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FMUP FACULDADE DE MEDICINA
UNIVERSIDADE DO PORTO

EFFECTIVENESS OF HEALTH SYSTEMS IN THE EUROPEAN UNION

JOÃO VASCO NUNES DOS SANTOS

TESE DE DOUTORAMENTO APRESENTADA
À FACULDADE DE MEDICINA DA UNIVERSIDADE DO PORTO EM
INVESTIGAÇÃO CLÍNICA E EM SERVIÇOS DE SAÚDE

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"One of the symptoms of approaching nervous breakdown is the belief that one's work is terribly important and that to take a holiday would bring all kinds of disaster. If I were a medical man, I should prescribe a holiday to any patient who considered his work important."

Bertrand Russell, The Conquest of Happiness

Effectiveness of health systems in the European Union

João Vasco Nunes dos Santos

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To my grandmother

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LIST OF PAPERS

(ao abrigo do Artigo 8º do Decreto-Lei n.º 388/70, fazem parte desta dissertação os seguintes trabalhos publicados ou em publicação)

European Union state of health from 1990 to 2017: time trends and its enlargements' effects.

Santos JV, Lobo M, Neiva RM, Viana J, Souza J, Dias CC, Cylus J, Ricciardi W, Freitas A.

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The state of health in the European Union (EU-28) in 2017: An analysis of the burden of diseases and injuries.

Santos JV, Souza J, Valente J, Alonso V, Ramalho A, Viana J, Ricciardi W, Freitas A.

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Risk factors and their contribution to population health in the European Union (EU-28) countries in 2007 and 2017.

Santos JV, Gorasso V, Souza J, Wyper GMA, Grant I, Pinheiro V, Viana J, Ricciardi W, Haagsma JA, Devleesschauwer B, Plass D, Freitas A.

European Journal of Public Health 2021; 31: 958-967.

Journal impact factor (2019): 3.367

Percentile (Public, Environmental & Occupational Health - SSCI): 75.28 (Q1)

Number of citations: Web of Science – 0; Scopus – 0; Google Scholar – 0.

Health expectancies in the European Union: same concept, different methods, different results.

Santos JV, Viana J, Devleesschauwer B, Haagsma JA, Costa-Santos C, Ricciardi W, Freitas A.

Journal of Epidemiology and Community Health 2021; 75: 764-771.

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Journal impact factor (2020): 3.710

Percentile (Public, Environmental & Occupational Health - SSCI): 80.97 (Q1)

Number of citations: Web of Science – 0; Scopus – 1; Google Scholar – 2.

ABSTRACT

Health planning and priority setting are essential for health systems, alongside monitoring and assessing health systems performance. For both ends, effectiveness and population health outcomes are the cornerstone of all possible analyses. In the European Union (EU), the monitoring of effectiveness of health systems is done mainly with mortality-based indicators, with only one morbidity-mortality indicator currently being reported, i.e. "healthy life years". However, it shows considerable problems for data comparability across countries. Additionally, regarding health determinants, EU reports lack a comprehensive and systematic approach for all risk factors focusing only on specific risk factors and age groups. This thesis aimed (1) to assess the differences of effectiveness when considering different groups of the European Union (e.g. enlargements), (2) to evaluate effectiveness of health systems in the European Union for benchmarking and describing trends, by reusing Global Burden of Diseases study data and (3) to compare different approaches of estimating effectiveness of health systems using a comprehensive health indicator. Different methods of measuring effectiveness of health systems in the European Union using burden of diseases and comprehensive morbidity-mortality indicators, such as disability-adjusted life years or healthy life expectancies, are presented. While applying such methods, it can be seen that different EU definitions lead to quite different average health status. Additionally, a clear and simple presentation of results is suggested in order to benchmark EU countries, assess trends and identify best practices. There is also a wide variation when using different healthy life expectancies throughout EU countries and over time. In the future, such implications in other domains of health system performance assessment should be addressed and studied, as well as closing the gap between the benefits or utility of economic evaluations and better population health outcomes.

Key-words: health systems; effectiveness; health system performance assessment; burden of diseases; health status; risk factors; population health; indicators; European Union.

RESUMO

O planeamento e a priorização em saúde são essenciais para os sistemas de saúde, assim como a monitorização e avaliação da performance dos sistemas de saúde. Para ambos os fins, a efetividade e os outcomes de saúde populacional são a pedra basilar de todas as possíveis análises. Na União Europeia (UE), a monitorização da efetividade dos sistemas de saúde é feita maioritariamente através de indicadores baseados em mortalidade, existindo apenas um indicador de morbi-mortalidade a ser reportado atualmente, i.e. "healthy life years". No entanto, este indicador tem importantes problemas relacionados com a comparabilidade dos dados entre países. Para além disso, no que concerne aos determinantes de saúde, os relatórios da UE não utilizam uma abordagem ampla e sistemática para a análise de todos os fatores de risco, focando assim e apenas em determinados fatores de risco e grupos etários. Esta tese teve como objetivos: (1) avaliar as diferenças da efetividade dos sistemas de saúde considerando diferentes grupos da UE (e.g. alargamentos); (2) avaliar a efetividade dos sistemas de saúde na UE para benchmarking e descrição de tendências; e (3) comparar diferentes abordagens na estimativa da efetividade dos sistemas de saúde através de indicadores de saúde de morbi-mortalidade. Diferentes métodos de medição da efetividade na EU utilizando a carga de doença e indicadores de morbi-mortalidade, como os anos de vida ajustados à incapacidade ou a esperança de vida saudável são apresentados. Com a aplicação destes métodos, pode verificar-se que diferentes definições de UE levam a uma média de "health status" bastante diferente. Para além disso, uma apresentação dos resultados clara e simples é sugerida para facilitar o benchmarking entre países da UE, avaliar tendências e identificar boas práticas. Existe também uma elevada variação nas estimativas quando se utilizam diferentes métodos de esperança de vida saudável nos países da UE e ao longo do tempo. No futuro tais implicações em outros domínios da avaliação de performance dos sistemas de saúde deveriam ser estudadas, bem como a aproximação entre benefícios ou utilidade das avaliações económicas e melhores outcomes de saúde populacional.

Palavras-chave: sistemas de saúde; efetividade; avaliação de performance de sistemas de saúde; carga de doença; health status; fatores de risco; saúde populacional; indicadores; União Europeia.

ABBREVIATIONS AND ACRONYMS

DALYs: disability-adjusted life years

EEA: European Economic Area

EU: European Union

GALI: Global Activity Limitation Indicator

GBD: Global Burden of Disease

HALE: healthy life expectancy

HSPA: Health system performance assessment

IHME: Institute for Health Metrics and Evaluation

LE: life expectancy

MCDA: multi-criteria decision analysis

OECD: Organisation for Economic Co-operation and Development

PBMA: programme budgeting and marginal analysis

WHO-CHOICE: WHO's Choosing Interventions that are Cost-Effective

WHO: World Health Organisation

YLDs: years lived with disability

YLLs: years of life lost

INTRODUCTION

Health planning and priority setting are probably the most important and potentially complex processes in health services, even more so in a resource scarcity setting, as it happens, at different levels, in all settings. Both health planning and priority setting can be done at all levels, micro (i.e. doctor decisions regarding patients' care), meso (i.e. hospital or community decisions) or macro (i.e. governmental decisions regarding health policy and resources allocation) [1-3]. This thesis focuses on the macro level and thus on the national health system level, although similar approaches can be designed at a regional or local level.

Clark and Weale proposed two sets of social values for process and content of health priority setting [2]. Regarding process values, transparency of the decision-making rules, accountability for priority setting, as well as the participation of a vast set of stakeholders including the public and health professionals, were suggested. In fact, the most common process measures on priority setting are stakeholder engagement, transparency, provision for revision of decision, use of evidence/information and enforcement [1]. On the other hand, content values proposed included social value judgements and cost-sharing, linked to justice/equity, solidarity and autonomy, but also cost and clinical effectiveness [2]. The standing question from these latter values is "How are cost and clinical effectiveness taken into account in priority setting decisions (...)?" [2].

Weale had defined effectiveness as "the ability of a procedure to accomplish a given end" [4]. It is seen as a "fundamental" domain of priority setting decisions and is related to the health benefits produced by some intervention. This should be well studied and measured through the health status of patients and, even if increasingly used for new interventions, the impact each intervention has at a macro level is still something to define and measure properly [2].

Aidem identified, through semi-structured interviews on health priority setting with different stakeholders including policymakers and hospital administrators in Norway, that "the health system should provide effective interventions to address current and future health burdens" [5]. Another mixed methods study, in which the participants ranked criteria for priority setting, top 3 were "size of health gain", "effectiveness" and "improvement in quality of life" [6]. Additionally, one of the common priority setting outcomes that have been used is the "extent to which decisions are based on evidence, improvements in decision-making quality and health outcomes" [1].

The most suitable current method for priority setting is programme budgeting and marginal analysis (PBMA) which considers (1) the available budget for the upcoming time period and (2) possible investments and disinvestments ranked in a way similar to a multi-criteria decision analysis (MCDA) [7-11]. This latter process, MCDA, has also been suggested as a good method to set health priorities [12,13]. Back in 2000, Bots and Hulshof showed a priority setting example using a MCDA already considering both mortality (i.e. life expectancy) and morbidity (i.e. prevalence of disease and quality of life) as criteria [14]. In analyses such as PBMA, health outcomes can be considered as a criterion to account for [15]. Indeed, for both MCDA and PBMA, effectiveness and intervention outcomes or benefits are commonly included criteria [8,9,11,16-18].

One of the difficulties after implementing a PBMA, as the example provided in a community care setting by Cornelissen et al. illustrates, is that: "We're relatively good at measuring outputs, we can provide fairly detailed analysis of what work is being done and what it costs us, but we are totally missing the actual health outcome pieces. So automatically if your system is privileging measuring health outputs there is no incentive in that system to switch to a system that actually measures the effectiveness of those outputs" [19]. While this can be more difficult for local settings, implementation on national contexts is yet to be more commonly applied, and the evaluation of health system effectiveness is yet to be refined.

One possible way of ranking new health interventions, programs or technologies is using incremental cost-effectiveness ratios, usually estimated and presented in economic evaluations [8,9,11]. However, the impact of such investments and disinvestments should be seen at a health system perspective rather than at a specific economic evaluation only, within specific population groups/samples. Thus, linking health measures and assessing health system performance is essential in order to understand and study the impact of health investments or disinvestments. In fact, despite efforts to implement this link, these have not been successful in evaluating health outcomes and implementing programming solutions [20]. It is interesting to note that Tromp and Baltussen, among the "health level" criteria for priority setting, included both "effectiveness on individual level" and "effectiveness on population level", and even "patient reported health status" [21].

Health system performance assessment (HSPA) in its turn also has several proposed frameworks with different dimensions [22-31]. The main objectives of HSPA are (1) to set goals and priorities, (2) to act as a focus for policymaking within health systems, (3) to measure progress towards achievement of goals, (4) to benchmark with other health systems and (5) to promote transparency and accountability [32]. The most common and traditional dimensions are the E3: effectiveness, efficiency and equity [27,33-35]. It needs to be highlighted that the effectiveness dimension and its indicators are commonly reused for the other two, i.e. efficiency and equity, as the outputs of these dimensions' analyses [36-38].

The most common indicators related to effectiveness of health systems typically include heath status indicators, health care outputs and sometimes quality indicators [24]. Health status indicators comprise infant mortality, maternal mortality, life expectancy, disability-adjusted life expectancy or DALYs [24,39,40]. Examples of health care output indicators include prescribed pharmaceuticals, procedures, screening coverage, immunization coverage, control of chronic diseases or avoidable hospitalizations [22,24,26]. While several countries show different concepts and operationalisations of effectiveness, the World Health Organisation (WHO) tends to consider only health status indicators [24]. In fact, the WHO and the Organisation for Economic Co-operation and Development (OECD) tend to define effectiveness as "improving health outcomes" [24]. While effectiveness can be seen as "the degree to which the objectives of a program, care, service or system are achieved" [41], its ultimate meaning (and related indicators) depends on whether we are analysing health care services or the entire health system. In fact, as Murray and Frenk stated, "the defining goal for the health system is to improve the health of the population" [28].

It is important to highlight though that the recent report on "Health system performance assessment in the WHO European Region" considers effectiveness as a crossing of "quality" with "health needs", including health outcome indicators in the "Improved health" domain, which leads to even more conceptual confusion [42]. This is not an isolated case as another example from New Zealand on HSPA does not include the effectiveness domain but rather a "healthy lives" domain, where years of life lost, amenable mortality, infant mortality, healthy life expectancy, self-rated general health, diabetes mellitus and risk factors' prevalence are included [43]. Instead, a systematic review by Kruk and Freedman, include health status, patient satisfaction, access and quality of care as sub-domains of the effectiveness domain [40]. In the opposite direction, the Belgian Health System Performance report included

effectiveness as a subdomain of quality [31]. In fact, these two concepts are not used homogeneously [24].

More recently, Peric et al., through an international survey of experts, have proposed a set of indicators to describe health systems performance, including domains of "health status" and "health determinants" [29]. In the first group, life expectancy, healthy life years and infant mortality rate were included, while in the latter "at risk of poverty or social exclusion rate", "body mass index", "prevalence of different smoking status, self-reported" and "unemployment rate" were considered [29].

The Institute for Health Metrics and Evaluation (IHME) started the Global Burden of Disease (GBD) study back in 1990 and has now collated large sets of data synthetized into comprehensive, comparable and internally consistent estimates of population health measures at regional, national and sub-national levels covering more than 350 causes of disease and injury, as well as 84 risk factors. Population health measures include those related to morbidity (both incidence and prevalence), mortality, years of life lost (YLLs), years lived with disability (YLDs), disability-adjusted life years (DALYs), life expectancy (LE), healthy life expectancy (HALE) and risk factor exposure [44-48].

Although DALYs have been previously pointed out as a "powerful tool for decision-making" and others used burden of disease directly for priority setting, to prioritize diseases based on their burden does not seem like a good plan, as it disregards economic approaches and concepts of marginal utility and cost opportunity [8,9,49]. However, burden of disease is sometimes considered as a criterion and, in some cases, as the sole criterion for priority setting, mainly in low-income countries [50-52]. Additionally, several European Health Technology Assessment Agencies have also used burden of disease as one of the criteria to prioritize technologies [53].

In another focus, one question is usually raised in projects such as this thesis: "What European group should we focus on: the European Union (EU), the WHO Europe region or the EU/EEA (European Economic Area)?" While this is not an easy decision to make and no response is incorrect, I personally believe that despite the few direct interventions that the EU can make in national health systems, it is the European group with the highest chance to design and promote health priorities that can be of real support to Member States [54-56]. In fact, the

European Commission's role in HSPA is increasingly higher, promoting standards for HSPA frameworks, and even having a specific expert group, including all Member States, for this end [57].

The EU has been facing several challenges for the past years, including ageing population, migration, unequal distribution of health professionals, increasing cost-demanding technologies and more recently the COVID-19 pandemic [58-62]. Indeed, such factors also trigger the need for EU health systems to have better and more precise health prioritization and allocation of resources processes [8,63,64].

Although the EU exerts some influence on Member States' health systems, in activities such as health research, pharmaceuticals or medical technology [54,65], most governments prefer no interventions from the EU on health policy, which usually requires important compromises between political parties [66]. In fact, one key factor of this (low) influence of the EU on Member States' health policy is the fact that it is a slow and difficult process, remaining mainly a regulatory, supportive and promoting institution [54-56]. However, the contribution of health to economic growth and social cohesion has placed population health high in the EU agenda, including the goal of promoting standards for HSPA frameworks [57,67].

Since 1992, the EU has been changing in size and nature totalizing 28 countries in 2019. Since the exit of the United Kingdom in 2020, the first exit since the EU was born, 27 countries remained. In fact, across studies, there are many differences in the EU groups considered, such as EU15, EU25 or others. However, there were no studies comparing the impact of considering different EU groups on the EU average health status. Additionally, it must be noted that population health status can be important for several reasons, including in the criteria for accessing the EU, this being one of the key issues for the Turkish accession [68].

Additionally, the "Health at a Glance: Europe - State of Health in the EU cycle" is published every two years, providing a "neutral, descriptive comparison of all EU countries based on publically available data and indicators" [69]. However, the only morbidity-mortality indicator is "healthy life years" which is calculated based on the disability measure of the Global Activity Limitation Indicator (GALI). Despite being frequently used, GALI has "differences across

countries in the formulation of the question on disability (...) limiting data comparability" [60-62,70]. Regarding health determinants, these reports also lack a comprehensive and systematic approach for all risk factors focusing only on specific risk factors and age groups [60-62].

On the other hand, while around 200 burden of disease studies have been performed considering estimates such as DALYs across the WHO European region, most were country- or disease-specific and none covered the full spectrum of diseases in an EU or WHO European region level [71].

Thus, there is still a lack of consistent and comprehensive evaluation, including morbidity-mortality indicators, of the effectiveness of health systems in the EU.

AIMS

While the general aim of the thesis was to analyse and propose ways of evaluating the effectiveness of health systems in the EU, the specific aims of this thesis were:

1) To assess the differences of effectiveness (health status indicators) when considering different groups of the European Union (e.g. enlargements).
2) To evaluate effectiveness of health systems in the European Union for benchmarking and describing trends, by reusing Global Burden of Diseases study data
3) To compare different approaches of estimating effectiveness of health systems using a comprehensive health indicator.

OUTLINE OF PAPERS

In the following sections, the already published papers included in this thesis are presented.

The first paper entitled "European Union state of health from 1990 to 2017: time trends and its enlargements' effects" addresses the first specific aim of assessing "differences of effectiveness (health status indicators) when considering different groups of the European Union (e.g. enlargements)".

The second and third papers entitled "The state of health in the European Union (EU-28) in 2017: An analysis of the burden of diseases and injuries" and "Risk factors and their contribution to population health in the European Union (EU-28) countries in 2007 and 2017" address the second specific aim of evaluating "effectiveness of health systems in the European Union for benchmarking and describing trends, by reusing Global Burden of Diseases study data".

The fourth paper entitled "Health expectancies in the European Union: same concept, different methods, different results" addressed the third specific aim of comparing "different approaches of estimating effectiveness of health systems using a comprehensive health indicator".

Supplementary materials of each paper are outlined in the annexes.

PAPER 1

European Union state of health from 1990 to 2017: time trends and its enlargements' effects.

Santos JV, Lobo M, Neiva RM, Viana J, Souza J, Dias CC, Cylus J, Ricciardi W, Freitas A.

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ORIGINAL ARTICLE

European Union state of health from 1990 to 2017: time trends and its enlargements' effects

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Abstract

Objectives We aimed to study health status' time trends in the European Union (EU) during 1990–2017 and its enlargements' impact.

Methods Using estimates from the Global Burden of Disease 2017 study and calculating age-sex-standardized rates, we have described time trends and analysed the differences between EU groups regarding the state of health. Interrupted time-series analyses were also performed in order to assess the enlargement impact in the EU state of health.

Results All age–sex-standardized rates (mortality, years of life lost, years lived with disability and disability-adjusted life years) declined (annualized rates of change of − 1.7%, − 1.52%, − 0.06% and − 1.01%, respectively) between 1990 and 2017 (except between 2014 and 2015). For EU-28, life expectancy and healthy life expectancy increased 5.9 and 4.6 years, respectively. With the EU-25 and EU-27 enlargements, all age–sex-standardized rates and life expectancies worsened (with statistical significance). The EU-28 enlargement revealed the same tendency, contrasting with the EU-15 one.

Conclusions Overall, the EU health status is improving, despite changes in its composition over the years. However, the average EU state of health declined with the 2004, 2007 and 2013 EU enlargements.

Keywords European Union · Health status · Public health · Burden of disease

Introduction

The idea of the European Union (EU) dates back to philosophers/visionaries such as Victor Hugo, who imagined a peaceful "United States of Europe" (Fontaine 2010). Although its initial goal was Franco-German peace and economic development, the goals are now more demanding, including security, economic and social solidarity and shared values (European Observatory on Health Systems and Policies 2004; Fontaine 2010; Greer et al. 2013).

In 1951, with the Treaty of Paris, the sustainable production of coal and steel was the reasoning behind the creation of the European Coal and Steel Community by six European countries (i.e. Belgium, the Federal Republic of Germany, France, Italy, Luxembourg and the Netherlands) (European Observatory on Health Systems and Policies 2004; Fontaine 2010). In 1957, the Treaty of Rome established the European Atomic Energy Community and the European Economic Community (Fontaine 2010). The first enlargement took place in 1973, with the accession of

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Denmark, Ireland and the UK (European Observatory on Health Systems and Policies 2004; Fontaine 2010).

Due to a growing need for European integration, the Treaty of Maastricht established the European Union in 1992. Since then, the EU has implemented several public health policies and has provided a framework for actions on public health and prevention of diseases (Azzopardi-Muscat et al. 2017; Cucic 2000; European Observatory on Health Systems and Policies 2004). Although this provided the Union greater authority, Member States retained the exclusive responsibility for delivering health to their populations (Cucic 2000). Nevertheless, the EU maintains an indirect impact on health services in Member States, with important influence in activities such as health research, medical training, pharmaceuticals, medical technology, telematics or social security (Cucic 2000; Fontaine 2010).

Since 1992, the EU has been changing in size and nature, totalling 28 countries until 31 January 2020, when the United Kingdom withdrew from it. Before the EU enlargement to 25 countries, Avgerinos et al. (2004) alerted that, with the inclusion of such a diverse group of countries with considerable dissimilarity regarding health status, an EU common healthcare policy should be outlined. In addition, McKee and Nolte (2004) pointed out that the accession of those ten countries, with an average wealth the equivalent to half of that of the EU-15 countries and a population size that amounted to a 28% increase in EU population, would certainly impact health and health policy, to an uncertain extent. Specifically, issues such as bridging the health gap, addressing specific health problems and improving health systems performance assessment (HSPA) should be addressed (Avgerinos et al. 2004).

Although an HSPA instrument with common indicators and shared comparable data from Member States could be used as a way to evaluate health care at an EU level, contributing to the setting of health priorities, policymaking, greater transparency and cross-country comparisons, there is no European-wide coherent framework (Braithwaite et al. 2017; Franklin 2017; Peric et al. 2017). Effectiveness, as one of the main dimensions of HSPA, includes state of health assessment (Braithwaite et al. 2017; Smith et al. 2008), the indicators of which should be comparable, valid, comprehensive, transparent and standardized, reflecting population health and enabling better priority setting (Etches et al. 2006; Parrish 2010).

Although there are some recent reports on the EU state of health (OECD 2018; Santos et al. 2019) that have already addressed time trends, and there has been a debate on the health impact of the EU enlargements (European Observatory on Health Systems and Policies 2004), there are no studies analysing the EU state of health time trends, comparing different EU groups or measuring the impact of the enlargement on the average EU health status. Thus, our main goal was to analyse health status' time trends in the European Union between 1990 and 2017, comparing different EU groups' compositions, and to study how the entry of new countries in the EU has affected these time trends, by using an interrupted time-series analysis.

Methods

We performed a retrospective study using health and demographic estimates from the Global Burden of Disease (GBD) 2017 study to assess health status within EU countries.

The GBD 2017 study was a collaborative effort to measure health at global, regional, country and sub-country levels, quantifying the burden of more than 350 diseases and injuries and 84 risk factors between 1990 and 2017 for 195 countries. The GBD produces estimates of mortality, years of life lost due to premature mortality (YLLs), years lived with disability (YLDs), disability-adjusted life years (DALYs), life expectancy, healthy life expectancy (HALE), morbidity (both prevalence and incidence) and risk factors exposure (GBD 2017 Causes of Death Collaborators 2018; GBD 2017 DALYs and HALE Collaborators 2018; GBD 2017 Disease and Injury Incidence and Prevalence Collaborators 2018; GBD 2017 Mortality Collaborators 2018; GBD 2017 Risk Factor Collaborators 2018).

We extracted the number of deaths for all causes, YLLs, YLDs, DALYs, life expectancy, HALE and population estimates using the GBD results tool (GBD Results Tool), for all EU countries between 1990 and 2017, by year, country, age and sex. Sub-totals were then computed for EU groups, as defined by the number of Member States in the EU composition at different time periods (i.e. EU founders, EU-9, EU-10, EU-12, EU-15, EU-25, EU-27 and EU-28—groups' definitions are presented in Supplementary Table 1).

Information regarding mortality, used in the GBD study, comes from country-specific vital registration (VR) systems. Countries with complete VR systems permitted the development of the GBD model life table system standard, driven almost exclusively by the observed age pattern of mortality in those countries. Within the 28 EU countries between 1990 and 2016, all but Cyprus had complete VR final estimates (95% or more VR data complete) throughout the studied period. The YLLs—a measure of premature mortality—are computed by the sum of each death multiplied by the GBD standard life expectancy at each age. More detailed information on the methodology regarding the estimation of mortality and of YLL can be found in the GBD 2017 study (GBD 2017 Causes of Death Collaborators 2018; GBD 2017 Mortality Collaborators 2018).

Prevalence and incidence measures reflect all the accessible information on disease occurrence, natural history and severity documented over multiple sources (e.g. hospital inpatient or epidemiological surveillance databases), satisfying minimum quality standards. For each disease, the GBD study combines all data sources and applies the Bayesian meta-regression tool DisMod-MR 2.1 for data pooling and bias adjustments (Flaxman et al. 2015). The used disability weights are constructed based on the population surveys by Salomon et al. (2012, 2015). A total of 234 health states are considered, and YLDs are computed using these metrics. DALYs are calculated by the sum of YLLs and YLDs. More detailed information on the methodology regarding the prevalence, incidence and YLDs estimation can be found in the GBD 2013, 2015, 2016 and 2017 Disease and Injury Incidence and Prevalence studies (GBD 2015 Disease and Injury Incidence and Prevalence Collaborators 2016; GBD 2016 Disease and Injury Incidence and Prevalence Collaborators 2017; GBD 2017 Disease and Injury Incidence and Prevalence Collaborators 2018; Global Burden of Disease Study 2013 Collaborators 2015).

Based on demographic prediction and the GBD model life tables, life expectancies for each age group are calculated and life expectancies at birth were analysed. HALE, the number of years that a person lives with full health, is calculated based on estimates of the number of YLDs and multiple-decrement life tables using the method developed by Sullivan (1971). More detailed information on the methodology regarding the estimation of life expectancies and HALEs can be found in the GBD 2017 study (GBD 2017 DALYs and HALE Collaborators 2018; GBD 2017 Mortality Collaborators 2018). The proportion between HALE and life expectancy, i.e. the share of life spent (adjusted for) in good health, was calculated.

Adjusting for the age and sex effect, we performed a direct age–sex standardisation using the 2017 EU-28 estimated population, as standard, when applicable to the indicators considered—population, age–sex composition and weights/proportions are presented in Supplementary Table 2. Even though the GBD provides estimates of crude and age-standardized rates, we built our indicators from absolute numbers allowing the calculation for each EU group, the EU-28 and the former ones (the latter not provided by the GBD). Moreover, our approach not only allowed us to adjust rates using a standard population of our choice, but mainly allowed us to adjust for sex, which was not considered in the revision of the European Standard Population (European Commission 2013).

Annualized rates of change were calculated dividing the difference in the values in a given year and the baseline year by the latter and then divided by the difference in years between both (e.g. ($HALE_{2004}$–$HALE_{1990}$/$HALE_{1990}$)/(2004–1990) provides the corresponding annualized rate of HALE change based on data observed between 1990 and 2004).

In order to study the impact of the enlargement in the state of health of the EU, we have plotted time trends between 1990 and 2017 and performed an interrupted time-series analysis. For each EU enlargement, we performed the following model, considering the time period between the previous and following enlargements (between the closer enlargements):

$$\text{Health} = \beta 0 + \beta 1\,\text{time} + \beta 2\,\text{enlarged}_{\text{EU}} + \beta 3\,\text{time} * \text{enlarged}_{\text{EU}}.$$

The variable "$\text{enlarged}_{\text{EU}}$" is equal to 0 before the enlargement occurs and equal to 1 for observations on or after the enlargement process. The variable "time*$\text{enlarged}_{\text{EU}}$" measures the time units (years) following the enlargement. β2 represents the immediate effects of the enlargement, whereas β3 indicates the slope change in the health status, following the enlargement process.

We used Microsoft Excel v16.0 and R v3.4 (R Core Team 2013) for data processing and statistical analysis.

Results

In 1990, when the EU was comprised of 12 countries (EU-12 group), there were a total of 2.22 million deaths and 107.6 million DALYs. Crude and age–sex-standardized mortality rates were of 1011 and 1479 deaths per 100,000 inhabitants, respectively, while for DALY rates were of 31,061 and 37,018 DALYs per 100,000 inhabitants, respectively. Figures 1 and 2 display the time trends of both mortality and DALY rates, respectively, for each EU group, also highlighting the EU-28 value at a specific time.

The crude mortality rate decreased until 2006 for all EU groups (lowest value of the time series), while from 2006 onwards, there was an increase, even considering the continuous enlargement of the EU (Fig. 1). The age–sex-standardized mortality rate described a decreasing trend, despite the discontinuities of increase observed with the enlargement to EU-25, EU-27 and EU-28, as well as in 2015 (Fig. 1). The crude DALY rate showed a decrease, with some increases in 2002/2003 (in most EU groups), in 2014/2015 and in 2016/2017 (Fig. 2). The age–sex-standardized DALY rate mainly showed a decrease except between 2014 and 2015. It also increased with the enlargements to EU-25, EU-27 and EU-28. Annualized rates of change for all studied population health metrics are presented in Tables 1 and 2.

In 2017, when the EU was comprised of 28 countries (EU-28 group), there were a total of 5.20 million deaths and 149.3 million DALYs. Crude and age–sex-

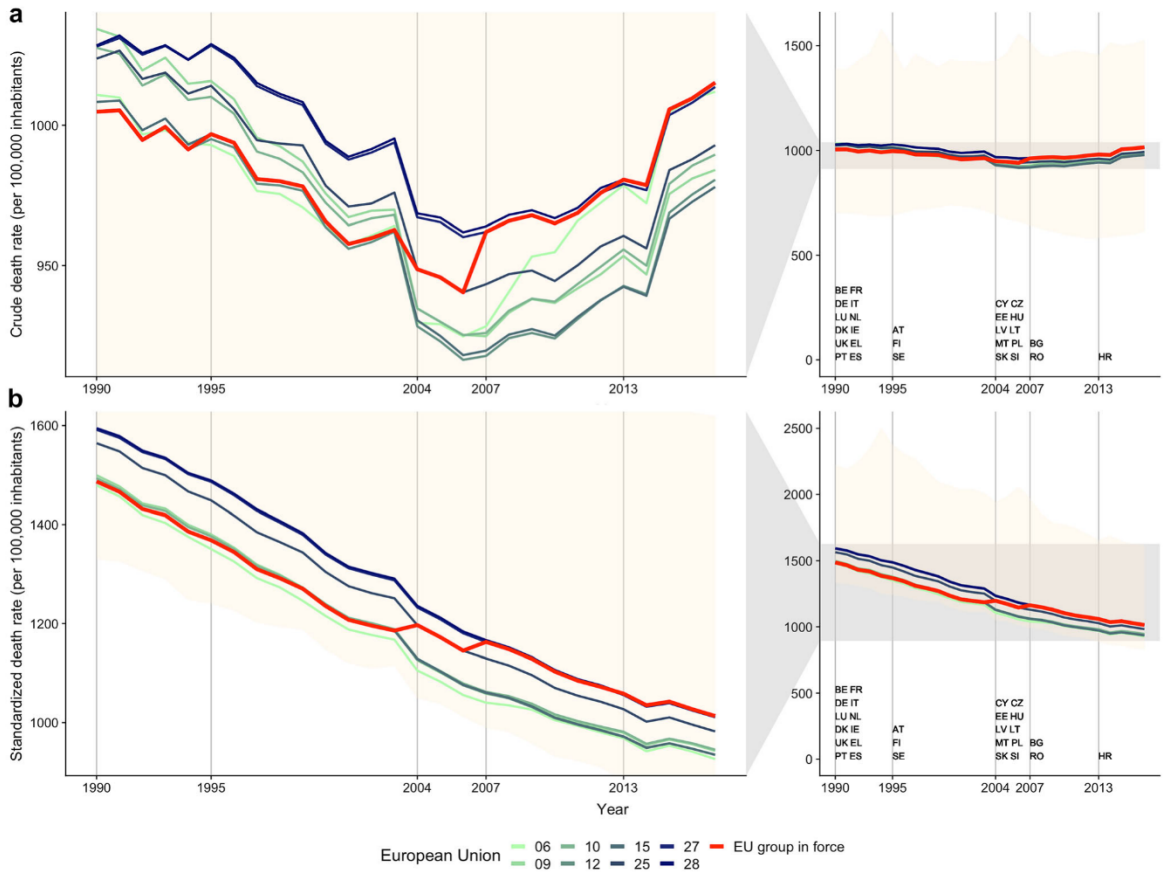


Fig. 1 Crude **(a)** and age–sex-standardized **(b)** rates (per 100,000 inhabitants) of mortality between 1990 and 2017 in European Union, by European Union group. In red are the lines of the EU groups in force in each year presented (color figure online)

standardized mortality rates were of 1015 and 1013 deaths per 100,000 inhabitants, respectively, while for DALY rates were of 29,135 and 29,082 DALYs per 100,000 inhabitants. The 2017 crude and age–sex-standardized mortality rates were lower when compared to the 1990 rates, considering each individual EU group, with the exception of EU-6 crude rate. When analysing the evolution of mortality rates throughout the changes of EU groups, we found that the EU-28 2017 crude mortality rate was the highest of the studied period, while the EU-28 1990 was the highest regarding age–sex-standardized rates (Fig. 1). EU-27 and EU-28 groups presented the highest age–sex-standardized death rate, followed by the EU-25 group (Fig. 1). Within each individual EU group, the 2017 DALY crude and age–sex-standardized rates were considerably lower than the 1990 rates (Fig. 2). The EU-27 and EU-28 groups had the highest age–sex-standardized DALY rates, followed closely by the EU-25 group (Fig. 2). Results for YLL and YLD are presented, respectively, in Supplementary Figure 1 and Supplementary Figure 2.

