collection enables comprehensive comparisons of lifestyle and metabolic risk factors across diverse European populations, an advantage often lacking in routine data sources. This approach is crucial for addressing the prevalence of diseases like DM and its associated risk factors, facilitating the development of informed policies and targeted interventions [71].

2. Objectives

Primary Objectives

Given the limited research on health inequalities and prevalence related to NCDs, such as DM, across Europe, this study aims:

1. To perform a systematic analysis of health inequalities in the age-standardized DALY rate for NCDs overall, as well as for 12 specific NCDs, across 30 European Economic Area (EEA) countries between 1990 and 2019.

2. To examine temporal trends in DM prevalence and its association with major lifestyle-related risk factors, including smoking, physical activity, fruit and vegetable consumption, and BMI, over three waves of the EHIS.

Secondary Objectives

To support these primary aims, the study also seeks to:

a) Provide a detailed description of the age-standardized DALY rate for NCDs in 2019, disaggregated by country and sex.

b) Analyze longitudinal trends in age-standardized DALY rates for each country and sex from 1990 to 2019, identifying differences in disease burden over time.

c) Determine country-specific and sex-specific ratios of age-standardized NCD DALY rates between 1990 and 2019.

d) Quantify health inequalities in NCD burden by calculating key inequality metrics, including the Gini Coefficient (GC) and the Slope Index of Inequality (SII), to assess the distribution of disease burden across different demographic groups.

e) Estimate the association between key risk factors and DM prevalence across 11 EU member states.

f) Evaluate the extent to which lifestyle behaviors contribute to the burden of DM within and across EU population.

3. Methodology

3.1 Inequalities in the burden of non-communicable diseases across European countries: a systematic analysis of the Global Burden of Disease 2019 study

3.1.1. Study design and data source

This study conducts a secondary analysis of the age-standardized DALY rate per 100,000 population for NCDs over a 30-year period, from 1990 to 2019, as reported in the GBD 2019 study [15]. A DALY represents the loss of one year of healthy life. The DALY metric is derived by summing two components: Years of Life Lost (YLL), which quantifies healthy years lost due to premature mortality, and Years Lived with Disability (YLDs), which measures healthy time lost due to living with disease or injury. To obtain the age-standardized DALY rates for NCDs by sex, country, and year, we utilized the interactive data visualization tools 'GBD Compare' [72] and 'GBD Results' [73] from the GBD 2019 database. This comprehensive dataset provides global, regional, and national estimates for 204 countries, including the 30 member states of the EEA as of 2019. The GBD 2019 study includes a vast range of health metrics, covering 369 diseases and injuries, 286 causes of death, 3,484 sequelae, 87 risk factors, and 23 age groups, for both sexes, over the 1990–2019 period [33, 74–76]. A more detailed explanation of the methodology used to calculate DALYs is available in previous literature [15].

Given that the prevalence and incidence of NCDs vary across different age groups, we opted to conduct our analysis using the global age-standardized rates available in the GBD tool. These rates facilitate meaningful comparisons of health outcomes across countries and over time, making them a widely used metric for benchmarking disease burden studies [33]. To account for potential sex-based differences, data were analyzed separately for males and females. The age-standardized DALY rate per 100,000 population was employed to quantify the overall burden of NCDs at both level 1 and level 2, reflecting the total years of healthy life lost due to these conditions.

3.1.2 Categorization of non-communicable diseases

The GBD database classifies health conditions into a hierarchical structure with four distinct levels. At the highest level (Level 1), diseases are grouped into three broad categories: Group I, which includes communicable, maternal, neonatal, and nutritional diseases; Group II, which consists of NCDs; and Group III, which covers injuries. Level 2 further subdivides these groups into 22 aggregated disease and injury categories. Levels 3 and 4 provide more precise classifications, with level 3 representing the most detailed categorization for some diseases, while others are further classified at level 4. For this study, our analysis focused exclusively on NCDs at Level 1, excluding conditions from Groups I and III. At Level 2, we examined specific NCD subcategories, including CVDs, chronic respiratory diseases, diabetes and kidney diseases, digestive diseases, mental disorders, musculoskeletal disorders, neoplasms, neurological disorders, sense organ diseases, skin and subcutaneous diseases, substance use disorders, and other NCDs. The latter category encompasses congenital birth defects, gynecological diseases, oral disorders, and endocrine, metabolic, blood, and immune system disorders.

3.1.3 Target countries

Our study included data from the following 30 EEA member states: Austria, Belgium, Bulgaria, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, the Republic of Cyprus, Romania, Slovakia, Slovenia, Spain, Sweden, and the UK. The EEA was established through the Agreement on the European Economic Area, an international treaty that extends the EU's single market to member countries of the European Free Trade Association, namely Iceland, Liechtenstein, and Norway. Although the UK was part of the EEA in 2019, it was included in our analysis to reflect the geopolitical context at the time. However, Liechtenstein was excluded from our study as the GBD 2019 database does not provide data for this country.

3.1.4 Statistical analysis

To assess inequalities across the 30 countries, by sex and over time, we utilized DALY rate ratios, an approach previously applied in similar studies [33]. This ratio is derived by dividing the age-standardized DALY rate of two countries, where the country with the higher rate serves as the numerator and the one with the lower rate as the denominator:

$$\frac{Higher\ ranking\ age\ standardized\ DALY\ rate}{Lower\ ranking\ age\ standardized\ DALY\ rate} = Ratio$$

For the year 2019, we calculated DALY rate ratios for each possible country pair (higher-ranking/lower-ranking) separately by sex. This resulted in 29 specific DALY rate ratios for each country included in the analysis. A ratio close to “1” represents a minimal disparity between the compared countries, whereas values greater than “1” indicate varying degrees of inequality [33].

To evaluate the changes in DALY rates between 1990 and 2019 for males and females, we employed the annual rate of change. This metric was determined through linear regression of the natural log of the mortality rate by year of death and expressed as a percentage by calculating the exponential of the β-coefficient minus one:

$$\left(exponential\left(\beta\ coefficient(LN[X])\right) - 1\right) = Annual\ rate\ of\ change$$

A lower annual rate of change reflects a greater reduction in DALY rates over the period, while the rate can also be negative, signifying a decline in DALY rates, or positive, indicating an increase [15]. Additionally, we generated maps to visualize the changes in age-standardized level 1 NCD DALYs, showing the annual rate of change stratified by EEA member states and sex between 1990 and 2019.

Additionally, we calculated the DALY rate ratio for each year and for each level 2 NCD by dividing the DALY rate of the highest-ranking country by that of the lowest-ranking country for each year from 1990 to 2019. A ratio close to "1" represents minimal inequality between countries, whereas values greater than "1" indicate increasing levels of inequality.

To assess DALY rate inequalities across countries, we employed the GC, a measure derived from the Lorenz curve family. The GC quantifies the degree of inequality among values and assesses how far they deviate from an equal distribution—in this case, the DALY rate. It is typically defined based on the Lorenz curve, which plots the cumulative proportion of DALY rates against the cumulative proportion of the population. A 45-degree line represents perfect equality, while the GC is calculated as twice the area between this equality line and the Lorenz curve. The GC ranges from 0 to 1, where 0 indicates perfect equality and 1 indicates total inequality [77]. We computed the GC using Stata’s ineqdeco module, which estimates inequality indices with subgroup decomposition. To ensure statistical robustness, bootstrap resampling was applied to derive 95% confidence intervals [78]. Additionally, the SII was used as a complementary measure of health inequality, estimating the average absolute difference in DALY rates across countries. This measure is derived from the beta coefficient (slope) of a linear regression applied to Pen's Parade, which ranks all countries by DALY rate from lowest to highest while considering their respective population shares. Both GC and SII provide valuable insights into the extent of DALY rate inequality across countries [77, 79].

The GBD database provides estimates accompanied by 95% uncertainty intervals (95% UI), which account for variability and potential errors in the modeling process. These intervals define a plausible range within which the true DALY rate is expected to fall [15]. The estimation of DALY rates is derived from 1,000 random samples drawn from the posterior distribution. In this study, the reported DALY rate corresponds to the mean value of these 1,000 draws. The 95% UI is determined by the 2.5th and 97.5th percentiles of the resulting distribution. To assess statistical differences, the 95% UI was analyzed: if two or more countries had overlapping intervals, the difference in the DALYs was considered not have statistical significance; otherwise, a significant difference was inferred.

The dataset was obtained directly from the GBD Results Tool and structured in Microsoft Excel [80]. Age-standardized DALY rate ratios and GC were computed using the ineqdeco module in STATA [81]. Tables and graphical representations were produced in Excel [80], while the maps were generated using MapChart [82].

3.2 Lifestyle and metabolic risk factors, and diabetes mellitus prevalence in European countries from three waves of the European Health Interview Survey

3.2.1 Study Design and Data source

A repeated cross-sectional study was conducted using data from three waves of EHIS 1, 2, and 3 [70]. The European Health Interview Survey began its first phase from 2006 to 2009, covering 17 EU member states. The second phase took place from 2013 to 2015, expanding to include all 28 EU member states, as well as Iceland, Norway, and Turkey. The third round of data collection (EHIS 3) occurred in 2019, including the same countries as the second phase, with the addition of Albania and Serbia. EHIS is a population-based study that gathers data on health conditions, healthcare use, and health determinants across Europe. It targets individuals aged 15 and older who reside in private households. For each participating country, a representative sample was chosen from various population sources such as registers, censuses, and dwelling records. The most common sampling technique employed was a multi-stage, stratified, or systematic (cluster) design, with the individual being the final sampling unit. To minimize non-response bias, account for the sample design, and ensure representativeness, each EU member state calculated weighting factors [83]. Further methodological details can be found elsewhere [83, 84]. The microdata for this analysis were provided by the Statistical Office of the European Union (Eurostat).

3.2.2 Study Population

Participants with missing data for any of the analyzed variables were excluded from the study. As a result, n = 22,970 (21.4%) participants were excluded in 2009, n = 7,436 (6.8%) in 2014, and n = 10,453 (9.5%) in 2019. The final sample sizes for analysis were N = 84,239 for EHIS 1 (2009), N = 101,355 for EHIS 2 (2014), and N = 99,006 for EHIS 3 (2019). The study population consisted of adults aged 20 years and older from 11 EU Member States: Bulgaria, Cyprus, Czechia, Greece, Spain, Hungary, Latvia, Poland, Romania, Slovenia, and Slovakia.

Only countries with available data across all survey waves were included. Responses from Austria, Belgium, and Estonia were excluded due to missing data on certain risk factors, while Malta was not included as weighting data was unavailable in the EHIS 1 wave.

3.2.3 Study Variables

All respondent data were self-reported and the responses for DM were used as the outcome variable, assessed through the question: “During the past 12 months, have you had diabetes?” Participants who responded “yes” were classified as having DM.

Demographic characteristics included sex and age groups (20–44, 45–64, and 65 and above). Socioeconomic factors encompassed education level, degree of urbanization, and labor status. Education level was determined based on the International Standard Classification of Education (ISCED) [85, 86]. For analysis, education levels were grouped into three categories in each survey: ISCED levels 0–2 (0–3 in EHIS 1) were combined into a "primary or less than primary education" category, ISCED levels 3–4 (4–5 in EHIS 1) into a "secondary education" category, and ISCED levels 5–8 (6–7 in EHIS 1) into a "higher education" category. Degree of urbanization was categorized into two groups: urban areas, which included densely and intermediately populated areas (in EHIS 1 and 2) and cities, towns, and suburbs (in EHIS 3); and rural areas, which encompassed less populated areas (in EHIS 1 and 2) and rural areas (in EHIS 3). Labor status was classified into three categories: employed, unemployed, and other (including students, pupils, retirees, individuals performing domestic tasks, those permanently disabled, individuals in compulsory military or community service, and other statuses).

Based on self-reported responses, five risk variables were evaluated in this study: (1) BMI, (2) smoking, (3) PA, (4) consumption of fruit and vegetables. By dividing body weight in kilograms by height in meters squared (kg/m2), the BMI was determined. Participants were divided into two groups according to their BMI for the analysis: underweight or normal (BMI < 25 kg/m2) and overweight or obese (BMI ≥ 25 kg/m2). Smoking status was divided into two categories: nonsmoker and current smoker, which included daily and occasional smokers. In terms of PA, the amount of time spent engaging in moderate-intensity PA each week (without walking) and the frequency of walking for at least ten minutes each day were calculated independently.

EHIS 1 took into account the amount of time spent engaging in moderate PA each week. In EHIS 2 and 3, the EHIS-Physical Activity Questionnaire (EHIS-PAQ) [87, 88] was used to measure the amount of time spent engaging in aerobic level PA. The weekly total of minutes spent on sports, fitness, or leisure physical activities, as well as cycling, was used to calculate health-enhancing physical activity (HEPA) [87]. The PA indication was classified as engaging in moderate-intensity PA for at least 150 minutes per week or not, in compliance with recommendations [89, 90]. Walking for at least 10 minutes a day was classified as never, one to six days a week, and every day. The analysis utilized the frequency of weekly consumption of fruits and vegetables separately. Intake of fruits and vegetables was divided into three categories: once or more per day, once to six times per week, and less frequently or never.

3.2.4 Statistical analysis

For each survey, the characteristics of the sample population were described using descriptive statistics. By using the sampling weights included in the database of EHIS surveys, we determined the weighted proportions and unweighted absolute number of respondents for each survey. Chi-square tests were used to examine group differences.

An estimate of the crude prevalence of DM was calculated. The 2013 revision of the European Standard Population was used for direct standardization in order to account for variations in the age structure of populations and to enable sufficient comparability of prevalence estimates. For the population aged 20 years and older, age-standardized prevalence of DM for each risk factor category was calculated using 5-year age groups [91].

To analyze the link between risk factors and DM, Poisson regression models were applied, incorporating adjustments for demographic and socioeconomic factors. Prevalence ratios (PRs) with 95% confidence intervals (CIs) were calculated and reported. The analysis was performed separately for each of the three datasets, and an additional pooled analysis was conducted. In the combined dataset, an interaction term was introduced between survey year and risk factors to determine whether the prevalence of DM varied over time based on these variables. Moreover, to examine shifts in risk factor prevalence across different European regions, the 11 countries included in the study were classified into two distinct groups based on the EuroVoc system: Central and Eastern Europe (comprising Bulgaria, Czechia, Hungary, Latvia, Poland, Romania, Slovenia, and Slovakia) and Southern Europe (including Cyprus, Greece, and Spain). This regional division reflects key socioeconomic contrasts between these two European regions [92].

Sampling weights were incorporated through the "svy" command in Stata. Model performance was evaluated using the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). Statistical significance was determined at a threshold of $p < 0.05$. All statistical analyses were conducted using STATA IC version 13.0 (StataCorp LP, College Station, Texas, USA) [81], while Microsoft Excel (Microsoft 365) was used to generate the figures [80].

3.2.5 Ethics statements

This dissertation is based on a secondary analysis of an anonymized, publicly accessible dataset that has previously been ethically approved at the national level by the organizations in charge of survey implementation. Therefore, no further ethics approval was needed. The study was carried out in accordance with all applicable rules and regulations. Regulation (EC) No. 1338/2008 of the European Parliament and the Council, which was adopted on December 16, 2008, led to the implementation of the EHIS. While EHIS wave 3 data collection followed Commission Regulation (EU) No. 2018/255, EHIS wave 2 data collection followed

Commission Regulation (EU) No. 141/2013. All respondents gave their informed consent before taking part in the survey. This study is based on the accepted Eurostat research proposal RPP 266/2020-LFS-EHIS.

4. Results

4.1 Inequalities in the burden of non-communicable diseases across European countries: a systematic analysis of the Global Burden of Disease 2019 study

4.1.1 Age-standardized NCDs DALY rate in 2019

Age-standardized DALY rates for NCDs level 1 and 2 by countries, 2019

The age-standardized DALY rates for level 1 and level 2 NCDs per 100,000 population and 95% UI for the 30 EEA Member States are shown in Table 1. The NCDs DALY rate varied from a low of 14,845 (95% UI: 12,379 to 17,682) in Iceland to a high of 24,342 (95% UI: 20,406 to 28,775) in Bulgaria. CVD was the leading cause of the NCDs DALY rate in Bulgaria, accounting for 9,570 (95% UI: 7,964 to 11,490) or 39.3% of NCDs; Romania came in second with 6,644 (95% UI: 5,673 to 7,840) or 32.2%, and Latvia with 6,603 (95% UI: 5,695 to 7,727) or 32.1%. Iceland had the lowest CVD-related DALY rate of 1,853 (95% UI: 1,669 to 2,032) of all NCDs, followed by Spain with 1,834 (95% UI: 1,699 to 1,958) at 11.9% and France with 1,628 (95% UI: 1,489 to 1,742) at 10.5%. The NCDs with the lowest DALY rate and percentage were sense organ diseases in Sweden with 340 (95% UI: 227 to 487) and 2.2%, substance use disorders in Italy with 344 (95% UI: 255 to 445) and 2.2%, and chronic respiratory illnesses in Estonia with 354 (95% UI: 294 to 426) and 1.9%.

Table 1: Age-standardized DALY rate per 100,000 population by NCDs and EEA Member States, 2019.