Life expectancy increased from 76.3 years in 1990 in the EU-12 group (75.1 years in the EU-28 group) to 80.9 years in 2017, in the EU-28 group (Table 2 and Fig. 3). The latter showed an annualized increase of 0.28%. HALE also increased, from 66.4 years in 1990 in the EU-12 group (65.1 years in the EU-28 group) to 69.7 years in 2017 within the EU-28 group (Table 2 and Fig. 3). The latter showed an annualized increase of 0.25%. Both indicators had a setback in the year 2015. HALE represented a proportion of near 87% of life expectancy. With the lower increase in HALE, in comparison with life expectancy, this proportion decreased slightly through the studied period (Table 2).

There was a gap between the EU-25, EU-27 and EU-28 groups and all the other groups, in both life expectancy and HALE. EU-27 and EU-28 groups were those with the lowest life expectancy and HALE throughout the studied time period, while the highest was the EU-6 group (Fig. 3).

Interrupted time-series analyses (Table 3) showed the value of discontinuity and slope changes of both crude and

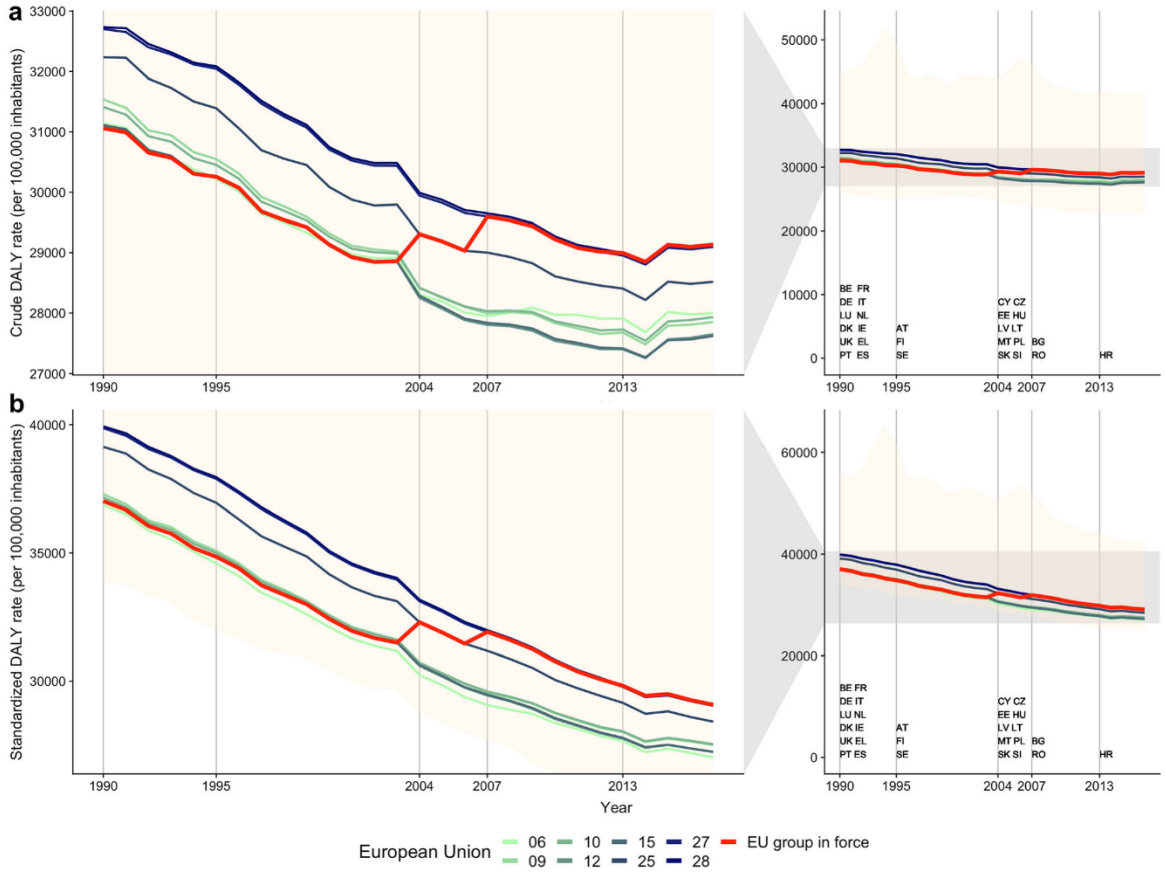


Fig. 2 Crude **(a)** and age–sex-standardized **(b)** rates (per 100,000 inhabitants) of disability-adjusted life years (DALYs) between 1990 and 2017 in European Union, by European Union group. In red are the lines of the EU groups in force in each year presented (color figure online)

age–sex-standardized rates, as well as for LE and HALE. While there were a statistically significant increase in those rates for the 2004 and 2007 enlargements and a non-statistically significant increase in the 2013 enlargement, the 1995 enlargement showed a non-statistically significant decrease for age–sex-standardized YLL and DALY rates. In LE and HALE, a similar pattern was observed (Table 3). A statistically significant difference in age–sex-standardized rates was also observed in the slope change in the 2013 EU enlargement.

Discussion

In this EU study, using estimates from the GBD 2017 study, we analysed time trends of health status indicators and the impact of the EU enlargements. All age–sex-standardized rates showed a decrease in 1990–2017, except between 2014 and 2015. YLD rates also decreased after 2000/2001 or 2005, depending on EU groups. Life expectancies showed the opposite trend. Thus, when adjusting for both age and sex, inhabitants from the EU are dying less, later and with less years lived with disability. In fact, this is translated into an increase in the life expectancy at birth of about 5.9 years and in healthy life expectancy of approximately 4.6 years (EU-28 group).

Regarding the EU enlargement, all age–sex-standardized rates and life expectancies worsened with the transition to EU-25 (in 2004), EU-27 (in 2007) and EU-28 (in 2013), while the 1995 enlargement showed the opposite effect for life expectancies as well as for age–sex-standardized YLL and DALY rates. The EU founders' group was the one that always presented the best health status' indicators.

Table 1 Annualized rate of change for crude and age–sex-standardized rates (per 100,000 inhabitants) of mortality, years of life lost (YLLs), years lived with disability (YLDs) and disability-adjusted life years (DALYs) between 1990 and 2017, in European Union and by EU group (only mortality rates were split into two periods as a clear trend change was found in 2006 crude rate)

	1990–2006		2006–2017	
	Mortality rate (%)	Age–sex-standardized mortality rate (%)	Mortality rate (%)	Age–sex-standardized mortality rate (%)
EU-6	− 0.53	− 1.79	0.86	− 1.12
EU-9	− 0.66	− 1.76	0.58	− 1.13
EU-10	− 0.62	− 1.73	0.63	− 1.13
EU-12	− 0.55	− 1.73	0.64	− 1.19
EU-15	− 0.56	− 1.72	0.59	− 1.20
EU-25	− 0.51	− 1.67	0.51	− 1.29
EU-27	− 0.41	− 1.61	0.51	− 1.31
EU-28	− 0.40	− 1.61	0.50	− 1.31

	1990–2017		1990–2017		1990–2017	
	YLLs rate (%)	Age–sex-standardized YLLs rate (%)	YLDs rate (%)	Age–sex-standardized YLDs rate (%)	DALYs rate (%)	Age–sex-standardized DALYs rate (%)
EU-6	− 0.87	− 1.54	0.35	− 0.05	− 0.37	− 0.99
EU-9	− 0.95	− 1.53	0.34	− 0.01	− 0.43	− 0.97
EU-10	− 0.92	− 1.52	0.35	− 0.01	− 0.41	− 0.96
EU-12	− 0.93	− 1.54	0.36	− 0.03	− 0.41	− 0.98
EU-15	− 0.94	− 1.54	0.36	− 0.03	− 0.42	− 0.98
EU-25	− 0.94	− 1.55	0.38	− 0.04	− 0.43	− 1.01
EU-27	− 0.91	− 1.52	0.39	− 0.06	− 0.41	− 1.01
EU-28	− 0.90	− 1.52	0.39	− 0.06	− 0.41	− 1.01

EU-6: Belgium, France, Italy, Luxembourg, the Netherlands and Germany; EU-9:EU-6, Denmark, Ireland and UK; EU-10:EU-9, Greece; EU-12:EU-10, Portugal and Spain; EU-15:EU-12, Austria, Finland and Sweden; EU-25:EU-15, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia; EU-27:EU-25, Bulgaria and Romania; EU-28:EU-27, Croatia

Time trends of EU health status

"Health at a Glance: Europe 2016" reported an increase in EU life expectancy at birth of 3 months per year, on average, possibly due to improved education, socio-economic conditions, lifestyle, more effective public health systems and healthcare achievements (OECD 2016; Mackenbach et al. 2013b). However, the more recent "Health at a Glance: Europe 2018" reported a decrease in life expectancy in 19 EU countries in 2015 related to a bad flu season and an increase in cardiovascular mortality in the winter months, which is reflected in our results (OECD 2018). In fact, this might be one of the reasons for the statistically significant slope change in the 2013 enlargement.

As stated in the "Health at a Glance: Europe 2016", the countries with the sharpest increase in life expectancy since 1990 were Estonia, Czech Republic, Lithuania and Bulgaria, i.e. all Central–Eastern European countries (OECD 2016). Central–Eastern European countries presented such an increase in life expectancy possibly due to cardiovascular mortality reduction, with the contributions of the opening of markets and subsequent access to healthy foods, medicines and improved health care, especially regarding hypertension (European Observatory on Health Systems and Policies 2004; Mackenbach et al. 2015; Zatonski 2007). It is known that a wide gap between Western and Central–Eastern Europe in terms of life expectancy exists (Boncz et al. 2014; European Observatory on Health Systems and Policies 2004; OECD 2016; Santos et al. 2019). In fact, this is reflected in our results, with EU-25, EU-27 and EU-28 having worse life expectancies than the other EU groups.

In terms of healthy life expectancy, the "Health at a Glance: Europe 2016" reported that there were virtually no gains for many EU countries between 2010 and 2014 (OECD 2016), though we found quite a constant increase in this period for different EU groups and an approximately 4.5-year increase throughout all periods. This might occur due to different concepts, methods and data sources for healthy life expectancy estimation. In fact, while Eurostat considers healthy life years as the number of years spent

Table 2 Life expectancy at birth (LE) and healthy life expectancy at birth (HALE) in 1990, years of accession of new countries and 2017, in European Union and by EU group

Life expectancy (years)	1990	1995	2004	2007	2013	2017	1990–2017 ARC (%)
EU-6	76.4	77.5	79.9	80.6	81.6	82.0	0.27
EU-9	76.3	77.3	79.7	80.4	81.4	81.7	0.27
EU-10	76.3	77.3	79.6	80.3	81.4	81.7	0.26
EU-12	**76.3**	77.3	79.7	80.4	81.5	81.9	0.27
EU-15	76.3	**77.3**	79.7	80.4	81.5	81.9	0.27
EU-25	75.4	76.4	**78.9**	79.5	80.8	81.3	0.29
EU-27	75.1	76.0	78.4	**79.2**	80.5	81.0	0.29
EU-28	75.1	75.9	78.4	79.1	**80.5**	**80.9**	0.29
HALE (years)	1990	1995	2004	2007	2013	2017	1990–2017 ARC
EU-6	66.5	67.4	69.3	69.8	70.5	70.8	0.24
EU-9	66.3	67.2	69.0	69.5	70.2	70.4	0.23
EU-10	66.3	67.2	68.9	69.5	70.2	70.4	0.23
EU-12	**66.4**	67.2	69.0	69.6	70.4	70.6	0.24
EU-15	66.4	**67.2**	69.0	69.5	70.3	70.6	0.24
EU-25	65.5	66.3	**68.3**	68.8	69.7	70.0	0.26
EU-27	65.2	66.0	67.9	**68.4**	69.4	69.7	0.26
EU-28	65.1	65.9	67.9	68.4	**69.4**	**69.7**	0.26
Proportion HALE/LE	1990	1995	2004	2007	2013	2017	
EU-6	87.0	87.0	86.7	86.6	86.4	86.3	
EU-9	86.9	86.9	86.6	86.4	86.3	86.2	
EU-10	86.9	86.9	86.6	86.4	86.3	86.2	
EU-12	**87.0**	86.9	86.6	86.5	86.3	86.3	
EU-15	86.9	**86.9**	86.6	86.5	86.3	86.2	
EU-25	86.8	86.8	**86.6**	86.4	86.2	86.1	
EU-27	86.8	86.8	86.6	**86.4**	86.2	86.1	
EU-28	86.8	86.8	86.6	86.4	**86.2**	**86.1**	

Annualized rates of change (ARC) between 1990 and 2017 are also presented for each EU group, as well as proportion of (HALE divided by LE). The corresponding expectancy for the EU group in force of each year is presented in bold

EU-6: Belgium, France, Italy, Luxembourg, the Netherlands and Germany; EU-9:EU-6, Denmark, Ireland and UK; EU-10:EU-9, Greece; EU-12:EU-10, Portugal and Spain; EU-15:EU-12, Austria, Finland and Sweden; EU-25:EU-15, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia; EU-27:EU-25, Bulgaria and Romania; EU-28:EU-27, Croatia

free of long-term activity limitation, i.e. disability-free life expectancy (OECD 2016), the GBD study considers it as the health-adjusted life expectancy (GBD 2017 DALYs and HALE Collaborators).

EU enlargement and impact on health status

The enlargement process, though complex, acts as a development engine for health protection policies (Guimarães and Freire 2007). It is a difficult process that needs to abide by the Copenhagen criteria (i.e. democracy, functioning market economy and the "acquis communautaire" (community acquis)—the EU rule of law). It allows the creation of an extended zone of peace and stability, the boost of economic growth and job creation, the increase in cultural diversity and the strengthening of the EU role in world affairs (European Observatory on Health Systems and Policies 2004). Concerns such as the process of harmonizing European and domestic legislation, the upward pressure on healthcare expenditure and pressure to improve population socio-economic status and health are linked to the EU accession (European Observatory on Health Systems and Policies 2004). On the other hand, the most important benefits might be the improvement in healthcare quality, the increasing focus on public health and the

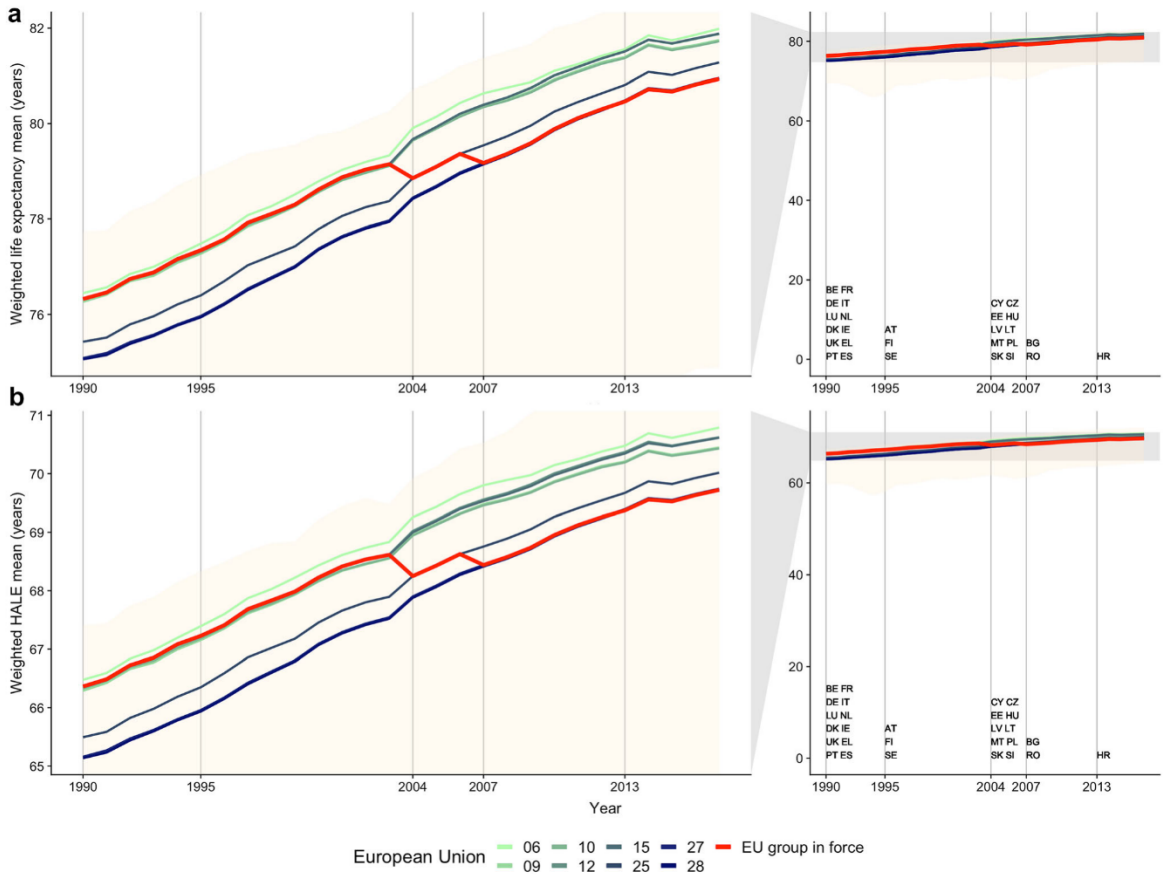


Fig. 3 Life expectancy (LE, in years)—**a** and healthy life expectancy (HALE)—**b** between 1990 and 2017 in European Union, by European Union group. In red are the lines of the EU groups in force in each year presented (color figure online)

strengthening of regulations and guidelines (European Observatory on Health Systems and Policies 2004).

For Romania and Bulgaria that have experienced a population decline, with an impoverished rural population and a large Roma community, their accession was full of opportunities for economic growth and healthcare improvement (McKee et al. 2007). However, different countries and different moments for the EU might mean different impacts or expectations (Avgerinos et al. 2004). In fact, we showed distinct impacts of enlargements, with the 1995 enlargement contrasting with the other studied enlargements. McKee and Nolte (2004) stated that any enlargement effects are likely to be gradual but substantial on the long-term and unpredictable, considering that health systems are influenced by the political and economic frameworks that surround them (Klazinga 2000). We aimed to study the immediate impact of enlargements on the average EU health status.

Other enlargements are also in discussion, namely for countries such as Iceland, Balkan countries or Turkey (Fontaine 2010; Kisa et al. 2007). In fact, population health may be one of the key issues of Turkish accession to the EU due to its considerably different health status (Kisa et al. 2007). Although we have focused on the EU enlargement process (until 2017), Brexit means a contraction of the EU. This will most likely impact health in the EU and in the UK, with expected effects ranging from negative to very negative (Fahy et al. 2017).

EU health policy and future trends

Avgerinos et al. (2004) pointed out the need for avoiding new "dividing lines" with the accession of countries lacking financial resources and with worse health indicators. One of the EU main goals is to reduce inequalities between Member States (e.g. it is the primary source of capital investment in healthcare infrastructure in poorer

Table 3 Coefficients and P-values of slope changes and discontinuity gaps from the discontinuity regression analyses regarding actual European Union health measures (crude and age–sex-standardized mortality, years of life lost (YLL), years lived with disability (YLD), disability-adjusted life years (DALY) rates, life expectancy and healthy life expectancy) for enlargement years

	Crude rate—coefficient (*P* value)				Age–sex-standardized rate—coefficient (*P* value)			
	1995	2004	2007	2013	1995	2004	2007	2013
Mortality								
Slope change	− 1.702	0.870	**5.399**	**7.886**	0.913	− 1.839	9.036	**9.209**
	(*0.312*)	(*0.804*)	**(0.007)**	**(0.007)**	(*0.736*)	(*0.756*)	(*0.169*)	**(0.005)**
Discontinuity gap	5.682	− 1.030	**25.278**	2.842	0.482	**49.497**	**53.810**	5.122
	(*0.342*)	(*0.856*)	**(< 0.001)**	(*0.670*)	(*0.960*)	**(< 0.001)**	**(0.008)**	(*0.481*)
YLL								
Slope change	− 13.572	35.690	35.440	**188.060**	− 0.771	12.390	82.420	**223.560**
	(*0.694*)	(*0.634*)	(*0.598*)	**(< 0.001)**	(*0.986*)	(*0.896*)	(*0.478*)	**(< 0.001)**
Discontinuity gap	− 3.522	**780.290**	**783.270**	60.550	− 50.998	**1294.240**	**1023.420**	83.030
	(*0.977*)	**(< 0.001)**	**(0.003)**	(*0.529*)	(*0.740*)	**(< 0.001)**	**(0.009)**	(*0.423*)
YLD								
Slope change	**20.294**	**13.303**	− 6.717	**− 7.437**	**23.722**	6.040	**5.320**	**− 7.054**
	(< 0.001)	**(0.077)**	(*0.650*)	**(< 0.001)**	**(< 0.001)**	(*0.489*)	**(0.038)**	**(< 0.001)**
Discontinuity gap	**26.169**	**48.211**	− 1.415	9.061	15.516	**188.045**	**53.147**	4.294
	(0.029)	**(0.002)**	(*0.966*)	(*0.058*)	(*0.251*)	**(< 0.001)**	**(< 0.001)**	(*0.136*)
DALY								
Slope change	6.722	49.000	28.720	**180.620**	22.950	18.430	87.740	**216.51**
	(*0.853*)	(*0.544*)	(*0.599*)	**(< 0.001)**	(*0.620*)	(*0.856*)	(*0.446*)	**(< 0.001)**
Discontinuity gap	22.647	**828.500**	**781.860**	69.610	− 35.480	**1482.290**	**1076.570**	87.330
	(*0.861*)	**(< 0.001)**	**(0.001)**	(*0.473*)	(*0.828*)	**(< 0.001)**	**(0.007)**	(*0.403*)
Life expectancy								
Slope change	0.024	0.021	− 0.053	**− 0.129**				
	(*0.282*)	(*0.649*)	(*0.451*)	**(< 0.001)**				
Discontinuity gap	0.049	**− 0.642**	**− 0.569**	− 0.041				
	(*0.527*)	**(< 0.001)**	**(0.012)**	(*0.539*)				
HALE								
Slope change	− 0.0004	0.008	− 0.043	**− 0.091**				
	(*0.982*)	(*0.837*)	(*0.409*)	**(< 0.001)**				
Discontinuity gap	0.030	**− 0.643**	**− 0.465**	− 0.033				
	(*0.643*)	**(< 0.001)**	**(0.007)**	(*0.497*)				

Statistically significant values are presented in bold. All *p* values are presented in italic

Member States) and its support might contribute to health improvements in new Member States, e.g. by means of institutional reforms (Fahy et al. 2017; Fontaine 2010; Greer et al. 2013; Mackenbach et al. 2013a; McKee 2005).

The EU is also facing several challenges such as an ageing population, migration, unequal distribution of health professionals, new technologies, increasing cost of health care and rise in non-communicable diseases and multi-morbidity (Azzopardi-Muscat et al. 2017; Franklin 2017; OECD 2016, 2018; Rechel et al. 2013). Thus, it is crucial to improve the performance and sustainability of the EU health systems (Franklin 2017). Despite its importance, one of the main challenges regarding EU support in health decision-making and policy actions in Member States is the fact that this is a slow and difficult process, one that requires consensus amongst all Member States, with the EU retaining a more regulatory, supportive and promoting role (Cucic 2000; Guimarães and Freire 2007; Greer 2014).

In fact, health policy is so high up in Member States' agendas that most governments do not want EU interference (Duncan 2002), depending mainly on themselves to implement policies (Franklin 2017; Guimarães and Freire 2007). Another challenge is the domestic politics of Member States: health policy usually requires a high level of compromise between political parties, with different agendas and goals (Duncan 2002).

Several scenarios for EU health systems have already been discussed, such as harmonization, deregulation or synchronization (Cucic 2000), but there are drawbacks and restrictions that have so far prevented their implementation. EU law can and does have a direct and indirect impact on health service provision, despite national efforts to retain healthcare control (Greer et al. 2013; Greer 2014; Duncan 2002). In fact, a more unified approach to external quality assurance of healthcare systems can be foreseen, given their systems convergence (Avgerinos et al. 2004; Klazinga 2000).

Improvement in the health status of a population will also have implications on countries' economies. In fact, non-communicable diseases alone result in the loss of 3.4 millions of potentially productive life years with a € 115 billion impact on the EU economy, with important economic losses of approximately 2% of gross domestic product (OECD 2016; Vandenberghe and Albrecht 2019). Health can contribute to economic performance in several ways, i.e. labour productivity, labour supply, education and savings/investment (Suhrcke et al. 2006). Moreover, health is a good investment not only as it is a capital good but also a consumption good, being an important component of global welfare and individual utility (Suhrcke et al. 2006; Mackenbach et al. 2011). In fact, it should not be a choice between health and economy, but rather choosing the way that can lead to a "mutually reinforced upward spiral" (McKee 2005). Further studies could also address economic factors and their relationship with these outcomes.

Limitations

Other health status indicators such as infant and amenable mortality or health systems outputs (i.e. volume of healthcare services) indicators could have been studied, but we decided not to include them (Peric et al. 2018). Also, and undoubtedly, the measurement of health depends on its definition, which is still in debate (Huber et al. 2011; Saracci 1997; Van-Spijk 2015; WHO 1992). Another limitation of this study is that the same disability weights are applied to all EU-28 countries. It also relies on the quality of data from death registries, which are compulsory in all EU countries (OECD 2018), and other databases collected in the EU. However, the GBD has collated a unique database of summary measures of health, calculating estimates with scientifically sound methods and several (and different type of) databases. Regarding the interrupted time-series analysis, we applied this method with few data points which might decrease its power (Bernal et al. 2017). We also did not adjust for other factors, such as the EU economic crisis; thus, we measured the crude differences in the EU state of health before and after enlargements.

Conclusion

Although the EU state of health improved between 1990 and 2017, some enlargements clearly decreased its average. In fact, 2004 and 2007 EU enlargements stand out, while the 1995 enlargement had the opposite effect. Despite this decline in the average health status associated with enlargements, inhabitants from the EU, regardless of the EU group considered, are dying less when adjusting for both age and sex, dying later and living less years with disability, i.e. YLD. This article also stresses the importance of comparing the comparable or, at least, stating which EU group is compared, as the EU founders state of health differs substantially from the EU-28 group.

Although the question raised by Etches et al. (2006), i.e. "Has the use of population health indicators improved the health of populations?", might remain, we are confident that this is in fact the case, possibly as the result of health indicators-based policies. Also, as pointed out by McKee and Nolte (2004), "enlargement brings challenges, but also opportunities" and independently from EU enlargements or contractions, as stated by Greer et al. (2013), "every stage offers opportunities to make the health of Europeans worse, or better".

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Compliance with ethical standards

Conflict of interest The author declares that they have no conflict of interest.

Ethical statement As we used secondary publicly available data sets, with complete anonymized data (gathered estimates), there was no need for an ethical statement.

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PAPER 2

The state of health in the European Union (EU-28) in 2017: An analysis of the burden of diseases and injuries.

Santos JV, Souza J, Valente J, Alonso V, Ramalho A, Viana J, Ricciardi W, Freitas A.

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The state of health in the European Union (EU-28) in 2017: an analysis of the burden of diseases and injuries

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Background: The Global Burden of Disease study has generated a wealth of data on death and disability in Europe. At a time of change for the European Union and European Region of WHO, with a new Health Commissioner and Regional Director, respectively, a review of health trends can contribute to identify outstanding needs and gaps. This paper reports a summary of the burden of disease in the European Union (EU) in 2017 (compared with 2007). **Methods:** For the whole EU and each country, mortality by causes of death, disability-adjusted life years (DALYs) and life expectancies are reported. **Results:** In 2017, the age-standardized mortality and DALY rates were of 452.6 and 19 663.3 per 100 000 inhabitants, respectively. The diseases contributing most to mortality were ischaemic heart disease (IHD), dementias and stroke, while low back pain and IHD accounted for the highest burden of DALYs. **Conclusions:** Overall, there was an improvement in the state of health in the EU but substantial differences between countries remain. Cardiovascular diseases still represent the major burden, although there have been substantial improvements. There are many opportunities for mutual learning among otherwise similar countries with different patterns of disease.

Introduction

Ever since the Treaty of Rome, successive European Economic Community (EEC) and European Union (EU) treaties have committed the now 28 Member States to an 'ever closer union' between the peoples of Europe. This aspiration has been pursued through both institutional developments, such as an elected Parliament and the single market, and policies to benefit all of the EU's 512 million citizens. Much has been achieved, especially in the poorer parts of Europe that have benefited from access to markets and structural funds, but differences remain, especially in health outcomes.[1–3] Formally, Member States retain competence for many policies that influence population health, most notably the organization of health systems.[4,5] However, better understanding of the contribution of health to economic growth and social cohesion has placed health outcomes firmly on the European agenda.[6] Even in the best-performing countries, there is a recognition that improved disease prevention is essential for ensuring sustainability of health systems.[3,7]

The Global Burden of Disease (GBD) Study has collated a unique database of summary measures of health at national and, in an increasing number of countries, sub-national level worldwide, covering more than 350 causes of disease and injury and 84 risk factors, producing estimates of mortality. Summary measures include years of life lost due to premature mortality (YLLs), years lived with disability (YLDs), disability-adjusted life years (DALYs), healthy life expectancy (HALE), life expectancy (LE), morbidity (both prevalence and incidence) and risk factor exposure.[7–10]

While the main GBD papers report the global picture, there is an increasing number of regional and national analyses, some in Europe,[11] making it possible to explore in more detail variations between countries that share many common characteristics. So far, however, to our knowledge, none have looked at the EU as a whole.

Here, we address this gap, using summary estimates from the GBD 2017 Study to describe the state of health in the EU-28 in 2017 and how it has changed since 2007. This is especially timely as a new European Commission takes office.

Methods

We examined estimates from the GBD 2017 study. The methodology used to generate GBD estimates has previously been published.[7–10] It combines data from multiple sources, applying a variety of models where data are missing or of poor quality, such as the Cause of Death Ensemble model (CODEm), allowing cross-country comparisons. We took 2017, the most recent year for which estimates are available, as our reference, measuring progress from 2007 and extracted estimates of each summary measure (described below), as well as the corresponding 95% uncertainty intervals, which are calculated by the GBD study using a Bayesian approach and 1000 draws for each metric.[7–10] National estimates and uncertainty intervals were compared with the same values for the EU as a whole. The change between 2007 and 2017 was expressed as a percentage of the 2007 value. More detailed information on data sources can be found in the GBD 2017 papers.[7–10]

Mortality, life expectancy and YLLs

Mortality data used in the GBD were obtained from national reports, which in Europe are primarily national statistical offices. Between 1950 and 2017, a median of 67 data sources (min = 46, max = 71) contributed to estimates of mortality in the 28 EU countries.[8] Each death is attributed to a single cause—the precursor of a

series of events leading to death, using rules applied by the International Classification of Diseases. Causes are organized in four levels, with increasing disaggregation.[9] YLLs—a measure of premature mortality—are computed as the sum of each death multiplied by the standard LE (derived from the lowest observed death rate for any age group in countries of more than 5 million population) at age of death.[9]

Disease and injury incidence, prevalence and YLDs

Prevalence and incidence were estimated from data on disease occurrence, natural history and severity taken from multiple sources (e.g. hospital inpatient/outpatient, disease registries, cohort studies, national/community surveys or epidemiological surveillance databases) satisfying minimum quality standards.[7] For each disease, all data sources are combined and the Bayesian meta-regression tool DisMod-MR 2.1 is used to generate pooled estimates.[7,12] Causes and their sequelae are also organized in a four-level hierarchy. Disability weights were constructed using population surveys and methods developed by Salomon and colleagues[13,14] are used to produce YLDs.[7]

DALYs and HALEs

DALYs are computed by summing YLLs and YLDs for each cause, age and sex.[10] HALE, the number of years expected to be lived in good health, is calculated from the number of YLDs using multiple-decrement life tables with Sullivan's method.[15]

The GBD study adheres to the Guidelines for Accurate and Transparent Health Estimates Reporting (GATHER) standards developed by WHO and others.[16] Microsoft Excel v16.0 was used for all analyses.

Results

In 2017, the EU had a total of 5 201 657 deaths [95%UI (uncertainty interval) 5 112 292–5 290 590], a crude mortality rate of 1015.2 (95%UI 997.8–1032.6), as well as 149 279 937 DALYs (95%UI 131 602 713–169 631 298) and a crude DALY rate of 29 135.3 DALYs per 100 000 inhabitants (95%UI 25 685.2–33 107.3). There was an age-standardized mortality rate of 452.6 (95%UI 444.6–460.2) and an age-standardized DALY rate of 19 663.3 (95%UI 17 003.9–22 728.3).

Figure 1 displays the 25 leading causes of age-standardized mortality (A) and DALYs (B) in 2007 and 2017 in the EU-28. In 2017, the five leading causes of mortality were ischaemic heart disease (IHD), stroke, Alzheimer's disease and other dementias, cancer of the trachea, bronchus and lung, and chronic obstructive pulmonary disease. Since 2007 the age-standardized mortality rate has fallen for all of the top 25 conditions, with the exception of pancreatic cancer, which showed a small increase. There were particularly large declines for IHD and stroke.

As noted above, DALYs combine mortality and disability, and in 2017 the ranking was headed by low back pain, followed by IHD, headache disorders, stroke and neonatal disorders. These were the same as in 2007, but with low back pain overtaking IHD and headache disorders overtaking stroke. Road injuries, which had been in 8th position in 2007, fell to 13th position. Among injuries, self-harm and falls still represent the highest burden in terms of mortality and DALY rates, though have decreased between 2007 and 2017. Again, the age-standardized rates fell for almost all conditions, in some cases such as IHD, substantially.

Figures 2 and 3 show the age-standardized mortality and DALY rates, respectively, for the 30-leading level three causes and for all causes both in the EU-28 and in each country, in 2017. Cells shaded green (or lighter grey) represent values where the upper limit of the 95%UI is below the lower 95%UI for the EU as a whole. Red (or darker) cells represent values where the lower 95%UI is above the higher 95%UI for the EU. Yellow (or medium grey) cells are all other values.

Turning first to mortality (figure 2), rates of IHD and stroke are highest in the post-2004 Member States in Central and Eastern Europe and lowest in Western Europe. The previous gap between northern European and Mediterranean countries has narrowed considerably, although it still exists. Respiratory cancer deaths reflect historical smoking rates and remain high in countries where smoking was especially prevalent, such as Denmark and the UK, while Hungary has long been recognized as an outlier with a very high rate. As would be expected given their shared aetiology, the pattern with chronic obstructive pulmonary disease is similar. The high rates of cirrhosis in the Baltic States and countries of South-East Europe reflect known patterns of alcohol consumption. The picture with regard to other conditions is complex but, especially where apparently similar countries diverge, as with road injuries in Belgium and the Netherlands, the scope for mutual learning is apparent.

Turning next to DALYs (figure 3), the picture is much more homogeneous for conditions where the disease burden is driven largely by disability, such as low back pain. Where it is driven substantially by mortality, as with IHD, the picture inevitably resembles that in figure 2.

Figures 2 and 3 also report all-cause mortality and DALYs, with four countries, Lithuania, Latvia, Romania and Bulgaria, significantly under-performing the others, while for mortality, Italy, Spain and France stand out as best performers.

From 2007 to 2017, the LE in the EU increased from 79.0 (95%UI 79.0–79.0) to 80.8 years (95%UI 80.6–81.0), while HALE increased from 68.3 (95%UI 65.3–70.9) to 69.6 years (95%UI 66.5–72.4). Figure 4 shows the changes in both expectancies by country. In both cases, the largest absolute growths are in the countries of Central and Eastern Europe, where the initial expectancies were the lowest.

The same occurred with age-standardized mortality and DALY rates (Supplementary figure S4), with a decrease in all countries. In the EU, all-causes age-standardized mortality rate fell by 14%, while age-standardized DALY rate fell by 9% (Supplementary table S1). From 2007 to 2017, three (level three) causes age-standardized mortality increased more than 10%, i.e. acute glomerulonephritis (27%), eating disorders (18%) and bacterial skin diseases (15%). More detailed inspection of the age-standardized DALY rates shows that acne vulgaris was the only level three cause increasing by more than 10%, i.e. 13%. Conversely, some causes such as acute hepatitis, tuberculosis or road injuries showed important declines.

Discussion

We have described the state of health of the EU-28 in 2017, comparing countries and assessing changes since 2007. We show that the age-standardized mortality and DALY rates have improved in all EU-28 countries.[1] These long-term improvements have been attributed to improved education, socio-economic conditions, stronger public health systems and advances in healthcare.[17] There is, however, no room for complacency. Other research has shown that, several countries in Western Europe have experienced stagnating LE after about 2010, coinciding with the imposition of austerity measures in the aftermath of the financial crisis.[18] Some experienced LE declines around 2015,[19] which might be also related with flu and excess winter mortality that year.[11]

Over the past decade, some Central and Eastern European countries have seen especially large gains in LE, with Estonia, Lithuania and Latvia in the forefront, a process that has narrowed the East–West EU gap,[1,3,4] even though there is much still to be done.

As expected, non-communicable diseases dominated the burden of disease, with cardiovascular diseases still the leading cause of death. However, there have been some remarkable improvements

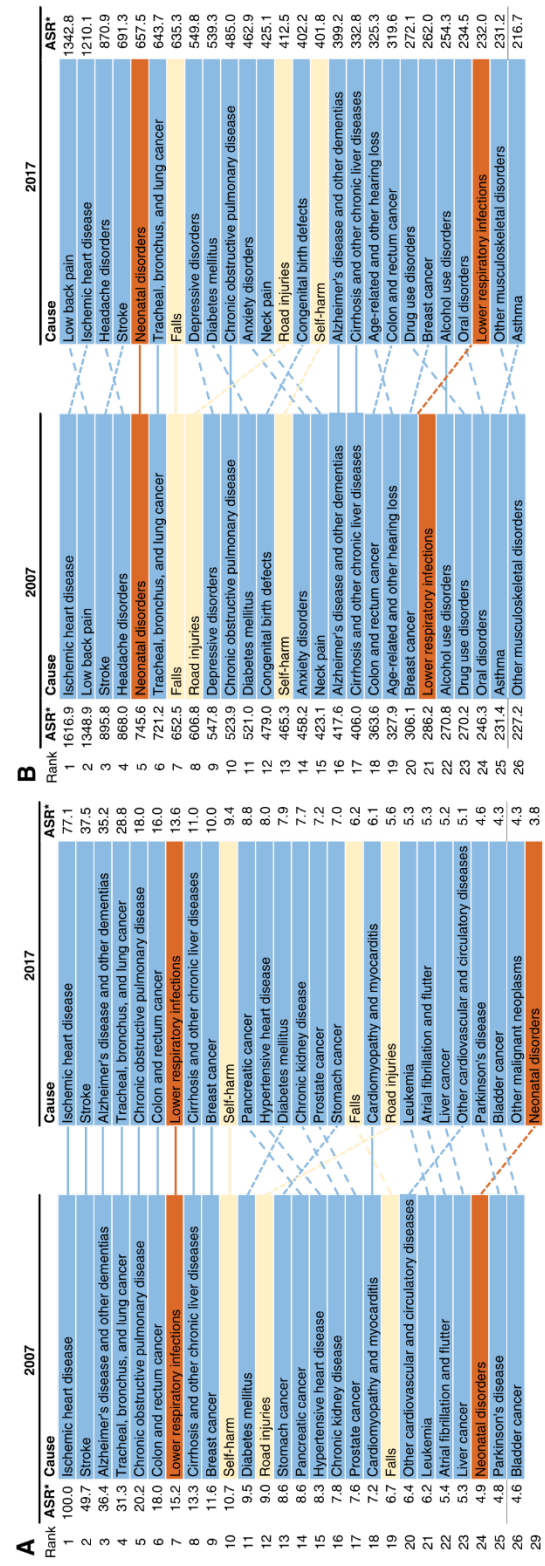


Figure 1 Ranks for top 25 causes (level three) of age-standardized rate of (A) mortality and (B) disability-adjusted life years in the European Union (28 countries), 2007–17

	All causes	Ischemic heart disease	Stroke	Alzheimer's disease and other dementias	Tracheal, bronchus, and lung cancer	Chronic obstructive pulmonary disease	Colon and rectum cancer	Lower respiratory infections	Cirrhosis and other chronic liver diseases	Breast cancer	Self-harm	Pancreatic cancer	Hypertensive heart disease	Diabetes mellitus	Chronic kidney disease	Prostate cancer	Stomach cancer	Falls	Cardiomyopathy and myocarditis	Road injuries	Leukemia	Atrial fibrillation and flutter	Liver cancer	Other cardiovascular and circulatory diseases	Parkinson's disease	Bladder cancer	Other malignant neoplasms	Brain and nervous system cancer	Non-rheumatic valvular heart disease	Neonatal disorders	Non-Hodgkin lymphoma
EU-28	453	77	38	35	29	18	16	14	11	10	9	9	8	8	8	7	7	6	6	6	5	5	5	5	5	4	4	4	4	4	4
Austria	419	82	23	32	24	15	13	5	12	10	11	10	11	10	12	7	6	7	8	4	5	6	5	3	5	3	4	4	5	3	4
Belgium	432	56	29	34	32	22	14	20	10	11	14	8	2	5	7	7	5	8	4	7	6	5	4	6	4	4	4	4	5	3	4
Bulgaria	741	220	136	38	27	20	19	13	16	10	9	9	36	10	10	6	9	4	5	9	4	5	6	16	5	4	4	6	1	6	2
Croatia	581	142	72	37	31	19	24	6	14	11	11	8	15	11	9	8	9	13	9	7	5	3	6	3	5	5	4	6	3	4	4
Cyprus	413	79	31	25	22	20	11	9	7	9	5	7	6	20	13	9	6	5	3	10	6	5	4	3	4	4	4	4	5	3	4
Czech Republic	536	147	48	35	27	16	21	16	12	9	11	11	6	14	6	7	6	7	5	7	5	4	4	8	4	4	4	4	3	2	3
Denmark	462	55	32	33	35	32	19	18	9	12	9	10	2	11	8	11	5	6	2	4	7	7	4	3	4	5	4	5	5	4	4
Estonia	561	141	37	34	25	8	15	9	14	9	13	9	52	5	9	8	11	5	10	6	5	4	4	4	4	3	5	4	2	2	3
Finland	432	89	33	56	20	10	11	5	13	8	13	10	7	3	4	8	5	10	5	4	4	5	4	3	5	2	4	4	5	2	5
France	373	38	21	34	29	9	14	11	9	10	12	9	3	6	5	7	5	8	3	5	6	5	7	6	4	4	5	4	3	4	4
Germany	460	85	29	33	28	19	15	11	12	11	10	10	10	9	11	7	7	7	6	5	6	7	4	6	5	4	5	4	6	4	4
Greece	451	92	55	35	33	18	12	14	6	10	4	8	6	4	12	7	7	3	4	10	6	5	6	4	5	5	3	6	3	4	2
Hungary	630	165	57	33	45	25	26	6	19	11	14	10	22	10	8	6	8	9	11	6	5	4	5	4	4	5	4	4	5	4	3
Ireland	419	71	28	34	27	24	16	18	6	11	8	8	2	6	8	9	6	4	4	3	6	6	4	3	4	3	4	4	3	3	4
Italy	368	51	30	34	24	13	13	7	8	9	5	8	11	10	7	5	8	4	4	6	5	5	7	2	4	4	4	4	3	3	4
Latvia	696	198	100	36	24	8	17	11	14	10	17	10	14	8	6	8	12	7	25	9	5	4	4	3	4	5	5	5	1	4	3
Lithuania	704	233	75	28	25	11	16	14	22	10	28	9	7	4	4	8	13	9	11	9	6	4	4	6	4	4	5	5	1	3	3
Luxembourg	431	61	30	38	30	19	16	13	11	11	9	10	4	6	8	7	5	8	4	5	6	7	5	10	6	4	4	5	5	2	4
Malta	452	104	36	35	22	14	14	19	5	12	5	9	5	13	10	5	6	6	5	3	5	5	2	4	6	4	4	4	3	6	4
Netherlands	436	50	29	38	36	25	19	16	5	12	9	10	2	8	7	9	7	9	3	4	6	5	3	4	5	5	5	4	5	4	4
Poland	567	131	53	37	39	15	22	16	13	9	14	9	6	9	5	7	9	8	18	9	5	5	3	4	5	5	5	5	2	4	3
Portugal	434	48	54	34	20	19	18	25	10	9	8	7	5	13	11	8	12	3	3	7	5	4	5	4	4	4	4	5	3	3	4
Romania	718	174	125	37	30	17	18	22	30	10	9	8	30	6	8	6	9	5	23	9	4	4	9	7	5	4	6	5	2	6	2
Slovakia	617	193	59	36	25	11	24	20	18	10	9	10	11	8	8	7	8	9	5	7	5	5	5	8	4	4	5	4	2	5	4
Slovenia	446	70	39	30	27	11	19	12	14	9	14	9	12	6	4	9	8	12	13	6	5	5	5	4	4	4	4	4	6	2	4
Spain	370	45	25	36	25	22	16	10	9	7	6	7	4	7	8	6	7	4	5	4	5	5	6	4	5	5	4	4	4	3	3
Sweden	396	72	30	34	19	15	14	11	6	9	11	8	5	7	6	10	4	7	3	3	4	9	3	4	5	4	4	4	4	2	4
United Kingdom	450	61	31	39	30	27	15	24	9	11	7	8	3	4	5	9	6	5	3	3	5	6	4	5	5	4	4	4	4	5	4

Figure 2 Age-standardized rates of mortality (per 100 000 inhabitants) by the 30-leading level three causes of death for the European Union for each country in 2017. Cells in green (or lighter grey) have a rate statistically significant lower than EU-28, red (or darker) higher and yellow (or medium grey) without statistically significant differences

	All causes	Low back pain	Ischemic heart disease	Headache disorders	Stroke	Neonatal disorders	Tracheal, bronchus, and lung cancer	Falls	Depressive disorders	Diabetes mellitus	Chronic obstructive pulmonary disease	Anxiety disorders	Neck pain	Road injuries	Congenital birth defects	Self-harm	Alzheimer's disease and other dementias	Cirrhosis and other chronic liver diseases	Age-related and other hearing loss	Colon and rectum cancer	Drug use disorders	Breast cancer	Alcohol use disorders	Oral disorders	Lower respiratory infections	Other musculoskeletal disorders	Asthma	Dermatitis	Other cardiovascular and circulatory diseases	Blindness and vision impairment	Pancreatic cancer
EU-28	19663	1343	1210	871	691	658	644	635	550	539	485	463	425	413	402	402	399	333	325	320	272	262	254	234	232	231	217	214	184	183	179
Austria	18621	1191	1134	921	445	752	549	550	463	542	460	470	416	347	382	459	367	346	288	241	293	237	267	261	73	265	199	160	136	175	197
Belgium	19465	1505	860	1079	526	467	711	629	630	577	608	454	422	446	339	613	381	281	302	275	225	282	231	289	261	252	180	202	239	180	162
Bulgaria	26542	1202	3719	731	2472	974	718	1074	389	649	637	325	297	646	633	377	442	546	406	431	170	290	213	255	454	17	133	115	527	285	201
Croatia	21599	1374	2018	732	1275	902	736	951	438	780	540	309	297	604	472	428	418	410	401	468	204	261	296	286	117	45	151	122	128	283	174
Cyprus	18287	1405	1376	909	534	680	468	488	482	756	461	472	481	632	284	228	337	168	300	227	149	269	120	235	134	281	216	161	116	170	135
Czech Republic	21382	1336	2088	727	905	531	598	1318	416	812	550	307	295	571	317	463	403	393	393	409	192	208	303	259	291	13	131	137	315	250	224
Denmark	19431	1582	785	762	562	552	719	483	470	790	685	469	527	318	391	359	372	291	261	362	334	285	420	293	216	293	219	286	134	105	190
Estonia	23218	1193	2024	845	856	749	555	907	579	653	344	261	298	448	349	555	401	523	406	305	649	230	904	245	284	32	116	192	109	132	190
Finland	19522	1196	1286	898	607	754	402	667	731	619	344	330	570	338	341	612	546	416	267	216	417	219	480	232	72	239	233	292	113	139	190
France	17833	1281	598	785	420	544	707	554	664	376	232	576	382	420	360	515	384	269	307	265	255	267	254	211	148	282	245	264	235	111	173
Germany	19580	1551	1242	779	543	653	638	518	569	470	563	565	478	351	376	414	385	354	294	306	242	286	315	248	183	267	178	193	206	174	198
Greece	19397	1288	1585	1057	851	628	738	444	644	508	539	511	464	653	464	155	397	173	320	231	204	267	112	258	224	262	196	141	134	115	171
Hungary	24252	1475	2621	732	1200	863	1116	1185	434	722	809	309	296	484	504	556	390	603	397	545	156	275	306	241	149	33	132	162	158	273	227
Ireland	18623	1184	1050	907	481	501	542	481	643	629	571	511	479	288	457	410	384	181	284	303	370	278	255	270	197	292	297	248	142	173	159
Italy	17022	1284	749	1110	458	516	487	422	528	601	304	499	481	396	344	201	396	221	328	265	258	245	55	182	110	327	138	200	107	200	165
Latvia	27057	1354	3187	848	1868	847	577	981	515	688	348	261	297	613	429	737	415	509	407	338	341	275	821	239	365	34	161	140	93	303	207
Lithuania	27525	1337	3513	855	1527	865	589	1098	643	559	401	261	297	613	521	1229	357	805	405	334	330	268	778	239	435	30	135	88	194	276	191
Luxembourg	19136	1373	867	1015	510	545	638	552	530	675	501	467	475	409	248	356	411	317	273	299	310	275	225	254	177	253	280	272	345	174	187
Malta	19286	1407	1552	899	597	743	465	578	486	913	384	468	477	286	627	201	392	163	299	279	289	313	124	226	274	266	229	171	132	174	184
Netherlands	18716	1483	741	915	520	643	757	445	587	612	589	579	508	272	406	397	413	138	283	365	187	314	127	271	201	314	265	259	139	98	197
Poland	23040	1284	2048	732	1093	911	890	1239	335	636	526	309	296	654	505	628	416	450	404	434	165	244	509	281	332	19	188	157	188	284	191
Portugal	18936	1318	730	910	824	486	465	365	662	910	428	474	481	411	313	284	383	310	306	359	160	234	172	234	344	305	321	187	168	180	136
Romania	26808	1346	2733	729	2211	997	760	1155	370	553	575	293	296	655	575	393	425	907	404	390	144	261	238	261	869	15	175	132	194	285	194
Slovakia	23466	1493	2754	731	1189	804	585	1277	365	589	427	309	296	553	544	403	405	604	395	501	145	258	356	237	430	18	121	137	308	273	204
Slovenia	19703	1417	1032	725	710	546	627	1461	450	555	393	307	295	555	366	582	352	437	382	368	250	220	376	302	158	21	171	122	135	259	185
Spain	17003	1089	731	1055	464	526	568	440	538	471	425	464	425	334	332	229	412	243	318	319	250	197	101	201	148	277	200	150	135	182	146
Sweden	18002	1256	1033	968	518	477	373	589	707	564	471	467	397	272	384	492	365	160	250	280	321	239	220	246	146	242	321	365	141	46	163
United Kingdom	20121	1396	1022	847	548	747	599	497	624	458	698	406	496	277	443	350	419	278	310	298	526	298	285	234	321	300	353	313	190	176	163

Figure 3 Age-standardized rates of DALYs (per 100 000 inhabitants) by the 30-leading level three causes for the European Union for each country in 2017. Cells in green (or lighter grey) have a rate statistically significant lower than EU-28, red (or darker) higher and yellow (or medium grey) without statistically significant differences

in IHD and stroke, as noted in previous analyses.[20] Research on trends prior to the period studied here points to reductions in some risk factors, especially smoking, although counteracted by rising obesity, coupled with improved primary and secondary prevention and treatment.[21] More generally, there is growing evidence of the importance of effective healthcare in improving health.[22] However, there is still an East–West EU gap, as previously mentioned.[23] One major contributor, that should be easily preventable in the short term, is road injuries, reflecting multi-faceted policies adopted in many Western countries over recent decades[24] although there is still a great deal that can be done.[25]

Limitations

This study has several limitations, many intrinsic to the methods used in the GBD 2017 study[7–10] and the use of common disability weights in all EU-28 countries.[13] It also relies on the data quality and availability of death registries, compulsory in all the EU countries,[1]

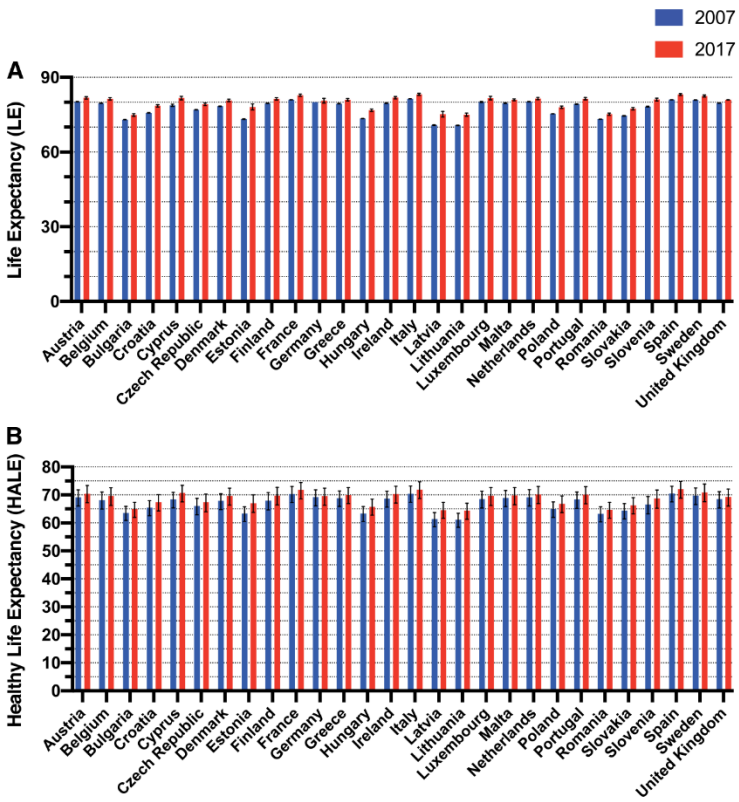


Figure 4 Life expectancy (A) and healthy life expectancy (B), in years, by country in the European Union (28 countries) in 2007 and 2017

and other information available in the EU. The GBD addresses data quality by redistributing deaths from what are terms 'garbage codes' but this has inevitable limitations.

Conclusions

Although health in the EU-28 has been improving, large differences between countries persist. Health outcomes remain much better in Western Europe (e.g. Spain, Italy or France) than in South-Eastern Europe or the Baltic states (e.g. Bulgaria, Romania, Latvia or Lithuania). Non-communicable diseases, particularly cardiovascular disease, continue to dominate. With the ageing of the EU-28 population, the absolute number of deaths or DALYs has been increasing, though all-cause age-standardized rates have fallen. This brief summary can only set the scene for more detailed analyses in and within each country. However, especially in relation to mortality, the degree of variation revealed shows that there is much to be done, with the pattern of disease burden providing a pointer to what might be taken into account by the new health leaders of the European Commission and WHO EURO.

Supplementary data

Supplementary data are available at *EURPUB* online.

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Conflicts of interest: None declared.

Key points

- In a systematic and structured approach, as part of the Global Burden of Disease 2017 study, the EU state of health and burden of diseases for 2017 was presented.
- There was an improvement in the state of health in the EU but substantial differences between countries remain, e.g. East–West EU gap.
- Cardiovascular diseases still represent the major burden, although there have been substantial improvements.
- There are many opportunities for mutual learning among otherwise similar countries with different patterns of disease.

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PAPER 3

Risk factors and their contribution to population health in the European Union (EU-28) countries in 2007 and 2017.

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Risk factors and their contribution to population health in the European Union (EU-28) countries in 2007 and 2017

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Background: The Global Burden of Disease (GBD) study has generated a wealth of data on death and disability outcomes in Europe. It is important to identify the disease burden that is attributable to risk factors and, therefore, amenable to interventions. This paper reports the burden attributable to risk factors, in deaths and disability-adjusted life years (DALYs), in the 28 European Union (EU) countries, comparing exposure to risks between them, from 2007 to 2017. **Methods:** Retrospective descriptive study, using secondary data from the GBD 2017 Results Tool. For the EU-28 and each country, attributable (all-cause) age-standardized death and DALY rates, and summary exposure values are reported. **Results:** In 2017, behavioural and metabolic risk factors showed a higher attributable burden compared with environmental risks, with tobacco, dietary risks and high systolic blood pressure standing out. While tobacco and air quality improved significantly between 2007 and 2017 in both exposure and attributable burden, others such as childhood maltreatment, drug use or alcohol use did not. Despite significant heterogeneity between EU countries, the EU-28 burden attributable to risk factors decreased in this period. **Conclusion:** Accompanying the improvement of population health in the EU-28, a comparable trend is visible for attributable burden due to risk factors. Besides opportunities for mutual learning across countries with different disease/risk factors patterns, good practices (i.e. tobacco control in Sweden, air pollution mitigation in Finland) might be followed. On the opposite side, some concerning cases must be highlighted (i.e. tobacco in Bulgaria, Latvia and Estonia or drug use in Czech Republic).

Introduction

The Global Burden of Disease (GBD) study is considered a powerful tool that allows the synthetization of large sets of data into comprehensive, comparable and internally consistent estimates of global population health. The GBD 2017 study provides population health measures [e.g. mortality, incidence, prevalence, years lived with disability, years of life lost due to premature death, disability-adjusted life years (DALY)] for 354 diseases and injuries in 195 countries and territories.[1] Global results showed important increases in the burden of non-communicable diseases (NCDs) between 2007 and 2017.[2,3] In the European Union (EU-28), a general decrease of the burden of disease was observed, with NCDs representing the leading causes of death and DALYs.[4]

Understanding which injuries and diseases drive the burden of disease is essential to identify potential areas for health improvements. However, to implement public health measures, it is important to pin down which shares of burden can be attributed to risk factors and are, therefore, amenable to public health interventions.[1] For instance, tackling dietary risks, high blood pressure and tobacco consumption can help to reduce health loss due to cardiovascular diseases.[5] In the GBD 2017 study, 84 behavioural, environmental and occupational, and metabolic risk factors were included using the comparative risk assessment (CRA) framework with exposures as input, allowing to calculate the population attributable fractions (PAF) and attributable burden of risk factors by age, sex and geographic locations.[1] This analysis provides insights into the trends of risk exposure and the association between risk factors and health outcomes. Globally, in 2017, 61% of deaths and 48% of DALYs were attributable to risk factors.[1]

While the GBD study provides global, regional, national and subnational portraits of population health, many burden of disease studies carried out in Europe focus on a limited number of countries or a subset of diseases/risk factors.[6] There are published reports on risk factors related burden in the EU-28, such as 'Health at a Glance', by the Organization for Economic Cooperation and Development and the European Commission.[7] However, they lack a comprehensive and systematic approach for all risk factors, focusing only on specific risk factors and age groups.[7] Thus, using GBD 2017 to study the EU and its countries allows a harmonized and comparable approach, which can highlight EU-specific results. Moreover, this allows for benchmarking of EU countries and

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identification of risk factors' patterns, which may lead to opportunities for mutual learning and collaborations between countries, especially regarding successful national policies in managing risk factors with a substantial impact on population health.

The aims of this paper were to assess the disease burden, estimated in deaths and DALYs, attributable to risk factors in the 28 EU countries and compare exposure to risks between these countries and over time, from 2007 to 2017.

Methods

We used estimates from the GBD 2017 study, which combined data from multiple sources, including mortality, morbidity and risk exposure.[1–3,8,9] Estimates of age-standardized death and DALY rates attributable to risk factors were extracted for the years 2007 and 2017 from the GBD 2017 Results Tool. The corresponding 95% uncertainty intervals (UIs), calculated in the GBD study using a Bayesian approach taking 1000 draws from relevant distributions for each metric, were also extracted. Summary exposure values (SEVs) for risk factors and their relations with the attributable burden in death and DALY rates were analyzed for the EU-28 countries for 2007 and 2017.

Country-specific estimates and UIs, also obtained from the GBD 2017 study, were compared with those estimated for the EU-28, as the sum of all 28 countries. The change between 2007 and 2017 was expressed as the percentage difference between both years. More information on data sources used by the Institute for Health Metrics and Evaluation can be found in the GBD 2017 study-related papers.[1–3,8,9]

Risk factors

Estimates on attributable deaths and DALYs for 84 behavioural, environmental and occupational, and metabolic risks for the EU-28 countries were obtained from the GBD 2017 study, organized into five hierarchical levels. At level 0, all risk factors are combined. Level 1 includes three categories: (i) environmental and occupational, (ii) metabolic and (iii) behavioural risk factors. Levels 2–4 include 19, 39 and 22 risk factors or risk factor groups, respectively, with each subsequent level considering risk factors that are more detailed, nested in the broader category above.

The CRA framework, following the establishment of a causal web of hierarchically organized risks that contribute to health outcomes (i.e. mortality and disability), is used in the GBD study to provide estimates on levels and trends in exposure, attributable deaths and DALYs by age, sex and geographic location for each one of the 84 risk factors.[1,10] First, each risk factor is associated with one or more health outcomes, forming a set of 476 risk–outcome pairs, and relative risks are estimated as a function of exposure, on the basis of evidence rules including meta-regressions of previous studies.[1,11] Levels of exposure for each age–sex–geography–year are estimated with the Bayesian meta-regression software, DisMod-MR 2.0, or spatial–temporal Gaussian process regression.[1,11] Afterwards, and relying on existing evidence, the level of exposure associated with minimum risk (i.e. theoretical minimum risk exposure level) is assessed.[1] Finally, PAF are estimated and multiplied by the overall burden estimates such as number of deaths or DALYs for each age–sex–geography–year, also providing the attributable burden while taking into account the combination and mediation of different risk factors.[1]

Summary exposure values

This metric refers to the risk-weighted prevalence of an exposure for each risk factor. SEVs are an easily comparable summary measure, ranging from 0% (no risk exposure in a given population) to 100% (maximum possible risk exposure). GBD considers the following equation to compute SEV:

$$SEV = \frac{\sum_{i=min}^{max} Prev_i * RR_i - 1}{RR_{max} - 1} \quad (1)$$

where $Prev_i$ and RR_i are the prevalence and relative risk of the risk category i, and RR_{max} is the maximum observed relative risk between categories. A more detailed methodological overview on SEV is available in the GBD 2015 study.[11]

Attributable burden due to more than one risk factor was only described for the level 1 risk factors: (i) behavioural; (ii) environmental and occupational; and (iii) metabolic. For deaths and DALY estimates, 19 level 2 risk factors are presented. For SEV estimates, level 2 risk factors were not available and, therefore, the top level 3 risk factors with higher EU attributable DALY burden were presented. Exceptions due to data availability include: (i) metabolic risks only available for level 2 risk factors estimates; and (ii) only level 4 branches of 'particulate matter pollution' and 'low birth weight and short gestation' were available and considered, except for 'household air pollution from solid fuels' which was not considered due to its low value.

Results

In 2017, 58.6% [95%UI: 56.0–61.3%; $N = 3\,049\,342$ (95%UI: 2 911 090–3 193 283)] of all deaths and 44.4% [95%UI: 41.9–47.3%; $N = 66\,210\,208$ (95%UI: 60 638 141–72 234 034)] of all DALYs in the EU-28 were attributed to risk factors (table 1). Including non-attributable deaths and DALYs (Supplementary figure 1), behavioural risk factors accounted for 38.7% of all deaths, followed by metabolic (36.8%) and environmental and occupational risks (7.9%), while for DALYs, metabolic risks represented the highest share in 2017 (36.8%), followed by behavioural (31.1%) and environmental and occupational risk factors (7.9%).

Whilst age-standardized death rates for all risk factors but drug use decreased between 2007 and 2017, the only risk factor for which the age-standardized DALY-rate estimate increased was childhood maltreatment (figure 1). Nevertheless, the exposure (SEV) to several risk factors increased in the EU, namely high fasting plasma glucose (18.1%), high body mass index (6.8%), short gestation for birth weight (3.3%), drug use (2.2%), diet high in sodium (1.7%), low birth weight for gestation (1.5%) and diet low in vegetables (0.7%). Besides these, other risk factors showed a significant increase, such as diet high in sugar-sweetened beverages (14.1%), occupational exposure to benzene (6.9%), diet high in processed meat (6.6%) or bullying victimization (4.1%)—table 1. On the other hand, some risk factors showed quite significant decreases such as unsafe sanitation (–33.8%), unsafe water source (–25.2%), ambient particulate matter pollution (–12.2%), diet high in trans fatty acids (–22.6%), smoking (–11.5%), iron deficiency (–10.2%)—figure 1C and table 1.

In a 10-year span, however, the EU-28 experienced a considerable decrease in age-standardized death and DALY rates attributed to risk factors (table 1). The highest all-cause attributable age-standardized death and DALY rates were observed for tobacco, high systolic blood pressure and dietary risks among level 2 risk factors (figure 2). When considering the ranking of the most detailed risk factors, besides tobacco, dietary risks, alcohol use and low physical activity (behavioural risks) and air pollution (environmental risk), there is a clear predominance of metabolic risks in both 2007 and 2017, with some even experiencing an improvement in the ranking, mainly for DALYs (Supplementary figure 2).