Cause	Austria			Belgium			Bulgaria			Croatia			Cyprus		
	DALY rate	95%UI	(%)	DALY rate	95%UI	(%)	DALY rate	95%UI	(%)	DALY rate	95%UI	(%)	DALY rate	95%UI	(%)
NCDs	**16,239**	**(13,738-19,152)**	**(100)**	**16,513**	**(13,920-19,413)**	**(100)**	**24,342**	**(20,406-28,775)**	**(100)**	**17,974**	**(14,981-21,351)**	**(100)**	**16,599**	**(14,057-19,448)**	**(100)**
CVDs	2,408	(2,225-2,552)	(14.8)	2,021	(1,879-2,144)	(12.2)	9,570	(7,964-11,490)	(39.3)	4,267	(3,532-5,131)	(23.7)	2,939	(2,629-3,303)	(17.7)
Chronic respiratory diseases	651	(544-777)	(4.0)	879	(763-1,012)	(5.3)	693	(576-819)	(2.8)	632	(524-748)	(3.5)	864	(707-1,028)	(5.2)
Diabetes and kidney diseases	790	(654-953)	(4.9)	694	(548-873)	(4.2)	1265	(1,039-1,516)	(5.2)	981	(775-1,229)	(5.5)	1165	(972-1,388)	(7.0)
Digestive diseases	674	(595-768)	(4.1)	641	(580-714)	(3.9)	1282	(1,045-1,554)	(5.3)	898	(731-1,083)	(5.0)	483	(423-555)	(2.9)
Mental disorders	1,905	(1,388-2,518)	(11.7)	1,875	(1,369-2,467)	(11.4)	1,349	(991-1,785)	(5.5)	1,451	(1,059-1,919)	(8.1)	1,915	(1,390-2,541)	(11.5)
Musculoskeletal disorders	1,971	(1,413-2,650)	(12.1)	2,042	(1,461-2,729)	(12.4)	1,544	(1,096-2,061)	(6.3)	1,600	(1,141-2,117)	(8.9)	2,225	(1,597-2,963)	(13.4)
Neoplasms	2,820	(2,682-2,968)	(17.4)	3,256	(3,096-3,421)	(19.7)	4,368	(3,485-5,458)	(17.9)	3,770	(2,989-4,719)	(21.0)	2,648	(2,366-2,944)	(16.0)
Neurological disorders	1,326	(734-2,203)	(8.2)	1,579	(775-2,769)	(9.6)	1,313	(784-2,066)	(5.4)	1,289	(732-2,047)	(7.2)	1,330	(690-2,273)	(8.0)
Sense organ diseases	392	(263-558)	(2.4)	409	(279-580)	(2.5)	618	(412-888)	(2.5)	606	(407-879)	(3.4)	397	(268-569)	(2.4)
Skin and subcutaneous diseases	711	(482-1,013)	(4.4)	730	(504-1,024)	(4.4)	454	(300-669)	(1.9)	444	(293-654)	(2.5)	719	(500-1,021)	(4.3)
Substance use disorders	659	(516-816)	(4.1)	601	(476-750)	(3.6)	384	(291-497)	(1.6)	523	(406-660)	(2.9)	358	(267-461)	(2.2)
Other NCDs	1,932	(1,486-2,487)	(11.9)	1,788	(1,348-2,322)	(10.8)	1,503	(1,189-1,904)	(6.2)	1,513	(1,157-1,950)	(8.4)	1,556	(1,184-2,026)	(9.4)

Cause	Czechia			Denmark			Estonia			Finland			France		
	DALY rate	95%UI	(%)	DALY rate	95%UI	(%)	DALY rate	95%UI	(%)	DALY rate	95%UI	(%)	DALY rate	95%UI	(%)
NCDs	**17,125**	**(14,441-20,203)**	**(100)**	**17,166**	**(14,672-19,955)**	**(100)**	**18,874**	**(15,777-22,305)**	**(100)**	**16,428**	**(13,963-19,205)**	**(100)**	**15,461**	**(13,059-18,230)**	**(100)**
CVDs	3,909	(3,314-4,605)	(22.8)	1,968	(1,833-2,091)	(11.5)	4,651	(3,813-5,715)	(24.6)	2,864	(2,653-3,031)	(17.4)	1,628	(1,489-1,742)	(10.5)
Chronic respiratory diseases	628	(529-728)	(3.7)	1030	(867-1,167)	(6.0)	354	(294-426)	(1.9)	618	(512-756)	(3.8)	554	(445-692)	(3.6)
Diabetes and kidney diseases	1,251	(960-1,590)	(7.3)	678	(576-798)	(4.0)	752	(600-928)	(4.0)	685	(512-889)	(4.2)	463	(383-558)	(3.0)
Digestive diseases	896	(748-1,062)	(5.2)	686	(616-768)	(4.0)	987	(805-1,203)	(5.2)	788	(717-873)	(4.8)	565	(512-629)	(3.7)
Mental disorders	1,385	(1,014-1,825)	(8.1)	1,794	(1,303-2,376)	(10.5)	1,573	(1,145-2,081)	(8.3)	1,887	(1,387-2,497)	(11.5)	2,045	(1,489-2,717)	(13.2)
Musculoskeletal disorders	1,548	(1,110-2,065)	(9.0)	2,485	(1,781-3,292)	(14.5)	1,510	(1,080-2,011)	(8.0)	2,037	(1,467-2,717)	(12.4)	2,055	(1,474-2,732)	(13.3)
Neoplasms	3,405	(2,813-4,137)	(19.9)	3,494	(3,304-3,675)	(20.4)	3,522	(2,774-4,417)	(18.7)	2,606	(2,442-2,778)	(15.9)	3,311	(3,133-3,473)	(21.4)
Neurological disorders	1,269	(725-2,038)	(7.4)	1,282	(712-2,110)	(7.5)	1,337	(810-2,094)	(7.1)	1,396	(763-2,301)	(8.5)	1,426	(791-2,290)	(9.2)
Sense organ diseases	595	(398-861)	(3.5)	374	(250-537)	(2.2)	642	(427-932)	(3.4)	388	(262-553)	(2.4)	402	(273-572)	(2.6)
Skin and subcutaneous diseases	454	(300-669)	(2.7)	776	(529-1,106)	(4.5)	553	(357-805)	(2.9)	748	(515-1,058)	(4.6)	843	(578-1,180)	(5.5)
Substance use disorders	515	(398-648)	(3.0)	890	(743-1,052)	(5.2)	1646	(1,350-1,989)	(8.7)	925	(785-1,079)	(5.6)	567	(453-697)	(3.7)
Other NCDs	1,271	(947-1,677)	(7.4)	1,709	(1,290-2,218)	(10.0)	1,345	(1,009-1,758)	(7.1)	1,484	(1,114-1,945)	(9.0)	1,602	(1,228-2,056)	(10.4)

Cause	Germany			Greece			Hungary			Iceland			Ireland		
	DALY rate	95%UI	(%)	DALY rate	95%UI	(%)	DALY rate	95%UI	(%)	DALY rate	95%UI	(%)	DALY rate	95%UI	(%)
NCDs	**17,277**	**(14,710-20,233)**	**(100)**	**17,222**	**(14,700-20,068)**	**(100)**	**20,458**	**(17,350-23,915)**	**(100)**	**14,845**	**(12,379-17,682)**	**(100)**	**16,792**	**(14,166-19,735)**	**(100)**
CVDs	2,601	(2,422-2,741)	**(100)**	3,198	(3,001-3,351)	(18.6)	5,420	(4,612-6,359)	(26.5)	1,853	(1,669-2,032)	(12.5)	2,193	(1,990-2,338)	(13.1)
Chronic respiratory diseases	749	(651-857)	(15.1)	724	(611-843)	(4.2)	947	(816-1,099)	(4.6)	768	(635-936)	(5.2)	969	(830-1,128)	(5.8)
Diabetes and kidney diseases	894	(723-1,099)	(4.3)	790	(638-967)	(4.6)	1020	(815-1,254)	(5.0)	533	(408-683)	(3.6)	622	(491-770)	(3.7)
Digestive diseases	742	(677-816)	(5.2)	470	(412-548)	(2.7)	1269	(1,063-1,489)	(6.2)	355	(305-411)	(2.4)	465	(413-533)	(2.8)
Mental disorders	1,899	(1,368-2,515)	(4.3)	2,260	(1,664-2,968)	(13.1)	1,394	(1,014-1,851)	(6.8)	1,761	(1,283-2,342)	(11.9)	2,202	(1,612-2,884)	(13.1)
Musculoskeletal disorders	2,211	(1,583-2,927)	(11.0)	2,031	(1,463-2,694)	(11.8)	1,605	(1,149-2,135)	(7.8)	2,253	(1,593-3,017)	(15.2)	2,273	(1,644-3,028)	(13.5)
Neoplasms	3,221	(3,063-3,368)	(12.8)	3,300	(3,134-3,471)	(19.2)	4,551	(3,772-5,494)	(22.2)	2,690	(2,449-2,963)	(18.1)	3,049	(2,859-3,244)	(18.2)
Neurological disorders	1,539	(811-2,545)	(18.6)	1,330	(662-2,277)	(7.7)	1,260	(729-2,007)	(6.2)	1,385	(749-2,286)	(9.3)	1,404	(766-2,318)	(8.4)
Sense organ diseases	393	(267-559)	(8.9)	419	(285-594)	(2.4)	614	(412-885)	(3.0)	399	(269-570)	(2.7)	397	(269-569)	(2.4)
Skin and subcutaneous diseases	717	(485-1,039)	(2.3)	677	(465-970)	(3.9)	489	(324-716)	(2.4)	753	(515-1,064)	(5.1)	728	(500-1,031)	(4.3)
Substance use disorders	618	(501-751)	(4.1)	432	(333-540)	(2.5)	490	(378-619)	(2.4)	672	(544-822)	(4.5)	824	(654-1,007)	(4.9)
Other NCDs	1,692	(1,287-2,189)	(3.6)	1,591	(1,221-2,077)	(9.2)	1,399	(1,084-1,781)	(6.8)	1,423	(1,052-1,872)	(9.6)	1,666	(1,283-2,137)	(9.9)

Cause	Italy			Latvia			Lithuania			Luxembourg			Malta		
	DALY rate	**95%UI**	**(%)**	**DALY rate**	**95%UI**	**(%)**	**DALY rate**	**95%UI**	**(%)**	**DALY rate**	**95%UI**	**(%)**	**DALY rate**	**95%UI**	**(%)**
NCDs	**15,753**	**(13,159-18,646)**	**(100)**	**20,566**	**(17,662-23,817)**	**(100)**	**20,070**	**(17,138-23,241)**	**(100)**	**15,740**	**(13,161-18,606)**	**(100)**	**15,953**	**(13,411-18,839)**	**(100)**
CVDs	2,032	(1,854-2,156)	(12.9)	6,603	(5,695-7,727)	(32.1)	5,824	(4,926-6,939)	(29.0)	1,981	(1,766-2,213)	(12.6)	2,511	(2,256-2,770)	(15.7)
Chronic respiratory diseases	539	(454-635)	(3.4)	391	(320-484)	(1.9)	424	(353-510)	(2.1)	787	(653-953)	(5.0)	674	(547-828)	(4.2)
Diabetes and kidney diseases	814	(658-992)	(5.2)	746	(600-923)	(3.6)	547	(434-683)	(2.7)	804	(618-1,020)	(5.1)	919	(744-1,129)	(5.8)
Digestive diseases	644	(553-752)	(4.1)	1069	(903-1,256)	(5.2)	1447	(1,215-1,729)	(7.2)	610	(531-700)	(3.9)	429	(371-495)	(2.7)
Mental disorders	1,954	(1,434-2,586)	(12.4)	1,614	(1,184-2,122)	(7.8)	1,716	(1,256-2,262)	(8.6)	1,850	(1,352-2,442)	(11.8)	1,903	(1,387-2,522)	(11.9)
Musculoskeletal disorders	2,184	(1,562-2,889)	(13.9)	1,531	(1,097-2,054)	(7.4)	1,496	(1,065-1,988)	(7.5)	2,141	(1,538-2,848)	(13.6)	2,224	(1,600-2,953)	(13.9)
Neoplasms	2,976	(2,823-3,081)	(18.9)	3,631	(3,056-4,324)	(17.7)	3,573	(2,929-4,312)	(17.8)	2,933	(2,618-3,306)	(18.6)	2,604	(2,358-2,889)	(16.3)
Neurological disorders	1,472	(740-2,567)	(9.3)	1,260	(758-1,994)	(6.1)	1,242	(748-1,967)	(6.2)	1,366	(753-2,213)	(8.7)	1,329	(711-2,222)	(8.3)
Sense organ diseases	530	(367-733)	(3.4)	691	(465-989)	(3.4)	688	(463-989)	(3.4)	380	(253-547)	(2.4)	405	(274-576)	(2.5)
Skin and subcutaneous diseases	733	(497-1,050)	(4.7)	419	(286-615)	(2.0)	441	(296-648)	(2.2)	728	(501-1,039)	(4.6)	748	(528-1,028)	(4.7)
Substance use disorders	344	(255-445)	(2.2)	1056	(864-1,267)	(5.1)	1053	(879-1,242)	(5.2)	664	(530-820)	(4.2)	466	(360-591)	(2.9)
Other NCDs	1,532	(1,156-1,999)	(9.7)	1,554	(1,192-1,986)	(7.6)	1,619	(1,242-2,073)	(8.1)	1,496	(1,108-1,976)	(9.5)	1,740	(1,350-2,224)	(10.9)

Cause	Netherlands			Norway			Poland			Portugal			Romania		
	DALY rate	95%UI	(%)	DALY rate	95%UI	(%)	DALY rate	95%UI	(%)	DALY rate	95%UI	(%)	DALY rate	95%UI	(%)
NCDs	**16,215**	**(13,797-19,002)**	**(100)**	**15,642**	**(13,123-18,527)**	**(100)**	**18,313**	**(15,640-21,393)**	**(100)**	**16,664**	**(14,085-19,599)**	**(100)**	**20,643**	**(17,686-23,857)**	**(100)**
CVDs	1,883	(1,737-2,009)	(11.6)	1,901	(1,747-2,027)	(12.2)	4,183	(3,595-4,832)	(22.8)	2,150	(1,997-2,282)	**(100)**	6,644	(5,673-7,840)	(32.2)
Chronic respiratory diseases	977	(816-1,136)	(6.0)	889	(719-1,049)	(5.7)	651	(541-783)	(3.6)	861	(706-1,064)	(12.9)	714	(602-851)	(3.5)
Diabetes and kidney diseases	637	(519-775)	(3.9)	650	(516-807)	(4.2)	951	(752-1,160)	(5.2)	980	(798-1,199)	(5.2)	781	(629-961)	(3.8)
Digestive diseases	438	(394-491)	(2.7)	510	(431-606)	(3.3)	1033	(874-1,211)	(5.6)	624	(571-690)	(5.9)	1501	(1,269-1,782)	(7.3)
Mental disorders	2,069	(1,519-2,734)	(12.8)	1,945	(1,427-2,580)	(12.4)	1,259	(930-1,651)	(6.9)	2,317	(1,672-3,082)	(3.7)	1,368	(1,007-1,805)	(6.6)
Musculoskeletal disorders	2,001	(1,435-2,655)	(12.3)	1,879	(1,333-2,519)	(12.0)	1,629	(1,167-2,169)	(8.9)	2,256	(1,628-2,974)	(13.9)	1,579	(1,122-2,113)	(7.6)
Neoplasms	3,614	(3,411-3,796)	(22.3)	2,844	(2,705-2,968)	(18.2)	4,192	(3,527-4,913)	(22.9)	3,135	(2,980-3,302)	(13.5)	3,998	(3,275-4,799)	(19.4)
Neurological disorders	1,414	(787-2,320)	(8.7)	1,474	(794-2,439)	(9.4)	1,337	(800-2,121)	(7.3)	1,291	(668-2,200)	(18.8)	1,249	(703-2,034)	(6.1)
Sense organ diseases	371	(249-538)	(2.3)	470	(317-664)	(3.0)	637	(431-912)	(3.5)	413	(283-589)	(7.7)	623	(416-896)	(3.0)
Skin and subcutaneous diseases	721	(497-1,019)	(4.4)	716	(484-1,022)	(4.6)	460	(307-676)	(2.5)	733	(504-1,038)	(2.5)	421	(281-624)	(2.0)
Substance use disorders	428	(325-538)	(2.6)	668	(555-790)	(4.3)	765	(609-934)	(4.2)	477	(344-634)	(4.4)	361	(274-463)	(1.7)
Other NCDs	1,663	(1,263-2,132)	(10.3)	1,697	(1,271-2,213)	(10.9)	1,216	(941-1,582)	(6.6)	1,428	(1,086-1,855)	(2.9)	1,405	(1,087-1,811)	(6.8)

Cause	Slovakia			Slovenia			Spain			Sweden			United Kingdom		
	DALY rate	95%UI	(%)	DALY rate	95%UI	(%)	DALY rate	95%UI	(%)	DALY rate	95%UI	(%)	DALY rate	95%UI	(%)
NCDs	**18,755**	**(15,624-22,338)**	**(100)**	**15,164**	**(12,511-18,272)**	**(100)**	**15,454**	**(13,046-18,341)**	**(100)**	**15,351**	**(12,978-18,096)**	**(100)**	**18,001**	**(15,317-21,079)**	**(100)**
CVDs	5,134	(4,207-6,179)	(27.4)	2,546	(2,068-3,143)	(16.8)	1,834	(1,699-1,958)	(11.9)	2,329	(2,149-2,483)	15.2)	2,362	(2,216-2,477)	(13.1)
Chronic respiratory diseases	476	(395-569)	(2.5)	505	(407-613)	(3.3)	752	(649-863)	(4.9)	786	(634-963)	(5.1)	1187	(1,004-1,392)	(6.6)
Diabetes and kidney diseases	848	(666-1,049)	(4.5)	697	(516-888)	(4.6)	789	(608-999)	(5.1)	615	(502-746)	(4.0)	780	(592-993)	(4.3)
Digestive diseases	1,242	(996-1,555)	(6.6)	864	(697-1,078)	(5.7)	551	(500-614)	(3.6)	466	(410-535)	(3.0)	889	(794-1,008)	(4.9)
Mental disorders	1,373	(1,015-1,817)	(7.3)	1,462	(1,071-1,929)	(9.6)	2,192	(1,614-2,905)	(14.2)	2,017	(1,474-2,653)	(13.1)	1,959	(1,437-2,590)	(10.9)
Musculoskeletal disorders	1,541	(1,099-2,049)	(8.2)	1,521	(1,081-2,033)	(10.0)	1,831	(1,298-2,442)	(11.8)	2,036	(1,472-2,692)	(13.3)	2,314	(1,671-3,050)	(12.9)
Neoplasms	3,762	(2,974-4,712)	(20.1)	3,341	(2,615-4,278)	(22.0)	2,977	(2,820-3,120)	(19.3)	2,672	(2,550-2,783)	(17.4)	3,302	(3,164-3,403)	(18.3)
Neurological disorders	1,281	(739-2,049)	(6.8)	1,249	(727-2,025)	(8.2)	1,350	(700-2,272)	(8.7)	1,321	(692-2,210)	(8.6)	1,434	(826-2,318)	(8.0)
Sense organ diseases	606	(400-878)	(3.2)	568	(377-825)	(3.7)	538	(370-749)	(3.5)	340	(227-487)	(2.2)	503	(342-711)	(2.8)
Skin and subcutaneous diseases	451	(296-662)	(2.4)	451	(297-665)	(3.0)	698	(481-986)	(4.5)	692	(469-985)	(4.5)	736	(505-1,043)	(4.1)
Substance use disorders	477	(356-616)	(2.5)	621	(490-775)	(4.1)	469	(354-605)	(3.0)	692	(569-818)	(4.5)	924	(730-1,136)	(5.1)
Other NCDs	1,564	(1,204-2,023)	(8.3)	1,337	(997-1,772)	(8.8)	1,472	(1,129-1,900)	(9.5)	1,386	(1,048-1,799)	(9.0)	1,609	(1,254-2,037)	(8.9)

Legend: %: percentage, UI: Uncertainty Interval, NCDs: non-communicable diseases, and CVDs: cardiovascular diseases.

Age-standardized level 1 NCDs DALY rate ratios by countries and sex, 2019

The 2019 age-standardized level 1 NCDs DALY rate ratio was nearly 1.00 for all countries, indicating that the DALY rates in are not very unequal (Fig. 1). For males, the statistically significant difference between Iceland and Bulgaria peaked at 1.90. To put it another way, the average NCDs DALY rate for men in Bulgaria was 1.9 times greater than the rate in Iceland. Overall, males had a larger ratio than females, indicating that the DALY rate for males varied more among countries. Bulgaria, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, and Slovakia were among the eastern European countries with the highest NCD DALY rate ratios for men when compared to the majority of other countries. A few ratios, including Denmark/Finland, Ireland/Austria, Spain/France, Ireland/Slovenia, Italy/Netherlands, and Poland/Slovakia, achieved a ratio of 1.00, indicating complete equality in DALY rates between two countries.