The comparison of age-standardized DALY rates revealed large differences between the EU-28 countries when considering level 2 risk factors—figure 2. Bulgaria (13 839 DALYs per 100 000 inhabitants), Romania (13 729), Latvia (13 445) and Lithuania (13 397) had the highest risk factors attributable burden, whereas Italy (5879.0), Spain (6281.1) and France (6170.7) had the lowest. In fact, most level 2 risk factors showed a particular heterogeneity throughout the EU-28, especially tobacco, dietary risks, high systolic

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Table 1 All-cause all-ages risk-attributable shares of deaths and DALYs , age-standardized death and DALY rates, as well as summary exposure values in 2017, and their percentage change between 2007 and 2017 for all risk factors and all levels, in EU-28

Risk (level)	Deaths attributable to risk factors (%), in 2017 (95% UI)	Age-standardized death rate (deaths per 100 000 inhabitants), in 2017 (95% UI)	Change of age-standardized death rate (%), 2007–17 (95% UI)	DALYs attributable to risk factors (%), in 2017 (95% UI)	Age-standardized DALY rate (DALYs per 100 000 inhabitants), in 2017 (95% UI)	Change of age-standardized DALY rate (%), 2007–17 (95% UI)	Summary exposure value (%), in 2017 (95% UI)	Change of summary exposure value (%), 2007–17 (95% UI)
All risk factors (0)	**58.6 (56.0–61.3)**	**263.8 (252.6–275.2)**	**–16.8 (–18.4 to –15.2)**	**44.4 (41.9–47.3)**	**7768.6 (7055.8–8586.8)**	**–13.8 (–15.6 to –12.1)**	**NA**	**NA**
Environmental/occupational risks (1)	**7.9 (7.0–8.9)**	**35.9 (31.8–40.3)**	**–20.7 (–23.7 to –18.0)**	**7.0 (6.3–7.7)**	**1243.2 (1062.4–1442.8)**	**–14.5 (–17.4 to –11.9)**	**NA**	**NA**
Unsafe water, sanitation and handwashing (2)	0.0 (0.0–0.1)	0.2 (0.1–03)	–14.8 (–20.7 to –8.9)	0.0 (0.0–0.1)	14.7 (8.0–23.9)	–21.5 (–29.2 to –14.9)	NA	NA
Unsafe water source (3)	0.0 (0.0–0.0)	0.1 (0.0–0.1)	–11.5 (–23.7 to –0.5)	0.0 (0.0–0.1)	8.9 (2.1–18.2)	–21.0 (–33.1 to –12.5)	1.3 (1.1–1.5)	–25.2 (–34.9 to –14.5)
Unsafe sanitation (3)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	–25.1 (–37.5 to –10.8)	0.0 (0.0–0.0)	3.7 (2.4–5.3)	–34.4 (–43.4 to –24.8)	2.0 (1.6–2.6)	–33.8 (–43.1 to –23.4)
No access; handwashing facility (3)	0.0 (0.0–0.0)	0.1 (0.1–0.1)	–15.5 (–20.9 to –9.3)	0.0 (0.0–0.0)	3.5 (2.0–5.5)	–20.0 (–27.2 to –13.1)	3.2 (3.0–3.4)	–5.5 (–10.3 to 0.2)
Air pollution (2)	4.6 (3.8–5.4)	20.4 (17.0–24.1)	–25.5 (–30.0 to –21.1)	3.2 (2.6–3.8)	492.3 (395.8–590.7)	–23.0 (–29.0 to –18.0)	NA	NA
Particulate matter pollution (3)	4.2 (3.4–5.0)	18.7 (15.2–22.2)	–26.9 (–32.3 to –22.1)	3.0 (2.4–3.7)	469.0 (371.2–567.9)	–23.6 (–29.9 to –18.4)	NA	NA
Ambient particulate matter pollution (4)	3.9 (3.1–4.7)	17.5 (14.1–21.0)	–25.6 (–31.4 to –20.5)	2.8 (2.2–3.5)	438.1 (341.0–537.2)	–22.0 (–28.9 to –16.1)	29.7 (21.6–42.2)	–12.2 (–21.6 to –3.8)
Household air pollution from solid fuels (4)	0.2 (0.2–0.3)	1.1 (0.5–1.5)	–42.3 (–54.0 to –27.9)	0.2 (0.1–0.3)	30.9 (22.2–42.2)	–41.4 (–53.6 to –26.0)	1.7 (1.0–4.2)	–29.8 (–45.6 to –12.3)
Ambient ozone pollution (3)	0.5 (0.2–0.8)	2.0 (0.7–3.4)	–7.5 (–10.4 to –4.2)	0.2 (0.1–0.3)	28.0 (10.2–46.5)	–8.2 (–11.2 to –4.9)	41.5 (15.6–53.4)	2.0 (0.6–3.7)
Other environmental risks (2)	1.3 (0.7–1.9)	5.4 (3.0–8.3)	–22.5 (–25.7 to –19.5)	0.7 (0.4–1.1)	104.7 (59.3–157.4)	–26.6 (–30.2 to –23.4)	NA	NA
Residential radon (3)	0.3 (0.2–0.5)	1.6 (0.8–2.6)	–9.1 (–13.2 to –5.0)	0.2 (0.1–0.4)	35.9 (17.5–59.4)	–11.8 (–16.2 to –7.4)	26.7 (14.9–40.4)	–0.8 (–1.8 to 0.1)
Lead exposure (3)	0.9 (0.4–1.6)	3.8 (1.7–6.3)	–27.0 (–31.4 to –24.0)	0.5 (0.2–0.8)	68.8 (32.7–114.2)	–32.5 (–37.6 to –29.1)	3.3 (1.2–6.3)	–27.7 (–36.4 to –20.1)
Occupational risks (2)	2.4 (2.0–2.8)	11.7 (9.9–13.5)	–10.1 (–13.2 to –6.9)	3.3 (3.0–3.6)	668.2 (554.5–804.8)	–4.8 (–6.9 to –2.7)	NA	NA
Occupational carcinogens (3)	1.9 (1.5–2.2)	8.8 (7.1–10.5)	–7.0 (–11.0 to –2.8)	1.1 (0.9–1.4)	116.7 (134.4–201.1)	–10.1 (–14.0 to –5.9)	NA	NA
Occupational exposure; asbestos (4)	1.7 (1.3–2.0)	7.7 (6.0–9.3)	–6.2 (–10.6 to –1.3)	1.0 (0.7–1.2)	137.1 (105.9–168.7)	–9.2 (–13.6 to –4.2)	3.8 (3.7–4.0)	0.4 (–3.7 to 5.2)
Occupational exposure; arsenic (4)	0.0 (0.0–0.1)	0.1 (0.0–0.3)	NA	0.0 (0.0–0.0)	3.8 (0.0–8.3)	NA	0.3 (0.0–0.7)	NA
Occupational exposure; benzene (4)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	–13.6 (–17.4 to –9.2)	0.0 (0.0–0.0)	0.8 (0.2–1.5)	–15.9 (–20.1 to –11.2)	0.7 (0.0–2.1)	6.9 (5.8–8.4)
Occupational exposure; beryllium (4)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	–3.2 (–7.5 to –1.1)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	–6.5 (–10.8 to –2.0)	0.0 (0.0–0.0)	3.7 (3.1–4.2)
Occupational exposure; cadmium (4)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	–6.7 (–10.8 to –2.4)	0.0 (0.0–0.0)	0.1 (0.1–0.1)	–9.9 (–14.1 to –5.5)	0.0 (0.0–0.0)	0.2 (–1.2 to 1.6)
Occupational exposure; chromium (4)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	–5.5 (–9.3 to –1.4)	0.0 (0.0–0.0)	0.2 (0.2–0.2)	–8.7 (–12.4 to –4.7)	0.1 (0.1–0.1)	1.3 (0.2–2.5)
Occupational exposure; diesel engine exhaust (4)	0.0 (0.0–0.0)	0.1 (0.1–0.1)	–3.6 (–7.1 to 0.6)	0.0 (0.0–0.0)	2.6 (2.3–3.0)	–6.9 (–10.5 to –2.9)	0.5 (0.4–0.5)	4.6 (3.5–5.9)
Occupational exposure; formaldehyde (4)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	–18.2 (–22.2 to –14.2)	0.0 (0.0–0.0)	0.1 (0.1–0.1)	–20.5 (–24.6 to –16.2)	0.2 (0.2– 0.2)	0.3 (–1.1 to 1.7)
Occupational exposure; nickel (4)	0.0 (0.0–0.1)	0.1 (0.0–0.4)	NA	0.0 (0.0–0.1)	3.2 (0.0–11.5)	NA	0.3 (0.0–1.2)	NA
Occupational exposure; polycyclic aromatic hydrocarbons (4)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	–5.0 (–9.0 to –0.6)	0.0 (0.0–0.0)	0.7 (0.6–0.8)	–8.2 (–12.2 to –3.7)	0.2 (0.2–0.2)	1.8 (0.8–2.9)
Occupational exposure; silica (4)	0.2 (0.1–0.3)	0.9 (0.3–1.4)	–13.3 (–21.0 to –9.6)	0.1 (0.0–0.2)	22.3 (6.7–36.9)	–14.7 (–21.0 to –11.3)	2.9 (0.4–9.4)	–0.3 (–1.8 to 1.4)
Occupational exposure; sulphuric acid (4)	0.0 (0.0–0.0)	0.0 (0.0–0.1)	–20.2 (–23.5 to –16.8)	0.0 (0.0–0.0)	0.9 (0.2–2.0)	–22.9 (–26.2 to –19.5)	0.4 (0.1–1.3)	–2.2 (–3.5 to –0.7)

(continued)

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Table 1 Continued

Risk (level)	Deaths attributable to risk factors (%), in 2017 (95% UI)	Age-standardized death rate (deaths per 100 000 inhabitants), in 2017 (95% UI)	Change of age-standardized death rate (%), 2007–17 (95% UI)	DALYs attributable to risk factors (%), in 2017 (95% UI)	Age-standardized DALY rate (DALYs per 100 000 inhabitants), in 2017 (95% UI)	Change of age-standardized DALY rate (%), 2007–17 (95% UI)	Summary exposure value (%), in 2017 (95% UI)	Change of summary exposure value (%), 2007–17 (95% UI)
Occupational exposure; trichloroethylene (4)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	1.8 (–2.6 to 6.4)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	–1.0 (–5.2 to –3.8)	0.1 (0.1–0.1)	2.5 (1.6–3.5)
Occupational asthmagens (3)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	–34.9 (–38.3 to –31.2)	0.1 (0.1–0.1)	18.6 (12.6–26.2)	–8.1 (–12.9 to –3.5)	11.3 (10.1–12.7)	–0.9 (–2.7 to 1.0)
Occupational particulate matter, gases and fumes (3)	0.4 (0.3–0.5)	1.6 (1.2–2.0)	–13.8 (–16.9 to –10.6)	0.3 (0.2–0.4)	45.7 (37.5–54.2)	–11.2 (–14.8 to –7.6)	4.2 (3.3–5.7)	–6.4 (–7.5 to –5.2)
Occupational noise (3)	NA (NA–NA)	0.0 (0.0–0.0)	0.00 (0.00–0.00)	0.2 (0.1–0.2)	34.3 (23.3–48.8)	–2.2 (–3.2 to –1.2)	4.4 (4.2–4.8)	–1.8 (–2.1 to –1.5)
Occupational injuries (3)	0.1 (0.1–0.1)	1.3 (1.2–1.3)	–22.8 (–26.6 to –18.5)	0.6 (0.5–0.7)	154.4 (125.7–190.9)	–4.4 (–10.4 to 1.7)	NA	NA
Occupational ergonomic factors (3)	NA (NA–NA)	0.0 (0.0–0.0)	0.00 (0.00–0.00)	1.0 (0.8–1.2)	248.3 (176.5–342.5)	0.2 (–1.6 to 2.1)	6.8 (5.9–7.9)	–1.9 (–3.6 to –0.3)
Behavioural risks (1)	**38.7 (37.1–40.3)**	**183.5 (176.6–190.9)**	**–19.3 (–21.0 to –17.6)**	**31.1 (28.9–33.4)**	**5702.2 (5232.5–6201.0)**	**–16.2 (–18.0 to –14.3)**	**NA**	**NA**
Child and maternal malnutrition (2)	0.2 (0.2–0.3)	4.0 (3.7–4.2)	–23.9 (–28.6 to –19.4)	1.2 (1.1–1.4)	563.0 (494.2–647.3)	–17.4 (–22.4 to –12.2)	NA	NA
Suboptimal breastfeeding (3)	0.0 (0.0–0.0)	0.1 (0.1–0.1)	–42.9 (–48.5 to –36.6)	0.0 (0.0–0.0)	8.5 (6.7–10.4)	–34.6 (–41.4 to –27.8)	NA	NA
Non-exclusive breastfeeding (4)	0.0 (0.0–0.0)	0.1 (0.1–0.1)	–43.5 (–49.0 to –37.1)	0.0 (0.0–0.0)	7.3 (5.7–8.8)	–37.6 (–43.8 to –31.2)	0.5 (0.4–0.6)	–1.1 (–3.5 to 1.6)
Discontinued breastfeeding (4)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	–30.6 (–39.4 to –19.2)	0.0 (0.0–0.0)	1.5 (0.5–2.7)	–10.2 (–17.5 to –2.8)	2.1 (2.1–2.2)	0.8 (–0.7 to 2.1)
Child growth failure (3)	0.1 (0.1–0.1)	0.5 (0.4–0.6)	–27.0 (–33.1 to –21.2)	0.1 (0.1–0.1)	30.8 (22.6–38.7)	–35.5 (–41.3 to –29.0)	NA	NA
Child underweight (4)	0.1 (0.1–0.1)	0.3 (0.2–0.4)	–4.3 (–11.7 to –3.0)	0.0 (0.0–0.0)	5.1 (3.9–6.0)	–19.0 (–27.4 to –12.1)	0.1 (0.1–0.1)	–5.7 (–7.7 to –3.9)
Child wasting (4)	0.1 (0.1–0.1)	0.5 (0.4–0.6)	–26.1 (–32.5 to –18.8)	0.1 (0.0–0.1)	29.0 (19.4–37.8)	–35.0 (–41.2 to –27.5)	0.1 (0.1–0.1)	–4.5 (–7.8 to –1.4)
Child stunting (4)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	–52.7 (–61.1 to –42.2)	0.0 (0.0–0.0)	2.4 (0.6–6.5)	–47.1 (–56.0 to –25.0)	0.3 (0.2–0.4)	–6.2 (–12.5 to –0.3)
Low-birth-weight and short gestation (3)	0.2 (0.1–0.2)	3.4 (3.1–3.6)	–23.2 (–28.5 to –18.1)	0.8 (0.7–1.0)	421.5 (378.4–472.8)	–16.8 (–22.7 to –10.0)	NA	NA
Low-birth-weight for gestation (4)	0.1 (0.1–0.1)	2.7 (2.5–2.8)	–22.7 (–28.1 to –17.4)	0.7 (0.6–0.9)	357.6 (316.9–407.5)	–15.2 (–21.8 to –7.3)	0.0 (0.0–0.0)	1.5 (–2.8 to 10.5)
Short gestation for birth weight (4)	0.1 (0.1–0.1)	2.7 (2.5–2.9)	–23.2 (–28.5 to –18.3)	0.7 (0.6–0.9)	364.2 (321.8–414.3)	–15.8 (–22.1 to –8.3)	0.0 (0.0–0.0)	3.3 (–1.6 to 8.3)
Iron deficiency (3)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	–29.4 (–34.4 to –24.6)	0.3 (0.2–0.4)	89.3 (56.7–138.6)	–9.8 (–18.4 to –0.4)	2.7 (1.9–3.6)	–10.2 (–15.4 to –5.1)
Vitamin A deficiency (3)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	–49.4 (–54.8 to –42.2)	0.0 (0.0–0.1)	20.3 (13.1–30.2)	–27.0 (–36.0 to –15.2)	1.2 (1.0–1.5)	–6.6 (–9.5 to –3.8)
Zinc deficiency (3)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	–28.9 (–40.8 to –4.1)	0.0 (0.0–0.0)	1.2 (0.4–2.7)	–9.4 (–28.0 to 28.8)	0.5 (0.2–1.0)	5.0 (–7.8 to 21.3)
Tobacco (2)	16.5 (15.8–17.2)	79.4 (76.2–82.8)	–20.2 (–22.0 to –18.4)	13.9 (12.7–15.1)	2269.4 (2093.6–2463.8)	–18.3 (–20.0 to –16.5)	NA	NA
Smoking (3)	15.7 (15.0–16.4)	75.4 (72.2–78.8)	–20.0 (–21.9 to –18.1)	13.3 (12.1–14.3)	2152.2 (1981.0–2337.5)	–18.2 (–19.9 to –16.4)	7.4 (6.5–8.4)	–11.5 (–13.0 to –10.0)
Chewing tobacco (3)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	–16.8 (–22.4 to –10.1)	0.0 (0.0–0.0)	0.4 (0.3–0.5)	–20.0 (–25.5 to –13.6)	0.1 (0.1–0.1)	–6.9 (–12.3 to –0.6)
Second-hand smoke (3)	1.3 (1.0–1.6)	6.2 (4.9–7.6)	–26.1 (–28.3 to –24.0)	1.1 (0.8–1.3)	183.4 (143.1–228.5)	–23.8 (–27.0 to –20.5)	35.4 (34.6–36.1)	–7.7 (–8.8 to –6.6)
Alcohol use (2)	6.0 (4.6–7.7)	20.4 (17.0–24.1)	–20.7 (–28.4 to –13.0)	6.7 (5.7–7.8)	1333.5 (1157.0–7768.6)	–18.8 (–24.2 to –13.7)	22.4 (15.1–31.0)	0.0 (–8.8 to –9.1)
Drug use (2)	0.8 (0.7–0.8)	5.1 (4.6–5.6)	1.9 (–1.6 to 5.2)	1.5 (1.3–1.6)	378.2 (319.8–436.7)	–1.6 (–4.7 to 1.4)	0.6 (0.4–0.9)	2.2 (–2.6 to 7.8)
Dietary risks (2)	18.3 (16.7–19.9)	79.2 (72.4–86.3)	–22.3 (–24.0 to –20.6)	10.8 (9.6–12.0)	1635.3 (1491.0–1805.7)	–20.5 (–22.6 to –18.4)	NA	NA
Diet low in fruits (3)	3.3 (1.8–5.1)	15.2 (8.6–23.2)	–23.7 (–26.6 to –21.0)	2.3 (1.3–3.4)	371.1 (221.8–549.6)	–22.0 (–25.6 to –18.1)	28.7 (22.8–33.0)	–2.0 (–3.9 to –0.5)
Diet low in vegetables (3)	2.3 (1.0–3.9)	9.7 (4.3–16.5)	–26.2 (–28.7 to –23.9)	1.2 (0.5–2.0)	175.8 (82.0–298.9)	–27.5 (–29.8 to –25.0)	24.2 (18.9–29.0)	0.6 (–1.4 to 2.8)
Diet low in legumes (3)	1.6 (0.7–2.7)	6.9 (2.9–11.5)	–23.3 (–25.1 to –21.3)	0.8 (0.3–1.4)	127.3 (53.5–209.8)	–26.11 (–28.1 to –24.2)	38.6 (35.9–41.0)	0.9 (0.3–1.7)
Diet low in whole grains (3)	5.0 (3.3–6.8)	22.1 (14.9–29.8)	–24.5 (–26.2 to –22.7)	3.4 (2.4–4.5)	539.2 (385.8–713.7)	–20.5 (–23.5 to –17.1)	43.9 (42.2–45.4)	0.1 (–0.3 to 0.4)
Diet low in nuts and seeds (3)	3.6 (2.2–5.1)	15.4 (9.5–22.0)	–25.1 (–27.2 to –23.2)	2.0 (1.3–2.9)	314.5 (206.8–435.1)	–23.9 (–27.2 to –20.1)	41.7 (38.9–43.9)	–2.8 (–4.1 to –1.8)
Diet low in milk (3)	0.3 (0.1–0.6)	1.6 (0.5–3.0)	–11.5 (–14.5 to –8.4)	0.2 (0.1–0.4)	32.2 (10.4–60.8)	–12.6 (–15.6 to –9.4)	28.0 (22.7–32.4)	–1.0 (–2.4 to 0.0)
Diet high in red meat (3)	0.1 (0.0–0.2)	0.6 (0.2–1.0)	–5.9 (–11.8 to 1.0)	0.2 (0.1–0.3)	30.4 (12.6–51.3)	6.6 (–3.8 to 15.8)	26.3 (23.9–28.8)	3.6 (–0.1 to 7.8)
Diet high in processed meat (3)	0.5 (0.1–1.0)	2.4 (0.5–4.6)	–15.3 (–19.4 to –7.8)	0.4 (0.2–0.7)	71.2 (27.5–121.1)	–8.4 (–14.9 to 8.1)	10.6 (8.2–12.9)	6.6 (3.2–11.1)
Diet high in sugar-sweetened beverages (3)	0.4 (0.0–0.8)	1.9 (0.2–3.8)	–10.6 (–16.7 to 0.2)	0.4 (0.1–0.6)	63.5 (20.6–110.9)	–2.6 (–11.3 to 28.0)	11.3 (5.8–12.6)	14.1 (7.9–21.4)
Diet low in fibre (3)	1.9 (1.1–2.8)	8.1 (4.8–12.2)	–21.0 (–23.2 to –18.6)	1.0 (0.6–1.5)	148.6 (87.3–225.7)	–23.2 (–25.5 to –20.6)	32.5 (27.8–36.2)	0.8 (–0.1 to 2.0)
Diet low in calcium (3)	0.5 (0.3–0.8)	2.4 (1.3–3.7)	–13.2 (–16.5 to –10.5)	0.3 (0.2–0.5)	45.6 (23.7–71.3)	–14.4 (–17.8 to –11.4)	20.9 (14.7–26.1)	–2.5 (–4.1 to –1.5)

(continued)

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Table 1 Continued

Risk (level)	Deaths attributable to risk factors (%), in 2017 (95% UI)	Age-standardized death rate (deaths per 100 000 inhabitants), in 2017 (95% UI)	Change of age-standardized death rate (%), 2007–17 (95% UI)	DALYs attributable to risk factors (%), in 2017 (95% UI)	Age-standardized DALY rate (DALYs per 100 000 inhabitants), in 2017 (95% UI)	Change of age-standardized DALY rate (%), 2007–17 (95% UI)	Summary exposure value (%), in 2017 (95% UI)	Change of summary exposure value (%), 2007–17 (95% UI)
Diet low in seafood omega-3 fatty acids (3)	2.4 (1.0–4.0)	10.4 (4.6–17.7)	−25.7 (−27.7 to −23.7)	1.2 (0.5–2.1)	183.6 (82.2–308.6)	−28.6 (−30.7 to −26.6)	36.5 (33.2–39.7)	−2.3 (−3.0 to −1.7)
Diet low in polyunsaturated fatty acids (3)	1.3 (0.6–2.3)	5.8 (2.4–9.8)	−25.3 (−31.0 to −21.7)	0.7 (0.3–1.2)	100.0 (41.1–169.6)	−27.9 (−31.9 to −24.8)	28.0 (23.3–32.0)	−2.6 (−4.3 to −1.3)
Diet high in trans fatty acids (3)	0.3 (0.1–0.8)	1.4 (0.2–3.7)	−40.1 (−56.7 to −33.6)	0.2 (0.0–0.5)	26.0 (4.0–69.0)	−42.4 (−59.1 to −35.7)	1.7 (0.3–4.1)	−22.6 (−45.0 to −13.7)
Diet high in sodium (3)	3.7 (0.5–8.2)	15.8 (2.3–34.4)	−20.7 (−28.5 to −16.1)	2.0 (0.3–4.4)	287.6 (47.8–622.5)	−21.1 (−27.2 to −15.2)	6.2 (0.9–12.6)	1.7 (−4.2 to 14.7)
Intimate partner violence (2)	0.0 (0.0–0.0)	0.1 (0.1–0.1)	−23.9 (−27.1 to −20.5)	0.1 (0.1–0.2)	35.7 (25.7–48.1)	−4.3 (−7.2 to −1.4)	1.1 (0.9–1.3)	−4.4 (−5.8 to −3.0)
Childhood maltreatment (2)	0.0 (0.0–0.0)	0.1 (0.1–0.2)	−7.8 (−14.0 to −1.6)	0.2 (0.2–0.3)	75.9 (54.0–103.3)	2.6 (0.4–5.1)	NA	NA
Childhood sexual abuse (3)	0.0 (0.0–0.0)	0.1 (0.1–0.2)	−7.8 (−14.0 to −1.6)	0.1 (0.1–0.2)	34.9 (24.7–47.5)	−1.4 (−3.6 to −0.8)	6.5 (5.6–7.5)	0.4 (−0.7 to 1.6)
Bullying victimization (3)	NA (NA–NA)	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.1 (0.1–0.1)	41.8 (27.1–61.3)	6.1 (2.6–10.9)	6.1 (3.0–11.6)	4.1 (1.5–8.2)
Unsafe sex (2)	0.4 (0.4–0.4)	2.4 (2.3–2.5)	−23.0 (−25.3 to −20.6)	0.5 (0.4–0.5)	98.5 (87.9–113.8)	−20.3 (−23.2 to −17.3)	NA	NA
Low physical activity (2)	2.9 (1.6–4.6)	11.9 (6.6–18.7)	−21.7 (−23.5 to −19.6)	1.4 (0.8–2.2)	194.4 (106.2–302.8)	−20.1 (−22.5 to −17.3)	0.5 (0.2–0.9)	0.6 (0.1–1.0)
Metabolic risks (1)	**36.8 (32.5–41.0)**	**153.3 (136.0–170.3)**	**−17.4 (−19.4 to −15.3)**	**22.7 (20.3–25.4)**	**3351.5 (2890.8–3819.4)**	**−14.3 (−16.8 to −12.0)**	**NA**	**NA**
High fasting plasma glucose (2)	14.9 (10.3–20.9)	60.4 (42.4–83.3)	−12.0 (−17.5 to −6.2)	9.2 (7.3–11.7)	1337.3 (1051.0–1657.4)	−5.7 (−11.7 to −0.7)	2.7 (2.0–3.7)	18.1 (6.9–33.6)
High LDL cholesterol (2)	9.3 (6.5–12.3)	39.5 (29.3–51.0)	−24.0 (−26.1 to −22.0)	4.8 (3.7–5.9)	714.9 (589.9–851.8)	−25.5 (−27.5 to −23.6)	14.3 (12.7–15.9)	−0.2 (−0.8 to 0.5)
High systolic blood pressure (2)	20.4 (17.6–23.1)	85.3 (74.8–95.3)	−21.5 (−23.0 to −20.1)	10.7 (9.4–12.2)	1524.9 (1371.6–1672.1)	−22.6 (−24.2 to −21.1)	7.8 (7.2–8.5)	−3.7 (−4.9 to −2.5)
High body mass index (2)	10.9 (6.8–15.5)	48.7 (31.0–68.5)	−14.2 (−16.8 to −11.3)	9.0 (6.0–12.1)	1460.2 (975.9–1985.4)	−9.7 (−12.5 to −6.5)	15.4 (12.5–19.3)	6.8 (4.7–9.2)
Low bone mineral density (2)	0.7 (0.7–0.7)	2.7 (2.6–2.9)	−6.8 (−10.0 to −3.6)	1.0 (0.8–1.1)	131.7 (111.4–166.3)	−3.3 (−5.0 to −1.8)	4.8 (4.1–5.6)	−0.9 (−4.8 to 3.0)
Impaired kidney function (2)	4.6 (4.1–5.2)	18.1 (16.2–20.3)	−14.9 (−18.0 to −11.8)	2.2 (2.0–2.5)	307.1 (275.8–339.5)	−16.3 (−18.9 to −13.6)	2.0 (0.9–5.3)	−0.4 (−2.7 to 2.2)

Figure 1 Relationship between summary exposure values and risk-attributable (all-cause) age-standardized death and DALY rates by level 2 risk factor with their percent changes between 2007 and 2017, in the EU-28. Each dot represents the EU-28 estimate and crossed lines the 95% uncertainty intervals.

blood pressure, high LDL cholesterol, impaired kidney function or unsafe sex (figure 2).

Regarding both age-standardized DALY and death rates, Bulgaria had the highest estimates for tobacco, dietary risks and high systolic blood pressure, the most burdensome level 2 risks, with lower percentage decreases when compared with the EU-28-average. Germany presented the lowest decrease in deaths attributed to tobacco, dietary risks and high systolic blood pressure and also displayed the lowest decreases in DALYs attributed to tobacco and high systolic blood pressure. On the other hand, Denmark showed the largest reduction in deaths and DALYs attributable to tobacco, despite presenting an age-standardized death rate that remained considerably higher than

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	All risk factors	Tobacco	Dietary risks	High systolic blood pressure	High body-mass index	High fasting plasma glucose	Alcohol use	High LDL cholesterol	Occupational risks	Child and maternal malnutrition	Air pollution	Drug use	Impaired kidney function	Low physical activity	Low bone mineral density	Other environmental risks	Unsafe sex	Childhood maltreatment	Intimate partner violence	Unsafe water, sanitation, and handwashing
EU 28	**7769**	2269	1635	1525	1460	1337	1333	715	668	563	492	378	307	194	132	105	99	76	36	15
Austria	**7073**	1961	1321	1361	1250	1315	1254	650	632	468	414	398	330	177	121	82	73	75	24	8
Belgium	**7243**	2444	1262	1141	1183	1273	1223	488	642	474	474	308	255	168	144	142	75	93	45	7
Bulgaria	**13839**	4631	4707	5056	3385	2276	1778	2348	582	915	1268	323	785	449	187	216	168	61	18	50
Croatia	**9924**	3184	2706	2523	2203	2142	1599	1157	681	565	803	286	462	272	234	116	80	56	32	36
Cyprus	**7003**	2358	1698	1515	1368	1713	635	815	654	512	590	190	382	208	109	85	51	60	29	7
Czech Republic	**9753**	2956	2614	2289	2093	2127	1794	1183	764	424	727	310	411	281	259	116	98	44	43	33
Denmark	**7740**	2399	1248	1136	1254	1689	1276	466	758	523	456	423	274	161	107	83	75	61	36	7
Estonia	**11122**	2634	2534	3026	2414	1887	2899	1248	520	407	405	904	540	231	156	94	185	107	34	46
Finland	**7273**	1389	1614	1527	1410	1470	1503	716	537	343	217	554	246	209	151	56	39	73	59	4
France	**6281**	1769	977	864	919	811	1293	384	826	410	286	354	190	122	123	99	85	81	42	4
Germany	**7664**	2240	1559	1444	1357	1284	1300	720	686	509	457	337	343	194	112	64	79	101	35	8
Greece	**7756**	3017	1768	1558	1503	1380	881	926	561	576	624	250	402	221	97	151	63	76	34	4
Hungary	**12036**	4008	3417	3379	2681	2246	2409	1514	659	679	996	223	518	324	246	184	108	49	23	64
Ireland	**6980**	1993	1323	1278	1280	1460	1249	573	561	446	351	444	273	194	96	94	68	87	22	5
Italy	**5879**	1625	1096	1012	1055	1208	667	424	587	498	395	384	232	145	99	113	90	62	47	4
Latvia	**13446**	3457	3986	3906	2903	2263	3197	1967	616	515	851	663	744	449	174	113	241	97	50	56
Lithuania	**13398**	3238	3877	4004	2613	1892	3855	2074	613	464	793	634	688	484	197	94	153	126	42	63
Luxembourg	**7154**	1998	1208	1283	1413	1510	1515	489	566	362	405	406	273	160	127	75	61	81	39	5
Malta	**7672**	2121	1856	1633	1689	2126	354	876	648	763	583	344	395	295	116	189	57	50	27	4
Netherlands	**6767**	2357	1158	1069	1170	1362	731	451	727	504	443	243	243	137	112	55	62	86	39	3
Poland	**10466**	3307	2687	2292	2215	1970	2046	1166	729	622	857	301	380	295	240	119	119	59	10	32
Portugal	**7403**	1777	1407	1161	1433	1830	1584	478	643	527	380	264	341	187	85	127	292	76	48	10
Romania	**13730**	3749	3623	4154	2873	1726	3296	1691	818	1320	1032	388	595	387	205	234	223	59	28	102
Slovakia	**10886**	2960	3293	3061	2411	1729	1854	1564	553	717	809	295	540	357	237	132	111	49	29	37
Slovenia	**7735**	2339	1590	1537	1611	1209	946	620	756	433	498	386	255	166	305	89	66	58	25	26
Spain	**6171**	1989	1028	1019	1134	1034	1119	428	503	492	325	319	234	137	94	137	109	55	33	4
Sweden	**6254**	1545	1368	1197	1169	1301	825	578	541	382	220	384	248	182	126	50	57	86	48	6
United Kingdom	**7365**	1870	1387	1131	1377	1121	932	606	659	702	418	611	228	180	102	68	78	85	39	6

Figure 2 Risk-attributable age-standardized DALY rates (DALYs per 100 000 inhabitants) by level 2 risk factors and by country, for the European Union (EU-28) in 2017. Green cells: estimate range that is below the EU-28 average range; red cells: estimate range above the average range; yellow cells: estimate range crossing the EU-28 average range

the EU-28-average. In terms of tobacco burden and exposure, Finland and Sweden showed the lowest estimates in 2017, while Latvia and Estonia were the only countries with an exposure increase despite not showing the same trend for disease burden (figure 3).

In terms of deaths and DALYs attributed to drug use, Estonia accounted for the largest burden by far, with little to no change in comparison to the EU-28-average. Portugal, Hungary and Greece presented the lowest rates but achieved the largest reduction in deaths and DALYs attributed to drug use, considerably better than the EU-28-average, whereas Czech Republic, Sweden and Netherlands stood out in the opposite direction. There was also an increase of the SEV for drug use in the EU-28, with Czech Republic showing by far the largest increase. However, the UK presented the highest SEV estimates for drug use in 2017, also reporting an increase in the exposure that was similar to that observed for the EU-28-average. Other relevant examples are Finland, as the best performer on air pollution, and Lithuania, as the worst in DALY rates due to childhood maltreatment. Additional country-specific age-standardized death and DALY rates for 19 level 2 risk factors, and SEV estimates for 18 level 3 risk factors with the highest attributable DALY-rates, including their percentage change between 2007 and 2017, are displayed in Supplementary figures 2, 3 and 4, respectively.

Discussion

Between 2007 and 2017, the EU experienced a considerable decrease in risk-attributable age-standardized death and DALY rates. However, an important share of the burden of disease in 2017 can still be attributed to selected risk factors in the EU-28 countries. In general, behavioural and metabolic risks remained the most important ones for all ages and both sexes. Tobacco, dietary risks and high systolic blood pressure were in the top three for both death and DALY rates, while metabolic risk factors closely followed.

Despite this improvement, there is heterogeneity in burden of disease attributable to risk factors across countries. Eastern and Central European countries generally had higher death and DALY rates attributable to risk factors when compared with the EU-28 average. Bulgaria in particular had the highest attributable DALY-rates.

Tobacco-attributable burden generally improved throughout the EU-28. Scandinavian countries were among the best performers in health outcomes and exposure: Finland had the lowest death and DALY rates on tobacco and the lowest exposure to smoking, followed by Sweden. Denmark led the decreasing trend of exposure and DALYs attributable to tobacco. Both Sweden and Finland have a long history of tobacco control, being among the first countries to sign the World Health Organization (WHO) Framework Convention on Tobacco Control and adopting measures that include offering alternatives to cigarettes (i.e. snus tobacco).[12] In addition, there have been efforts at the EU-level, including actions on excise duties for tobacco products (2011) and targeting the manufacturing, trade and taxation of tobacco products.[13,14] Raising taxes on tobacco was widely adopted in the EU in 2012, when 22 countries complied with the minimum tax level recommended by the WHO.[15] Despite a clear progress in Europe in recent years,[16] Bulgaria still showed an important burden attributable to tobacco, having the highest death and DALY rate and the highest exposure to smoking in the EU. In addition, Latvia and Estonia were the only European countries with increases in exposure since 2007. The same trend is not found for burden as there is a high time lag between exposure and the reflection on its burden. For Bulgaria, some reasons may explain our findings: (i) difficulties in implementing smoking regulatory policies; and (ii) an economy highly dependent on the tobacco industry, an important source of income, with extremely effective lobbying.[2] Considering that Bulgaria has one of the lowest health expenditures in the EU-28 and underdeveloped preventive actions, the EU has a key role to play in coordinating guidelines and best practice exchange, monitoring health systems/programmes and producing legislation/regulations that, for example, in the case of the tobacco and food industries, lead to effective industry self-regulation.[17]

Metabolic risk factors also represent an important threat. In particular, Bulgaria again showed a much higher burden attributable to

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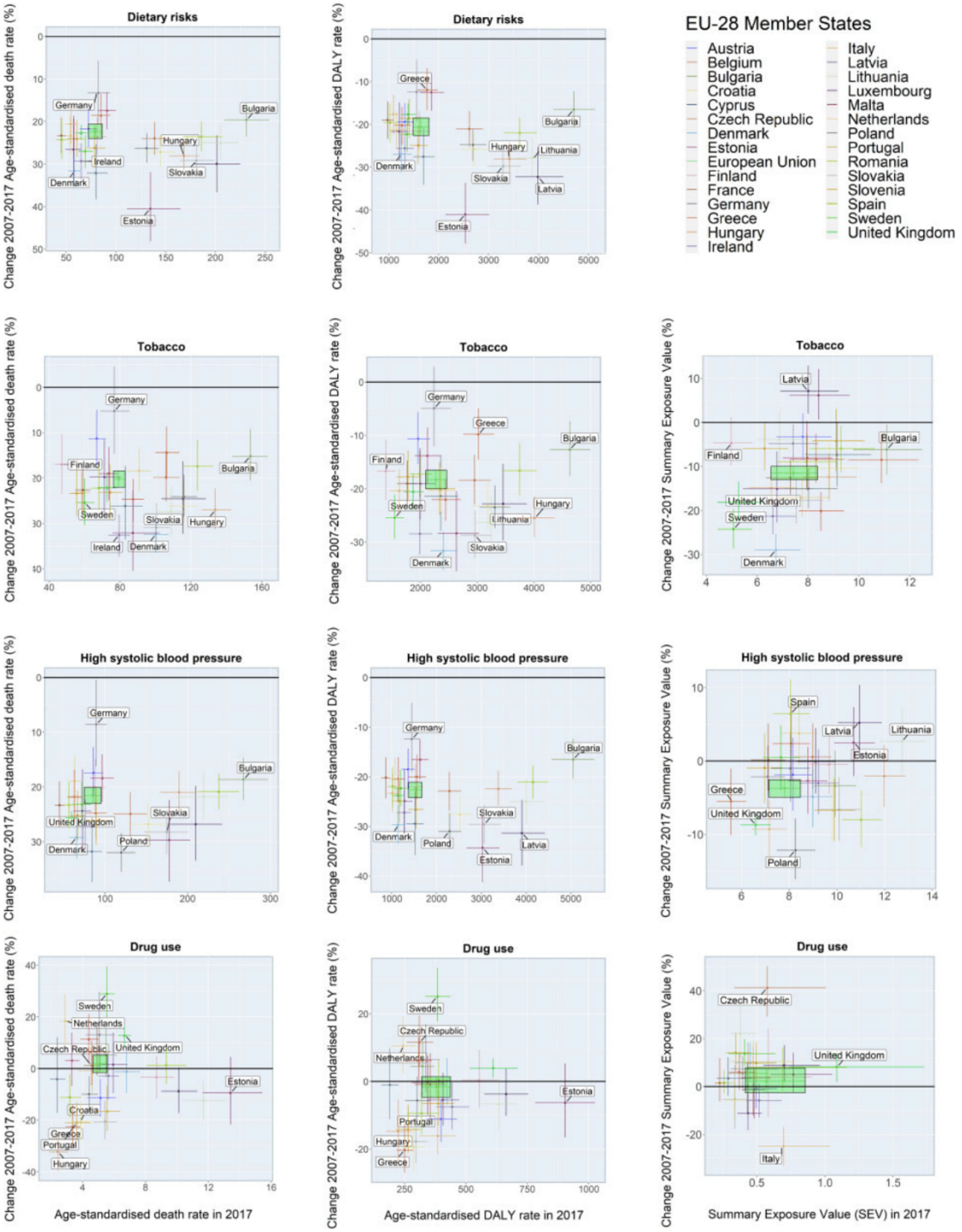


Figure 3 Relationship between SEV and risk-attributable (all-cause) age-standardized death and DALY rates for selected risk factors and their percent changes between 2007 and 2017, in EU-28. Each dot represents one EU-28 country and crossed lines the 95% uncertainty intervals. The green boxes represent the EU-28 estimate and its uncertainty interval

high systolic blood pressure, the levels of which were also alarming in Germany with the smallest burden reduction in the EU. Highly connected to this risk factor are dietary risks.[18] In fact, the countries with the best estimates (and changes from 2007) in high systolic blood pressure also showed the best results for dietary risks (e.g. Estonia). These two risk factors show great changes in burden, but remain a persistent problem in the EU-28. Many EU countries took actions acknowledging that metabolic risk factors and unhealthy diets contribute to overweight/obesity.[19] Interventions vary from product reformulation, taxes or new labelling schemes to marketing, awareness-raising campaigns and promotion of active modes of transport.[20,21] Many initiatives are currently active at the EU-level,

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including the Physical Activity Strategy and Nutrition Action Plan, while individual countries carry their own national strategies/programmes.[19] For example, France and Italy have adopted several policies/programmes over the years to tackle obesity and show the lowest level of burden attributable to dietary risks and high systolic blood pressure.[19]

Drug use was the only level 2 risk factor that showed an increased death rate, with great heterogeneity between countries. Estonia had the highest death rate and Cyprus the lowest; while Sweden, the Netherlands and Czech Republic showed the highest increases in deaths. Illicit drug policy remains a debated topic. In the EU, different approaches are taken by national governments, despite several EU Action Plans and Drug Strategies. Even though consensus exists on the approach towards drug trafficking, the coexistence of opposing paradigms when it comes to drug use(rs) makes the adoption of a common policy difficult (e.g.: the liberal Dutch policy focusing on reducing harm for drug users vs. Sweden's 'zero tolerance' to eradicate drug use from society).[22,23] These examples show that it will be difficult to achieve a 'one-size-fits-all' drug policy in the EU, who should continue to play a guiding role both on legislation and platforms for best practices sharing, promoting a whole-of-society approach, fundamental for effective drug policies.[24]

Globally, alcohol-attributable burden, measured in total DALYs, was the highest for Eastern and Central Europe.[25] Alcohol use in the EU in 2017 seemed to be similar to that of 2007. However, alcohol-attributable death and DALY rates declined. Even though some progress was made, there is still need for a stronger EU alcohol strategy focusing on (i) harmonizing EU legislation in the prevention of alcohol harm; (ii) specific laws for alcoholic beverages and (iii) a truly comprehensive and regulatory alcohol policy.[26] The WHO recently recommended (2020) more generalized taxation on alcoholic beverages related to their alcohol content,[27] complemented by regulatory measures, e.g. regulating physical availability or drink-driving counter-measures.[28] However, EU directives governing alcohol duties pose significant challenges. Recently, both Scotland and Wales were the first among the EU-28 to implement minimum unit pricing on alcohol purchases, a policy proven to be effective in reducing alcohol consumption.[29]

When it comes to EU DALY rates and childhood maltreatment, this was the only level 2 risk factor that showed an increase, mainly due to increased bullying, despite international efforts. The Council of Europe's Strategy for the Rights of the Child 2016–21 prioritizes the eradication of violence against children, including all forms of bullying (school bullying and cyber-bullying[30,31]). Progress has been achieved, with implementation of national legislation and activities (media campaigns, conferences and lectures/publications), as well as best practice sharing amongst member states.[32] However, countries like Lithuania, with the highest attributable DALY rate in 2017 and some of the EU's highest levels of school bullying since 1994,[33] have only recently started to improve its implementation, through stronger legislation, greater engagement with schools and educational communities and targeted media campaigns.[32,34]

Intimate partner violence showed a decrease in both attributable burden and exposure in the EU. In fact, the EU has established several resolutions towards the strengthening of the rights and protections of victims, calling on Member States to improve national laws and policies to combat violence against women.[35] However, with recent insights from the COVID-19 pandemic impact, this positive trend might change.

Regarding air pollution, attributable deaths and DALY rates decreased for the EU, as well as the exposure to ambient particulate matter pollution, with Finland maintaining the lowest estimates and still showing a decreasing trend. In fact, emissions of many air pollutants have decreased substantially in Europe over the past decades, with further recent initiatives by the EU Commission such as the Clean Air Policy Package and Programme for Europe.[36] Finland's air quality is one of the best globally due to strong environmental regulations, such as the National Air Pollution Control Programme 2030, which aims to bring down emissions and concentrations of pollutants to levels even lower than those required in EU legislation.[37]

The EU already does much for health when it comes to environmental, labour and consumer protection policies, with visible and positive effects, but the legal space for EU action in other domains remains immense.[17] However, the fact that, ultimately, health policy is still a responsibility of each country poses a limitation to the extent that the EU can act. The big steps in EU public health policy seem to follow crises—what political scientists call 'focusing events'.[17] In the wake of COVID-19, its impact on healthcare and evidence that the direct costs of NCDs in the EU will continue to grow in the future,[38] it is clear that much remains to be done and the focus should be on strengthening EU health policy. Initiatives such as 'State of Health in the EU' and the EU 'Health Programme' stand out as important tools for the improvement of European Health.[17]

Limitations

This study presents several limitations, and many of them are intrinsic to the relying data and methods used in the GBD, namely the availability and quality of primary data (in particular for exposure and morbidity), the use of the same disability weights and severity distribution, PAF estimation and other techniques implemented within the CRA framework.[9,11] Despite the GBD 2017 study aiming to update the GBD CRA framework with improved methods, new risks and risk–outcome pairs, as well as presenting new data regarding risk exposure levels and risk–outcome associations at a global level, there are still specific limitations related to CRA estimates.[2] Additionally, the use of a world standard population may lead to important differences when compared with the EU age structure.[39]

Conclusion

Although an overall improvement was observed from 2007 to 2017, the risk factor attributable burden of disease in the EU-28 remains high. The significant burden of disease attributable to risk factors in the EU-28 underlines the room for acting in order to reduce the part of burden of disease that is avoidable by tackling risk factors like tobacco and dietary risks, by means of public health interventions. There are many opportunities for mutual learning among countries with different patterns of disease and risk factors, be it through sharing good practices and policies, or highlighting concerning cases. This paper can be a first step for more detailed analyses, further decomposition of these results (e.g. age groups, sex, subnational estimates) and future mutual learning between Member States. There is clearly much to be done, with risk factors prevention serving as a strategic future direction for upcoming times in the EU.

Supplementary data

Supplementary data are available at *EURPUB* online.

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Conflicts of interest: None declared.

Ethics approval

The study was not appraised by an Ethical Committee as it is only the reuse of publicly available secondary data, despite complying with the Declaration of Helsinki.

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Key points

- Despite a general improvement, risk factor attributable burden of disease in the EU-28 remains high, with behavioural and metabolic risk factors standing out.
- Important heterogeneity between countries was observed, and good practices with possible public health implications were identified.
- This paper can be a first step for more detailed analyses and future mutual learning between Member States, as there is clearly much to be done regarding risk factors prevention in the EU.

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PAPER 4

Health expectancies in the European Union: same concept, different methods, different results.

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Health expectancies in the European Union: same concept, different methods, different results

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ABSTRACT

Background Healthy life expectancy (HLE) is a population health measure that combines mortality and morbidity, which can be calculated using different methods. In this study, we aimed to assess the correlation, reliability and (dis)agreement between two estimates monitored in the European Union (EU), that is, the European Commission's HLE based on self-perceived health (SPH-HLE) and the Institute for Health Metrics and Evaluation's HLE based on disability weight (DW-HLE), by sex, and comparing these results with LE and proportion of life spent in good health (%GH).

Methods We performed a retrospective study in the EU28 countries, between 2010 and 2017. The HLE methods differ in definition, measurement and valuation of health states. While SPH-HLE relies directly on one question, DW-HLE relies on epidemiological data adjusted for DW. Spearman's r, intraclass correlation coefficient, information-based measure of disagreement and Bland-Altman plots were used to assess reliability, correlation and disagreement in HLE resulting from both methods and in LE or %GH measured by both institutions.

Results Correlation and reliability between SPH-HLE and DW-HLE were good (better for males), with low disagreement, and were even better for LE between both institutions. The HLE Bland-Altman plots suggest a variability range of approximately 6 years for both sexes, higher for females. There was also an increasing HLE difference between methods with higher average HLE for both sexes.

Conclusion We showed wide variations between both methods with a clear and different high impact on female and male HLE, showing a tendency for countries with higher health expectancies to yield larger gaps between SPH-HLE and DW-HLE.

INTRODUCTION

Health expectancy, also called healthy life expectancy (HLE), was first conceptualised by Sanders,[1] and operationalised by Sullivan, defining it as a 'Mortality–Morbidity Index'.[2] In fact, this concept emerged from the need to measure not only quantity of life but also quality of life.[3]

Health expectancy can be considered a 'general term referring to the entire class of indicators expressed in terms of life expectancy in a given state of health'.[4] According to the Réseau Espérance de Vie en Santé, 'health expectancies are indicators of current health and mortality conditions.'[4]

Population health measures, such as health expectancy, have been used in different policy settings such as retirement, budgets and sustainable development[5] and were identified by experts, by the European Commission (EC) and by the World Health Organization (WHO) as indicators for health system performance assessment,[6–8] having been formally adopted by the latter two.

Several health expectancies have been described,[3 9] and they can vary in four dimensions, as Murray *et al* stated: (1) calculation methods; (2) definition and measurement of health states; (3) valuation of health states and (4) inclusion of other social values.[3 10]

Health expectancies can be calculated in a period or a cohort, such as standard life tables.[9] The Sullivan method, a 'prevalence-rate' method, the most commonly used method, considers a single-decrement life table and cross-sectional prevalence of health states by age groups and gender. The other main method, that is, multistate method, explicitly considers incidence, recovery and mortality, by using longitudinal cohort data.[3 9–11]

Each health expectancy is based on a specific definition of health and its domains, as well as on the measurement of health states, with differences for example in self-reported vs observed health.[9] Valuation of health states can be differentiated by (1) the individuals valuating it, (2) type of valuation question, (3) type of health state presentation for valuation elicitation, (4) range of health states and (5) combination of valuation questions and type of deliberative process.[9]

Several health expectancy indicators are currently being used.[10] For the European Union (EU) and all 28 EU countries, to the best of our knowledge, four health expectancy at birth indicators are currently used for monitoring and publicly reported—two by the EC, one by the WHO and one by the Institute for Health Metrics and Evaluation (IHME)—Global Burden of Disease (GBD) study. However, different methods are used, for example, while both the WHO and the IHME produce estimates using disability weights (DWs), the EC reports estimates based on self-reported health status.[12] WHO only provided publicly available estimates for 2010, 2015 and 2016[13] and the EC's 'healthy life years' (HLY), also called disability-free life expectancy (DFLE), had several substantial breaks in time series (ie, changes in methods/results) for different EU countries at different times,[14] and thus, were not considered in this study.

However, several questions may arise. These population health measures are as appealing as misunderstood and careful analysis of what they

reflect is important. If the same concept is being measured, are there differences in the interpretation? More importantly, do they (un)systematically differ across countries and over time? It is, therefore, important to evaluate the (systematic) differences obtained using different methods.

In this study, we aimed to assess the correlation, reliability and (dis)agreement between two of those estimates, that is, EC's 'HLE based on self-perceived health' (SPH)[15] and IHME/GBD's 'HLE' (DW-HLE),[16] commonly referred by the GBD study as HALE, by sex. As these estimates rely on life tables for their calculation, and in order to compare the results, we also performed these analyses for life expectancy (LE) and for the proportion of life spent in good health (%GH) from the EC and IHME/GBD.

METHODS

We performed a retrospective observational study, comparing HLE from the EC (available through Eurostat)—SPH-HLE—and from the IHME (available through GBD study)—DW-HLE—for all EU28 countries, between 2010 and 2017. EU estimates were also directly obtained from the IHME/GBD study and the Eurostat.

Those estimates are built through different methods. While both use the same calculation method, that is, the Sullivan method,[2] they differ in the definition, measurement and valuation of health states (ie, second and third issue, as stated by Murray *et al*[9]), as well as in the life tables used.

Self-perceived health - healthy life expectancy

In order to calculate SPH-HLE, the measurement of health state is based on a self-assessed general health question, as commonly applied, that is, '(How is your health in general? Is it…[very good][good][fair][bad][very bad])', thus being a single-attribute ordinal health measure.[15] This question is applied as part of the EU statistics on income and living conditions questionnaire, which occurs yearly since 2010 in all EU28 countries on a cross-sectional sample of inhabitants with 16 years of age or older, by country.[17 18] In 2017, samples ranged from 3902 in Malta to 22 743 in Greece, though with different sample design methods, as well as variability in the mode of administration between countries.[17–19]

For calculation, a dichotomous variable is created, by considering good perceived health (ie,[very good][good][fair] answers) and less than good perceived health (ie,[bad][very bad] answers).[15] In order to calculate SPH-HLE, age-specific mortality rates and prevalence of 'less than good' perceived health are used.[15 17] Some assumptions are considered such as using responses from 16 to 19 years old group to 15–19 years old group and considering the prevalence of less than good perceived health for people with less than 15 years old as half of that of the 16–19 group.[15]

Disability weight - healthy life expectancy

The GBD 2017 study used all available 'up-to-date' epidemiological data and improved standardised methods to provide a comparative assessment of health loss across 359 diseases and injuries and 73 age and sex groups for 195 countries and territories, including all EU28 countries.[20] The GBD approach includes several key principles and assumptions for measures' estimation such as garbage code redistribution and borrowing strength across time or geography as in some regions/years data might be sparse or unavailable, which might increase the stability over time.

In order to calculate DW-HLE, age and sex specific mortality and years lived with disability (YLDs) are used, by incorporating average DWs in the life tables.[20] YLDs are estimated as the product of causes and sequelae prevalence and the DW for the 235 health states considered, adjusted for comorbidity using a Monte Carlo simulation approach.[20 21] DWs represent the magnitude of health loss and are measured on a scale between 0 (full health) and 1 (death).[22] For each health state—presented with a brief lay description—there is an associated DW. DWs for health states were calculated by using simple paired comparison questions (asking respondents to choose who was the healthier overall between two particular health states), complemented with 'population health equivalence' questions (asking respondents to compare the health benefits of different life-saving or health-improving programmes).[22 23] This was performed, first, using household surveys by means of computer-assisted face-to-face interviews in Bangladesh, Indonesia, Peru and Tanzania and by computer-assisted telephone interviews in the USA; followed by an international open-access web-based survey, including respondents from 167 countries; and, later, a web-based survey in Hungary, Italy, the Netherlands and Sweden totaling the sample size to 60 890.[22–24]

LE and proportion of life spent in %GH

To overcome life tables' differences as a possible source of bias we also compared LE calculated from the EC (EC-LE) and from the IHME (IHME-LE), which mainly differ on the age groups considered (the IHME considers age groups 100+, while the EC considers the maximum age class as 85+), population estimates and further modelling/adjustments performed mainly on IHME estimates.[25 26]

Proportion of life spent in %GH was calculated by dividing the HLE by the LE for each method.

Statistical analyses

Descriptive statistics for HLE method and LE estimates were produced by sex, considering both central tendency and dispersion measures.

We evaluated correlation, reliability and (dis)agreement between the resulting HLE of the two methods (SPH-HLE and DW-HLE). The same was done for LE (EC-LE and IHME-LE) and %GH estimates (EC-%GH and IHME-%GH) produced by the EC versus IHME. Indeed, two scales can be highly correlated but with poor agreement between them, for example, one scale systematically measures more than the other. The terms reliability and agreement are frequently used interchangeably in the literature. However, they are conceptually distinct. Reliability can be defined as the ability of a measurement to differentiate between subjects or objects (in this case, between methods) and agreement as the degree to which scores or ratings are identical. Both concepts provide different information about the quality of measurements. In this study, following the Guidelines for Reporting Reliability and Agreement Studies all these concepts (correlation, reliability and agreement) were assessed,[27] with more detailed information in online supplemental appendix 1.

To assess the correlation, due to the low number of observations (n=28 countries) and non-normal distribution of the values, Spearman's rank order correlation coefficient (r) was calculated by year and sex, between methods. For this analysis, 10 000 bootstrap samples were drawn to calculate 95% confidence intervals (CIs). As there is dependence between observations (there were eight observations/country, ie, 8 years per country, for both measures), an overall Spearman's r value was

presented considering all observations and 95% CIs were not calculated for this overall coefficient.

In order to study reliability, the intraclass correlation coefficient (ICC) (two-way random-effects model) was calculated by year and sex, while the information-based measure of disagreement (IBMD) was also calculated in order to study the concept of (dis)agreement.[27] The ICC ranges from 0 (no reliability) to 1 (perfect reliability). The IBMD is based on the amount of information contained in the differences among observations, so IBMD ranges from 0 (no disagreement/perfect agreement) to 1 (perfect disagreement/no agreement). As there is dependence between observations (eight observations/country), overall ICC and IBMD values were presented but 95% CIs were only presented for each year.

Bland and Altman plots, by sex, with limits of agreement were plotted. However, the Bland and Altman 95% limits of agreement procedure relies on the assumptions that the mean and standard deviation (SD) of the methods' differences do not depend on the magnitude of the measurement, which were not fulfilled in the studied data. Moreover, the observations were not independent. In order to overcome the problem of assumptions' violation, we performed a Bland and Altman methodology for dealing with the relationship between mean of differences and the magnitude of the measurement using linear regression.[28 29] Instead of using linear regression, a mixed model for repeated measures was applied due to the repetition of each measure eight times (years) for each country.

We used Microsoft Excel V.16.0, IBM SPSS Statistics V.24.0 and R V.4.0.0 for data processing and statistical analysis.

RESULTS

In the EU, SPH-HLE in females increased from 74.9 years (range: 65.0–80.1) in 2010 to 76.7 years (range: 68.6–80.8) in 2017, while DW-HLE increased from 70.6 years (range: 66.5–73.0) to 71.2 years (range: 67.6–73.6). For males, there was an increase of SPH-HLE from 71.4 years (range: 60.1–76.8) in 2010 to 73.4 years (range: 62.6–78.1) in 2017, using SPH, while using DW it increased from 67.0 years (range: 58.8–69.5) to 68.0 years (range: 60.4–70.6). Table 1 displays the summary measures (central tendency and variability) by sex and year for both HLE estimates, but also for LE and %GH estimates. All data are presented in online supplemental file 1.

A good positive correlation was found between SPH-HLE and DW-HLE for males (r=0.876), higher than for females (r=0.706) (table 2). The correlation was even higher when comparing life expectancies, while for %GH there was almost no correlation between IHME-%GH and EC-%GH. Online supplemental file 2 includes the scatter plots for all measures by sex.

Reliability followed the same pattern, with the HLE comparison being good but higher for males (ICC (males)=0.919; ICC (females)=0.657) - Table 2. Life expectancies showed an almost optimum reliability, while reliability for %GH was almost null.

Disagreement (IBMD) was quite low for all measures and sexes (HLE: 0.082 for males and 0.086 for females; LE: 0.005 for both males and females; %GH: 0.084 for males and 0.079 for females), but it was the lowest between LE measures, with similar values between HLE and %GH - Table 2.

Correlation (Spearman's r), ICC and IBMD results are presented by sex and by year between SPH-HLE and DW-HLE, between EC-LE and IHME-LE and between EC-%GH and IHME-%GH in table 2.

Figure 1 shows the Bland-Altman plot for the difference between all the estimates (SPH-HLE vs DW-HLE, EC-LE vs IHME-LE and EC-%GH vs IHME-%GH) for both males and females. Each number within the plot represents one estimate (ie, HLE, LE or %GH) from a specific country in that specific year and each colour (in those numbers) represents one country. Regarding HLE, for males, the linear model can be represented as 'difference (SPH-HLE – DW-HLE)=−25.026 + 0.430 mean HLE', while for females this model can be described as 'difference (SPH-DW)=−67.898 + 0.997 mean HLE' (figure 1A,B). In the countries with the highest mean HLE, there was a difference between HLE higher than 5 years.

DISCUSSION

We performed a retrospective study in order to study the correlation, reliability and (dis)agreement of EC's 'HLE based on SPH' (SPH-HLE) and IHME/GBD's 'HLE' (DW-HLE) by sex, between 2010 and 2017. However, as these estimates rely on life tables and in order to allow for a comparison, we also studied these properties for LE and proportion of life spent in GH between both institutions' estimates. Despite the fact that correlation and reliability between the two methods of assessing health expectancy are generally good, with low disagreement, these properties were even better when comparing life expectancies between both institutions. Proportion of life spent in GH, as a product of both measures (health expectancy and LE) relies on both, with properties closer to the health expectancies' values. In health expectancies (the main outcome of this study), correlation and reliability were higher for males than for females. Besides that, despite the previously described male and female health survival paradox (whereby women generally live longer, but in poorer health, than men),[30] all HLEs (all countries, all years) were higher for females in both methods.

Correlation, reliability or (dis)agreement did not show much variation over time. However, there was a general increase of health expectancies and an increase of the difference between SPH-HLE and DW-HLE for several countries, between 2010 and 2017.

Despite the 'good performance' observed in the results for correlation, reliability and disagreement between both HLE methods, the Bland-Altman plots suggest a variability range (ie, random error) of approximately 6 years of HLE for both sexes, that is, ±3 years, when considering 95% of the observations. Again, this variability is higher for females, approximately 3.3 years, than for males, approximately 2.7 years. This variability is quite high when considering HLE differences between countries or throughout time. This important variability persists in the plots comparing %GH, while for LE this range was lower than 2 years, highlighting that LE estimates of both institutions are quite closer than for HLE or %GH.

There is a systematic error described in the HLE Bland-Altman plots, showing a positive linear model, with an increasing HLE difference between methods with higher HLE for both sexes. In other words, countries (or country-years) with higher HLE also have higher differences between SPH-HLE and DW-HLE. The same pattern was found for %GH for the above-mentioned reasons. Life expectancies did not show an increase of differences for higher values, even though there was an increased dispersion of differences in these higher values.

Interestingly, the HLE Bland and Altman slope among females was approximately double than that from males. Also, while the difference between methods was approximately zero for those country-years with lowest HLE for males, differences for country years with lowest HLEs among females were negative, with almost no differences at around 69 years of mean HLE.

Table 1 Summary descriptive measures for health expectancies (HLE), life expectancies (LE) and proportions of life spent in good health (%GH) by method, sex and year, for EU28 countries between 2010 and 2017

	Health expectancy (years)			
	Based on self-perceived health (SPH-HLE)		Based on disability weights (DW-HLE)	
	Male	Female	Male	Female
	min **median** max (IQR); mean	min **median** max (IQR); mean	min **median** max (IQR); mean	min **median** max (IQR); mean
2010	60.1 **72.1** 76.8 (9.6); 69.6	65.0 **75.2** 80.1 (8.7); 73.2	58.8 **67.4** 69.5 (6.2); 65.6	66.5 **70.0** 73.0 (2.1); 69.7
2011	59.9 **72.3** 76.7 (8.4); 69.9	65.0 **74.7** 80.5 (8.8); 73.3	59.2 **67.7** 69.6 (6.1); 65.9	66.9 **70.1** 73.0 (1.9); 69.9
2012	60.3 **72.6** 76.7 (8.6); 70.2	65.3 **75.6** 80.8 (8.0); 73.7	59.4 **67.9** 69.8 (6.1); 66.1	67.0 **70.2** 73.2 (1.9); 70.0
2013	61.3 **72.8** 77.7 (8.4); 70.6	66.5 **75.4** 79.9 (7.6); 74.0	59.4 **68.1** 70.1 (6.0); 66.3	67.1 **70.4** 73.3 (1.8); 70.1
2014	61.6 **73.4** 77.5 (8.4); 70.9	66.6 **75.8** 81.0 (7.6); 74.4	59.9 **68.3** 70.2 (5.9); 66.5	67.2 **70.8** 73.4 (1.9); 70.3
2015	62.8 **73.1** 78.0 (9.1); 71.1	67.0 **75.2** 80.5 (8.1); 74.5	60.1 **68.3** 70.2 (5.7); 66.6	67.4 **70.8** 73.3 (2.2); 70.3
2016	62.2 **73.8** 78.0 (9.3); 71.7	67.7 **75.9** 81.3 (7.6); 75.2	60.2 **68.3** 70.5 (5.4); 66.7	67.5 **70.7** 73.5 (1.9); 70.5
2017	62.6 **73.6** 78.1 (9.0); 71.9	68.6 **76.2** 80.8 (7.9); 75.5	60.4 **68.4** 70.6 (5.4); 66.8	67.6 **70.8** 73.6 (1.8); 70.5
Overall	59.9 **72.6** 78.1 (8.3); 70.7	65.0 **75.4** 81.3 (7.7); 74.2	58.8 **68.0** 70.6 (5.4); 66.3	66.5 **70.5** 73.6 (2.1); 70.2
	Life expectancy (years)			
	European Commission (EC-LE)		Institute of Health Metrics and Evaluation (IHME-LE)	
	Male	Female	Male	Female
	min **median** max (IQR); mean	min **median** max (IQR); mean	min **median** max (IQR); mean	min **median** max (IQR); mean
2010	67.6 **77.4** 79.6 (6.7); 75.6	77.4 **83.0** 85.5 (3.4); 82.0	67.6 **77.1** 79.4 (6.4); 75.5	77.4 **82.6** 85.0 (3.2); 81.7
2011	68.1 **77.9** 79.9 (6.3); 76.0	77.8 **83.1** 85.7 (3.2); 82.2	68.2 **77.5** 79.6 (6.3); 75.8	77.7 **82.7** 85.0 (2.9); 81.9
2012	68.4 **77.9** 79.9 (6.3); 76.1	77.9 **83.1** 85.5 (2.9); 82.2	68.5 **77.7** 80.0 (6.3); 76.1	78.1 **82.8** 85.2 (3.0); 82.1
2013	68.5 **78.1** 80.3 (6.5); 76.5	78.6 **83.2** 86.1 (3.0); 82.5	68.5 **78.0** 80.1 (6.1); 76.4	78.4 **83.0** 85.4 (2.8); 82.2
2014	69.1 **78.7** 80.7 (6.1); 76.8	78.0 **83.6** 86.2 (3.1); 82.9	69.1 **78.4** 80.3 (6.1); 76.7	78.0 **83.2** 85.5 (2.9); 82.5
2015	69.2 **78.6** 80.4 (6.5); 76.8	78.2 **83.3** 85.7 (3.3); 82.6	69.4 **78.4** 80.3 (6.2); 76.7	78.3 **83.0** 85.5 (3.3); 82.5
2016	69.5 **78.8** 81.0 (6.1); 77.1	78.5 **83.6** 86.3 (2.9); 83.0	69.5 **78.5** 80.7 (5.8); 76.9	78.5 **83.0** 85.7 (2.7); 82.7
2017	69.8 **78.9** 80.8 (6.3); 77.2	78.4 **83.7** 86.1 (3.2); 82.9	69.6 **78.5** 80.8 (5.6); 77.0	78.6 **83.1** 85.8 (2.6); 82.8
Overall	67.6 **78.2** 81.0 (6.0); 76.5	77.4 **83.1** 86.3 (3.0); 82.6	67.6 **78.1** 80.8 (5.8); 76.4	77.4 **82.9** 85.8 (2.9); 82.3
	Proportion of life spent in GH (%)			
	EC-%GH		IHME-%GH	
	Male	Female	Male	Female
	min **median** max (IQR); mean	min **median** max (IQR); mean	min **median** max (IQR); mean	min **median** max (IQR); mean
2010	83.5 **92.8** 97.3 (4.7); 91.9	78.6 **90.2** 96.4 (7.1); 89.2	85.1 **87.0** 88.0 (0.9); 86.9	84.6 **85.5** 86.4 (0.6); 85.4
2011	84.8 **92.7** 97.2 (4.4); 91.9	80.9 **89.9** 97.0 (7.1); 89.2	85.0 **86.9** 87.9 (0.9); 86.9	84.6 **85.4** 86.4 (0.6); 85.3
2012	85.3 **93.1** 97.2 (3.7); 92.1	81.4 **90.5** 97.2 (5.8); 89.6	85.0 **86.9** 87.9 (0.9); 86.8	84.6 **85.4** 86.3 (0.6); 85.3
2013	84.7 **92.6** 96.9 (4.5); 92.2	81.1 **90.2** 96.2 (6.5); 89.6	85.0 **86.9** 87.9 (0.9); 86.8	84.6 **85.3** 86.2 (0.6); 85.3
2014	85.1 **92.7** 96.5 (4.4); 92.2	81.4 **90.6** 96.1 (6.0); 89.8	84.9 **86.8** 87.9 (0.9); 86.8	84.5 **85.3** 86.3 (0.6); 85.3
2015	86.0 **92.3** 97.0 (4.2); 92.5	82.2 **90.3** 96.0 (5.9); 90.2	85.0 **86.8** 87.9 (0.9); 86.8	84.5 **85.3** 86.2 (0.7); 85.3
2016	86.8 **93.2** 96.9 (4.5); 92.9	83.3 **91.3** 96.3 (5.4); 90.6	85.0 **86.8** 87.9 (0.9); 86.8	84.5 **85.2** 86.2 (0.6); 85.2
2017	86.7 **93.3** 97.1 (3.5); 93.1	84.6 **91.5** 96.2 (5.7); 91.0	85.1 **86.8** 87.9 (0.9); 86.8	84.5 **85.2** 86.2 (0.5); 85.2
Overall	83.5 **92.9** 97.3 (4.1); 92.4	78.6 **90.4** 97.2 (5.8); 90.0	84.9 **86.9** 88.0 (0.9) 86.8	84.5 **85.3** 86.4 (0.6); 85.3

EU, European Union; GH, good health.