The only ratio with statistically significant difference for females peaked at 1.50 between Slovenia and Bulgaria. Comparing Bulgaria to practically every other EEA country, it was found to have the greatest levels of inequality, especially among women. Italy/Finland, Lithuania/Denmark, Austria/Luxembourg, Austria/Malta, Malta/Luxembourg, UK/Latvia, Spain/France, and many other comparisons between countries were found to be at a 1.00 ratio.

Countries			AT	BE	BG	HR	CY	CZ	DK	EE	FI	FR	DE	GR	HU	IS	IE	IT	LV	LT	LU	MT	NL	NO	PL	PT	RO	SK	SI	ES	SE	UK
	Female		16009	16314	20822	16161	16589	15642	17194	16414	15845	15322	17077	16777	17989	14816	16896	15771	17803	17208	15964	16000	16545	15894	15821	16190	17920	16769	13910	15301	15707	17766
		Male	16716	16931	28589	20315	16599	19000	17301	22234	17243	15831	17713	17835	23763	15033	16779	15977	24497	24160	15675	16136	16044	15551	21445	17412	23955	21341	16812	15864	15115	18370
AT	16009	16716	1.00	1.02	1.30	1.01	1.04	1.02	1.07	1.03	1.01	1.04	1.07	1.05	1.12	1.08	1.06	1.02	1.11	1.07	1.00	1.00	1.03	1.01	1.01	1.01	1.12	1.05	1.15	1.05	1.02	1.11
BE	16314	16931	1.01	1.00	1.28	1.01	1.02	1.04	1.05	1.01	1.03	1.06	1.05	1.03	1.10	1.10	1.04	1.03	1.09	1.05	1.02	1.02	1.01	1.03	1.03	1.01	1.10	1.03	1.17	1.07	1.04	1.09
BG	20822	28589	***1.71***	***1.69***	1.00	1.29	1.26	1.33	1.21	1.27	1.31	1.36	1.22	1.24	1.16	1.41	1.23	1.32	1.17	1.21	1.30	1.30	1.26	1.31	1.32	1.29	1.16	1.24	***1.50***	1.36	1.33	1.17
HR	16161	20315	1.22	1.20	1.41	1.00	1.03	1.03	1.06	1.02	1.02	1.05	1.06	1.04	1.11	1.09	1.05	1.02	1.10	1.06	1.01	1.01	1.02	1.02	1.02	1.00	1.11	1.04	1.16	1.06	1.03	1.10
CY	16589	16599	1.01	1.02	***1.72***	1.22	1.00	1.06	1.04	1.01	1.05	1.08	1.03	1.01	1.08	1.12	1.02	1.05	1.07	1.04	1.04	1.04	1.00	1.04	1.05	1.02	1.08	1.01	1.19	1.08	1.06	1.07
CZ	15642	19000	1.14	1.12	***1.50***	1.07	1.14	1.00	1.10	1.05	1.01	1.02	1.09	1.07	1.15	1.06	1.08	1.01	1.14	1.10	1.02	1.02	1.06	1.02	1.01	1.04	1.15	1.07	1.12	1.02	1.00	1.14
DK	17194	17301	1.03	1.02	***1.65***	1.17	1.04	1.10	1.00	1.05	1.09	1.12	1.01	1.02	1.05	1.16	1.02	1.09	1.04	1.00	1.08	1.07	1.04	1.08	1.09	1.06	1.04	1.03	1.24	1.12	1.09	1.03
EE	16414	22234	***1.33***	1.31	1.29	1.09	1.34	1.17	1.29	1.00	1.04	1.07	1.04	1.02	1.10	1.11	1.03	1.04	1.08	1.05	1.03	1.03	1.01	1.03	1.04	1.01	1.09	1.02	1.18	1.07	1.05	1.08
FI	15845	17243	1.03	1.02	***1.66***	1.18	1.04	1.10	1.00	1.29	1.00	1.03	1.08	1.06	1.14	1.07	1.07	1.00	1.12	1.09	1.01	1.01	1.04	1.00	1.00	1.02	1.13	1.06	1.14	1.04	1.01	1.12
FR	15322	15831	1.06	1.07	***1.81***	1.28	1.05	1.20	1.09	***1.40***	1.09	1.00	1.11	1.09	1.17	1.03	1.10	1.03	1.16	1.12	1.04	1.04	1.08	1.04	1.03	1.06	1.17	1.09	1.10	1.00	1.03	1.16
DE	17077	17713	1.06	1.05	***1.61***	1.15	1.07	1.07	1.02	1.26	1.03	1.12	1.00	1.02	1.05	1.15	1.01	1.08	1.04	1.01	1.07	1.07	1.03	1.07	1.08	1.05	1.05	1.02	1.23	1.12	1.09	1.04
GR	16777	17835	1.07	1.05	***1.60***	1.14	1.07	1.07	1.03	1.25	1.03	1.13	1.01	1.00	1.07	1.13	1.01	1.06	1.06	1.03	1.05	1.05	1.01	1.06	1.06	1.04	1.07	1.00	1.21	1.10	1.07	1.06
HU	17989	23763	***1.42***	***1.40***	1.20	1.17	***1.43***	1.25	***1.37***	1.07	***1.38***	***1.50***	**1.34**	***1.33***	1.00	1.21	1.06	1.14	1.01	1.05	1.13	1.12	1.09	1.13	1.14	1.11	1.00	1.07	1.29	1.18	1.15	1.01
IS	14816	15033	1.11	1.13	***1.90***	1.35	1.10	1.26	1.15	***1.48***	1.15	1.05	1.18	1.19	***1.58***	1.00	1.14	1.06	1.20	1.16	1.08	1.08	1.12	1.07	1.07	1.09	1.21	1.13	1.07	1.03	1.06	1.20
IE	16896	16779	1.00	1.01	***1.70***	1.21	1.01	1.13	1.03	1.33	1.03	1.06	1.06	1.06	***1.42***	1.12	1.00	1.07	1.05	1.02	1.06	1.06	1.02	1.06	1.07	1.04	1.06	1.01	1.21	1.10	1.08	1.05
IT	15771	15977	1.05	1.06	***1.79***	1.27	1.04	1.19	1.08	1.39	1.08	1.01	1.11	1.12	***1.49***	1.06	1.05	1.00	1.13	1.09	1.01	1.01	1.05	1.01	1.00	1.03	1.14	1.06	1.13	1.03	1.00	1.13
LV	17803	24497	***1.47***	***1.45***	1.17	1.21	***1.48***	1.29	***1.42***	1.10	***1.42***	***1.55***	***1.38***	***1.37***	1.03	***1.63***	***1.46***	***1.53***	1.00	1.03	1.12	1.11	1.08	1.12	1.13	1.10	1.01	1.06	1.28	1.16	1.13	1.00
LT	17208	24160	***1.45***	***1.43***	1.18	1.19	***1.46***	1.27	***1.40***	1.09	***1.40***	***1.53***	***1.36***	***1.35***	1.02	***1.61***	***1.44***	***1.51***	1.01	1.00	1.08	1.08	1.04	1.08	1.09	1.06	1.04	1.03	1.24	1.12	1.10	1.03
LU	15964	15675	1.07	1.08	***1.82***	1.30	1.06	1.21	1.10	***1.42***	1.10	1.01	1.13	1.14	***1.52***	1.04	1.07	1.02	***1.56***	***1.54***	1.00	1.00	1.04	1.00	1.01	1.01	1.12	1.05	1.15	1.04	1.02	1.11
MT	16000	16136	1.04	1.05	***1.77***	1.26	1.03	1.18	1.07	1.38	1.07	1.02	1.10	1.11	***1.47***	1.07	1.04	1.01	***1.52***	***1.50***	1.03	1.00	1.03	1.01	1.01	1.01	1.12	1.05	1.15	1.05	1.02	1.11
NL	16545	16044	1.04	1.06	***1.78***	1.27	1.03	1.18	1.08	***1.39***	1.07	1.01	1.10	1.11	***1.48***	1.07	1.05	1.00	***1.53***	***1.51***	1.02	1.01	1.00	1.04	1.05	1.02	1.08	1.01	1.19	1.08	1.05	1.07
NO	15894	15551	1.07	1.09	***1.84***	1.31	1.07	1.22	1.11	***1.43***	1.11	1.02	1.14	1.15	***1.53***	1.03	1.08	1.03	***1.58***	***1.55***	1.01	1.04	1.03	1.00	1.00	1.02	1.13	1.06	1.14	1.04	1.01	1.12
PL	15821	21445	1.28	1.27	1.33	1.06	1.29	1.13	1.24	1.04	1.24	1.35	1.21	1.20	1.11	***1.43***	1.28	1.34	1.14	1.13	1.37	1.33	1.34	1.38	1.00	1.02	1.13	1.06	1.14	1.03	1.01	1.12
PT	16190	17412	1.04	1.03	***1.64***	1.17	1.05	1.09	1.01	1.28	1.01	1.10	1.02	1.02	***1.36***	1.16	1.04	1.09	***1.41***	***1.39***	1.11	1.08	1.09	1.12	1.23	1.00	1.11	1.04	1.16	1.06	1.03	1.10
RO	17920	23955	***1.43***	***1.41***	1.19	1.18	***1.44***	1.26	***1.38***	1.08	***1.39***	***1.51***	***1.35***	***1.34***	1.01	***1.59***	***1.43***	***1.50***	1.02	1.01	***1.53***	***1.48***	***1.49***	***1.54***	1.12	1.38	1.00	1.07	1.29	1.17	1.14	1.01
SK	16769	21341	1.28	1.26	1.34	1.05	1.29	1.12	1.23	1.04	1.24	1.35	1.20	1.20	1.11	***1.42***	1.27	1.34	1.15	1.13	1.36	1.32	1.33	1.37	1.00	1.23	1.12	1.00	1.21	1.10	1.07	1.06
SI	13910	16812	1.01	1.01	***1.70***	1.21	1.01	1.13	1.03	1.32	1.03	1.06	1.05	1.06	***1.41***	1.12	1.00	1.05	***1.46***	***1.44***	1.07	1.04	1.05	1.08	1.28	1.04	***1.42***	1.27	1.00	1.10	1.13	1.28
ES	15301	15864	1.05	1.07	***1.80***	1.28	1.05	1.20	1.09	***1.40***	1.09	1.00	1.12	1.12	***1.50***	1.06	1.06	1.01	***1.54***	***1.52***	1.01	1.02	1.01	1.02	1.35	1.10	***1.51***	1.35	1.06	1.00	1.03	1.16
SE	15707	15115	1.11	1.12	***1.89***	1.34	1.10	1.26	1.14	***1.47***	1.14	1.05	1.17	1.18	***1.57***	1.01	1.11	1.06	***1.62***	***1.60***	1.04	1.07	1.06	1.03	***1.42***	1.15	***1.58***	***1.41***	1.11	1.05	1.00	1.13
UK	17766	18370	1.10	1.09	***1.56***	1.11	1.11	1.03	1.06	1.21	1.07	1.16	1.04	1.03	1.29	1.22	1.09	1.15	1.33	1.32	1.17	1.14	1.14	1.18	1.17	1.06	1.30	1.16	1.09	1.16	1.22	1.00

Figure 1: Ratio of age-standardized level 1 NCDs DALY rates for EEA Member States by sex, 2019.

Legend: shades of blue correspond to ratios close to 1, suggesting equality, whereas shades of red mark greater divergence from 1, indicating inequality. Ratios that are underlined and bolded highlight a statistically significant difference in DALY rates between the countries being compared, based on non-overlapping 95% uncertainty intervals. Values related to females are positioned above the diagonal line, while those for males are placed below it. AT: Austria, BE: Belgium, BG: Bulgaria, HR: Croatia, CY: Cyprus, CZ: Czechia, DK: Denmark, EE: Estonia, FI:

Finland, FR: France, DE: Germany, GR: Greece, HU: Hungary, IS: Iceland, IE: Ireland, IT: Italy, LV: Latvia, LT: Lithuania, LU: Luxembourg, MT: Malta, NL: Netherlands, NO: Norway, PL: Poland, PT: Portugal, RO: Romania, SK: Slovakia, SI: Slovenia, ES: Spain, SE: Sweden, UK: United Kingdom.

4.1.2 Changes in NCDs DALY rate between 1990 and 2019

Age-standardized level 1 DALY rates by countries and sex between 1990 and 2019

Figure 2 illustrates the trajectory of NCD DALY rates per 100,000 individuals for both males and females across the included countries, including the period from 1990 to 2019. Across the board, there was a consistent downward trend—DALY rates due to NCDs steadily declined in every country throughout the three decades.

Among males, clear inequalities were evident at the beginning of the observation period. In 1990, some countries reported notably higher DALY rates than others. Hungary topped the list with a rate of 35,066 (95% UI: 33,073 to 37,161), followed by Bulgaria at 31,747 (95% UI: 29,430 to 34,157). On the lower end, Slovenia registered 25,431 (95% UI: 21,152 to 30,611), while Iceland had the lowest rate at 19,589 (95% UI: 17,405 to 21,931). In contrast, the distribution of DALY rates among females was more uniform across EU countries, as indicated by overlapping 95% uncertainty intervals. In 1990, the highest rates were seen in Bulgaria (23,997; 95% UI: 21,538 to 26,836) and Romania (23,579; 95% UI: 21,253 to 26,158). France recorded the lowest female DALY rate, at 17,868 (95% UI: 14,979 to 21,155).

By1994, Latvia, Estonia, and Lithuania stood out with the highest NCD DALY rates for both men and women. While most countries began to see a reduction in these rates between 1990 and 1997, Bulgaria deviated from this general trend, showing no significant decline. In 2007, male DALY rates in the same Baltic countries surged again, reaching new highs. Among females, however, the peak rates in that year shifted slightly—Latvia and Lithuania remained among the top, but Hungary emerged as the third.

As the study concluded in 2019, a clear spread in DALY rates was observed. For men, the highest rate was recorded in Bulgaria at 28,589, while Iceland reported the lowest at 15,033. Female rates ranged from 20,822 in Bulgaria down to 13,910 in Slovenia. The inequalities between those countries were statistically significant, as demonstrated by non-overlapping 95% UI. Additionally, Bulgaria held the highest DALY rates across the entire period for both sexes, consistently outpacing all other countries.

Premature mortality, as measured by YLL, declined steadily across all countries during the study period, closely mirroring the downward trajectory observed in overall DALY rates. This decline was accompanied by relatively tight UI, suggesting that the YLL estimates were measured with a higher degree of precision. On the other hand, YLD figures remained largely unchanged. The consistency in YLD rates across countries and between sexes, combined with their notably wide 95% UI, points to minimal statistical differences in non-fatal health burdens across the region (see Appendix 1).

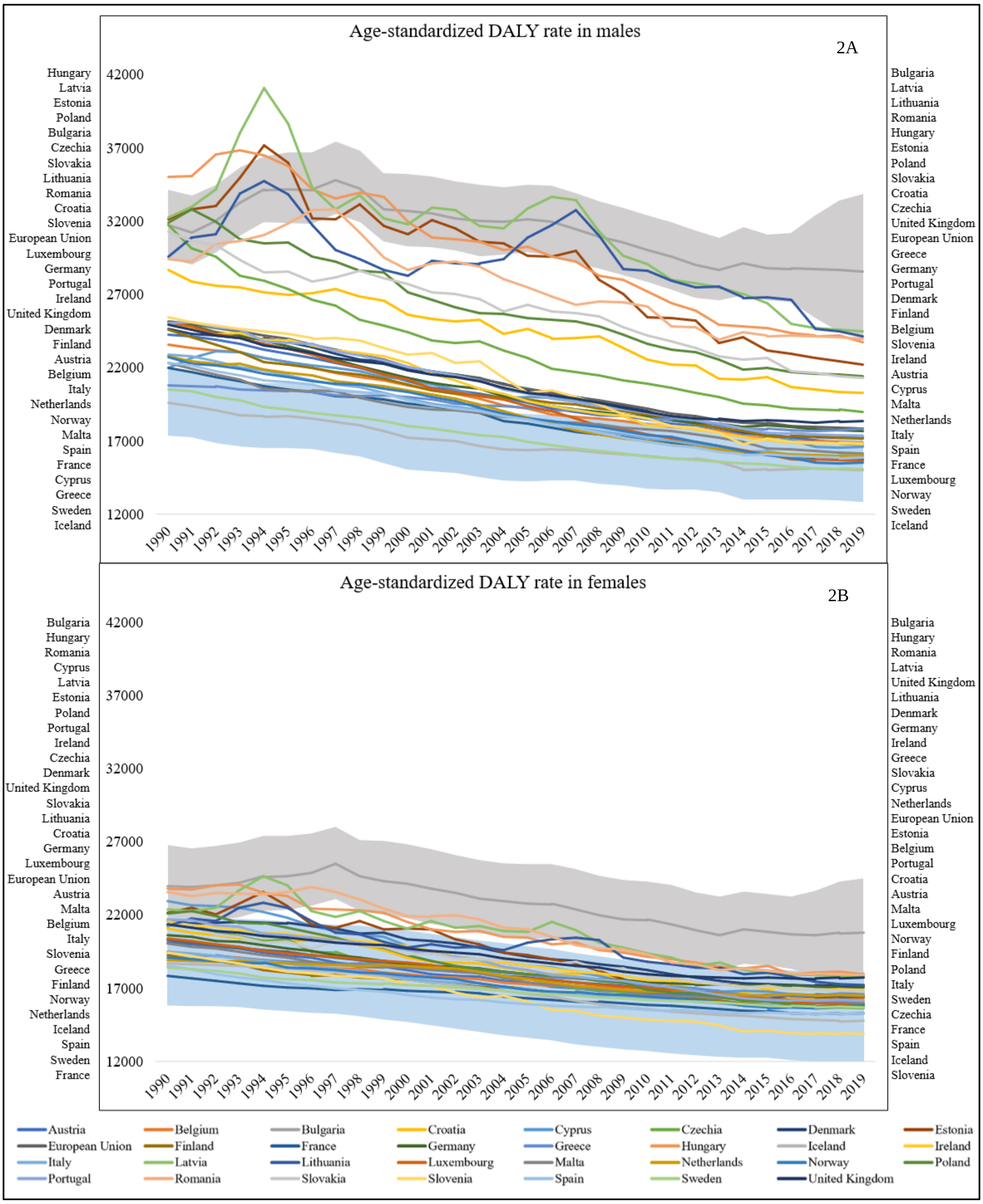

Figure 2: Age-standardized level 1 NCDs DALY rates by EEA Member States from1990 to 2019 for males (2A) and females (2B).

Legend: 95% UI for the country with the highest overall DALY rate (Bulgaria) is represented by a grey shaded band, while the interval for the country with the lowest rate (Iceland) is shown in blue. Within each graph, the sequence of country lines matches the sequence of country labels listed alongside it.

Annual rate of change in age-standardized NCDs DALY rates

As shown in Figure 3, the annual change in NCD DALY rates among females varied significantly across countries. The smallest reduction was recorded in the Netherlands, at –0.12 (95% UI: –0.10 to –0.15), while the most substantial declines occurred in Slovenia and Poland, at –0.28 (95% UI: –0.17 to –0.40) and –0.28 (95% UI: –0.21 to –0.35), respectively. Among women, the largest declines—around –0.27 to –0.28—were reported in Poland, Slovakia, Cyprus, and Czechia. In contrast, countries like Sweden, France, Greece, Bulgaria, and the Netherlands saw more modest changes, ranging from –0.15 to –0.12.

For males, reductions were generally more pronounced. The smallest decrease was seen in Bulgaria, at –0.10 (95% UI: 0.06 to –0.23), whereas Czechia experienced the steepest drop at –0.40 (95% UI: –0.32 to –0.47). In general, male populations showed deeper reductions in DALY rates: in 18 countries, annual changes ranged between –0.29 and –0.40, surpassing the maximum rate of reduction observed in females (–0.28). The most significant improvements for men were noted in Czechia, Luxembourg, and Slovenia, with rates falling between –0.34 and –0.40. Meanwhile, Bulgaria, Greece, and Lithuania recorded the smallest decreases, with changes between –0.10 and –0.18.

Further breakdowns of annual DALY rate changes for Level 2 NCDs—specifically CVDs chronic respiratory diseases, diabetes and kidney diseases, digestive disorders, and substance use disorders—are available in Appendix 2, segmented by sex and country.

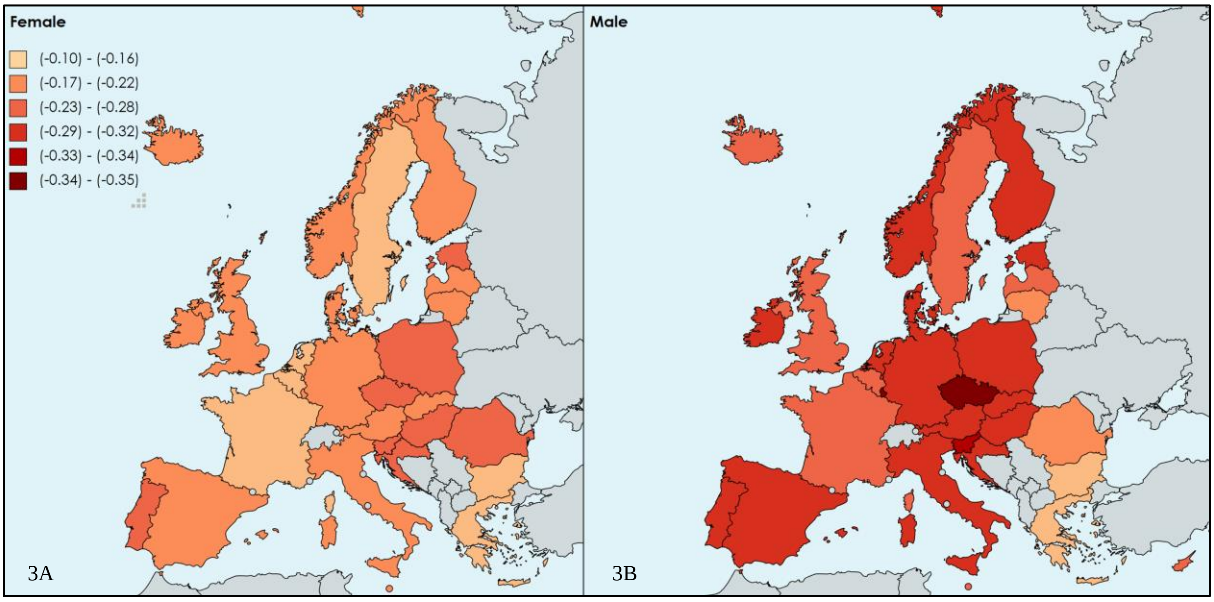

Figure 3: Age-standardized level 1 NCDs DALY annual rate of change between 1990 and 2019, for females (3A) and males (3B).

4.1.3 NCDs DALYs rate ratios by level 2 NCD cause of diseases

Figure 4 displays the annual progression of age-standardized DALY rate ratios for Level 2 NCDs between 1990 and 2019. Throughout this period, five disease groups consistently stood out with high burden inequalities, each maintaining a DALY rate ratio of 2.68 or higher. These included CVDs, digestive diseases, diabetes and kidney diseases, substance use disorders, and chronic respiratory diseases. Among these, CVDs exhibited the most marked increase in inequality with the DALY rate ratio rising from 3.66 in 1990 to 5.88 by 2019. In contrast, digestive diseases and diabetes and kidney disorders saw a decline in their rate ratios over the same period, suggesting a relative narrowing of burden between countries. On the other end of the spectrum, conditions such as musculoskeletal disorders, mental health disorders, neoplasms, and sense organs diseases consistently recorded lower DALY rate ratios—remaining below 2.23 across the 30-year timeframe. While the rankings of these lower-burden NCDs shifted slightly over time, their overall inequality between countries remained low.

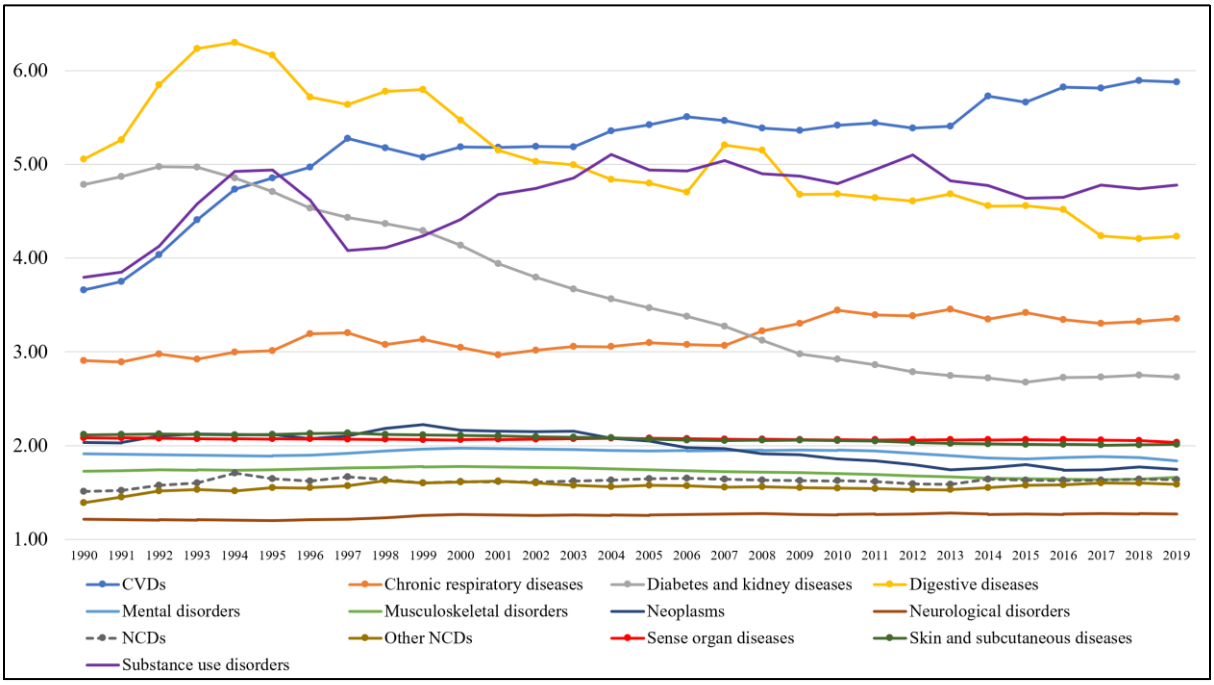

Figure 4: Age-standardized DALY rate ratio by level 2 cause of disease between 1990 and 2019.

Legend: Ratios: highest-ranking DALY rate divided by the lowest-ranking per year of the study period. NCDs: non-communicable diseases and CVDs: cardiovascular diseases.

4.1.4 Assessing health inequalities in NCDs by using Gini coefficient and Slope Index

Figure 5 presents trends in inequality across countries for Level 1 NCDs, as measured by the GC. Overall, inequality levels remained relatively low. The lowest GC values were recorded in the final years of the study, reaching 0.064 (95% CI: 0.044 to 0.083) in 2017 and dropping slightly to 0.063 (95% CI: 0.040 to 0.086) in 2019. In contrast, the highest inequality across countries was observed in 1994, 1995, and 2007, with GC values of 0.085 (95% CI: 0.065 to 0.106), 0.084 (95% CI: 0.067 to 0.101), and 0.080 (95% CI: 0.052 to 0.108), respectively. Among Level 2 NCDs, five conditions stood out with the highest GC values, reflecting greater inequalities: CVDs, chronic respiratory diseases, diabetes and kidney diseases, digestive diseases, and substance use disorders. CVDs exhibited the sharpest rise in inequality, with GC increasing from 0.191 in 1990 to 0.278 (95% CI: 0.214 to 0.342) in 2019. Substance use disorders followed a similar upward trajectory, though at a lower scale, increasing from 0.184 (95% CI: 0.140 to 0.228) to 0.212 (95% CI: 0.161 to 0.263) over the same period.

Digestive diseases maintained a consistently high GC, fluctuating within a narrow range—between 0.217 (95% CI: 0.162 to 0.273) and 0.224 (95% CI: 0.185 to 0.262). Interestingly, while diabetes and kidney diseases ranked second in 1990 in terms of inequality (GC: 0.194; 95% CI: 0.137 to 0.251), their GC declined steadily over time, dropping to 0.133 (95% CI: 0.106 to 0.160) in 2019 and placing them fifth in 2019's rankings. Chronic respiratory diseases showed modest change, with values ranging from 0.145 in 1990 to 0.152 (95% CI: 0.113 to 0.191) by 2019. In contrast, a cluster of NCDs—including mental disorders, musculoskeletal disorders, neoplasms, sense organs diseases, neurological disorders, skin and subcutaneous diseases, and other NCDs—demonstrated consistently lower inequality levels between 0.026 (95% CI: 0.020 to 0.032) and 0.125 (95% CI: 0.112 to 0.139) across the 30-year period.

As shown in Figure 6 and Appendix 3, the highest SII values were observed among level 1 NCDs, starting at 0.851 (95% CI: 0.730–0.972) in 1990 and decreasing to 0.592 (95% CI: 0.470–0.715) by 2019. Notably, this trend peaked twice—first in 1994 at 0.951 (95% CI: 0.781–1.121), and again in 2007 at 0.871 (95% CI: 0.679–1.063). CVDs mirrored the pattern of level 1 NCDs, with comparable SII values across the same years: 0.852 (0.708–0.997) in 1990, 0.997 (0.776–1.245) in 1994, 0.784 (0.569–1.000) in 2007, and dropping to 0.531 (0.381–0.681) in 2019. Among level 2 NCDs, neoplasms stood out with elevated but relatively stable inequality over time—starting at 0.161 (0.136–0.185) in 1990 and declining slightly to 0.132 (0.111–0.153) in 2019. In contrast, several other level 2 conditions consistently showed SII values near zero throughout the period. These included chronic respiratory diseases, diabetes and kidney diseases, digestive diseases, mental and musculoskeletal disorders, neurological and substance use disorders, as well as other NCDs, diseases of the sense organs, and skin and subcutaneous tissue disorders. Their SII values ranged from just 0.021 (neurological disorders in 1990) to a maximum of 0.115 (digestive diseases in 1992).

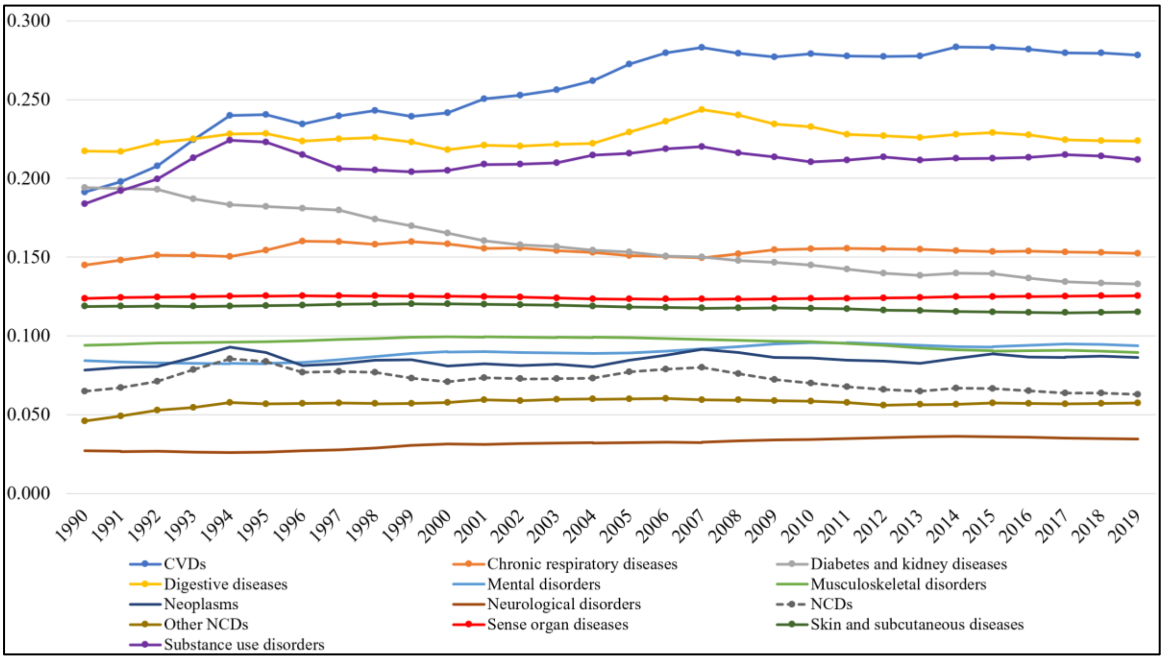

Figure 5: Gini coefficient of age-standardized NCDs DALY rate in EEA Member States, 1990-2019.

Legend: NCDs: non-communicable diseases and CVDs: cardiovascular diseases.

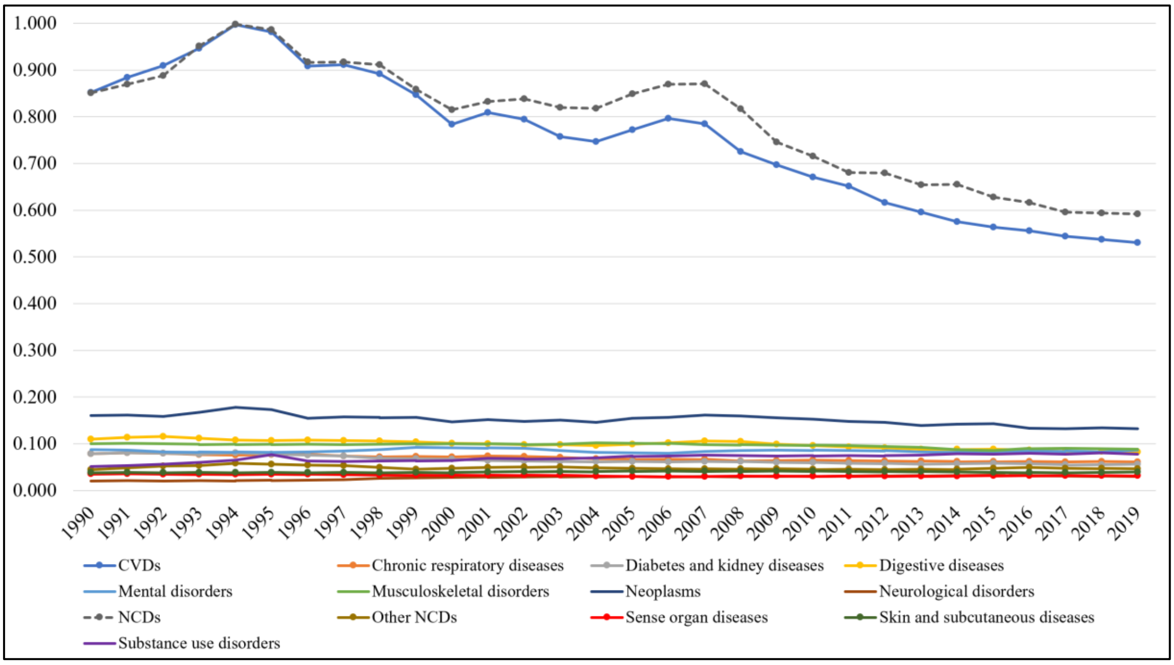

Figure 6: Slope Index of Inequality of age-standardized NCDs DALY rate in EEA Member States, 1990-2019.

Legend: NCDs: non-communicable diseases and CVDs: cardiovascular diseases.

4.2 Lifestyle and metabolic risk factors, and diabetes mellitus prevalence in European countries from three waves of the European Health Interview Survey

4.2.1 Characteristics of the study population

Table 2 presents participant counts and weighted percentages by DM status, stratified by demographic, socioeconomic characteristics, and relevant risk factors. Across 2009, 2014, and 2019, significant age-related differences emerged, with older adults, specifically those aged 65 and above, making up the largest share of individuals with DM: 51.8% in 2009, rising to 56.8% in 2014, and reaching 60.2% by 2019. Educational attainment among those with DM was predominantly at the primary level; however, this proportion steadily declined over time. Urban residence among DM participants also became more common across survey waves, increasing from 59.2% to 70.4%. When examining labor status, a consistently greater proportion of individuals with DM fell into the "Other" category—which included retirees, individuals with disabilities, and others outside the formal workforce—compared to non-DM respondents. This group accounted for 76.3% in 2009, 76% in 2014, and 75.5% in 2019.

Throughout all three survey waves, the majority of individuals with DM consistently reported higher BMI levels compared to those without DM—77.8% in 2009, 78.4% in 2014, and 79.7% in 2019. Interestingly, people living with DM also reported consuming fruits and vegetables more frequently than their non-DM counterparts. Daily fruit intake was noted by 71.9%, 62.8%, and 60.0% of DM participants across the respective waves, while vegetable consumption at least once per day was reported by 65.1%, 51.2%, and 48.7%. When it came to physical activity, around half of all respondents said they walked for at least 10 minutes daily, with a slightly higher proportion among those without DM. However, overall engagement in moderate physical activity—defined as 150 minutes per week—remained low across all years and was consistently lower among those with DM. Smoking prevalence also differed by DM status, with current smoking being less common among individuals with DM—18.2%, 18.1%, and 18.5%—compared to those without the condition (as detailed in Table 2).

Table 2: Characteristics of study population by diabetes status and survey.