Despite not being within the scope of this study, it would be interesting to break these results down by other determinants of health (in addition to sex), to assess further sources of variation.

There are some specific countries standing out when analysing the HLE Bland-Altman plots. In the upper limit of agreement there is Romania, while in the lower limit of agreement there are Portugal, Croatia and Italy, for both sexes. We can draw from these results that comparing to other countries with close HLE, those countries are in extremes regarding the difference between SPH-HLE and DW-HLE. However, conclusions must be taken carefully because while Portugal and Croatia (in the lower limit of agreement for both sexes) have a higher (negative) difference for females, the difference is quite close to 0 for males. Also, although Italy is close to the lower limit of agreement, it has a positive difference as it is among those countries with highest HLE. Interestingly, Italy has a quite higher (positive) difference between SPH-HLE and DW-HLE in 2010 and 2017 when compared with the other (intermediate) years. The 2015–2016 difference at least might be explained by a break in the time series for SPH-HLE, which only occurred between 2015 and 2016 for this country, Bulgaria, Luxembourg and the Netherlands.[15]

The HLE results from both methods differ considerably for both sexes and across countries. However, it could be easier to analyse and compare estimates considering the systematic (positive linear) relation. The same is applicable for the %GH, while for life expectancies there are no considerable differences besides the (non-systematic) dispersion of differences in the highest values of LE.

There are undoubtedly important methodological differences between DW-HLE and SPH-HLE. For example, while DW-HLE considers all inhabitants (though indirectly) and uses the same DWs for the health states in all countries; SPH-HLE uses samples not always so representative (such as in Germany,

Table 2 Spearman's rho correlation, intraclass correlation coefficient (ICC) and information-based measure of disagreement (IBMD) between health expectancy, life expectancy and proportion of life spent in good health methods, by sex and by year, for EU28 countries between 2010 and 2017

	Spearman's r (95% CI)		ICC (95% CI)		IBMD (95% CI)	
	Health expectancy		Health expectancy		Health expectancy	
	Male	Female	Male	Female	Male	Female
2010	0.890 (0.767 to 0.939)	0.679 (0.422 to 0.827)	0.908 (0.802 to 0.958)	0.629 (0.198 to 0.828)	0.082 (0.068 to 0.096)	0.080 (0.062 to 0.095)
2011	0.881 (0.720 to 0.948)	0.648 (0.334 to 0.814)	0.921 (0.829 to 0.963)	0.634 (0.209 to 0.831)	0.080 (0.065 to 0.092)	0.077 (0.057 to 0.093)
2012	0.862 (0.670 to 0.946)	0.622 (0.322 to 0.801)	0.925 (0.838 to 0.965)	0.634 (0.209 to 0.831)	0.080 (0.067 to 0.093)	0.078 (0.060 to 0.095)
2013	0.834 (0.637 to 0.926)	0.639 (0.327 to 0.823)	0.917 (0.821 to 0.962)	0.653 (0.249 to 0.839)	0.085 (0.072 to 0.098)	0.079 (0.061 to 0.094)
2014	0.839 (0.639 to 0.928)	0.638 (0.312 to 0.826)	0.918 (0.823 to 0.962)	0.645 (0.233 to 0.836)	0.085 (0.070 to 0.098)	0.082 (0.061 to 0.098)
2015	0.836 (0.623 to 0.932)	0.688 (0.389 to 0.863)	0.921 (0.830 to 0.964)	0.668 (0.282 to 0.846)	0.087 (0.073 to 0.100)	0.081 (0.063 to 0.098)
2016	0.873 (0.732 to 0.936)	0.735 (0.470 to 0.879)	0.923 (0.833 to 0.964)	0.694 (0.339 to 0.858)	0.094 (0.081 to 0.107)	0.089 (0.071 to 0.104)
2017	0.864 (0.698 to 0.931)	0.732 (0.483 to 0.860)	0.923 (0.834 to 0.964)	0.699 (0.351 to 0.861)	0.097 (0.084 to 0.109)	0.090 (0.072 to 0.107)
Overall	0.876*	0.706*	0.919 *	0.657 *	0.082 *	0.086 *
	Life expectancy		Life expectancy		Life expectancy	
	Male	Female	Male	Female	Male	Female
2010	0.930 (0.771 to 0.997)	0.942 (0.800 to 0.997)	0.995 (0.989 to 0.998)	0.996 (0.991 to 0.998)	0.004 (0.002 to 0.008)	0.005 (0.003 to 0.007)
2011	0.945 (0.808 to 0.948)	0.940 (0.810 to 0.997)	0.996 (0.992 to 0.998)	0.994 (0.988 to 0.997)	0.004 (0.002 to 0.007)	0.007 (0.005 to 0.008)
2012	0.977 (0.906 to 0.946)	0.940 (0.786 to 0.998)	0.999 (0.997 to 0.999)	0.994 (0.987 to 0.997)	0.003 (0.002 to 0.005)	0.004 (0.003 to 0.006)
2013	0.950 (0.803 to 0.998)	0.958 (0.856 to 0.996)	0.996 (0.991 to 0.998)	0.995 (0.990 to 0.998)	0.004 (0.002 to 0.007)	0.005 (0.003 to 0.007)
2014	0.930 (0.764 to 0.992)	0.916 (0.727 to 0.996)	0.996 (0.991 to 0.998)	0.987 (0.972 to 0.994)	0.005 (0.003 to 0.008)	0.007 (0.005 to 0.010)
2015	0.960 (0.847 to 0.998)	0.922 (0.753 to 0.996)	0.997 (0.994 to 0.999)	0.987 (0.973 to 0.994)	0.005 (0.003 to 0.007)	0.004 (0.002 to 0.007)
2016	0.937 (0.800 to 0.996)	0.949 (0.819 to 0.998)	0.994 (0.987 to 0.997)	0.986 (0.971 to 0.994)	0.006 (0.003 to 0.009)	0.005 (0.003 to 0.009)
2017	0.963 (0.862 to 0.997)	0.938 (0.790 to 0.995)	0.994 (0.988 to 0.997)	0.984 (0.965 to 0.993)	0.007 (0.005 to 0.009)	0.006 (0.004 to 0.009)
Overall	0.956*	0.955*	0.996 *	0.990 *	0.005 *	0.005 *
	Proportion of life spent in good health		Proportion of life spent in good health		Proportion of life spent in good health	
	Male	Female	Male	Female	Male	Female
2010	0.270 (−0.081 to 0.538)	−0.262 (−0.566 to 0.124)	0.219 (−0.687 to 0.639)	−0.082 (−1.338 to 0.499)	0.080 (0.067 to 0.092)	0.076 (0.060 to 0.092)
2011	0.296 (−0.066 to 0.567)	−0.223 (−0.546 to 0.158)	0.246 (−0.630 to 0.651)	−0.079 (−1.332 to 0.501)	0.078 (0.063 to 0.090)	0.074 (0.057 to 0.090)
2012	0.284 (−0.068 to 0.563)	−0.209 (−0.522 to 0.165)	0.264 (−0.591 to 0.659)	−0.061 (−1.293 to 0.509)	0.080 (0.066 to 0.094)	0.076 (0.059 to 0.092)
2013	0.284 (−0.067 to 0.565)	−0.152 (−0.467 to 0.217)	0.235 (−0.654 to 0.646)	−0.062 (−1.294 to 0.509)	0.082 (0.068 to 0.095)	0.075 (0.057 to 0.090)
2014	0.328 (−0.012 to 0.578)	−0.100 (−0.416 to 0.246)	0.243 (−0.636 to 0.650)	−0.054 (−1.277 to 0.512)	0.082 (0.068 to 0.094)	0.077 (0.060 to 0.092)
2015	0.321 (−0.038 to 0.590)	−0.085 (−0.410 to 0.266)	0.250 (−0.620 to 0.653)	−0.045 (−1.257 to 0.517)	0.086 (0.072 to 0.099)	0.080 (0.062 to 0.096)
2016	0.416 (0.081 to 0.660)	0.064 (−0.296 to 0.422)	0.334 (−0.439 to 0.692)	0.023 (−1.111 to 0.548)	0.091 (0.079 to 0.102)	0.085 (0.068 to 0.099)
2017	0.387 (0.031 to 0.636)	0.041 (−0.300 to 0.374)	0.333 (−0.442 to 0.691)	0.015 (−1.129 to 0.544)	0.094 (0.081 to 0.104)	0.088 (0.070 to 0.103)
Overall	0.323*	−0.141*	0.249 *	−0.056 *	0.084 *	0.079 *

Spearman's r—95% CIs were calculated based on 10 000 bootstrap samples.
*95% CIs were not calculated (Spearman's r, ICC and IBMD applied for all years and all countries).
EU, European Union.

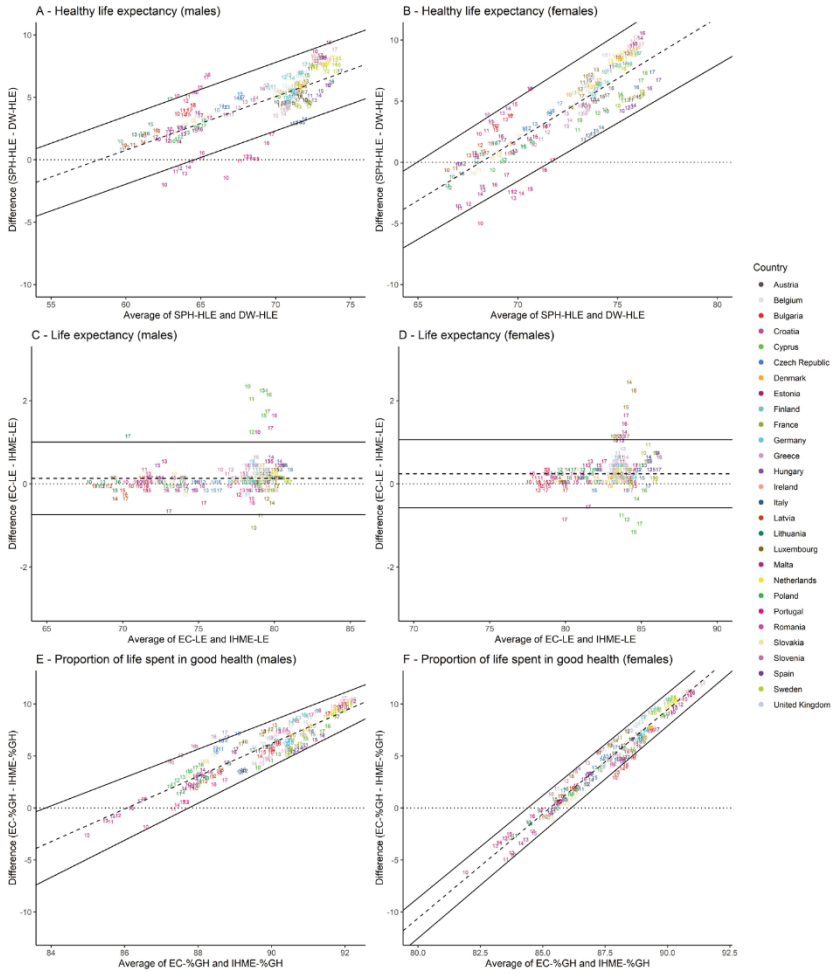


Figure 1 Bland and Altman plots for assessing differences between health expectancy methods (A and B), as well as life expectancies (C and D) and proportion of life spent in good health (E and F), for males and females among EU28 countries between 2010 and 2017. Each "dot" corresponds to country-year, with each color representing one country and each number a year (e.g. 2010 = "10"). The middle line represents the linear model, while the outer lines represent the 95% CIs. DW, disability weight; EC, European Commission; GH, good health; HLE, healthy life expectancy; IHME, Health Metrics and Evaluation; SPH, self-perceived health.

Spain and Ireland) and considers a dichotomous health state; even though both use Sullivan's method and consider a wide and subjective definition of health.[15 17–24] However, the major difference is that DW-HLE is based greatly on epidemiological (diseases and injuries) data, by determining severity distributions to map prevalence data to DW and by applying the same DW for the health states in different countries, while SPH-HLE is based purely on SPH. Further differences may result from the use of different life tables by IHME and Eurostat.

There is some debate on whether SPH makes a good measure of health status for cross-country comparison or for countries' time trends.[31 32] In fact, Maddox and Douglass stated that SPH 'clearly measure something more—and something less—than objective medical ratings' and Jylhä that 'hardly any other measure of health is more widely used and more poorly understood'[33 34] being a multidimensional concept possibly more related to the physical health domain or vitality.[35 36] Several factors may influence SPH: age, gender, income, education, unemployment, health behaviours or even culture, but related to the reporting behaviour as well.[37] However, reporting behaviour also plays a role in SPH and we have to bear in mind that different scales of the same measure can yield different results even if highly correlated, as well as different modes of administration or different valuation questions.[37–40] Thus, caution must be taken for cross-country analysis regarding SPH-based health expectancies, or even when comparing SPH-HLE by sex.

Not focusing on the male and female difference regarding health expectancies, we showed important differences in the differences between methods (SPH-HLE and DW-HLE) and how these are distributed throughout the average health expectancies. In fact, women and men value their own health differently but a differential reporting behaviour between genders is still on debate.[41–44]

However, caution must be taken as these publicly reported measures are not adjusted for other determinants and even more caution as SPH-HLE relies in a dichotomous valuation and, as Murray *et al* argue, these valuations are extremely sensitive to variation in the arbitrary threshold definition, creating

important problems for cross-national comparisons or analysis throughout time.[9]

Despite the good correlation, reliability and low disagreement, there are some systematic differences that might be related to cultural and socioeconomic factors or reporting behaviour. For instance, Jürges has found that Southern European countries 'underrate' their health,[45] which is consistent with our results for Portugal, Croatia and Italy, even though the same trend was observed for Germany,[46] which was not found in our study. Besides that, Jürges pointed out that Danish and Swedish inhabitants tended to 'overrate' their health, in line with our results.[45] However, as previously stated, we showed a general systematic difference, for both males and females with countries with a higher health expectancy showing a larger gap between SPH-HLE and DW-HLE than those with the lowest ones.

As for LE and %GH, while the differences between EC (EC-LE) and IHME (IHME-LE) might rely on the different age groups considered (IHME considers age groups 100+, while EC maximum age class is 85+), population estimates or further modelling/adjustments performed mainly on IHME estimates,[25 26] the differences found for %GH depend on both measures (HLE and LE), as it is a product of both.

Limitations

Each health expectancy method has its own limitations. As mentioned above, the SPH-HLE method is hampered by the dichotomous valuation of health, the surveyed sample and the subjectivity of the question. The DW-HLE method, on the other hand, is hampered by the use of the same DWs, as well as severity distributions, for all countries (not country-specific), which are overall limitations of the GBD study.[12 20 21 47] Other overall limitations of the GBD study include the availability and clinical bias on data regarding non-fatal outcomes, the reliance of the disease severity distribution on the available literature or the assumption of independent distributions of comorbidity.[21] Both HLE methods also rely on the quality of the data from death registries, which are compulsory in all EU countries, with the IHME/GBD approach relying on morbidity information as well.

What is already known on this subject

- Health expectancy is a population health metric combining both mortality and morbidity, used for several health policy and planning purposes. There are many possible methods and specific health expectancy indicators are being monitored for the European Union with the aforementioned purposes.

What this study adds

- In this study, we showed that the 'healthy life expectancy based on self-perceived health' (SPH-HLE) calculated by the European Commission and the 'healthy life expectancy' (DW-HLE) calculated by the Global Burden of Disease study show important variations with a clear and quite different impact on female and male health expectancies. We also showed a tendency for countries with higher health expectancies to yield higher gaps between SPH-HLE and DW-HLE. This can have important implications when using or comparing health metrics for health policy and planning.

Besides the limitations inherent to each health expectancy method, the study itself presents some limitations, namely the low number of observations, the difficulty in aggregating data for several years due to dependence between observations and not considering uncertainty intervals that can have an impact on the results when analysing such indicators.[48] In fact, uncertainty intervals are only systematically provided for DW-HLE. Additionally, we did not analyse the formally used health expectancy by the EC (DFLE/HLY) due to the aforementioned breaks in the time series.[5 14]

CONCLUSIONS

Health expectancy indicators emerged from the need to measure not only quantity (ie, mortality) but also quality of life.[3] They are currently collected and monitored for EU countries using several methods and by different institutions. They have an increasing importance on health policies and programmes, as well as in the definition of health priorities or health system performance comparisons. In this study, by assessing the correlation, reliability and (dis)agreement between two of those estimates, that is, EC's 'HLE based on SPH' and IHME/GBD's 'HLE' (DW-HLE), we showed that caution must be taken when reusing these measures. Indeed, while both measures share the same concept, estimates can differ widely, with a distinct impact on female and male health expectancies, and with a tendency for countries with higher health expectancies to yield larger gaps between SPH-HLE and DW-HLE.

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DISCUSSION

Main findings

First of all, it is essential to define the EU group and to have the same set of countries when considering an EU analysis. In the first paper, we found a clear difference when using different EU definitions as well as the impact that enlargements can have when considering indicators of the EU overall. In fact, the 2004 and 2007 enlargements stood out as the ones where the EU average health status decreased the most, while the 1995 enlargement showed the opposite effect [72]. Thus, comparing the comparable is paramount when assessing health systems performance. The recent change in the EU with Brexit, in 2020, and its impact on the EU average health status is yet to be studied.

The effectiveness of the EU national health systems can be easily benchmarked using morbidity-mortality indicators such as DALYs or HALEs. In fact, in this thesis, GBD 2017 study estimates were reused in order to compare each country to the EU overall estimate, presenting results in an easily interpretable way for benchmarking health systems. This in turn can be used to identify best practices and highlight opportunities for mutual learning among otherwise similar countries with different patterns of disease. In fact, benchmarking cause-specific morbidity-mortality indicators can be essential to identify potential areas for health improvements.

The EU population health status has been improving since 1990, with a step back between 2014 and 2015, possibly related to flu and excess winter mortality that season. Considering the EU-28, there was an increase of about 5.9 years in the life expectancy and 4.6 years in the healthy life expectancy at birth between 1990 and 2017 [72].
There is an East-West gap when it comes to the effectiveness of health systems in the EU, considering health status or health determinants indicators [73]. Road injuries mirror this gap well, linked to health promotion policies adopted in Western countries still to be implemented in several Eastern countries [73]. However, some Central and Eastern European countries had large health gains between 2007 and 2017, such as Estonia, Lithuania and Latvia, contributing to the narrowing of this gap [73].

In 2017, the national health systems presenting best effectiveness estimates were Spain, Italy and France, while Bulgaria, Romania, Latvia and Lithuania stood out on the opposite end [73,74].

Non-communicable diseases still dominate the burden of diseases, with cardiovascular diseases remaining the leading cause of death, even with the improvements in the last decade. However, when looking at a morbidity-mortality indicator such as age-standardised DALY rates, low back pain and headache disorders are leading causes, showing the importance of having comprehensive morbidity-mortality indicators [73].
In fact, most cause-specific age-standardised death and DALY rates have been decreasing, but some causes, such as acute glomerulonephritis, eating disorders and bacterial skin diseases, showed a 10% increase of age-standardised death rates between 2007-2017, with only acne vulgaris showing such an increase for age-standardised DALY rate at an EU level [73].

It is important to highlight that linking population health to attributable health determinants can provide important information on the effectiveness of health systems. In fact, by acknowledging this we can understand that more than half of deaths and almost half of DALYs in the EU in 2017 were attributed to specific risk factors, with behavioural risk factors leading that contribution [74]. As expected, the East-West gap remains in the risk-factors-attributable population health, with similar country patterns. As for health status, that fraction attributable to risk factors also decreased between 2007 and 2017 in the EU, although burden of disease attributable to some risk factors showed an increasing trend, namely age-standardised death rate due to drug use and age-standardised DALY rate due to childhood maltreatment [74]. Again, the importance of using morbidity-mortality indicators rather than mortality indicators is well noted, showing clearly different results.
Additionally, estimating exposure to risk factors can also be an important method to analyse trends and patterns in the EU. Some concerning increases were detected, such as for high body-mass index [74]. This assessment also allows associating population health to best practices on health policies, such as those related to tobacco consumption in Finland or Sweden, as opposite to Bulgaria.

Besides the currently reported in "Health at a Glance: Europe - State of Health in the EU cycle", it is important to include morbidity in a comprehensive measure rather than looking only at mortality or prevalence/incidence indicators separately [69]. In fact, ranking causes or risk factors by age-standardised DALYs or by age-standardised death rates is clearly different and leads to quite different results. Nevertheless, even if considering only YLLs instead of death rates, this would already add much more information to burden of disease estimates.

The "Health at a Glance: Europe - State of Health in the EU cycle" currently reports health expectancy at birth using GALI as the original health valuation question, which is already quite a methodological drawback, mainly regarding data comparability across countries [60-62].

In fact, health expectancies, as a measure that combines morbidity and mortality, are quite useful tools for policy making, benchmarking and as part of HSPA monitoring, with all its associated goals [32,75]. Such indicators have become increasingly more important and reused. Actually, in 2016, Ottersen et al. proposed to use lifetime health loss in "healthy life years" by condition, in order to adapt the cost-effectiveness threshold for health interventions [76].

While there are so many ways of producing such indicators, varying in (1) calculation methods, (2) definition and measurement of health status, (3) valuation of health states and (4) inclusion of other social values, only three indicators are currently and yearly produced for the EU [77,78]. However, the "healthy life years" indicator based on GALI has many breaks in the time series besides the aforementioned problems on data comparability across countries [60-62,77]. The remaining options, disability weights-based health expectancy, produced within the GBD study, and the self-perceived health-based health expectancy, produced by the European Commission, still have several drawbacks. In fact, while the self-perceived health-based indicator is calculated by the Eurostat dichotomizing the five health "states" and the subjectivity of a self-rating general heath question, the GBD study uses the same disability weights and severity distributions in all countries [77].

Despite both indicators measuring the same concept, there are wide differences across countries and time, with a distinct impact on female and male health expectancies, as well as a tendency for countries with higher health expectancies to also show wider differences between indicators [77]. Replacing this single-attribute ordered health measure of self-

perceived health by multi-attribute health measures in the European surveys, namely in the EU Statistics on Income and Living Conditions (EU-SILC) and in the European Health Interview Survey (EHIS) could be an interesting solution for monitoring and evaluating the effectiveness of EU health systems [79,80]. In fact, using patient-reported outcome measures such as EQ-5D or SF-6D, and considering the tariffs assessed for each country would be a step into a more comprehensive assessment. Such approach, would allow the adoption of a value-based health system approach, much wider than the value-based health care used for specific interventions or settings, and the integration of public participation in such efforts.

Finally, although there was a recent attempt to design an EU approach to health system performance assessment, with a specific Expert Group on Health Systems Performance Assessment set by the European Commission with all Ministries of Health as contributors, the results are still far from a full framework, without a clear operationalization of equity and using "% of patients with impaired independence showing improvement on a relevant scale", "% of patients who report positive outcome measures in the defined review period" and "% of patients showing improvement for the selected health outcome, on a relevant scale" as health domains indicators [81,82]. On the other hand, the Expert Panel on Effective Ways of Investing in Health, constituted by academic and professional experts rather than institutional representatives, had previously included equity as a dimension, as well as suggested the use of "healthy life years", "perceived health status", "population health risk factors" and "self-reported well-being", pointing out towards better possibilities of an improved and common EU HSPA [83].

Strengths and limitations

Using GBD study estimates has several strengths, including comparability throughout time and across countries worldwide. Moreover, all available epidemiological information is used in order to compute comprehensive estimates such as age-standardised DALY rates or healthy life expectancy.

On the other hand, there are several limitations of using GBD study estimates for assessing effectiveness of health systems. Firstly, it is dependent on data availability and data quality mainly regarding morbidity and risk factors exposure. Additionally, the use of the same disability weights and severity distributions across countries is still far from reflecting true

population health estimates, under-estimating the potential gap or differences between countries [44-48,84].

However, compared to the currently used health status indicators reported by the European Commission or other European institutions, there are several improvements such as the comprehensive health status indicators, considering both morbidity and mortality, using several burden of disease estimates but also broader general indicators such as health expectancies.

Nevertheless, the concept of health itself is still a topic in debate, with many different perspectives. In fact, measuring health is not an easy task, with many conceptual, social and philosophical aspects that must be considered [85-87].

Future research

It is essential to monitor population health indicators for assessing health systems' effectiveness but also to estimate other HSPA dimensions such as efficiency and equity. Some efforts have been made in the last few decades by the European Commission, the WHO and the IHME. However, we are still quite far from optimal approaches, such as monitoring health status according to population preferences. In fact, there is a clear missing link between economic evaluations used for health technology assessments or policy/public health interventions and health systems performance assessment or priority setting.

In order to close this gap, health systems' effectiveness assessment and priority setting should also be more studied and improved. This thesis provides one option of bridging this gap but much remains to be done. European Union national burden of disease can and must be boosted by European institutions with yearly surveys measuring health or health dimensions, more tailored to current needs of health planning and priority-setting, including through the use of multi-attribute health measures. In fact, although the WHO's Choosing Interventions that are Cost-Effective (WHO-CHOICE) framework suggests measuring intervention outcomes as DALYs averted and, lately, through time spent in each health state considered in the GBD study, there is still a lot to do regarding its application in the real-world setting, as there are still many limitations in using disability weights and the GBD study results [88,89]. As Mooney and Wiseman stated, one major problem of such approach, still to be improved, is that "a change in health status is assumed to be valued the same everywhere (...) and that all health services are about disease reduction and that alone" [90]. Thus, new

health valuations, such as preference-based health measures, should be considered in population health surveys across the EU.

The connection and impact between economic evaluations and the macro level of population health is still a topic open to debate and to be better developed technically. It is interesting to note that Blum, back in 1972, included "health aspects" as criteria for priority-setting, of which "deaths", "disability", "disease", "discomfort and pain" or "distress or danger to others" were some of those considered [89]. Thus, even in the beginning of the 1970s, both morbidity and mortality, as well as different dimensions of health, were considered for priority-setting [91].

Marginal analysis considered in priority setting methods such as PBMA can be improved with the bridge between new interventions or technologies and the overall/national impact assessed through effectiveness analysis of health systems, leading to clearer and easier decision-making processes.

CONCLUSIONS

This thesis shows different possible estimation methods of effectiveness of health systems in the European Union by proposing increasing the use of comprehensive morbidity-mortality indicators such as DALYs or healthy life expectancies. As expected, it is stated that it is important to compare the comparable and using the same definition of EU when doing such an exercise. It also highlights the wide variation of using different healthy life expectancies across EU countries and throughout time. Using burden of diseases estimates and a full comprehensive approach, either on causes or risk factors, a clear and simple presentation of results is suggested in order to benchmark EU countries, assess trends and identify best practices. In the future, such implications in other domains of HSPA, as well as closing the gap between benefits of economic evaluations and better population health outcomes should be addressed and studied.

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ANNEX 1

Supplementary material of paper 1 "European Union state of health from 1990 to 2017: time trends and its enlargements' effects"

Supplementary Table 1 – List of new European Union countries by year of accession, since the foundation.

Year	**1957**	**1973**	**1981**	**1986**	**1995**	**2004**	**2007**	**2013**
Group	**EU6 - founders**	**EU9**	**EU10**	**EU12**	**EU15**	**EU25**	**EU27**	**EU28**
New countries	Belgium	Denmark	Greece	Portugal	Austria	Cyprus	Bulgaria	Croatia
	France	Ireland		Spain	Finland	Czech Republic	Romania	
	Italy	United Kingdom			Sweden	Estonia		
	Luxembourg					Hungary		
	Netherlands					Latvia		
	Germany					Lithuania		
						Malta		
						Poland		
						Slovakia		
						Slovenia		

Supplementary Table 2 – Estimates of the proportion by age group and sex of the European Union population for all 28 countries in 2017 – used as standard populations for age-sex direct standardization.

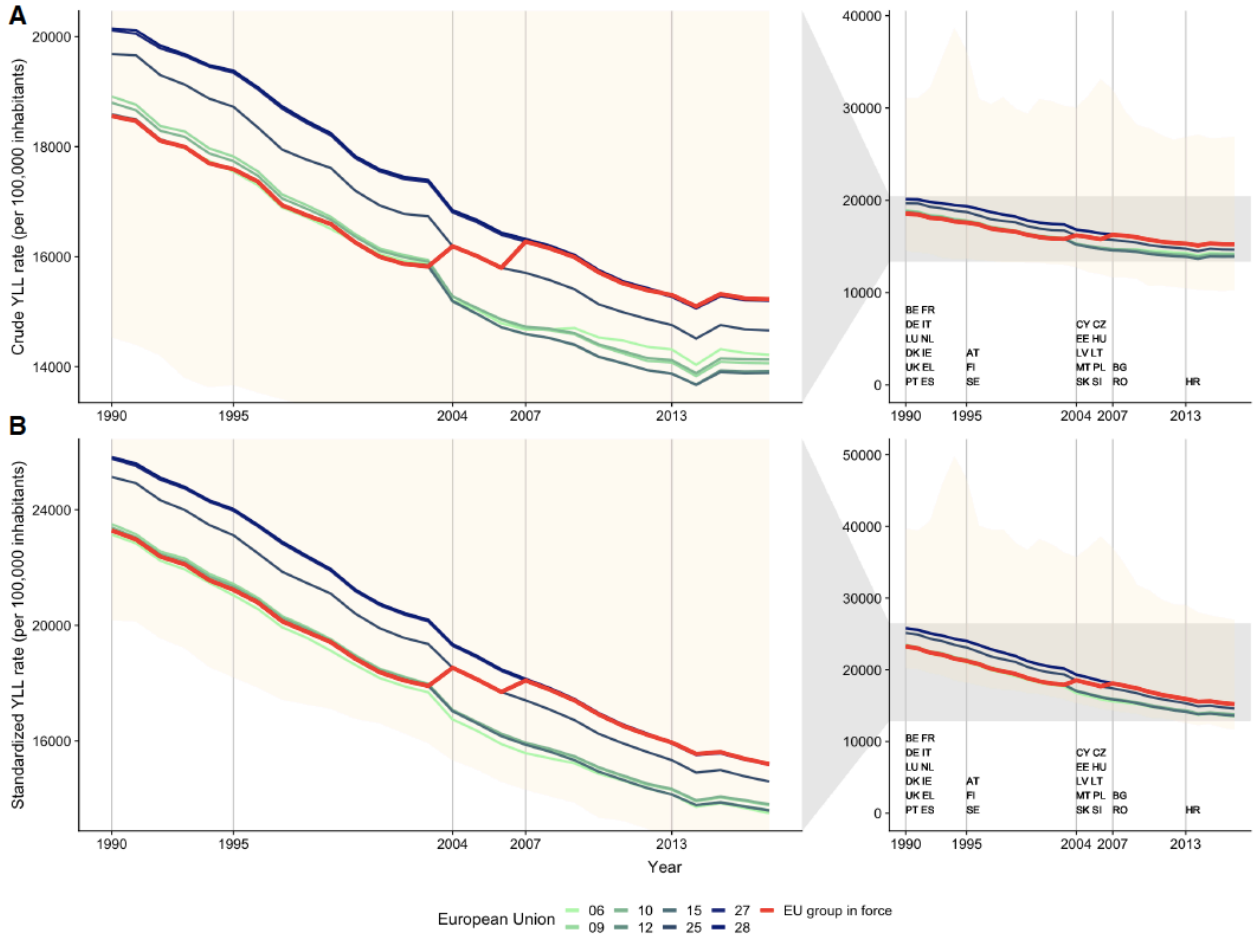
Age groups	Males	Females
0-4	2540,07	2411,09
5-9	2735,12	2595,77
10-14	2680,78	2544,72
15-19	2710,48	2557,87
20-24	2867,60	2728,92
25-29	3176,81	3085,35
30-34	3294,01	3240,58
35-39	3437,45	3396,57
40-44	3526,83	3496,82
45-49	3652,01	3654,28
50-54	3591,61	3636,90
55-59	3301,14	3433,84
60-64	2960,72	3191,44
65-69	2662,74	2981,62
70-74	2047,52	2417,10
75-79	1641,17	2140,21
80-85	1131,61	1713,72
85-89	601,92	1121,52
90-94	210,04	514,90
95+	86,71	280,46
TOTAL	100.000,02	

Supplementary Table 3 – Crude and age-sex-standardized rates (per 100,000 inhabitants) of mortality, years of life lost (YLLs), years lived with disability (YLDs) and Disability-adjusted life years (DALYs) in 1990, years of accession of new countries and 2017, in European Union and by European Union group. In bold are the rates of the EU groups in force in each year presented. The corresponding rate for the EU group in force of each year is presented in bold.