		EHIS 1					EHIS 2					EHIS 3				
		DM (n = 5615)		non-DM (n = 78,624)			DM (n = 8229)		non-DM (n = 93,126)			DM (n = 9,221)		non-DM (n = 89,785)		
		%	n	%	n	*p*-value*	%	n	%	n	*p*-value*	%	n	%	n	*p*-value*
Sex	Male	46.5	2437	47.8	35,227	**0.041**	47.5	3630	47.6	41,726	0.225	47.4	4159	47.5	40,611	0.814
	Female	53.5	3178	52.3	43,397		52.5	4599	52.4	51,400		52.6	5062	52.6	49,174	
Age	20–44	7.3	300	50.1	33,899	**< 0.001**	6.9	397	47.1	36,833	**< 0.001**	5.6	329	44.0	31,350	**< 0.001**
	45–64	40.9	2171	33.6	28,581		36.3	2678	34.3	33,562		34.2	2718	35.6	32,878	
	65 +	51.8	3144	16.3	16,144		56.8	5154	18.6	22,731		60.2	6174	20.4	25,557	
Education level	Primary	53.9	3113	30.9	24,995	**< 0.001**	49.8	4074	28.9	26,644	**< 0.001**	42.3	3806	25.0	22,343	**< 0.001**
	Secondary	36.4	1976	47.8	38,148		38.8	3264	46.6	44,952		43.3	4043	46.9	42,494	
	Tertiary	9.7	526	21.4	15,481		11.4	891	24.5	21,530		14.4	1372	28.1	24,948	
Residential area	Rural	40.8	2613	39.6	36,704	0.831	34.4	3254	34.4	35,741	**0.038**	29.6	3317	29.5	31,056	**0.008**
	Urban	59.2	3002	60.4	41,920		65.6	4975	65.7	57,385		70.4	5904	70.5	58,729	
Labour status	Employed	19.9	979	56.1	41,654	**< 0.001**	18.7	1299	53.5	46,260	**< 0.001**	21.2	1549	57.2	45,846	**< 0.001**
	Other	76.3	4473	35.2	31,206		76.0	6615	36.4	38,767		75.5	7411	36.0	38,726	
	Unemployed	3.9	163	8.8	5764		5.2	315	10.1	8099		3.3	261	6.7	5213	
Body mass index	$< 25 kg/m^2$	22.2	1219	46.6	35,815	**< 0.001**	21.6	1760	46.3	41,398	**< 0.001**	20.3	1839	44.1	37,759	**< 0.001**
	$\geq 25 kg/m^2$	77.8	4396	53.4	42,809		78.4	6469	53.7	51,728		79.7	7382	55.9	52,026	
Frequency of eating vegetables	Once or more a day	65.1	3689	61.2	48,797	**< 0.001**	51.2	4221	46.5	43,307	**< 0.001**	48.7	4287	44.1	38,509	**< 0.001**
	1–6 times a week	29.8	1665	34.6	26,666		44.0	3639	49.0	45,636		47.4	4535	52.4	47,677	
	Less than once a week or never	5.1	261	4.3	3161		4.8	369	4.5	4183		3.9	399	3.6	3599	
Frequency of eating fruits	Once or more a day	71.9	3931	63.6	49,528	**< 0.001**	62.8	4873	54.4	48,697	**< 0.001**	60.0	5204	52.5	44,916	**< 0.001**
	1–6 times a week	21.4	1288	29.1	23,424		31.0	2827	39.2	38,134		33.0	3344	40.8	38,702	
	Less than once a week or never	6.8	396	7.3	5672		6.3	529	6.4	6295		7.0	673	6.7	6167	
Physical activity#	≥ 150 min moderate PA per week	41.7	2358	56.3	44,808	**< 0.001**	13.5	1012	26.7	22,743	**< 0.001**	14.9	1236	28.5	22,172	**< 0.001**
	< 150 min moderate PA per week	58.3	3257	43.7	33,816		86.5	7217	73.3	70,383		85.1	7985	71.5	67,613	
Frequency of walking for 10 min per week	Never	22.9	1440	15.5	13,848	**< 0.001**	23.9	2142	13.8	14,882	**< 0.001**	20.2	2324	11.3	14,375	**< 0.001**
	Everyday	48.0	2563	50.8	38,450		38.8	2999	47.0	42,008		40.0	3439	48.0	40,644	
	1–6 days a week	29.2	1612	33.7	26,326		37.4	3088	39.3	36,236		39.8	3458	40.8	34,766	
Smoking status	Non-smoker	81.8	4680	67.1	54,098	**< 0.001**	82.0	6906	71.2	67,468	**< 0.001**	81.5	7646	73.1	66,204	**< 0.001**
	Current smoker	18.2	935	32.9	24,526		18.1	1323	28.8	25,658		18.5	1575	26.9	23,581	

Legend: % : weighted proportions; n: unweighted number of participants; DM: diabetes mellitus; EHIS: European Health Interview Survey; PA; physical activity. Statistically significant differences are highlighted in bold. In EHIS wave 1, physical activity was measured based on the weekly time spent engaging in moderate-intensity activities. For EHIS waves 2 and 3, HEPA was calculated by totaling the minutes per week participants spent on sports, fitness, recreational activities, and cycling.

4.2.2 Age-standardized prevalence of DM by risk factors

Within the study sample, crude DM prevalence showed a steady rise across the survey years, 6.7% in 2009, increasing to 8.1% in 2014, and reaching 9.3% by 2019. When adjusted for age in the population aged 20 and above, the overall prevalence also increased, from 7.01% in 2009 to 7.96% in 2019 (Table 3). Individuals with a BMI ≥25 kg/m² consistently exhibited nearly double the age-standardized prevalence of DM compared to those with a BMI below 25, with prevalence rising from 8.13% to 9.39% over time. Higher DM prevalence was also observed among participants who reported consuming fruits daily in 2009 and 2014, and vegetables daily in 2014 and 2019, relative to those with less frequent intake. Conversely, participants who engaged in at least 150 minutes of moderate-intensity physical activity per week, or walked at least 10 minutes daily, tended to have lower age-standardized DM prevalence than those who were less physically active. Although non-smokers had a higher prevalence of DM compared to current smokers, this gap narrowed across the survey years. Detailed estimates of age-standardized DM prevalence by risk factor, country, and survey wave are provided in Appendix 4-6.

Table 3: Age-standardized prevalence of diabetes mellitus by socioeconomic variables and risk factors by waves of EHIS.

		EHIS1		EHIS2		EHIS3	
		%	95% CI	%	95% CI	%	95% CI
DM	Yes	7.01	(7.01–7.02)	7.70	(7.7–7.71)	7.97	(7.96–7.97)
Sex	Male	7.22	(7.21–7.23)	8.16	(8.16–8.17)	8.48	(8.47–8.49)
	Female	6.79	(6.78–6.8)	7.29	(7.28–7.3)	7.52	(7.52–7.53)
Education level	Primary	7.84	(7.83–7.85)	8.69	(8.68–8.7)	8.91	(8.9–8.92)
	Secondary	6.79	(6.78–6.8)	7.56	(7.56–7.57)	8.00	(7.99–8.01)
	Tertiary	5.08	(5.07–5.1)	5.95	(5.94–5.97)	6.35	(6.34–6.36)
Labour status	Employed	3.43	(3.41–3.45)	4.55	(4.53–4.58)	5.35	(5.31–5.39)
	Other	8.42	(8.41–8.43)	9.38	(9.37–9.39)	9.50	(9.49–9.51)
	Unemployed	9.02	(8.78–9.26)	5.80	(5.76–5.85)	6.95	(6.8–7.1)
Residential area	Rural	6.89	(6.88–6.9)	7.40	(7.39–7.41)	7.64	(7.63–7.65)
	Urban	7.12	(7.11–7.12)	7.87	(7.87–7.88)	8.12	(8.11–8.12)
Body mass index	<25 kg/m^2	4.61	(4.6–4.62)	4.92	(4.92–4.93)	5.07	(5.06–5.08)
	≥ 25 kg/m^2	8.13	(8.12–8.14)	9.13	(9.13–9.14)	9.39	(9.38–9.4)
Frequency of eating vegetables	Once or more a day	7.16	(7.15–7.16)	8.01	(8–8.01)	8.50	(8.49–8.5)
	1–6 times a week	6.56	(6.55–6.57)	7.36	(7.35–7.37)	7.48	(7.48–7.49)
	Less than once a week or never	8.51	(8.48–8.54)	8.04	(8.02–8.07)	8.22	(8.2–8.25)
Frequency of eating fruits	Once or more a day	7.23	(7.22–7.23)	8.08	(8.07–8.09)	8.34	(8.34–8.35)
	1–6 times a week	6.33	(6.32–6.34)	7.02	(7.01–7.03)	7.21	(7.2–7.22)
	Less than once a week or never	7.23	(7.21–7.26)	7.94	(7.91–7.96)	9.05	(9.02–9.07)
Physical activity	≥ 150 min moderate PA per week	5.92	(5.91–5.93)	6.05	(6.04–6.06)	6.27	(6.26–6.29)
	<150 min moderate PA per week	8.00	(7.99–8.01)	8.06	(8.05–8.07)	8.40	(8.39–8.41)
Frequency of walking for at least 10 min continuously per week	Never	8.70	(8.69–8.72)	10.13	(10.12–10.15)	10.78	(10.76–10.8)
	Everyday	6.62	(6.61–6.63)	6.75	(6.74–6.75)	7.18	(7.18–7.19)
	1–6 days a week	6.49	(6.47–6.5)	7.56	(7.56–7.57)	7.89	(7.89–7.9)
Smoking status	Non-smoker	7.27	(7.27–7.28)	7.81	(7.8–7.81)	8.03	(8.02–8.04)
	Current smoker	6.11	(6.09–6.12)	7.05	(7.04–7.07)	7.63	(7.62–7.65)

Legend: CI: Confidence interval; DM: diabetes mellitus; EHIS: European Health Interview Survey; PA: physical activity.

4.2.3 Association between risk factors and diabetes mellitus prevalence over time

Table 4 presents findings from the Poisson regression analysis, highlighting consistent associations between DM and risk factors across the three survey years. Being overweight or obese (BMI ≥25 kg/m^2) was strongly linked with higher prevalence of DM in all waves—PRs were 1.75 (95% CI: 1.61–1.89) in 2009, 1.83 (95% CI: 1.72–1.95) in 2014, and 1.85 (95% CI: 1.73–1.98) in 2019. Similarly, engaging in less than 150 minutes of moderate physical activity per week was significantly associated with increased likelihood of DM: PRs of 1.24 (95% CI: 1.16–1.34), 1.39 (95% CI: 1.27–1.51), and 1.40 (95% CI: 1.29–1.52) for the respective years. On the other hand, current smoking showed a negative association with DM—PRs of 0.79 (95% CI: 0.71–0.86) in 2009, 0.90 (95% CI: 0.83–0.97) in 2014, and 0.93 (95% CI: 0.86–0.99) in 2019. Similarly, walking at least 10 minutes daily was linked to a lower probability of reporting DM, with PRs decreasing across waves: 0.87 (95% CI: 0.79–0.94), 0.73 (95% CI: 0.68–0.78), and 0.71 (95% CI: 0.66–0.76). Even walking one to six days per week showed a protective association—PRs of 0.87 (95% CI: 0.79–0.95) in 2009, 0.82 (95% CI: 0.76–0.87) in 2014, and 0.78 (95% CI: 0.73–0.84) in 2019.

Those who ate fruit one to six times weekly were less likely to report DM than daily consumers in 2014 (PR 0.87; 95% CI: 0.81–0.93) and 2019 (PR 0.88; 95% CI: 0.82–0.94). A similar pattern was seen with vegetable intake in 2009 (PR 0.92; 95% CI: 0.85–0.99) and 2019 (PR 0.90; 95% CI: 0.84–0.95), where non-daily consumption was associated with a slightly lower prevalence of DM. In the pooled dataset, a significant interaction of the survey year with moderate level physical activity ($p = 0.008$), walking every day ($p = 0.001$) and smoking ($p = 0.044$) was observed in the multivariable analysis (Table 3).

Stratified regional analysis showed that both PA and BMI were consistently linked to DM across all survey waves, regardless of geographical region. However, the association between smoking and DM appeared to be region-specific, present in Central and Eastern European countries but not observed in Southern Europe. In terms of dietary habits, Southern European populations reported a higher intake of fruits and vegetables compared to those in Central and Eastern Europe, as detailed in Appendix 7.

Table 4. Association between risk factors and diabetes mellitus by waves of EHIS. All models were adjusted for sex, age, education level, labour status, residential area, and country.

		EHIS1		EHIS2		EHIS3		p-value for interaction*
		PR	95% CI	PR	95% CI	PR	95% CI	
Body mass index	<25kg/m² (reference)							
	≥25 kg/m²	**1.75**	**(1.61–1.89)**	**1.83**	**(1.72–1.95)**	**1.85**	**(1.73–1.98)**	0.410
Frequency of eating vegetables	Once or more a day (reference)							
	1–6 times a week	**0.92**	**(0.85–0.99)**	0.96	(0.89–1.02)	**0.9**	**(0.84–0.95)**	0.363
	Less than once a week or never	1.07	(0.91–1.25)	0.96	(0.83–1.12)	**0.86**	**(0.76–0.99)**	0.146
Frequency of eating fruits	Once or more a day (reference)							
	1–6 times a week	0.93	(0.85–1.02)	**0.87**	**(0.81–0.93)**	**0.88**	**(0.82–0.94)**	0.207
	Less than once a week or never	1.02	(0.89–1.18)	0.96	(0.85–1.08)	**1.12**	**(1.00–1.25)**	0.507
Physical activity#	≥150 min moderate PA per week (reference)							
	<150 min moderate PA per week	**1.24**	**(1.16–1.34)**	**1.39**	**(1.27–1.51)**	**1.4**	**(1.29–1.52)**	**0.008**
Frequency of walking for at least 10 min continuously per week	Never (reference)							
	Everyday	**0.87**	**(0.79–0.94)**	**0.73**	**(0.68–0.78)**	**0.71**	**(0.66–0.76)**	**0.001**
	1–6 days a week	**0.87**	**(0.79–0.95)**	**0.82**	**(0.76–0.87)**	**0.78**	**(0.73–0.84)**	0.076
Smoking status	Non-smoker (reference)							
	Current smoker	**0.79**	**(0.71–0.86)**	**0.9**	**(0.83–0.97)**	**0.93**	**(0.86–0.99)**	**0.044**
ΔAIC			-6,956,911		-9,020,697		-9,392,992	
ΔBIC			-6,956,659		-9,020,440		-9,392,735	

Legend: CI: confidence interval; PR: prevalence ratio; PA: physical activity; and EHIS: European Health Interview Survey. The values ΔAIC and ΔBIC represent the differences between the null and full regression models (ΔAIC = AICnull - AICfull, with AICnull corresponding to the null model and AICfull to the full model). Statistically significant findings are highlighted in bold. The *p-value refers to the interaction between survey year and risk factors. In EHIS wave 1, physical activity was measured based on weekly time spent at a moderate intensity, whereas in EHIS waves 2 and 3, health-enhancing physical activity (HEPA) was calculated by adding the minutes per week spent on sports, fitness, recreational activities, and cycling.

5. Discussion

This dissertation captures both a cross-sectional view of NCD-related DALY rates in 2019 and their progression over the last thirty years, incorporating measures such as DALY rate ratios, GC, and SII to highlight the extent of health inequalities among EEA countries. Over the period from 1990 to 2019, all 30 EEA countries experienced a consistent decline in age-standardized DALY rates for NCDs in both sexes. While the absolute burden has decreased, the relative positions of countries have shifted very little, indicating that reductions occurred in parallel across the region. This uniform pace of improvement meant that the proportional inequalities between countries remained largely intact, even as overall DALY rates trended downward. In essence, although health outcomes improved across the board and income inequality between countries narrowed during these decades [93], the inequalities in NCD burden persisted, suggesting that progress was evenly distributed, but not sufficient to close the health gap between nations.

Drawing on data from three separate waves of the EHIS, this study is the first to comprehensively examine how lifestyle-related risk factors have shaped the prevalence of DM across 11 EU member states over the span of a decade, from 2009 to 2019. Unlike single-point analyses, the repeated cross-sectional design enabled a dynamic look at how DM prevalence has evolved in parallel with changes in BMI and behaviour patterns. Interestingly, individuals with DM more often reported engaging in healthier behaviours, such as consuming fruits and vegetables regularly and refraining from smoking. Yet, paradoxically, they also exhibited a greater tendency toward physical inactivity and higher BMI compared to those without DM. Notably, the overall prevalence of DM continued its upward trend throughout the study period, with particularly sharp increases seen in groups characterized by excess weight, sedentary lifestyles, and active smoking.

In the GBD analysis, Western European countries such as Austria, Belgium, Denmark, and Iceland demonstrated a relatively gradual decline in NCD-related DALY rates over the study period. In contrast, the trend in the EU-11 countries, comprising Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia, revealed a more complex pattern. Several of these countries, particularly Bulgaria, Latvia, Lithuania, and Estonia, experienced considerable volatility in their DALY rates, with notable peaks occurring around 1994 and again in 2007. A striking surge in NCD DALY rates was seen between 1990 and 1997, especially among males in Bulgaria. Although these countries later followed a downward trend in DALY rates similar to that observed in Western Europe, their starting point was significantly higher, indicating a delayed but ultimately comparable trajectory of health improvement. The sharp spike in 1994 can be interpreted in the context of profound geopolitical and socioeconomic upheaval following the collapse of the Soviet Union and the fall of communist regimes. The resulting institutional shifts, including major transformations in healthcare systems, likely contributed to rising mortality from NCDs and widening health inequalities during this period [94]. In the Baltic states, such as Latvia, Lithuania, and Estonia, DALY rates from NCDs spiked dramatically in 1991, peaked in 1994, and then receded by 1996. In Bulgaria and elsewhere, the deterioration in health outcomes through the early 1990s corresponds closely with the broader economic crisis, culminating in the hyperinflation crisis of 1996–1997. These patterns underscore the profound and delayed health consequences of the economic and political turmoil that marked the post-socialist transition in several EEA countries.

Another sudden increase in NCD-related DALY rates emerged around 2004, particularly in Latvia, Lithuania, and Estonia, coinciding with their accession to the EU. One possible explanation for this rise is the increased emigration of younger populations following EU enlargement [95]. The upward trend culminated in 2007 before gradually giving way to a decline, suggesting a temporary deterioration in population health after the 2004 and 2007 expansions [96]. Despite this, some research has found no clear evidence that joining the EU significantly influenced mortality convergence between newer and older Member States [95]. The 2008 Great Recession introduced additional strain on health systems across the EEA [97]. In response to the crisis, many governments-imposed austerity measures, which often included reduced healthcare spending and more restricted access to medical services. These cutbacks played a role in deepening health inequalities across the EU-27 [98]. Beyond direct health system impacts, the economic downturn triggered widespread socio-economic instability, marked by rising unemployment, growing poverty, declining quality of life, and increases in anxiety, suicide, alcoholism, and malnutrition [97, 99]. These worsening social determinants likely intensified the burden of NCDs, both epidemiologically and economically [100]. Still, drawing a direct year-by-year link between socio-economic shocks and changes in DALYs is challenging, given the slow-developing nature of most NCDs and their often-long latency periods [101]. Adding further complexity, country-level variations in key behavioral risk factors, such as physical inactivity and obesity, may have also widened health inequalities. These risk factors saw marked increases in parts of Europe between 2004 and 2015, yet their contribution to YLL rates from NCDs may take decades to fully emerge [102, 103]. Finally, health inequalities between countries are shaped by a broad array of structural factors, not just economic shifts or lifestyle risks. Differences in the density of healthcare professionals, national health expenditures, and investment in preventive public health measures all contribute significantly to the uneven burden of NCDs across Europe [104–106].