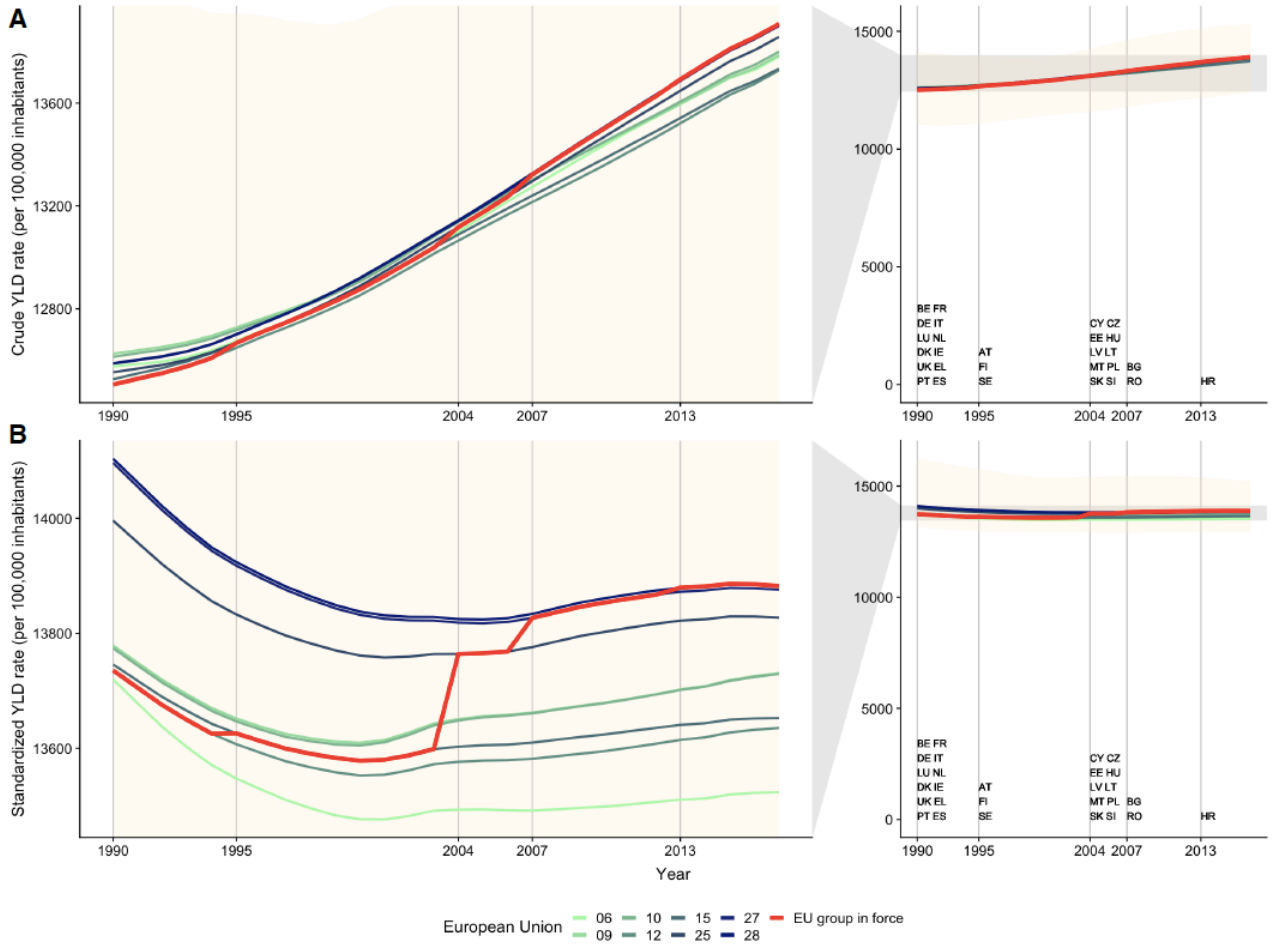
	Crude rate						Age-sex-standardized rate					
Mortality	**1990**	**1995**	**2004**	**2007**	**2013**	**2017**	**1990**	**1995**	**2004**	**2007**	**2013**	**2017**
EU6	1011	993	930	928	979	1012	1479	1351	1105	1040	968	926
EU9	1034	1016	935	925	953	984	1499	1380	1126	1058	979	943
EU10	1028	1010	935	926	956	990	1494	1376	1129	1062	981	945
EU12	**1005**	995	928	918	943	981	**1487**	1369	1127	1059	971	935
EU15	1008	**997**	930	920	942	978	1486	**1368**	1129	1061	972	935
EU25	1024	1014	**949**	943	961	993	1564	1449	**1197**	1129	1027	982
EU27	1028	1028	967	**962**	979	1014	1592	1486	1232	**1163**	1056	1011
EU28	1028	1029	969	964	**981**	**1015**	1595	1489	1236	1166	**1059**	**1013**
YLLs												
EU6	18,561	17,547	15,206	14,673	14,313	14,217	23,140	21,040	16,743	15,576	14,151	13,499
EU9	18,911	17,820	15,274	14,694	14,078	14,063	23,504	21,432	17,054	15,895	14,311	13,774
EU10	18,798	17,735	15,279	14,728	14,120	14,132	23,384	21,348	17,073	15,935	14,338	13,808
EU12	**18,556**	17,600	15,185	14,588	13,876	13,920	**23,283**	21,259	17,024	15,863	14,144	13,603
EU15	18,587	**17,588**	15,196	14,595	13,871	13,885	23,271	**21,226**	17,031	15,867	14,146	13,586
EU25	19,681	18,723	**16,189**	15,705	14,757	14,660	25,136	23,115	**18,529**	17,403	15,332	14,594
EU27	20,115	19,344	16,803	**16,274**	15,268	15,196	25,768	23,967	19,294	**18,090**	15,906	15,166
EU28	20,144	19,382	16,843	16,322	**15,303**	**15,227**	25,827	24,024	19,347	18,149	**15,945**	**15,199**
YLDs												
EU6	12,576	12,674	13,100	13,274	13,596	13,781	13,720	13,547	13,493	13,492	13,511	13,524
EU9	12,625	12,727	13,140	13,300	13,598	13,787	13,779	13,652	13,651	13,662	13,702	13,731
EU10	12,613	12,717	13,138	13,301	13,606	13,800	13,774	13,647	13,649	13,661	13,702	13,729
EU12	**12,505**	12,648	13,065	13,215	13,522	13,728	**13,736**	13,607	13,577	13,582	13,615	13,635
EU15	12,526	**12,667**	13,089	13,240	13,542	13,734	13,746	**13,626**	13,603	13,610	13,641	13,653
EU25	12,553	12,668	**13,118**	13,297	13,648	13,858	13,996	13,833	**13,764**	13,776	13,822	13,827
EU27	12,587	12,699	13,141	**13,322**	13,686	13,901	14,097	13,918	13,819	**13,827**	13,872	13,876
EU28	12,588	12,701	13,144	13,327	**13,693**	**13,908**	14,104	13,924	13,825	13,834	**13,880**	**13,883**

DALYs												
EU6	31,137	30,221	28,306	27,948	27,909	27,997	36,860	34,587	30,236	29,067	27,662	27,023
EU9	31,536	30,547	28,414	27,994	27,676	27,850	37,282	35,084	30,705	29,557	28,014	27,505
EU10	31,411	30,452	28,417	28,029	27,726	27,932	37,159	34,995	30,721	29,596	28,039	27,538
EU12	**31,061**	30,248	28,250	27,804	27,398	27,648	**37,018**	34,866	30,601	29,445	27,759	27,238
EU15	31,112	**30,255**	28,285	27,835	27,413	27,619	37,017	**34,852**	30,634	29,477	27,787	27,239
EU25	32,234	31,391	**29,307**	29,002	28,406	28,517	39,132	36,947	**32,293**	31,179	29,155	28,421
EU27	32,702	32,043	29,944	**29,596**	28,955	29,097	39,865	37,884	33,112	**31,917**	29,778	29,042
EU28	32,732	32,083	29,988	29,649	**28,995**	**29,135**	39,931	37,948	33,172	31,983	**29,824**	**29,082**

Supplementary Figure 1 – Crude (A) and age-sex-standardized (B) rates (per 100,000 inhabitants) of years of life lost (YLL) in European Union, by European Union group. In red are the lines of the EU groups in force in each year presented.



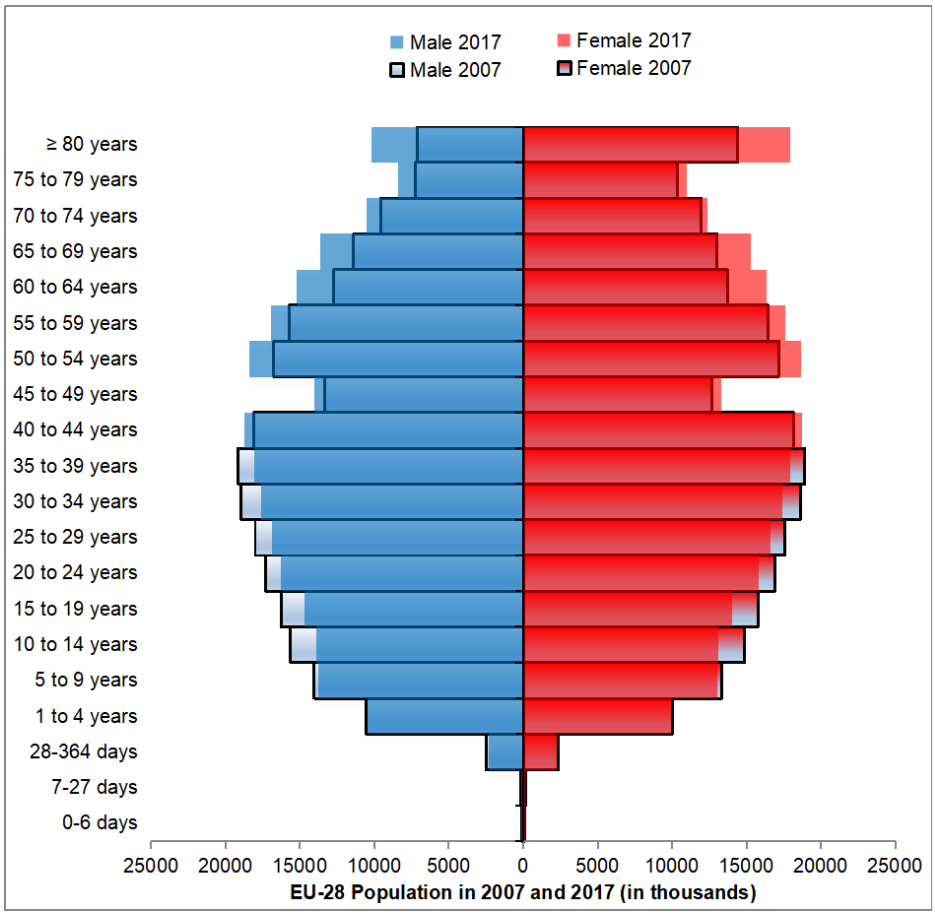
Supplementary Figure 2 – Crude (A) and age-sex-standardized (B) rates (per 100,000 inhabitants) of years lived with disability (YLD) in European Union, by European Union group. In red are the lines of the EU groups in force in each year presented.



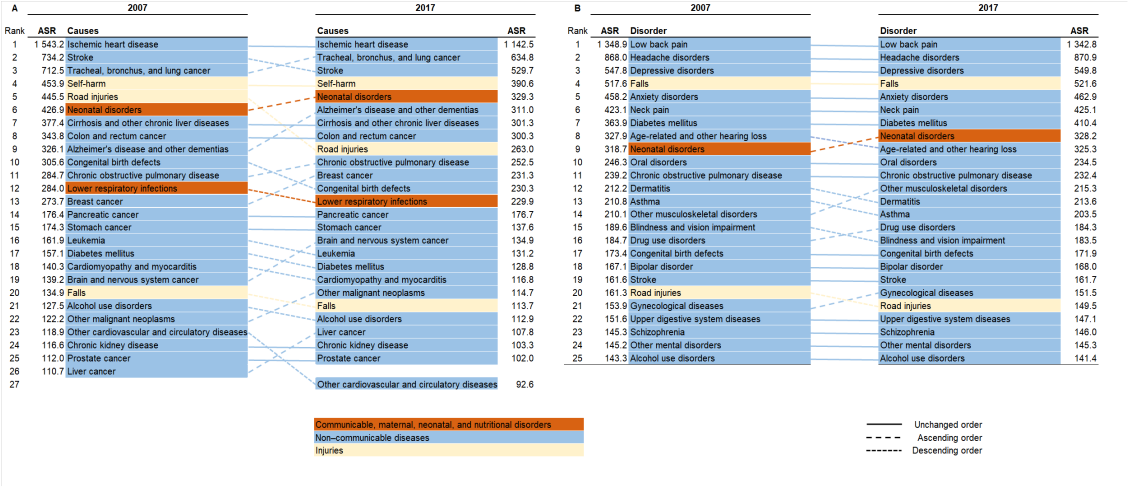
ANNEX 2

Supplementary material of paper 2 "The state of health in the European Union (EU-28) in 2017: An analysis of the burden of diseases and injuries".

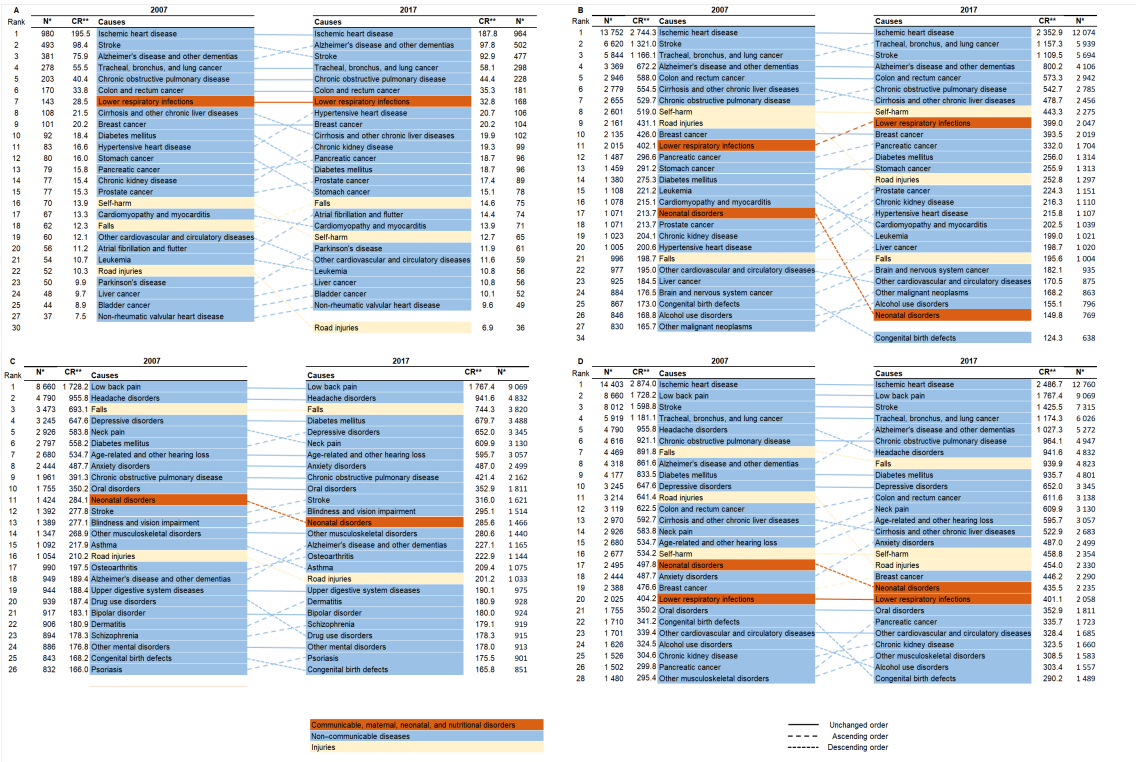
Supplementary Figure 1 – Population pyramid of the European Union (28 countries) in 2007 and 2017.



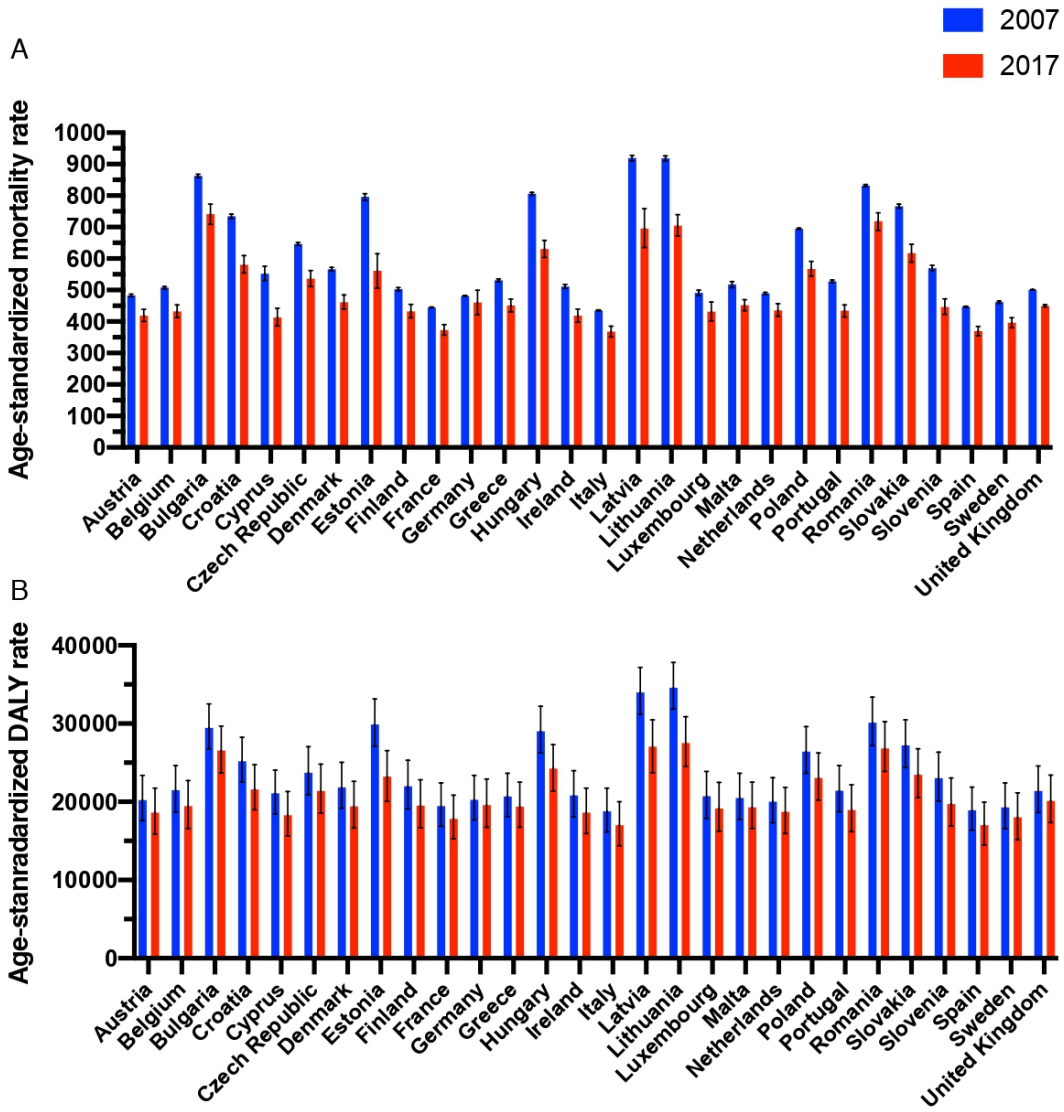
Supplementary Figure 2 – Ranks for top 25 causes (level 3) of age-standardized rate of (A) years of life lost and (B) years lived with disability in the European Union (28 countries), 2007 to 2017.



Supplementary Figure 3 – Ranks for top 25 causes (level 3) of number of (A) deaths, (B) years of life lost, (C) years lived with disability and (D) disability-adjusted life years – in thousands – in the European Union (28 countries), 2007 to 2017.



Supplementary Figure 4 – All-cause age-standardized rates of (A) mortality and (B) DALYs (per 100,000 inhabitants) by country in the European Union (28 countries) in 2007 and 2017.



Supplementary Table 1 – Top 10 causes of age-standardized rates of (A) mortality and (B) DALYs (per 100,000 inhabitants), by sex, in the European Union (28 countries) in 2017.

Causes		Mortality (ASR)		YLL (ASR)		YLD (ASR)		DALY (ASR)	
		2017	% 2007	2017	% 2007	2017	% 2007	2017	% 2007
Total	All causes	452.59 (444.60-460.18)	-14%	8 946.79 (8 782.71-9 099.76)	-18%	10 716.55 (8 060.45-13 838.30)	0%	19 663.35 (17 003.94-22 728.35)	-9%
A	Communicable. maternal. neonatal. and nutritional diseases	21.22 (20.76-21.66)	-16%	682.54 (655.22-707.48)	-23%	685.37 (513.32-881.45)	-1%	1 367.91 (1 196.02-1 567.04)	-13%
A.1	HIV/AIDS and sexually transmitted infections	0.69 (0.67-0.71)	-36%	31.63 (30.34-33.58)	-38%	24.83 (14.84-39.57)	5%	56.46 (46.44-71.10)	-24%
A.1.1	HIV/AIDS	0.64 (0.63-0.65)	-37%	29.07 (28.69-29.48)	-39%	12.65 (6.97-19.84)	13%	41.72 (35.96-49.04)	-29%
A.1.1.1	HIV/AIDS - Drug-susceptible Tuberculosis	0.07 (0.05-0.11)	-40%	3.36 (2.08-5.07)	-42%	0.11 (0.07-0.15)	-37%	3.47 (2.17-5.18)	-42%
A.1.1.2	HIV/AIDS - Multidrug-resistant Tuberculosis without extensive drug resistance	0.01 (0.00-0.01)	-45%	0.26 (0.16-0.40)	-47%	0.00 (0.00-0.01)	-36%	0.26 (0.16-0.41)	-47%
A.1.1.3	HIV/AIDS - Extensively drug-resistant Tuberculosis	0.00 (0.00-0.00)	-5%	0.11 (0.07-0.16)	-10%	0.00 (0.00-0.00)	15%	0.11 (0.07-0.17)	-10%
A.1.1.4	HIV/AIDS resulting in other diseases	0.56 (0.52-0.59)	-37%	25.34 (23.39-26.83)	-38%	12.54 (6.85-19.70)	14%	37.88 (32.31-45.44)	-27%
A.1.2	Sexually transmitted infections excluding HIV	0.05 (0.03-0.07)	-21%	2.56 (1.32-4.46)	-21%	12.18 (6.14-22.97)	-2%	14.74 (8.27-25.77)	-6%
A.1.2.1	Syphilis	0.03 (0.01-0.05)	-22%	2.07 (0.83-3.96)	-22%	0.84 (0.58-1.14)	-4%	2.91 (1.66-4.77)	-17%
A.1.2.2	Chlamydial infection	0.00 (0.00-0.00)	-19%	0.09 (0.09-0.10)	-17%	2.83 (1.39-5.70)	-2%	2.92 (1.48-5.79)	-2%
A.1.2.3	Gonococcal infection	0.01 (0.01-0.01)	-19%	0.26 (0.25-0.28)	-17%	1.56 (0.75-3.19)	-5%	1.82 (1.00-3.44)	-7%
A.1.2.4	Trichomoniasis	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	1.90 (0.77-4.05)	-2%	1.90 (0.77-4.05)	-2%
A.1.2.5	Genital herpes	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	2.33 (0.76-5.60)	0%	2.33 (0.76-5.60)	0%
A.1.2.6	Other sexually transmitted infections	0.00 (0.00-0.00)	-18%	0.14 (0.13-0.15)	-17%	2.72 (1.50-5.06)	-3%	2.86 (1.63-5.20)	-4%
A.2	Respiratory infections and tuberculosis	14.18 (13.84-14.54)	-12%	246.10 (239.96-252.20)	-21%	129.75 (76.99-204.17)	-1%	375.84 (325.50-450.19)	-15%
A.2.1	Tuberculosis	0.57 (0.55-0.59)	-41%	15.00 (14.41-15.60)	-46%	2.09 (1.38-2.90)	-21%	17.09 (16.09-18.11)	-44%
A.2.1.1	Latent tuberculosis infection	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%
A.2.1.2	Drug-susceptible tuberculosis	0.51 (0.49-0.53)	-41%	13.41 (12.72-14.03)	-45%	2.03 (1.34-2.82)	-21%	15.43 (14.42-16.46)	-43%
A.2.1.3	Multidrug-resistant tuberculosis without extensive drug resistance	0.04 (0.03-0.05)	-52%	1.05 (0.82-1.31)	-56%	0.05 (0.03-0.08)	-29%	1.11 (0.86-1.37)	-55%
A.2.1.4	Extensively drug-resistant tuberculosis	0.02 (0.01-0.02)	-17%	0.54 (0.41-0.68)	-24%	0.01 (0.01-0.01)	21%	0.54 (0.42-0.69)	-23%
A.2.2	Lower respiratory infections	13.58 (13.25-13.95)	-10%	229.92 (224.06-235.83)	-19%	2.11 (1.39-3.02)	-1%	232.03 (225.90-238.18)	-19%

A.2.3	Upper respiratory infections	0.02 (0.02-0.02)	-35%	1.01 (0.92-1.14)	-27%	104.24 (60.58-165.82)	0%	105.25 (61.57-166.82)	-1%
A.2.4	Otitis media	0.00 (0.00-0.00)	-2%	0.18 (0.15-0.20)	9%	21.30 (12.62-34.30)	-1%	21.48 (12.81-34.48)	-1%
A.3	Enteric infections	0.95 (0.90-1.01)	-10%	18.60 (17.18-20.38)	-16%	52.30 (35.24-72.95)	4%	70.90 (54.24-90.90)	-2%
A.3.1	Diarrheal diseases	0.91 (0.86-0.97)	-10%	16.86 (15.77-17.91)	-16%	52.29 (35.24-72.94)	4%	69.15 (52.26-89.55)	-2%
A.3.2	Typhoid and paratyphoid	0.00 (0.00-0.00)	-18%	0.03 (0.02-0.04)	-26%	0.00 (0.00-0.00)	-1%	0.03 (0.02-0.04)	-25%
A.3.2.1	Typhoid fever	0.00 (0.00-0.00)	-18%	0.02 (0.01-0.02)	-25%	0.00 (0.00-0.00)	40%	0.02 (0.01-0.02)	-24%
A.3.2.2	Paratyphoid fever	0.00 (0.00-0.00)	-19%	0.01 (0.00-0.02)	-30%	0.00 (0.00-0.00)	-16%	0.01 (0.00-0.02)	-28%
A.3.3	Invasive Non-typhoidal Salmonella (iNTS)	0.04 (0.02-0.06)	-12%	1.61 (0.76-3.11)	-11%	0.00 (0.00-0.01)	3%	1.62 (0.77-3.12)	-11%
A.3.5	Other intestinal infectious diseases	0.00 (0.00-0.00)	-26%	0.10 (0.05-0.17)	-32%	0.00 (0.00-0.00)	-34%	0.10 (0.05-0.17)	-32%
A.4	Neglected tropical diseases and malaria	0.02 (0.01-0.06)	-57%	0.84 (0.42-3.12)	-48%	12.60 (7.53-19.38)	-10%	13.44 (8.23-20.14)	-14%
A.4.1	Malaria	0.00 (0.00-0.00)	-100%	0.00 (0.00-0.00)	-100%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	-100%
A.4.2	Chagas disease	0.00 (0.00-0.00)	-100%	0.00 (0.00-0.00)	-100%	0.08 (0.05-0.11)	18%	0.08 (0.05-0.11)	-62%
A.4.3	Leishmaniasis	0.00 (0.00-0.04)	-70%	0.27 (0.00-2.57)	-63%	0.00 (0.00-0.00)	-54%	0.27 (0.00-2.57)	-63%
A.4.3.1	Visceral leishmaniasis	0.00 (0.00-0.04)	-70%	0.27 (0.00-2.57)	-63%	0.00 (0.00-0.00)	-62%	0.27 (0.00-2.57)	-63%
A.4.3.2	Cutaneous and mucocutaneous leishmaniasis	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	-10%	0.00 (0.00-0.00)	-10%
A.4.4	African trypanosomiasis	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%
A.4.5	Schistosomiasis	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%
A.4.6	Cysticercosis	0.00 (0.00-0.00)	-39%	0.02 (0.01-0.02)	-41%	9.92 (5.43-15.40)	-10%	9.94 (5.45-15.41)	-10%
A.4.7	Cystic echinococcosis	0.00 (0.00-0.01)	-42%	0.11 (0.06-0.15)	-45%	0.26 (0.16-0.39)	-4%	0.37 (0.27-0.51)	-21%
A.4.8	Lymphatic filariasis	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%
A.4.9	Onchocerciasis	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%
A.4.10	Trachoma	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%
A.4.11	Dengue	0.00 (0.00-0.00)	10%	0.04 (0.03-0.04)	10%	0.00 (0.00-0.00)	0%	0.04 (0.03-0.04)	10%
A.4.12	Yellow fever	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%
A.4.13	Rabies	0.00 (0.00-0.00)	-21%	0.02 (0.02-0.02)	-23%	0.00 (0.00-0.00)	-29%	0.02 (0.02-0.02)	-23%
A.4.14	Intestinal nematode infections	0.00 (0.00-0.00)	-40%	0.00 (0.00-0.00)	-45%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	-45%
A.4.14.1	Ascariasis	0.00 (0.00-0.00)	-40%	0.00 (0.00-0.00)	-45%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	-45%
A.4.14.2	Trichuriasis	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%