For certain level 2 NCDs, inequalities in DALY rates between countries were especially high. When comparing countries with the highest and lowest DALY rates, the rate ratios reached striking levels, for example, digestive diseases in 1996 had a rate ratio of 6.29, while diabetes and kidney diseases in 2019 showed a ratio of 2.73. Such cases highlight a profound degree of inequality. These findings are reinforced by GC values, which indicate that inequalities among countries are more pronounced for these specific disease groups compared to others. This pattern signals the urgent need for more focused and tailored disease prevention strategies at the EU level. Many of these conditions, such as DM, CVDs, chronic respiratory diseases, and substance use disorders, are heavily influenced by modifiable lifestyle factors, including poor nutrition, excessive alcohol consumption, and smoking. While these behaviors are deeply embedded, they are not immutable. Strategic intervention at the population level through education, regulation, and promotion of healthier choices could significantly reduce the burden. Countries exhibiting high DALY rates should prioritize strengthening their public health responses to these risk factors. Japan serves as a useful example: it consistently reports among the lowest NCD DALY rates globally, thanks to a comprehensive public health framework that emphasizes physical activity, balanced diets, and stringent anti-smoking policies [107, 108]. Furthermore, SII analysis suggests that the substantial improvement in NCD-related health outcomes across EEA countries over the past 30 years has been driven primarily by absolute gains in CVD reduction, underscoring the importance of sustained cardiovascular prevention and management efforts.

A decline in health inequalities related to diabetes and kidney disease is evident across both measurement approaches, whether comparing country pairs through DALY rate ratios or assessing overall inequality via the GC. However, the pattern for CVD shows a different outcome, with both methods indicating a rise in inequality. This divergence is likely due to unequal progress: while some countries have achieved notable success in reducing CVD-related DALYs, thanks to effective prevention, treatment advances, and reductions in key risk factors, others have seen far less improvement, resulting in only slight declines or stagnation in their CVD burden. The drop in CVD mortality is largely credited to public health advancements targeting major modifiable risks, including smoking, hypertension, and elevated cholesterol [109]. Meanwhile, diabetes and kidney diseases appear to follow a different trajectory. These conditions are primarily driven by physical inactivity and obesity—two areas where progress in Europe has been insufficient over the past three decades [66]. On a global level, the picture is similarly discouraging, with few success reports in combating these risk factors. Despite the more substantial reduction in CVD burden compared to DM over the same period [110], both remain pressing public health concerns across the region. Tackling these diseases continues to require sustained investment in effective, risk-based prevention and treatment strategies [66, 111].

The WHO Global NCD Action Plan 2013–2030 sets out a clear agenda: reduce the exposure to major risk factors, such as tobacco, alcohol abuse, unhealthy eating, and lack of physical activity, and ensure health systems are equipped to manage and support those with, or at high risk of, leading NCDs such as CVD, DM, cancer, and chronic respiratory diseases. Despite this broad mandate, tobacco control remains the only area where consistent and coordinated action has taken root globally. The FCTC, which became legally binding in 2005, marked a significant step forward. Within the EU, a legal framework has also emerged, using a variety of tools to curb tobacco use: restrictions on marketing, public education initiatives, taxation, and medical support for cessation. Still, in countries where tobacco control policies are weaker, smoking continues to be more prevalent [112]. Among EU-27 nations, those that have adopted more comprehensive strategies to tackle smoking tend to see greater success, including lower smoking rates and increased cessation [113]. Conversely, similar momentum is lacking when it comes to tackling other behavioral risk factors. No binding treaties or legal instruments exist at the international or EU level to regulate behaviors like alcohol consumption. Efforts in this area have lagged significantly behind tobacco control and remain fragmented and largely voluntary [114]. Additionally, there's limited evidence evaluating the effectiveness of current alcohol-related policies [115, 116]. Within the EU, measures that do exist are often piecemeal, focused on restricting access, adjusting pricing, promoting awareness, identifying risky drinking patterns, and providing brief interventions in clinical or community settings [117–119].

Effective policy has the potential to reduce health inequalities and build the foundation for equitable access to good health across populations. The WHO Health Equity Policy Tool (2019) outlines five foundational elements that shape opportunities for a healthy life: health services, income security and social protection, living conditions, social and human capital, and employment and working conditions. These pillars are closely linked to policy domains where strong evidence supports meaningful action. Addressing inequalities in NCD outcomes requires an interconnected policy approach. This means going beyond healthcare alone to include structural interventions, such as improvements in housing and transport, and tackling the commercial influences on health. Examples include regulating the marketing of harmful products, applying taxes on unhealthy goods, encouraging the production and accessibility of fruits and vegetables, and removing high-sugar, high-fat, and high-salt snacks from vending machines, particularly in schools and workplaces. To truly make a difference, these policies must target both physiological and behavioral risk factors associated with NCDs, with particular emphasis on reaching populations in lower socioeconomic brackets, where the burden of disease is often greatest [120].

In Europe, clear sex-based inequalities in health outcomes are evident. Across all analyses, males consistently experienced higher DALY burdens compared to females. However, when looking at trends from 1990 to 2019, the annual reduction in DALY rates among men was more pronounced, suggesting a decline in the male NCD burden over that period. In cases where the DALY rate ratio between female populations appeared highly equal, this could be often due to both countries in comparison exhibiting similarly elevated DALY rates. This near-equality in ratios doesn't necessarily indicate favorable outcomes; rather, it reflects a limitation in the ratio itself where high values in both populations can mask real inequalities. Further analysis reveals a distinct pattern between mortality and morbidity indicators: YLL due to NCDs is markedly higher among men, while women register higher YLD figures. This inverse relationship likely comes from underlying differences in behavior, occupational risks, and healthcare engagement [121]. Men across Europe are more likely to engage in harmful behaviors, such as heavy alcohol use and smoking, and are disproportionately represented in hazardous occupations involving exposure to toxins or dangerous conditions [122, 123]. Conversely, women tend to be more health-conscious, utilize preventive services more frequently, and participate in screening programs at higher rates. This proactive approach to health may contribute to their longer life expectancy and the higher proportion of life lived with disability [121]. It is also plausible that the long-term trends observed in DALY rates for NCDs across the three decades were largely influenced by changes in YLL, with YLD playing a smaller role in shaping the overall burden.

Compared to earlier research on health inequalities in Europe, this study stands out due to several methodological strengths: an extended 30-year follow-up period, improved data quality and availability, the inclusion of all EEA countries, and the consistent use of age-standardized measures [74, 121, 124]. By drawing on age-standardized DALY rates from the GBD study, we ensured comparability across populations with differing demographic structures, enabling a more accurate and validated assessment of both mortality and disability due to NCDs. The use of these standardized rates allowed us to analyze trends across a wide range of economic contexts and age distributions, creating a coherent foundation for comparison. To reduce potential biases in inequality measurement, we went beyond simple ratios by incorporating additional metrics such as the SII and the GC. These indicators offer both absolute and relative views of inequality, enriching the interpretation of inequalities. Our decision to examine level 2 NCD categories further deepened the analysis by revealing disease-specific patterns of inequality that may be obscured at more aggregated levels. Recognizing the policy relevance of sex-based differences, we also systematically assessed sex inequalities throughout the study. One of the key aims of this work was to enhance accessibility and clarity of findings. By presenting a comprehensive array of detailed tables and visualizations, we aimed to support deeper insights into cross-country differences, not only highlighting gaps between the countries with the highest and lowest DALY rates but also allowing nuanced comparisons among all possible country pairs within the EEA. In doing so, the study provides a broad and detailed perspective on international inequalities, capturing both extremes and subtler variations across the entire sample of nations included.

Between 2009 and 2019, the age-standardized prevalence of DM across EU countries showed a progressive rise, increasing from 7.01% to 7.96%. This upward trend aligns with earlier research documenting similar growth in DM prevalence throughout the EU [6, 125–127]. A systematic review covering 10 EU member states further highlighted that not only has the prevalence increased since 2009, but incidence and mortality related to DM have also followed the same trajectory [17]. These patterns suggest that current public health strategies and DM management efforts may be falling short in curbing the disease's progression [128, 129]. Our findings also revealed that, over the ten-year period, there was a growth in the proportion of people with DM who had completed secondary or tertiary education. However, despite this improvement, individuals with DM still tended to have lower educational levels compared to those without the condition. This mirrors trends observed in other EU-based studies, which have consistently reported a link between lower levels of education and higher DM prevalence [130–132]. The role of education in both the prevention and effective management of DM is well established [133, 134]. Higher educational achievement often correlates with greater income, better access to health information, and healthier lifestyle choices, all of which contribute to improved outcomes such as effective glycaemic control [135, 136].

Our analysis highlights a persistent inequality in labour status between individuals with and without DM. Although this disparity remained stable across the three EHIS waves, showing no significant statistical variation over time, the difference itself was notable and consistent. People living with DM were less likely to hold formal jobs, likely due to the physical and functional limitations that often accompany the disease, which can hinder participation in structured or physically demanding work environments [137, 138]. These findings point to the ongoing need for labour market policies and targeted support systems that address the employment barriers faced by individuals with DM [139]. When examining geographic differences, DM prevalence was slightly higher in urban areas overall. However, the rate of increase between 2009 and 2019 was more pronounced in rural regions. While urban settings typically report higher DM prevalence globally, likely due to better diagnostic coverage and access to healthcare services [62], this gap may be narrowing. One ecological study examining multiple countries found a general association between urbanization (measured via agglomeration index) and higher T2D prevalence. However, in high-income countries, this trend appeared less tied to urbanization itself and more to environmental factors, such as rising obesity and sedentary lifestyles, that contribute to a diabetogenic context [140].

A substantial body of evidence has established a strong association between overweight and an increased risk of chronic illnesses, including T2D [141, 142]. Elevated BMI plays a central role in the onset of insulin resistance, which is a primary mechanism in the pathogenesis of T2D [143]. In our analysis, we observed an evident rise in the age-standardized prevalence of DM among individuals classified as overweight or obese during the study period. Among all modifiable risk factors assessed, high BMI demonstrated the most robust association with DM, highlighting the urgent need for focused strategies that address the intricate relationship between body weight and disease risk. Despite growing awareness, more than half of the adult population in many EU countries continues to live with overweight or obesity [144]. Public health policies aimed at curbing obesity have, so far, failed to reverse this trend. At best, rates have plateaued. This stagnation points to the limitations of conventional approaches and reinforces the necessity for a fresh policy framework. Such a framework should move away from stigmatizing narratives and instead embrace a coordinated, interdisciplinary model of prevention and care [145].

Previous research has consistently demonstrated that regular physical activity can significantly improve blood glucose regulation and reduce the risk of complications related to DM [146, 147]. Despite this, our findings show that individuals with DM were less likely to meet recommended physical activity guidelines compared to those without the condition. This discrepancy may indicate that the beneficial effects of physical activity are not being fully realized within the DM population, possibly due to barriers in sustaining active lifestyles. Also, engaging in at least 150 minutes of moderate-intensity exercise per week, as well as incorporating daily 10-minute walks, was consistently linked to a lower prevalence of DM across all survey waves. Nonetheless, a recent analysis revealed considerable inconsistency in the implementation of physical activity policies across EU member states, with the majority lacking active frameworks to promote such behaviours [128]. With regard to smoking, participants diagnosed with DM were less likely to be current smokers than those without DM. However, this difference narrowed across the survey waves. Interestingly, some recent studies have reported a lack of the expected positive correlation between smoking and DM [148, 149]. One possible interpretation is that individuals with DM may be more likely to adjust their behaviour following medical advice, such as quitting smoking in line with physicians' recommendations [149]. Moreover, the observed inverse association appeared specific to Central and Eastern European countries, implying that tobacco control efforts may vary in effectiveness by region, and that smoking behaviour remains deeply influenced by socioeconomic factors [150]. Importantly, while a negative association between smoking and DM was observed in certain contexts, this does not imply any health benefit to tobacco use.

A healthy diet, particularly one rich in fruits and vegetables, has long been associated with the prevention of NCDs, including T2D [60]. In our analysis, individuals with DM reported consuming fruits and vegetables more frequently than those without the condition. This aligns with earlier cross-sectional studies that also observed greater intake of these foods among diabetic populations compared to non-diabetic counterparts [148, 151]. One likely explanation is that individuals with DM are more likely to receive dietary guidance from healthcare professionals and may be more conscious of making healthier food choices as part of disease management [148]. However, the overall evidence linking fruit and vegetable intake to reduced risk of T2D remains inconclusive. Several large-scale meta-analyses of cohort studies have suggested either no effect or only a modest association between higher consumption and lower DM risk [152, 153]. Similarly, some research has found no significant link between dietary fiber intake from these sources and DM incidence [154]. Interestingly, our findings also revealed that higher fruit and vegetable consumption among individuals with DM was more common in Southern EU countries. This regional difference highlights the role of broader contextual factors, such as culture, geography, and education, in shaping dietary behaviours [155]. In fact, cross-national variations in food habits across the EU have been consistently attributed to these regional and sociocultural influences [156–158].

Our findings consistently showed that among the modifiable risk factors examined, only elevated BMI (≥25 kg/m²) and physical inactivity maintained a significant association with DM across all survey waves. This underscores the critical need for sustained efforts aimed at prevention of obesity, weight management, and the promotion of regular physical activity in order to mitigate the growing burden of DM within EU member states. Although both individual EU countries and the EU as a collective have developed various strategies targeting these issues, the impact appears limited. The Physical Activity Fact Sheet 2021 outlines 23 indicators reflecting national efforts and policy measures across member states to foster more active lifestyles [159]. While promoting physical activity among youth is a key focus at the EU level, the rollout of supporting infrastructure remains uneven. For instance, only five countries have implemented the European guidelines aimed at improving leisure-time physical activity environments [160]. Despite the presence of numerous initiatives, the scale and effectiveness of current measures fall short of what is needed. To create meaningful change, particularly among older populations, stronger, more coordinated interventions are essential at the EU level. Comprehensive action that goes beyond fragmented policies will be necessary to effectively support healthier behaviours and reduce DM risk across diverse demographic groups.

This dissertation, while robust in the approach, is not without limitations, many of which come from the underlying structure of the GBD study itself, as previously documented [15]. These include uncertainties linked to incomplete or low-quality data, potential misclassification or underreporting of non-fatal conditions, and the overall scarcity of primary data, particularly for morbidity-related metrics. Beyond the limitations inherent to GBD, a few are specific to our analysis. One notable issue concerns the measurement of inequality using DALY rates over a 30-year span, where initial comparisons were made only between the countries with the highest and lowest values. To address this oversimplification, additional inequality measures such as the GC, SII, and contingency tables were integrated into the analysis to provide a broader view across all countries and time points. For assessing statistical significance, we relied on the commonly accepted method of evaluating overlap between 95% UIs. This method is effective when intervals do not overlap, clearly indicating significance. However, it can be less reliable when intervals overlap slightly, since significance might still exist in those cases but remain undetected using this rule alone. Despite this limitation, we opted for 95% UIs over conventional confidence intervals, as they better account for model-based uncertainty and are therefore more appropriate for GBD-derived estimates. Using p-values from Poisson regression, for instance, would have resulted in nearly all comparisons being statistically significant due to the sensitivity of that model to DALY differences alone, something that would not offer meaningful interpretation in this context. In contrast, the UI approach considers a broader set of epidemiological parameters embedded in the GBD 2019 methodology, offering a more cautious and nuanced interpretation. Another constraint was the exclusion of

Liechtenstein from our EEA analysis, as GBD does not provide estimates for this microstate. Additionally, we assumed linear trends when calculating annual changes in DALY rates. While this assumption holds for most countries, it may not be suitable for some former Soviet nations, where historical patterns show more erratic shifts. To mitigate this, we visually plotted annual changes for each country, offering a clearer picture of year-by-year variation. Data quality also varies widely between countries. In response to such disparities, GBD employs Bayesian modeling to adjust for missing or inconsistent data. However, this method carries its own risks—particularly when estimates are derived from neighboring countries that may not share the same data profile, potentially leading to distorted results in non-fatal disease estimates. Finally, while health inequality exists both between and within countries, the present analysis focused exclusively on between-country comparisons, which should be acknowledged as a limitation in fully capturing the complexity of inequality in the EEA region.

A key concern is the reliance on self-reported data for all variables, including both health behaviours and DM status on the EHIS database. This approach introduces the possibility of both information and social desirability bias, which could partially explain unexpected findings, such as the inverse association observed between smoking and DM. Respondents may underreport behaviours perceived as negative, such as tobacco use, to present themselves in a more favourable light [161]. Despite this limitation, earlier research has demonstrated a relatively strong concordance between self-reported DM and medical record data, suggesting that DM status is generally reported with reasonable accuracy [162, 163]. Another constraint is the lack of information regarding DM type, as the EHIS does not differentiate between type 1 DM and T2D. While each type has distinct pathophysiological features and risk profiles, it is widely accepted that T2D predominates in the adult population sampled, and likely accounts for the majority of reported cases in this study. Also, we combined underweight and normal-weight individuals primarily due to the relatively small number of underweight participants, which limited the statistical power to analyze them separately; however, distinguishing low BMI could result in a more nuanced understanding. Finally, the cross-sectional design inherently restricts our ability to infer causality. Without longitudinal follow-up, we cannot establish temporal links between risk factor exposure and the development of DM, which limits interpretation of the observed associations. Given that this study focused on a select group of EU member states, the findings may not be directly generalizable to the EU population as a whole. Moreover, the exclusion of countries and individuals with incomplete data may have introduced bias into our estimates. It is possible that participants included in the analysis differ in meaningful ways from those with missing data, which could have led to either underestimation or overestimation of the prevalence of key risk factors. Additionally, the absence of data from specific countries may have influenced overall results. According to available evidence [155], DM tends to be more prevalent in Southern and Central/Eastern European regions. As such, omitting Nordic and Western countries from the analysis could have skewed the overall estimated prevalence upward. Another important limitation relates to inconsistencies in the assessment of physical activity across the survey waves. In the first EHIS wave, physical activity was measured using a modified version of the International Physical Activity Questionnaire – Short, which gathered information on the frequency of vigorous activity, moderate activity, and walking. Due to methodological challenges identified in wave 1, a new domain-specific tool, the EHIS-PAQ, was introduced in subsequent waves. This version assessed PA levels within distinct settings relevant to public health, such as work, transportation, and leisure time [87]. As a result, different measures were applied across waves: in wave 1, we focused on moderate-intensity PA, while in waves 2 and 3, we evaluated health-enhancing physical activity (HEPA). These variations in measurement methodology may have influenced the consistency and comparability of PA-related associations across time points.

5.5. New findings

The study reveals that while the overall burden of NCDs in the EEA has decreased from 1990 to 2019, significant disparities remain between countries and demographic groups. Digestive diseases, diabetes and kidney disorders, substance use disorders, CVDs, and chronic respiratory conditions are the NCDs most affected by international inequality. Despite a generally narrow inequality in DALYs within individual countries, cross-national and sex-based variations in disease burden highlight the need for more targeted and socially aware health policies across the EEA.

- All 30 EEA member states experienced a decrease in NCD-related DALY rates during the study period, indicating progress in public health interventions and healthcare access.
- GC analysis indicated that the inequality in level 1 NCD DALYs within each country is relatively narrow, suggesting more uniform distribution of disease burden internally.
- Digestive diseases, diabetes and kidney diseases, substance use disorders, CVDs, and chronic respiratory diseases show the highest levels of inequality in disease burden among EEA countries.
- Across all survey waves, individuals with DM consistently presented with higher BMI and lower levels of physical activity, reinforcing these as key modifiable risk factors.
- These risk factors play a significant role in both the development and ongoing management of DM, especially T2D.
- Evidence from the study supports that lifestyle changes, particularly weight loss and increased physical activity, are effective in improving glycaemic control and overall health in individuals with T2D.

- The reduction in NCD burden varied by sex and region, with men experiencing a faster rate of decline compared to women, and Central European countries showing the most pronounced improvements.
- The study emphasizes the role of underlying social inequalities in shaping health outcomes. Tailored health policies that address social determinants are crucial to reducing these disparities.
- Beyond individual behavior, the study emphasizes the importance of creating supportive environments for healthy living and addressing social inequalities that contribute to unhealthy lifestyles.
- Effective interventions must not only target modifiable risk factors but also consider the broader socio-economic background. Emphasis should be placed on reducing health inequalities both between and within European countries.

  A dual approach is recommended:

  (1) EU-Level Policies: Broad, harmonized strategies for primary DM prevention across the EU.

  (2) National and Regional Policies: Tailored approaches that reflect specific population needs and contextual factors..

6. Summary

T2D continues to be a widespread health challenge globally, accompanied by rising healthcare costs. An investigation was performed regarding long-term trends related to the prevalence, incidence, mortality, and economic impact of T2D in the 28 member countries of the EU, including the UK. The analysis revealed a consistent upward trajectory across all these indicators over recent decades. These findings highlight the urgent need for targeted public health strategies in the EU to curb the growing T2D burden and help alleviate the associated financial strain on healthcare systems.

Despite general improvements in population health across Europe, disparities persist, particularly in the context of NCDs. To better understand this issue, the study assessed age-standardized DALY rates across 30 countries in the EEA between 1990 and 2019. Twelve major NCDs were evaluated, with trends assessed by sex and over time. Using DALY rate ratios, the GC, and the SII, the research revealed that overall DALY rates declined, more so in females than males. Nevertheless, countries like Bulgaria consistently showed the highest DALY rates, especially for CVDs, digestive issues, diabetes and kidney conditions, substance use disorders, and chronic respiratory illnesses. The most significant disparity in 2019 was between Bulgaria and Iceland among males. While overall inequality in level 1 NCD DALY rates across the region remains relatively low, certain disease categories continue to show pronounced inequalities between countries. Addressing these gaps requires country-specific prevention strategies and improved healthcare accessibility.

Additionally, with T2D on the rise, from a 7.01% prevalence in 2009 to 7.96% in 2019, we also explored behavioral risk factors such as smoking, physical inactivity, low intake of fruits and vegetables, and increased BMI. Analysis from three waves of the EHIS across 11 EU nations confirmed strong links between higher BMI, sedentary behavior, smoking, and DM prevalence. These findings underscore the importance of lifestyle-focused interventions aimed at promoting weight control and physical activity to effectively manage and prevent DM across EU populations.

Author's contributions:

1- Inequalities in the burden of non-communicable diseases across European countries: a systematic analysis of the Global Burden of Disease 2019 study

The author has contributed in the conceptualization, data curation and visualization, formal analysis, methodology, writing: original draft, and writing: review and editing.

2- Lifestyle and metabolic risk factors, and diabetes mellitus prevalence in European countries from three waves of the European Health Interview Survey

The author has contributed in the conceptualization, data curation and visualization, formal analysis, methodology, writing: original draft, and writing: review and editing.

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7.2 References by the library

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List of publications related to the dissertation

1. Kovács, N., Shahin, B., **Soares, A. C. A.**, Mahrouseh, N., Varga, O.: Lifestyle and metabolic risk factors, and diabetes mellitus prevalence in European countries from three waves of the European Health Interview Survey.
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2. **Soares, A. C. A.**, Mahrouseh, N., Gabrani, J., Charalampous, P., Cuschieri, S., Grad, D. A., Unim, B., Mechili, E. A., Chen-Xu, J., Devleesschauwer, B., Gaetano, I., Lippe, E. v. d., Baravelli, C. M., Fischer, F., Weye, N., Balaj, M., Haneef, R., Economou, M., Haagsma, J. A., Varga, O.: Inequalities in the burden of non-communicable diseases across European countries: a systematic analysis of the Global Burden of Disease 2019 study.
Int J Equity Health. 22 (1), 1-20, 2023.
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List of other publications

3. **Soares, A. C. A.**, Lovas, S., Mahrouseh, N., Chamouni, G., Shahin, B., Mustafa, E. O. A., Muhlis, A. N. A., Njuguna, D. W., Israel, F. E. A., Gammoh, N., Chandrika, N., Atuhaire, N. C., Ashkar, I., Chatterjee, A., Charles, R., Alzuhaily, H., Almusfy, A., Díaz Benavides, D., Alshakhshir, F. K., Varga, O.: Primary Prevention of Type 2 Diabetes Mellitus in the European Union: a Systematic Review of Interventional Studies.
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09 May, 2025

8. Keywords

Health inequality, European Union, European Economic Area, Non-communicable diseases, DALY rate, Global Burden of Disease, Risk factors, Epidemiology

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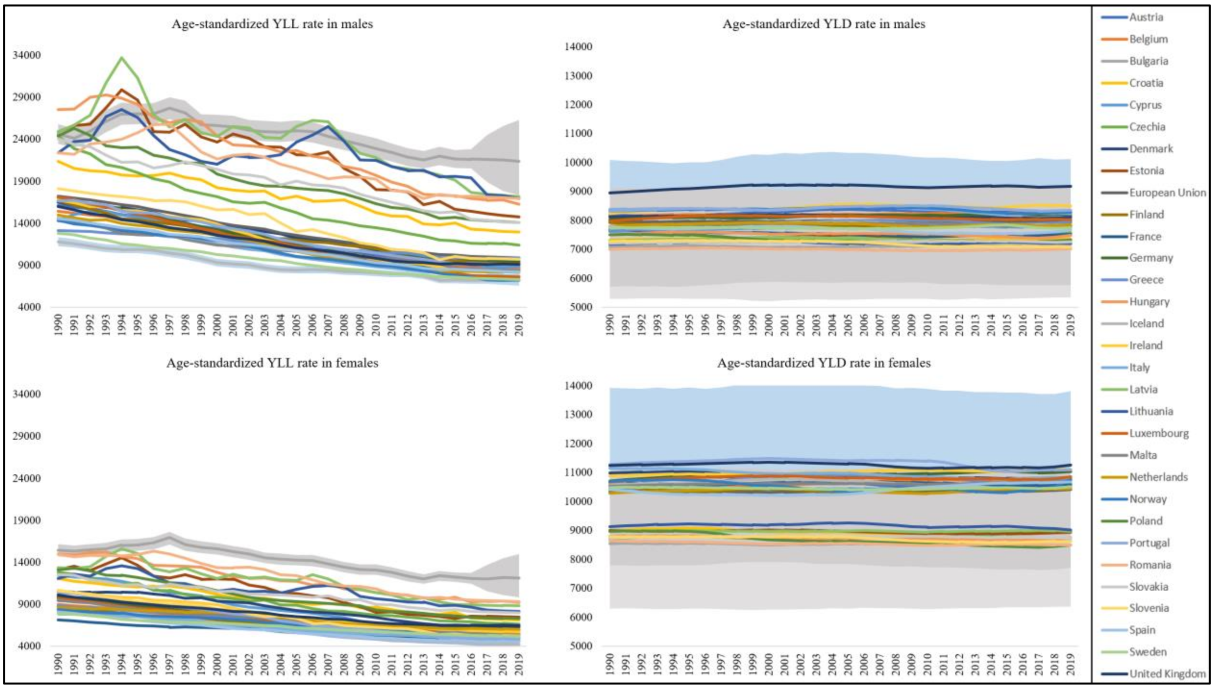
I hope I have made you all proud.

Thank you!

10. Appendix

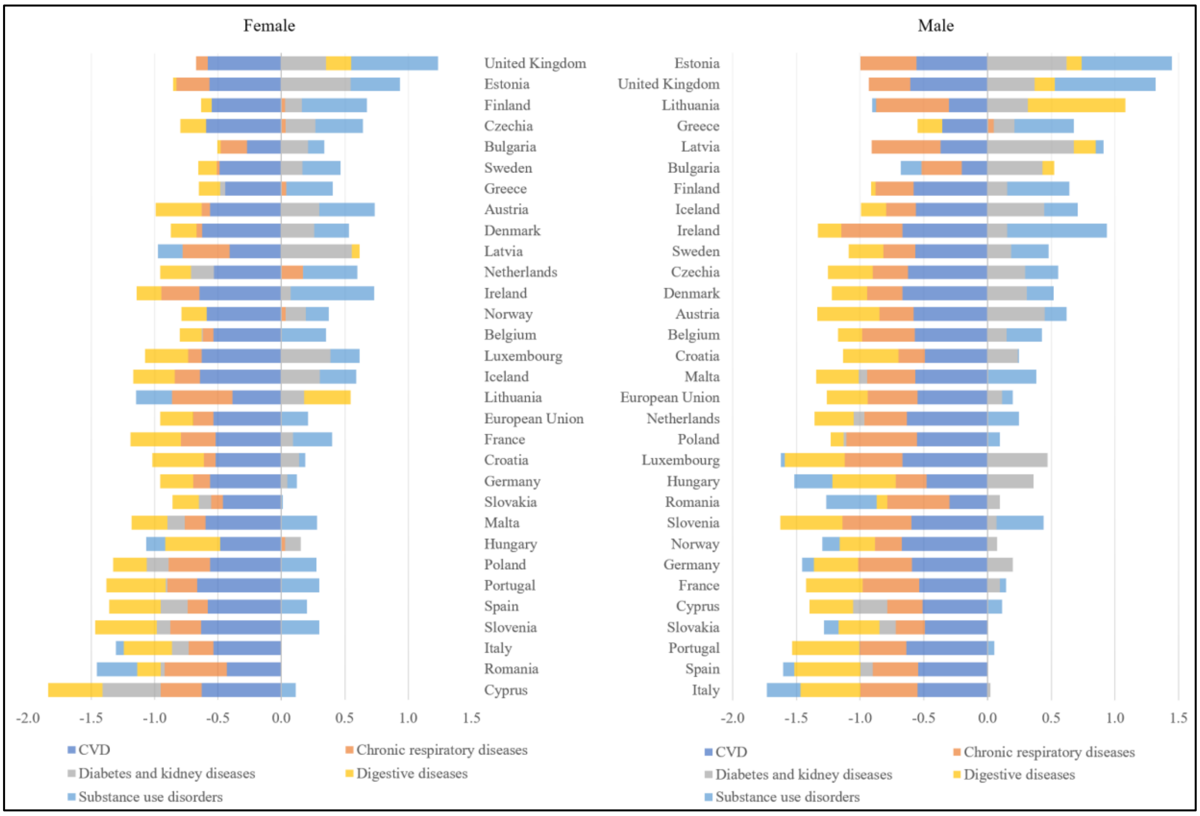
Appendix 1: Age-standardized NCDs YLLs and YLDs rate for EEA Member States by sex, 1990-2019



Legend: UI 95% for the overall highest (Bulgaria) and lowest (Iceland) DALYs rate are shown in grey and blue shaded band, respectively.

Appendix 2: Age-standardized level 2 NCDs DALY annual rate of change by EEA Member States, 1990-2019

Among females, the United Kingdom recorded the highest annual rate of change, with Estonia and Finland following closely behind. Conversely, Cyprus, Romania, and Italy showed the lowest rates of change for females. Within the EEA, females experienced the most modest annual decline in CVDs at -0.54, followed by digestive diseases at -0.26 and chronic respiratory diseases at -0.16. For males, Estonia led with the highest annual change in DALY rates, followed by the United Kingdom, while the lowest changes were observed in Italy, Spain, and Portugal. Among males in the EEA, the sharpest annual decrease was seen in CVDs at -0.55, with chronic respiratory diseases and digestive diseases following at -0.39 and -0.32, respectively.



Legend: CVDs: cardiovascular diseases.

Appendix 3: Slope Index of Inequality of age-standardized level 1 and 2 NCDs DALYs rates, 1990-2019

Cause	1990			1991			1992			1993			1994			1995		
	Coef.	95% CI		Coef.	95% CI		Coef.	95% CI		Coef.	95% CI		Coef.	95% CI		Coef.	95% CI	
CVDs	0.852	0.708	0.997	0.884	0.725	1.043	0.909	0.734	1.084	0.947	0.751	1.142	0.997	0.776	1.245	0.982	0.750	1.214
Chronic respiratory diseases	0.078	0.071	0.086	0.081	0.074	0.087	0.080	0.073	0.087	0.077	0.069	0.085	0.076	0.068	0.084	0.077	0.068	0.085
Diabetes and kidney diseases	0.078	0.061	0.096	0.081	0.063	0.099	0.080	0.060	0.099	0.078	0.058	0.099	0.080	0.060	0.101	0.078	0.058	0.098
Digestive diseases	0.110	0.089	0.131	0.114	0.091	0.136	0.115	0.088	0.143	0.111	0.080	0.142	0.108	0.076	0.139	0.107	0.076	0.139
Mental disorders	0.087	0.071	0.104	0.086	0.070	0.103	0.083	0.067	0.099	0.083	0.066	0.099	0.082	0.066	0.098	0.082	0.066	0.098
Musculoskeletal disorders	0.100	0.092	0.108	0.102	0.093	0.110	0.101	0.092	0.109	0.099	0.090	0.108	0.099	0.091	0.107	0.099	0.091	0.107
Neoplasms	0.161	0.136	0.185	0.162	0.136	0.187	0.159	0.130	0.187	0.168	0.140	0.195	0.178	0.148	0.208	0.173	0.143	0.203
Neurological disorders	0.021	0.019	0.023	0.021	0.019	0.023	0.021	0.019	0.023	0.022	0.020	0.023	0.021	0.019	0.023	0.022	0.020	0.024
NCDs	0.851	0.730	0.972	0.869	0.741	0.997	0.888	0.748	1.029	0.951	0.781	1.121	0.998	0.803	1.220	0.986	0.795	1.178
Other NCDs	0.045	0.038	0.051	0.048	0.040	0.056	0.052	0.042	0.062	0.054	0.043	0.064	0.058	0.048	0.068	0.056	0.046	0.066
Sense organ diseases	0.035	0.032	0.039	0.036	0.032	0.040	0.035	0.032	0.039	0.035	0.032	0.039	0.035	0.032	0.039	0.035	0.031	0.039
Skin and subcutaneous diseases	0.038	0.031	0.045	0.039	0.032	0.046	0.039	0.032	0.046	0.039	0.032	0.046	0.039	0.032	0.046	0.039	0.032	0.046
Substance use disorders	0.051	0.040	0.063	0.054	0.041	0.067	0.056	0.042	0.070	0.060	0.043	0.078	0.065	0.045	0.086	0.076	0.054	0.098
Cause	1996			1997			1998			1999			2000			2001		
	Coef.	95% CI		Coef.	95% CI		Coef.	95% CI		Coef.	95% CI		Coef.	95% CI		Coef.	95% CI	
CVDs	0.909	0.677	1.140	0.911	0.662	1.160	0.892	0.639	1.146	0.847	0.608	1.086	0.784	0.549	1.019	0.809	0.569	1.050
Chronic respiratory diseases	0.077	0.069	0.086	0.074	0.065	0.083	0.072	0.063	0.081	0.073	0.064	0.082	0.072	0.062	0.081	0.074	0.064	0.084
Diabetes and kidney diseases	0.076	0.057	0.095	0.073	0.055	0.091	0.069	0.052	0.087	0.068	0.051	0.085	0.067	0.051	0.083	0.064	0.049	0.079
Digestive diseases	0.108	0.079	0.136	0.107	0.078	0.135	0.106	0.078	0.134	0.104	0.077	0.131	0.101	0.077	0.125	0.100	0.079	0.122
Mental disorders	0.083	0.067	0.099	0.085	0.069	0.101	0.087	0.072	0.103	0.092	0.076	0.108	0.092	0.075	0.108	0.092	0.075	0.108
Musculoskeletal disorders	0.099	0.091	0.108	0.098	0.089	0.107	0.099	0.090	0.108	0.100	0.091	0.109	0.100	0.091	0.109	0.100	0.090	0.110
Neoplasms	0.155	0.127	0.183	0.157	0.128	0.186	0.157	0.125	0.188	0.157	0.122	0.191	0.147	0.114	0.180	0.151	0.121	0.182
Neurological disorders	0.023	0.021	0.025	0.024	0.021	0.026	0.026	0.023	0.028	0.027	0.025	0.030	0.028	0.026	0.031	0.029	0.026	0.032

NCDs	0.917	0.739	1.096	0.917	0.732	1.103	0.911	0.723	1.100	0.859	0.692	1.025	0.815	0.657	0.972	0.833	0.664	1.001
Other NCDs	0.054	0.045	0.063	0.053	0.043	0.063	0.049	0.039	0.059	0.046	0.037	0.055	0.048	0.039	0.056	0.050	0.042	0.058
Sense organ diseases	0.035	0.031	0.039	0.034	0.031	0.038	0.033	0.030	0.037	0.033	0.030	0.036	0.033	0.030	0.036	0.033	0.029	0.036
Skin and subcutaneous diseases	0.039	0.032	0.046	0.039	0.032	0.046	0.039	0.031	0.046	0.039	0.032	0.047	0.039	0.032	0.047	0.040	0.032	0.047
Substance use disorders	0.063	0.045	0.081	0.062	0.046	0.078	0.064	0.048	0.079	0.064	0.049	0.079	0.064	0.049	0.080	0.069	0.052	0.086
Cause	**2002**			**2003**			**2004**			**2005**			**2006**			**2007**		
	Coef.	**95% CI**		**Coef.**	**95% CI**		**Coef.**	**95% CI**		**Coef.**	**95% CI**		**Coef.**	**95% CI**		**Coef.**	**95% CI**	
CVDs	0.794	0.555	1.034	0.757	0.527	0.987	0.747	0.519	0.975	0.772	0.538	1.005	0.797	0.564	1.030	0.784	0.569	1.000
Chronic respiratory diseases	0.073	0.064	0.082	0.071	0.062	0.080	0.068	0.060	0.077	0.067	0.058	0.075	0.067	0.058	0.075	0.067	0.058	0.075
Diabetes and kidney diseases	0.063	0.048	0.077	0.062	0.049	0.076	0.062	0.049	0.075	0.062	0.050	0.075	0.061	0.048	0.074	0.062	0.050	0.074
Digestive diseases	0.098	0.077	0.119	0.098	0.078	0.119	0.096	0.076	0.115	0.099	0.080	0.119	0.102	0.082	0.123	0.106	0.084	0.128
Mental disorders	0.091	0.073	0.108	0.085	0.067	0.103	0.081	0.062	0.101	0.080	0.061	0.100	0.080	0.061	0.099	0.083	0.064	0.102
Musculoskeletal disorders	0.099	0.090	0.109	0.099	0.090	0.108	0.102	0.094	0.111	0.101	0.094	0.109	0.101	0.093	0.108	0.099	0.091	0.106
Neoplasms	0.148	0.116	0.179	0.150	0.118	0.183	0.146	0.114	0.178	0.155	0.123	0.187	0.157	0.126	0.187	0.161	0.130	0.192
Neurological disorders	0.030	0.027	0.032	0.030	0.027	0.033	0.030	0.028	0.033	0.030	0.028	0.033	0.030	0.027	0.033	0.030	0.028	0.033
NCDs	0.838	0.671	1.005	0.820	0.658	0.982	0.818	0.652	0.983	0.849	0.671	1.027	0.869	0.678	1.060	0.871	0.679	1.063
Other NCDs	0.050	0.043	0.058	0.050	0.043	0.057	0.049	0.041	0.056	0.047	0.040	0.055	0.047	0.039	0.055	0.046	0.039	0.054
Sense organ diseases	0.033	0.029	0.036	0.032	0.029	0.036	0.031	0.027	0.034	0.030	0.027	0.034	0.030	0.027	0.034	0.030	0.027	0.034
Skin and subcutaneous diseases	0.041	0.033	0.048	0.041	0.034	0.048	0.041	0.034	0.048	0.041	0.034	0.048	0.042	0.034	0.049	0.041	0.034	0.049
Substance use disorders	0.068	0.052	0.084	0.068	0.052	0.000	0.069	0.052	0.087	0.074	0.056	0.091	0.074	0.057	0.091	0.076	0.058	0.094
Cause	**2008**			**2009**			**2010**			**2011**			**2012**			**2013**		
	Coef.	**95% CI**		**Coef.**	**95% CI**		**Coef.**	**95% CI**		**Coef.**	**95% CI**		**Coef.**	**95% CI**		**Coef.**	**95% CI**	
CVDs	0.726	0.526	0.925	0.697	0.506	0.889	0.671	0.485	0.857	0.651	0.471	0.831	0.617	0.444	0.789	0.596	0.429	0.763
Chronic respiratory diseases	0.063	0.055	0.072	0.064	0.056	0.072	0.065	0.057	0.073	0.064	0.056	0.072	0.063	0.056	0.071	0.063	0.055	0.070
Diabetes and kidney diseases	0.062	0.051	0.073	0.060	0.051	0.070	0.060	0.050	0.070	0.059	0.050	0.068	0.058	0.050	0.067	0.057	0.048	0.066
Digestive diseases	0.105	0.084	0.125	0.100	0.081	0.118	0.097	0.078	0.115	0.093	0.077	0.109	0.091	0.075	0.107	0.088	0.073	0.104
Mental disorders	0.086	0.066	0.105	0.087	0.068	0.106	0.086	0.066	0.106	0.086	0.066	0.106	0.086	0.066	0.106	0.083	0.062	0.104

Musculoskeletal disorders	0.098	0.090	0.105	0.097	0.088	0.106	0.097	0.088	0.105	0.096	0.088	0.105	0.095	0.086	0.104	0.093	0.083	0.102
Neoplasms	0.159	0.133	0.186	0.156	0.130	0.182	0.153	0.129	0.177	0.148	0.124	0.172	0.146	0.123	0.169	0.139	0.118	0.160
Neurological disorders	0.030	0.027	0.033	0.031	0.028	0.033	0.031	0.028	0.033	0.031	0.028	0.034	0.032	0.029	0.034	0.032	0.030	0.034
NCDs	0.817	0.648	0.986	0.746	0.590	0.903	0.716	0.565	0.866	0.680	0.544	0.816	0.680	0.553	0.807	0.654	0.527	0.780
Other NCDs	0.046	0.040	0.053	0.046	0.040	0.052	0.046	0.040	0.051	0.046	0.040	0.052	0.045	0.039	0.051	0.046	0.040	0.052
Sense organ diseases	0.031	0.028	0.034	0.031	0.028	0.034	0.031	0.028	0.034	0.031	0.028	0.034	0.031	0.028	0.034	0.031	0.028	0.034
Skin and subcutaneous diseases	0.041	0.034	0.049	0.042	0.034	0.049	0.041	0.034	0.049	0.041	0.034	0.048	0.041	0.034	0.048	0.040	0.033	0.048
Substance use disorders	0.075	0.058	0.092	0.074	0.058	0.091	0.075	0.058	0.091	0.075	0.058	0.092	0.074	0.056	0.093	0.075	0.058	0.093

Cause	**2014**			**2015**			**2016**			**2017**			**2018**			**2019**		
	Coef.	**95% CI**		**Coef.**	**95% CI**		**Coef.**	**95% CI**		**Coef.**	**95% CI**		**Coef.**	**95% CI**		**Coef.**	**95% CI**	
CVDs	0.575	0.411	0.739	0.564	0.410	0.718	0.556	0.403	0.709	0.544	0.395	0.694	0.537	0.387	0.687	0.531	0.381	0.681
Chronic respiratory diseases	0.062	0.054	0.069	0.062	0.055	0.069	0.062	0.055	0.069	0.061	0.054	0.068	0.062	0.055	0.069	0.061	0.054	0.068
Diabetes and kidney diseases	0.057	0.048	0.066	0.058	0.050	0.067	0.057	0.048	0.066	0.055	0.046	0.065	0.056	0.047	0.065	0.057	0.048	0.066
Digestive diseases	0.088	0.073	0.104	0.089	0.074	0.104	0.087	0.072	0.102	0.084	0.070	0.098	0.083	0.070	0.097	0.083	0.070	0.096
Mental disorders	0.083	0.063	0.103	0.084	0.063	0.104	0.084	0.064	0.105	0.084	0.064	0.104	0.083	0.063	0.102	0.086	0.068	0.104
Musculoskeletal disorders	0.087	0.076	0.098	0.085	0.074	0.097	0.090	0.081	0.100	0.090	0.081	0.100	0.090	0.080	0.099	0.089	0.079	0.098
Neoplasms	0.142	0.118	0.166	0.143	0.119	0.167	0.134	0.111	0.156	0.132	0.110	0.155	0.134	0.112	0.156	0.132	0.111	0.153
Neurological disorders	0.032	0.030	0.035	0.033	0.031	0.035	0.032	0.030	0.034	0.031	0.029	0.034	0.031	0.028	0.033	0.030	0.028	0.032
NCDs	0.655	0.523	0.788	0.628	0.503	0.752	0.616	0.490	0.742	0.595	0.472	0.718	0.594	0.469	0.719	0.592	0.470	0.715
Other NCDs	0.045	0.039	0.052	0.047	0.041	0.053	0.049	0.044	0.055	0.047	0.041	0.054	0.047	0.041	0.054	0.047	0.041	0.053
Sense organ diseases	0.031	0.028	0.034	0.032	0.029	0.035	0.032	0.029	0.035	0.032	0.029	0.035	0.032	0.029	0.035	0.032	0.028	0.035
Skin and subcutaneous diseases	0.039	0.032	0.047	0.039	0.032	0.046	0.039	0.032	0.046	0.039	0.032	0.045	0.039	0.031	0.046	0.039	0.031	0.047
Substance use disorders	0.079	0.061	0.000	0.078	0.062	0.094	0.080	0.063	0.096	0.078	0.060	0.095	0.080	0.062	0.098	0.078	0.060	0.096

Legend: CVDs: cardiovascular diseases; CI: Confidence Interval; NCDs: non-communicable diseases; Coef.: Coefficient.

Appendix 4: Association between risk factors and diabetes mellitus by waves of EHIS in Central and Eastern European and Southern European countries

		EHIS1				EHIS2				EHIS3			
		CEE		SOUTHERN		CEE		SOUTHERN		CEE		SOUTHERN	
		PR	95% CI	PR	95% CI	PR	95% CI	PR	95% CI	PR	95% CI	PR	95% CI
Body mass index	<25kg/m2 (reference)												
	≥25 kg/m2	**1.83**	**(1.66-2.03)**	**1.63**	**(1.43-1.84)**	**1.92**	**(1.78-2.07)**	**1.68**	**(1.51-1.88)**	**2.02**	**(1.87-2.2)**	**1.61**	**(1.43-1.8)**
Frequency of eating vegetables	once or more a day (reference)												
	1-6 times a week	0.90	(0.81-1.01)	0.93	(0.82-1.05)	1.00	(0.92-1.08)	**0.88**	**(0.8-0.98)**	**0.88**	**(0.82-0.96)**	**0.88**	**(0.8-0.97)**
	less than once a week or never	1.10	(0.91-1.34)	0.97	(0.75-1.26)	0.93	(0.79-1.09)	1.02	(0.75-1.38)	**0.84**	**(0.72-0.97)**	0.98	(0.64-1.5)
Frequency of eating fruits	once or more a day (reference)												
	1-6 times a week	0.98	(0.88-1.11)	0.88	(0.75-1.02)	**0.90**	**(0.83-0.98)**	**0.79**	**(0.7-0.89)**	0.93	(0.85-1.01)	**0.81**	**(0.72-0.92)**
	less than once a week or never	1.15	(0.98-1.36)	0.84	(0.65-1.09)	1.10	(0.96-1.26)	**0.72**	**(0.55-0.95)**	**1.22**	**(1.07-1.38)**	0.97	(0.76-1.23)
Physical activity#	>=150 min moderate PA per week (reference)												
	<150 min moderate PA per week	**1.23**	**(1.12-1.34)**	**1.23**	**(1.1-1.38)**	**1.29**	**(1.15-1.44)**	**1.46**	**(1.28-1.66)**	**1.50**	**(1.33-1.68)**	**1.33**	**(1.18-1.49)**
Frequency of walking for at least 10 min continuously per week	never (reference)												
	everyday	**0.81**	**(0.72-0.9)**	0.94	(0.83-1.06)	**0.73**	**(0.67-0.8)**	**0.72**	**(0.64-0.8)**	**0.75**	**(0.69-0.82)**	**0.64**	**(0.57-0.72)**
	1-6 days a week	**0.84**	**(0.75-0.94)**	0.90	(0.78-1.03)	**0.85**	**(0.79-0.93)**	**0.75**	**(0.67-0.84)**	**0.84**	**(0.77-0.91)**	**0.70**	**(0.62-0.79)**
Smoking status	non-smoker (reference)												
	current smoker	**0.73**	**(0.64-0.82)**	0.88	(0.76-1.02)	**0.84**	**(0.77-0.91)**	1.01	(0.89-1.16)	**0.89**	**(0.82-0.97)**	1.00	(0.88-1.14)

Legend: Sex, age, education, labour status, area of residence, and country were controlled for in all models. CI: confidence interval; PR: prevalence ratio; PA: physical activity; EHIS: European Health Interview Survey; and CEE: Central and Eastern Europe. Significant outcomes appear in bold. #Physical activity measurement varied across EHIS waves: in EHIS 1, it was based on time spent on moderate physical activity per week; in EHIS 2 and 3, HEPA was derived by summing weekly minutes of sports, fitness, recreational activities, and cycling.

Appendix 5: Age-standardised prevalence of diabetes mellitus by metabolic and lifestyle risk factors in EHIS 1

EHIS 1 (2009)		Bulgaria	Cyprus	Czech Republic	Greece	Spain	Hungary	Latvia	Poland	Romania	Slovenia	Slovakia
DM	yes	4.9	7.6	7.5	8.6	6.9	8.9	4.6	7.1	3.4	7.5	8.7
Body mass index	<25kg/m2	3.9	5.5	5.1	5.9	4.8	5.1	2.4	4.6	2.2	6.4	5.7
	≥25 kg/m2	5.5	9.0	8.4	9.7	7.9	10.8	5.6	8.2	4.5	7.9	10.2
Smoking status	non-smoker	5.4	7.6	8.2	8.9	6.9	8.9	5.1	7.5	3.9	7.6	9.0
	current smoker	2.2	7.0	na	7.3	6.8	8.4	2.5	5.5	1.4	8.6	na
Eating vegetables	Once or more a day	4.8	7.5	7.1	8.7	7.0	8.7	5.0	7.2	4.0	7.7	9.8
	1-6 times a week	4.9	8.2	7.8	8.1	6.6	9.2	4.1	6.7	2.5	6.0	7.4
	Less than once a week or never	7.9	7.4	na	9.9	7.2	10.5	2.3	9.7	5.1	na	8.2
Eating fruits	Once or more a day	4.8	7.7	7.0	8.3	7.1	9.0	4.8	7.0	4.6	7.5	9.3
	1-6 times a week	5.0	7.8	8.2	8.8	6.1	8.9	4.2	6.8	2.8	7.3	7.3
	Less than once a week or never	5.7	5.7	na	10.0	4.8	11.1	4.5	9.2	2.6	na	na
Physical activity	>=150 min moderate PA per week	3.8	6.9	6.3	7.5	6.2	7.1	3.5	6.4	3.2	6.5	7.1
	<150 min moderate PA per week	5.7	8.2	9.0	9.5	7.4	10.4	5.8	7.8	4.7	7.9	9.7
Walking for at least 10 min continuously per week	never	9.0	8.5	na	10.8	7.3	11.2	6.9	8.3	na	10.0	10.8
	everyday	4.4	6.9	6.7	7.5	7.0	8.0	4.6	6.8	3.1	7.0	7.7
	one to six days a week	4.9	6.8	8.6	8.3	6.2	8.2	3.9	6.7	3.6	6.4	8.0

1.4 11.2

Legend: The age-standardized prevalence of diabetes was estimated for individuals aged 20 and above, stratified by 5-year age groups, using the 2013 revision of the European Standard Population. The label "na" denotes either missing data or instances where fewer than five respondents were recorded in at least one age group. DM: diabetes mellitus. The heatmap was generated in Microsoft Excel (Microsoft 365).

Appendix 6: Age-standardised prevalence of diabetes mellitus by metabolic and lifestyle risk factors in EHIS 2

EHIS 2 (2014)		Bulgaria	Cyprus	Czech Republic	Greece	Spain	Hungary	Latvia	Poland	Romania	Slovenia	Slovakia
DM	yes	6.7	8.6	8.6	9.1	7.8	8.8	5.0	8.0	5.5	7.5	8.8
Body mass index	<25kg/m2	4.1	5.5	5.3	6.7	5.0	4.8	1.7	4.4	4.8	5.1	6.3
	≥25 kg/m2	8.1	10.3	10.0	10.4	9.4	10.9	6.5	9.7	5.9	8.9	10.0
Smoking status	non-smoker	7.0	8.4	8.5	9.5	7.7	9.5	5.3	8.1	5.8	7.7	8.9
	current smoker	4.5	8.2	9.2	8.0	7.9	5.3	3.7	7.7	3.4	6.2	6.9
Eating vegetables	Once or more a day	6.9	8.6	8.6	9.4	8.1	7.7	5.2	7.9	6.7	7.5	8.7
	1-6 times a week	6.3	8.5	8.5	7.5	7.5	10.1	5.0	8.0	5.1	7.7	9.0
	Less than once a week or never	7.6	7.9	7.9	12.0	10.0	9.9	3.4	8.6	4.9	na	9.1
Eating fruits	Once or more a day	7.1	8.6	8.3	9.5	8.1	9.1	4.8	7.9	6.7	7.7	8.5
	1-6 times a week	6.2	8.3	8.5	8.7	6.8	7.5	5.0	8.0	5.0	7.0	8.9
	Less than once a week or never	7.1	na	10.9	7.8	8.6	10.7	5.6	9.6	5.4	8.6	11.3
Physical activity	>=150 min moderate PA per week	na	6.5	5.6	na	5.8	7.6	3.6	7.6	2.5	5.5	5.6
	<150 min moderate PA per week	6.8	9.3	9.0	9.3	8.8	9.4	5.3	8.1	5.6	8.5	9.5
Walking for at least 10 min continuously per week	never	9.9	8.9	12.5	11.5	10.0	10.6	6.4	9.5	na	8.1	11.3
	everyday	5.8	6.3	6.8	7.8	7.2	7.6	4.3	7.1	4.7	6.8	7.7
	one to six days a week	6.6	7.4	8.8	8.5	7.0	9.6	5.6	8.2	5.9	8.0	8.8

1.7 12.5

Legend: The age-standardized prevalence of diabetes was estimated for individuals aged 20 and above, stratified by 5-year age groups, using the 2013 revision of the European Standard Population. The label "na" denotes either missing data or instances where fewer than five respondents were recorded in at least one age group. DM: diabetes mellitus. The heatmap was generated in Microsoft Excel (Microsoft 365).

Appendix 7: Age-standardised prevalence of diabetes mellitus by metabolic and lifestyle risk factors in EHIS 3

EHIS 3 (2019)		Bulgaria	Cyprus	Czech Republic	Greece	Spain	Hungary	Latvia	Poland	Romania	Slovenia	Slovakia
DM	yes	6.8	9.0	9.4	7.7	7.8	9.3	5.8	9.2	5.5	8.3	8.8
Body mass index	<25kg/m2	4.8	5.8	5.7	5.2	5.6	5.2	2.5	4.7	4.2	4.8	5.9
	≥25 kg/m2	8.0	10.8	10.9	8.9	9.1	11.1	7.3	11.3	6.2	9.9	9.9
Smoking status	non-smoker	7.2	9.0	9.1	7.7	7.8	9.3	5.8	9.5	5.8	8.5	8.8
	current smoker	5.5	7.7	10.5	7.6	8.3	8.4	4.6	7.5	5.3	6.9	8.7
Eating vegetables	Once or more a day	6.8	8.7	8.9	7.9	8.0	9.7	6.2	9.8	7.0	8.8	8.8
	1-6 times a week	6.8	9.0	9.2	7.3	7.8	9.0	5.6	8.7	5.0	7.3	8.7
	Less than once a week or never	na	13.5	13.0	na	na	9.2	5.1	7.1	6.3	7.1	10.7
Eating fruits	Once or more a day	7.3	8.9	8.8	7.4	8.0	10.1	5.8	9.5	6.3	8.8	8.3
	1-6 times a week	6.4	9.0	9.1	7.5	7.2	7.7	5.6	8.5	5.0	7.7	9.3
	Less than once a week or never	7.6	10.3	15.1	10.5	7.9	8.2	7.5	10.8	6.5	5.2	10.4
Physical activity	>=150 min moderate PA per week	7.7	8.4	4.7	4.4	6.4	6.7	3.9	7.2	na	6.4	4.4
	<150 min moderate PA per week	6.9	8.9	10.3	8.0	8.7	10.3	6.2	9.6	5.6	9.0	9.7
Walking for at least 10 min continuously per week	never	12.1	9.2	12.1	13.3	10.7	10.3	7.4	11.6	6.4	9.6	13.3
	everyday	6.6	na	7.9	6.0	7.2	8.6	4.9	8.7	4.8	7.8	7.5
	one to six days a week	6.1	7.5	9.9	6.6	7.8	9.6	6.2	8.9	5.9	7.9	9.1

2.5 15.1

Legend The age-standardized prevalence of diabetes was estimated for individuals aged 20 and above, stratified by 5-year age groups, using the 2013 revision of the European Standard Population. The label "na" denotes either missing data or instances where fewer than five respondents were recorded in at least one age group. DM: diabetes mellitus. The heatmap was generated in Microsoft Excel (Microsoft 365).