A.4.14.3	Hookworm disease	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%
A.4.15	Food-borne trematodiases	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	2.34 (0.51-5.50)	-8%	2.34 (0.51-5.50)	-8%
A.4.16	Leprosy	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	-7%	0.00 (0.00-0.00)	-7%
A.4.17	Ebola	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%
A.4.18	Zika virus	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%
A.4.19	Guinea worm disease	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%
A.4.20	Other neglected tropical diseases	0.01 (0.00-0.01)	-6%	0.39 (0.23-0.60)	-10%	0.00 (0.00-0.00)	-45%	0.39 (0.23-0.60)	-10%
A.5	Other infectious diseases	1.15 (1.01-1.20)	-19%	46.47 (43.45-50.38)	-23%	19.24 (13.08-27.03)	-5%	65.71 (59.03-74.42)	-18%
A.5.1	Meningitis	0.31 (0.30-0.37)	-31%	16.26 (15.17-20.28)	-35%	3.36 (2.34-4.51)	-17%	19.62 (17.97-23.55)	-33%
A.5.1.1	Pneumococcal meningitis	0.07 (0.07-0.09)	-28%	3.33 (3.06-4.16)	-32%	0.58 (0.40-0.80)	-58%	3.91 (3.58-4.67)	-38%
A.5.1.2	H influenzae type B meningitis	0.11 (0.10-0.13)	-33%	6.54 (6.06-8.23)	-37%	0.13 (0.09-0.19)	-41%	6.68 (6.18-8.35)	-37%
A.5.1.3	Meningococcal meningitis	0.03 (0.03-0.03)	-34%	1.57 (1.40-1.95)	-38%	0.54 (0.37-0.74)	-25%	2.12 (1.87-2.49)	-35%
A.5.1.4	Other meningitis	0.10 (0.09-0.12)	-29%	4.81 (4.42-5.93)	-34%	2.10 (1.46-2.86)	22%	6.92 (6.08-8.04)	-23%
A.5.2	Encephalitis	0.23 (0.19-0.24)	-9%	9.53 (8.27-10.67)	-15%	1.56 (1.07-2.12)	-4%	11.09 (9.78-12.21)	-14%
A.5.3	Diphtheria	0.00 (0.00-0.00)	-32%	0.01 (0.01-0.01)	-25%	0.00 (0.00-0.00)	-53%	0.01 (0.01-0.01)	-25%
A.5.4	Whooping cough	0.01 (0.00-0.01)	10%	0.61 (0.10-1.05)	10%	0.55 (0.32-0.87)	-4%	1.16 (0.55-1.75)	3%
A.5.5	Tetanus	0.00 (0.00-0.00)	-40%	0.08 (0.07-0.09)	-41%	0.00 (0.00-0.00)	-40%	0.08 (0.07-0.09)	-41%
A.5.6	Measles	0.00 (0.00-0.00)	-23%	0.16 (0.11-0.18)	-24%	0.02 (0.01-0.02)	20%	0.17 (0.13-0.20)	-21%
A.5.7	Varicella and herpes zoster	0.05 (0.03-0.08)	-17%	1.20 (0.63-2.51)	-19%	3.36 (2.02-5.05)	0%	4.56 (3.04-6.56)	-6%
A.5.8	Acute hepatitis	0.13 (0.12-0.13)	-46%	3.83 (3.57-4.17)	-44%	3.73 (2.41-5.52)	-1%	7.56 (6.25-9.33)	-29%
A.5.8.1	Acute hepatitis A	0.03 (0.03-0.04)	-43%	1.48 (1.33-1.70)	-42%	2.52 (1.59-3.70)	-1%	4.00 (3.06-5.21)	-21%
A.5.8.2	Acute hepatitis B	0.07 (0.06-0.08)	-47%	1.80 (1.61-2.01)	-46%	0.97 (0.62-1.49)	0%	2.77 (2.36-3.32)	-35%
A.5.8.3	Acute hepatitis C	0.00 (0.00-0.01)	-52%	0.16 (0.10-0.24)	-49%	0.05 (0.03-0.10)	-17%	0.21 (0.13-0.33)	-44%
A.5.8.4	Acute hepatitis E	0.02 (0.01-0.02)	-43%	0.40 (0.33-0.48)	-42%	0.18 (0.11-0.27)	-2%	0.58 (0.47-0.71)	-34%
A.5.9	Other unspecified infectious diseases	0.42 (0.29-0.45)	1%	14.79 (11.84-18.09)	-1%	6.66 (4.21-10.33)	-2%	21.45 (17.58-26.03)	-1%
A.6	Maternal and neonatal disorders	3.82 (3.56-4.07)	-23%	333.21 (309.96-354.70)	-23%	331.52 (241.88-441.52)	3%	664.73 (573.68-775.66)	-12%
A.6.1	Maternal disorders	0.07 (0.07-0.07)	-24%	3.92 (3.74-4.08)	-24%	3.30 (2.17-4.71)	8%	7.21 (6.08-8.71)	-12%
A.6.1.1	Maternal hemorrhage	0.01 (0.01-0.01)	-28%	0.51 (0.41-0.62)	-28%	0.61 (0.40-0.88)	-17%	1.11 (0.88-1.39)	-23%

A.6.1.2	Maternal sepsis and other maternal infections	0.00 (0.00-0.01)	-33%	0.23 (0.19-0.29)	-34%	0.26 (0.12-0.46)	0%	0.49 (0.35-0.69)	-20%
A.6.1.3	Maternal hypertensive disorders	0.01 (0.01-0.01)	-31%	0.39 (0.31-0.47)	-31%	1.40 (0.79-2.28)	21%	1.78 (1.17-2.69)	4%
A.6.1.4	Maternal obstructed labor and uterine rupture	0.00 (0.00-0.00)	-34%	0.10 (0.09-0.12)	-34%	0.43 (0.22-0.72)	2%	0.53 (0.33-0.82)	-8%
A.6.1.5	Maternal abortion and miscarriage	0.01 (0.01-0.01)	-35%	0.55 (0.48-0.65)	-36%	0.14 (0.08-0.22)	1%	0.69 (0.59-0.81)	-31%
A.6.1.6	Ectopic pregnancy	0.00 (0.00-0.00)	-41%	0.08 (0.06-0.12)	-42%	0.01 (0.00-0.01)	-2%	0.09 (0.06-0.13)	-40%
A.6.1.7	Indirect maternal deaths	0.01 (0.00-0.01)	-22%	0.31 (0.25-0.38)	-23%	0.00 (0.00-0.00)	0%	0.31 (0.25-0.38)	-23%
A.6.1.8	Late maternal deaths	0.00 (0.00-0.00)	-10%	0.17 (0.12-0.27)	-11%	0.00 (0.00-0.00)	0%	0.17 (0.12-0.27)	-11%
A.6.1.9	Maternal deaths aggravated by HIV/AIDS	0.00 (0.00-0.00)	-27%	0.00 (0.00-0.00)	-29%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	-29%
A.6.1.10	Other maternal disorders	0.03 (0.03-0.03)	-12%	1.58 (1.41-1.79)	-12%	0.47 (0.31-0.68)	38%	2.05 (1.79-2.32)	-4%
A.6.2	Neonatal disorders	3.75 (3.49-3.99)	-23%	329.29 (306.05-350.70)	-23%	328.22 (239.48-438.39)	3%	657.52 (566.68-768.94)	-12%
A.6.2.1	Neonatal preterm birth	2.00 (1.86-2.13)	-23%	175.80 (163.12-187.20)	-23%	124.48 (87.69-172.15)	4%	300.28 (259.66-350.22)	-14%
A.6.2.2	Neonatal encephalopathy due to birth asphyxia and trauma	0.76 (0.67-0.84)	-20%	66.67 (59.01-73.56)	-20%	77.99 (48.28-119.86)	4%	144.65 (113.50-186.66)	-9%
A.6.2.3	Neonatal sepsis and other neonatal infections	0.22 (0.18-0.32)	-26%	19.55 (16.13-27.76)	-26%	110.60 (59.43-184.35)	2%	130.14 (79.13-203.59)	-4%
A.6.2.4	Hemolytic disease and other neonatal jaundice	0.02 (0.01-0.02)	-34%	1.33 (1.20-1.50)	-34%	3.33 (2.47-4.29)	-4%	4.66 (3.79-5.63)	-15%
A.6.2.5	Other neonatal disorders	0.75 (0.67-0.82)	-25%	65.95 (58.69-71.87)	-25%	11.83 (8.73-15.62)	4%	77.78 (69.79-84.96)	-22%
A.7	Nutritional deficiencies	0.41 (0.39-0.43)	-4%	5.70 (5.49-5.98)	-10%	115.13 (72.20-183.10)	-11%	120.83 (77.89-188.84)	-11%
A.7.1	Protein-energy malnutrition	0.31 (0.21-0.36)	-2%	3.93 (2.90-4.39)	-6%	0.17 (0.04-0.41)	-46%	4.10 (3.08-4.66)	-9%
A.7.2	Iodine deficiency	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	11.77 (5.87-21.81)	2%	11.77 (5.87-21.81)	2%
A.7.3	Vitamin A deficiency	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	15.17 (9.03-24.52)	-24%	15.17 (9.03-24.52)	-24%
A.7.4	Dietary iron deficiency	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	87.99 (55.63-137.14)	-10%	87.99 (55.63-137.14)	-10%
A.7.5	Other nutritional deficiencies	0.10 (0.07-0.19)	-12%	1.77 (1.35-2.79)	-18%	0.02 (0.00-0.04)	-48%	1.79 (1.38-2.79)	-18%
B	Non-communicable diseases	402.88 (395.55-409.92)	-13%	7 224.87 (7 087.85-7 355.66)	-16%	9 011.35 (6 763.22-11 625.92)	0%	16 236.22 (13 977.84-18 837.95)	-8%
B.1	Neoplasms	134.22 (131.12-137.08)	-8%	2 884.26 (2 819.93-2 948.71)	-11%	161.46 (117.59-210.62)	3%	3 045.72 (2 963.18-3 133.01)	-10%
B.1.1	Lip and oral cavity cancer	1.80 (1.74-1.87)	-11%	45.00 (43.24-46.82)	-15%	2.24 (1.62-2.94)	-5%	47.24 (45.33-49.31)	-15%
B.1.2	Nasopharynx cancer	0.46 (0.44-0.48)	-16%	11.82 (11.25-12.50)	-19%	0.38 (0.28-0.51)	-18%	12.21 (11.62-12.92)	-19%
B.1.3	Other pharynx cancer	1.38 (1.32-1.45)	-4%	37.98 (36.15-39.86)	-8%	1.15 (0.82-1.50)	7%	39.13 (37.18-41.12)	-7%

B.1.4	Esophageal cancer	3.36 (3.25-3.48)	-8%	75.19 (72.56-77.92)	-11%	1.11 (0.80-1.44)	-3%	76.30 (73.73-79.12)	-10%
B.1.5	Stomach cancer	6.99 (6.76-7.22)	-19%	137.56 (132.80-142.27)	-21%	3.06 (2.27-3.92)	-6%	140.62 (135.67-145.41)	-21%
B.1.6	Colon and rectum cancer	16.00 (15.46-16.54)	-11%	300.26 (289.74-310.76)	-13%	19.37 (14.32-25.16)	-2%	319.63 (307.40-332.00)	-12%
B.1.7	Liver cancer	5.18 (5.03-5.35)	-2%	107.82 (104.26-111.44)	-3%	1.52 (1.08-2.00)	4%	109.33 (105.77-113.06)	-3%
B.1.7.1	Liver cancer due to hepatitis B	0.63 (0.53-0.73)	-6%	16.36 (14.05-18.90)	-7%	0.21 (0.14-0.29)	2%	16.57 (14.22-19.13)	-7%
B.1.7.2	Liver cancer due to hepatitis C	2.07 (1.88-2.27)	-2%	39.13 (35.27-42.97)	-2%	0.58 (0.41-0.77)	2%	39.71 (35.77-43.75)	-2%
B.1.7.3	Liver cancer due to alcohol use	1.84 (1.67-2.02)	-1%	38.87 (35.10-43.04)	-2%	0.54 (0.39-0.72)	5%	39.41 (35.63-43.64)	-2%
B.1.7.4	Liver cancer due to NASH	0.41 (0.35-0.47)	3%	7.70 (6.68-8.76)	2%	0.11 (0.08-0.15)	10%	7.81 (6.79-8.88)	2%
B.1.7.5	Liver cancer due to other causes	0.24 (0.21-0.28)	-2%	5.75 (4.99-6.54)	-3%	0.08 (0.05-0.10)	7%	5.83 (5.06-6.63)	-3%
B.1.8	Gallbladder and biliary tract cancer	2.19 (2.07-2.30)	-14%	39.97 (37.76-42.01)	-15%	0.75 (0.53-0.99)	-5%	40.72 (38.56-42.94)	-15%
B.1.9	Pancreatic cancer	8.81 (8.55-9.11)	2%	176.74 (171.34-183.12)	0%	1.78 (1.25-2.33)	-1%	178.52 (173.05-184.66)	0%
B.1.10	Larynx cancer	1.37 (1.32-1.41)	-18%	33.14 (32.05-34.33)	-21%	2.01 (1.45-2.64)	-6%	35.15 (33.88-36.52)	-21%
B.1.11	Tracheal. bronchus. and lung cancer	28.79 (27.91-29.67)	-8%	634.83 (615.06-654.84)	-11%	8.82 (6.43-11.19)	1%	643.65 (623.93-665.14)	-11%
B.1.12	Malignant skin melanoma	1.88 (1.26-2.06)	0%	48.60 (33.66-55.68)	-4%	6.94 (4.15-10.01)	17%	55.54 (37.94-63.41)	-1%
B.1.13	Non-melanoma skin cancer	0.79 (0.76-0.82)	-7%	12.82 (12.30-13.37)	-12%	0.59 (0.34-1.03)	21%	13.41 (12.83-14.09)	-11%
B.1.13.1	Non-melanoma skin cancer (squamous-cell carcinoma)	0.79 (0.76-0.82)	-7%	12.82 (12.30-13.37)	-12%	0.56 (0.31-0.99)	21%	13.37 (12.81-14.07)	-11%
B.1.13.2	Non-melanoma skin cancer (basal-cell carcinoma)	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.03 (0.01-0.07)	17%	0.03 (0.01-0.07)	17%
B.1.14	Breast cancer	9.99 (9.61-10.40)	-14%	231.28 (222.26-240.90)	-15%	30.68 (21.41-41.75)	-5%	261.97 (247.36-277.28)	-14%
B.1.15	Cervical cancer	1.83 (1.76-1.90)	-18%	49.21 (47.22-51.21)	-19%	2.54 (1.78-3.37)	-11%	51.75 (49.60-53.99)	-19%
B.1.16	Uterine cancer	1.35 (1.30-1.41)	-1%	26.42 (25.26-27.60)	-1%	5.39 (3.82-7.25)	15%	31.81 (29.75-33.94)	1%
B.1.17	Ovarian cancer	3.34 (3.19-3.49)	-11%	76.15 (72.56-79.50)	-12%	3.34 (2.41-4.34)	-11%	79.49 (75.76-83.03)	-12%
B.1.18	Prostate cancer	7.18 (5.77-9.31)	-6%	101.98 (83.46-135.19)	-9%	20.77 (14.60-29.56)	2%	122.75 (99.43-163.15)	-7%
B.1.19	Testicular cancer	0.14 (0.13-0.15)	-17%	6.25 (5.89-6.61)	-20%	2.12 (1.44-2.95)	3%	8.37 (7.57-9.30)	-15%
B.1.20	Kidney cancer	3.44 (3.07-3.59)	-1%	72.76 (66.92-76.06)	-4%	3.25 (2.29-4.44)	-2%	76.01 (69.78-79.64)	-4%
B.1.21	Bladder cancer	4.33 (4.17-4.47)	-5%	70.09 (67.39-72.71)	-8%	6.88 (5.06-9.07)	-1%	76.97 (73.68-80.64)	-7%
B.1.22	Brain and nervous system cancer	4.16 (3.29-4.42)	-1%	134.87 (113.19-147.70)	-3%	4.68 (3.32-6.41)	22%	139.55 (116.85-152.62)	-2%
B.1.23	Thyroid cancer	0.42 (0.40-0.44)	-13%	8.80 (8.42-9.19)	-16%	2.30 (1.60-3.22)	-6%	11.10 (10.26-12.14)	-14%
B.1.24	Mesothelioma	0.97 (0.93-1.02)	2%	19.36 (18.54-20.38)	-3%	0.50 (0.35-0.66)	0%	19.86 (18.99-20.94)	-3%

B.1.25	Hodgkin lymphoma	0.36 (0.31-0.46)	-22%	12.05 (10.79-15.98)	-24%	1.96 (1.31-2.93)	0%	14.01 (12.41-18.82)	-22%
B.1.26	Non-Hodgkin lymphoma	3.62 (3.50-3.74)	-6%	80.66 (77.60-83.48)	-10%	5.08 (3.63-6.77)	9%	85.74 (82.25-89.44)	-9%
B.1.27	Multiple myeloma	2.22 (1.91-2.60)	-2%	41.31 (36.55-49.84)	-5%	2.58 (1.78-3.42)	7%	43.89 (38.78-52.87)	-4%
B.1.28	Leukemia	5.35 (5.15-5.54)	-14%	131.19 (125.23-136.66)	-19%	5.11 (3.76-6.62)	-8%	136.30 (130.10-142.41)	-19%
B.1.28.1	Acute lymphoid leukemia	0.48 (0.46-0.50)	-20%	22.53 (21.39-24.02)	-23%	0.93 (0.62-1.30)	-9%	23.46 (22.21-25.15)	-22%
B.1.28.2	Chronic lymphoid leukemia	1.01 (0.96-1.05)	-13%	16.04 (15.32-16.90)	-16%	2.51 (1.84-3.23)	-4%	18.55 (17.48-19.72)	-15%
B.1.28.3	Acute myeloid leukemia	2.08 (1.97-2.18)	-2%	54.16 (50.82-57.32)	-7%	0.55 (0.39-0.72)	-2%	54.71 (51.23-57.87)	-7%
B.1.28.4	Chronic myeloid leukemia	0.42 (0.40-0.44)	-32%	8.50 (8.11-8.98)	-37%	0.22 (0.16-0.30)	-28%	8.72 (8.34-9.20)	-37%
B.1.28.5	Other leukemia	1.36 (1.31-1.42)	-21%	29.97 (28.78-31.49)	-29%	0.89 (0.64-1.16)	-14%	30.86 (29.59-32.44)	-28%
B.1.29	Other malignant neoplasms	4.29 (3.81-4.55)	-4%	114.75 (105.62-126.77)	-6%	14.01 (9.81-19.19)	57%	128.75 (118.26-144.68)	-2%
B.1.30	Other neoplasms	2.23 (1.45-2.91)	2%	45.38 (30.73-62.90)	0%	0.56 (0.36-0.82)	-4%	45.95 (31.23-63.50)	-1%
B.1.30.1	Myelodysplastic. myeloproliferative. and other hematopoietic neoplasms	2.17 (1.42-2.84)	2%	42.13 (28.55-58.33)	0%	0.56 (0.36-0.82)	-4%	42.69 (29.10-58.94)	0%
B.1.30.2	Benign and in situ intestinal neoplasms	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%
B.1.30.3	Benign and in situ cervical and uterine neoplasms	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%
B.1.30.4	Other benign and in situ neoplasms	0.05 (0.03-0.07)	-3%	3.25 (2.06-4.59)	-3%	0.00 (0.00-0.00)	0%	3.25 (2.06-4.59)	-3%
B.2	Cardiovascular diseases	150.45 (147.27-153.78)	-20%	2 202.13 (2 154.71-2 254.62)	-24%	411.46 (305.39-529.87)	-2%	2 613.59 (2 493.48-2 744.73)	-21%
B.2.1	Rheumatic heart disease	1.60 (1.53-1.72)	-20%	25.61 (24.57-27.12)	-26%	0.51 (0.35-0.71)	-9%	26.12 (25.05-27.60)	-26%
B.2.2	Ischemic heart disease	77.07 (74.94-81.10)	-23%	1 142.49 (1 109.87-1 189.53)	-26%	67.59 (46.58-92.21)	-8%	1 210.08 (1 172.72-1 257.57)	-25%
B.2.3	Stroke	37.52 (36.51-39.50)	-24%	529.65 (515.89-552.13)	-28%	161.69 (117.81-204.26)	0%	691.34 (643.38-736.58)	-23%
B.2.3.1	Ischemic stroke	20.29 (19.71-21.39)	-24%	234.07 (227.66-243.47)	-27%	124.82 (91.35-157.53)	2%	358.89 (324.00-392.19)	-19%
B.2.3.2	Intracerebral hemorrhage	13.99 (13.55-14.70)	-26%	222.74 (215.51-230.80)	-30%	18.21 (13.25-23.32)	-14%	240.95 (231.89-250.33)	-29%
B.2.3.3	Subarachnoid hemorrhage	3.25 (3.13-3.68)	-20%	72.84 (69.92-83.35)	-24%	18.66 (13.41-23.71)	0%	91.50 (85.29-101.14)	-20%
B.2.4	Hypertensive heart disease	7.98 (4.51-8.70)	-4%	97.24 (67.92-106.05)	-10%	13.00 (8.81-17.93)	-10%	110.23 (80.63-121.46)	-10%
B.2.5	Non-rheumatic valvular heart disease	3.76 (2.97-3.99)	1%	47.98 (40.60-51.29)	-4%	8.08 (4.63-12.53)	1%	56.06 (48.12-61.53)	-4%
B.2.5.1	Non-rheumatic calcific aortic valve disease	3.08 (2.28-3.30)	4%	37.84 (30.75-40.21)	-1%	4.74 (2.67-7.32)	3%	42.58 (35.13-46.31)	-1%
B.2.5.2	Non-rheumatic degenerative mitral valve disease	0.64 (0.53-0.90)	-11%	9.43 (7.98-12.55)	-15%	3.32 (1.89-5.20)	-2%	12.75 (10.70-16.05)	-12%

B.2.5.3	Other non-rheumatic valve diseases	0.04 (0.02-0.05)	7%	0.72 (0.48-0.95)	-2%	0.02 (0.01-0.03)	-4%	0.74 (0.49-0.97)	-2%
B.2.6	Cardiomyopathy and myocarditis	6.11 (5.53-6.36)	-15%	116.82 (109.55-122.26)	-17%	14.98 (10.24-20.60)	0%	131.80 (123.67-140.05)	-15%
B.2.6.1	Myocarditis	0.75 (0.54-0.85)	-30%	14.14 (10.83-15.61)	-24%	2.13 (1.47-2.92)	-2%	16.27 (12.91-18.16)	-22%
B.2.6.2	Alcoholic cardiomyopathy	1.25 (0.91-1.42)	-17%	35.04 (26.62-38.55)	-18%	4.32 (2.95-6.03)	0%	39.36 (30.78-43.19)	-16%
B.2.6.3	Other cardiomyopathy	4.11 (3.85-4.41)	-11%	67.64 (64.32-77.01)	-14%	8.53 (5.78-11.85)	0%	76.17 (71.64-85.73)	-13%
B.2.7	Atrial fibrillation and flutter	5.33 (5.07-6.18)	-2%	53.47 (50.69-63.30)	-3%	47.66 (32.66-64.96)	-4%	101.12 (85.22-120.16)	-4%
B.2.8	Aortic aneurysm	2.94 (2.85-3.03)	-19%	50.59 (48.83-52.29)	-20%	0.00 (0.00-0.00)	0%	50.59 (48.83-52.29)	-20%
B.2.9	Peripheral artery disease	1.76 (0.98-3.13)	10%	22.80 (12.37-38.97)	9%	5.61 (2.71-9.85)	-8%	28.41 (17.64-45.58)	5%
B.2.10	Endocarditis	1.29 (1.01-1.54)	0%	22.87 (18.72-27.76)	-5%	1.04 (0.70-1.44)	-2%	23.91 (19.83-28.71)	-4%
B.2.11	Other cardiovascular and circulatory diseases	5.08 (4.88-5.32)	-21%	92.61 (89.36-95.88)	-22%	91.30 (61.94-127.64)	1%	183.92 (154.26-220.94)	-12%
B.3	Chronic respiratory diseases	20.90 (20.35-21.52)	-11%	306.20 (297.81-315.45)	-12%	461.34 (363.32-574.68)	-3%	767.54 (671.88-879.02)	-7%
B.3.1	Chronic obstructive pulmonary disease	18.03 (17.39-18.84)	-11%	252.55 (243.62-264.04)	-11%	232.43 (193.02-271.64)	-3%	484.98 (444.68-526.61)	-7%
B.3.2	Pneumoconiosis	0.23 (0.22-0.25)	-25%	3.22 (3.01-3.44)	-30%	0.33 (0.22-0.47)	-13%	3.56 (3.32-3.80)	-28%
B.3.2.1	Silicosis	0.11 (0.10-0.14)	-35%	1.46 (1.28-1.90)	-40%	0.10 (0.06-0.15)	-17%	1.56 (1.37-2.00)	-39%
B.3.2.2	Asbestosis	0.08 (0.03-0.09)	5%	1.13 (0.54-1.32)	0%	0.06 (0.04-0.09)	-9%	1.19 (0.61-1.39)	-1%
B.3.2.3	Coal workers pneumoconiosis	0.03 (0.03-0.04)	-32%	0.44 (0.39-0.59)	-35%	0.07 (0.05-0.10)	-13%	0.51 (0.45-0.67)	-33%
B.3.2.4	Other pneumoconiosis	0.01 (0.01-0.02)	-36%	0.20 (0.15-0.26)	-37%	0.10 (0.06-0.15)	-9%	0.30 (0.24-0.37)	-30%
B.3.3	Asthma	0.62 (0.58-0.65)	-32%	13.22 (12.55-14.02)	-36%	203.50 (133.49-289.00)	-3%	216.72 (146.76-301.89)	-6%
B.3.4	Interstitial lung disease and pulmonary sarcoidosis	1.83 (1.23-2.09)	7%	31.39 (22.35-35.27)	3%	8.44 (5.64-11.95)	2%	39.82 (29.99-45.73)	3%
B.3.5	Other chronic respiratory diseases	0.20 (0.19-0.21)	-11%	5.82 (5.40-6.13)	-15%	16.64 (13.28-19.94)	10%	22.46 (19.11-25.88)	2%
B.4	Digestive diseases	22.04 (21.23-22.76)	-15%	486.31 (465.54-504.21)	-18%	270.81 (190.86-369.49)	-1%	757.12 (670.52-860.26)	-12%
B.4.1	Cirrhosis and other chronic liver diseases	10.96 (10.51-11.44)	-18%	301.28 (288.46-314.25)	-20%	31.52 (22.17-43.03)	10%	332.79 (316.61-350.30)	-18%
B.4.1.1	Cirrhosis and other chronic liver diseases due to hepatitis B	1.38 (1.20-1.59)	-24%	40.13 (34.90-46.17)	-26%	3.54 (2.49-4.86)	4%	43.67 (38.11-49.87)	-24%
B.4.1.2	Cirrhosis and other chronic liver diseases due to hepatitis C	2.31 (1.98-2.74)	-19%	63.16 (53.45-75.75)	-21%	6.58 (4.56-9.06)	13%	69.74 (59.33-82.65)	-19%
B.4.1.3	Cirrhosis and other chronic liver diseases due to alcohol use	4.78 (4.27-5.24)	-17%	135.58 (121.08-148.07)	-20%	12.96 (9.14-17.74)	10%	148.54 (133.28-161.81)	-18%
B.4.1.4	Cirrhosis due to NASH	0.97 (0.77-1.20)	-13%	26.31 (20.73-32.81)	-15%	2.52 (1.74-3.54)	17%	28.82 (23.10-35.40)	-13%
B.4.1.5	Cirrhosis and other chronic liver diseases due to other causes	1.52 (1.22-1.88)	-13%	36.10 (29.17-45.38)	-16%	5.92 (4.08-8.07)	8%	42.02 (34.26-51.67)	-13%
B.4.2	Upper digestive system diseases	1.75 (1.69-1.83)	-23%	31.21 (29.75-32.44)	-24%	147.15 (92.51-227.14)	-3%	178.36 (123.66-258.08)	-7%

B.4.2.1	Peptic ulcer disease	1.60 (1.55-1.68)	-24%	28.33 (27.00-29.45)	-25%	6.82 (4.55-9.74)	-4%	35.15 (32.41-38.36)	-22%
B.4.2.2	Gastritis and duodenitis	0.15 (0.14-0.15)	-7%	2.89 (2.73-3.07)	-10%	65.13 (41.71-95.30)	-6%	68.02 (44.70-98.10)	-6%
B.4.2.3	Gastroesophageal reflux disease	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	75.19 (40.27-127.27)	0%	75.19 (40.27-127.27)	0%
B.4.3	Appendicitis	0.12 (0.11-0.12)	-23%	2.58 (2.41-2.71)	-26%	1.80 (1.16-2.48)	-1%	4.37 (3.74-5.07)	-18%
B.4.4	Paralytic ileus and intestinal obstruction	2.05 (1.70-2.40)	-8%	31.94 (26.90-37.43)	-9%	0.50 (0.34-0.68)	5%	32.44 (27.34-37.81)	-9%
B.4.5	Inguinal. femoral. and abdominal hernia	0.41 (0.34-0.53)	-11%	5.60 (4.78-7.02)	-13%	47.86 (32.10-66.53)	0%	53.46 (37.68-72.23)	-1%
B.4.6	Inflammatory bowel disease	0.90 (0.51-1.02)	0%	15.58 (9.20-17.49)	-3%	21.22 (14.75-28.88)	-5%	36.80 (28.05-45.28)	-4%
B.4.7	Vascular intestinal disorders	1.88 (1.73-1.97)	-15%	27.35 (25.17-28.84)	-14%	0.56 (0.38-0.76)	6%	27.91 (25.70-29.43)	-14%
B.4.8	Gallbladder and biliary diseases	1.32 (1.23-1.42)	1%	16.97 (15.85-17.97)	-2%	0.47 (0.32-0.66)	5%	17.44 (16.40-18.45)	-2%
B.4.9	Pancreatitis	1.30 (1.18-1.38)	-15%	33.15 (30.48-34.87)	-17%	7.86 (3.96-13.41)	-1%	41.02 (36.29-47.16)	-15%
B.4.10	Other digestive diseases	1.34 (1.28-1.44)	-11%	20.65 (19.58-21.64)	-12%	11.88 (8.15-15.95)	6%	32.53 (28.72-36.80)	-6%
B.5	Neurological disorders	44.00 (42.78-44.98)	-3%	499.98 (482.68-513.02)	-5%	1 113.60 (756.81-1 521.65)	0%	1 613.59 (1 262.60-2 020.69)	-2%
B.5.1	Alzheimer's disease and other dementias	35.20 (34.28-35.99)	-3%	311.04 (301.29-319.51)	-5%	88.14 (62.83-114.38)	-4%	399.18 (372.36-427.24)	-4%
B.5.2	Parkinson's disease	4.63 (4.23-5.22)	-3%	54.75 (50.60-63.11)	-4%	14.87 (10.12-20.31)	-2%	69.62 (63.34-78.21)	-3%
B.5.3	Epilepsy	1.18 (0.96-1.24)	-10%	43.90 (40.04-46.82)	-15%	95.63 (47.53-165.86)	-1%	139.53 (89.95-210.57)	-6%
B.5.4	Multiple sclerosis	0.64 (0.46-0.70)	-1%	19.27 (14.44-21.82)	-4%	19.64 (14.01-25.52)	2%	38.92 (32.32-45.58)	-1%
B.5.5	Motor neuron disease	1.16 (1.10-1.22)	2%	29.40 (27.81-30.77)	-1%	1.28 (0.91-1.71)	8%	30.68 (29.07-32.17)	-1%
B.5.6	Headache disorders	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	870.95 (578.20-1 236.44)	0%	870.95 (578.20-1 236.44)	0%
B.5.6.1	Migraine	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	769.84 (495.39-1 114.51)	0%	769.84 (495.39-1 114.51)	0%
B.5.6.2	Tension-type headache	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	101.11 (57.39-158.91)	1%	101.11 (57.39-158.91)	1%
B.5.7	Other neurological disorders	1.19 (1.10-1.25)	4%	41.63 (38.90-44.25)	-3%	23.10 (13.12-37.44)	14%	64.72 (54.19-79.27)	3%
B.6	Mental disorders	0.02 (0.02-0.02)	18%	1.01 (0.88-1.13)	18%	1 775.35 (1 320.71-2 298.65)	1%	1 776.36 (1 321.72-2 299.70)	1%
B.6.1	Schizophrenia	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	146.05 (110.88-178.88)	1%	146.05 (110.88-178.88)	1%
B.6.2	Depressive disorders	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	549.75 (390.07-748.65)	0%	549.75 (390.07-748.65)	0%
B.6.2.1	Major depressive disorder	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	423.86 (298.54-578.57)	0%	423.86 (298.54-578.57)	0%
B.6.2.2	Dysthymia	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	125.89 (84.39-184.04)	2%	125.89 (84.39-184.04)	2%
B.6.3	Bipolar disorder	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	168.05 (105.98-248.06)	1%	168.05 (105.98-248.06)	1%
B.6.4	Anxiety disorders	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	462.86 (330.13-614.58)	1%	462.86 (330.13-614.58)	1%

B.6.5	Eating disorders	0.02 (0.02-0.02)	18%	1.01 (0.88-1.13)	18%	97.83 (63.33-142.45)	6%	98.84 (64.37-143.47)	6%
B.6.5.1	Anorexia nervosa	0.01 (0.01-0.02)	17%	0.76 (0.61-0.88)	17%	24.71 (15.23-36.83)	4%	25.47 (16.03-37.57)	5%
B.6.5.2	Bulimia nervosa	0.00 (0.00-0.01)	20%	0.26 (0.19-0.38)	21%	73.12 (46.22-110.13)	6%	73.37 (46.45-110.36)	6%
B.6.6	Autism spectrum disorders	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	83.96 (57.77-115.30)	1%	83.96 (57.77-115.30)	1%
B.6.7	Attention-deficit/hyperactivity disorder	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	11.51 (6.98-18.27)	0%	11.51 (6.98-18.27)	0%
B.6.8	Conduct disorder	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	90.62 (54.73-144.48)	-1%	90.62 (54.73-144.48)	-1%
B.6.9	Idiopathic developmental intellectual disability	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	19.43 (6.75-35.40)	-12%	19.43 (6.75-35.40)	-12%
B.6.10	Other mental disorders	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	145.30 (95.86-201.28)	0%	145.30 (95.86-201.28)	0%
B.7	Substance use disorders	5.10 (4.91-5.31)	-3%	200.64 (193.42-208.90)	-6%	325.74 (232.81-429.55)	-1%	526.37 (432.32-630.10)	-3%
B.7.1	Alcohol use disorders	3.19 (3.03-3.35)	-9%	112.90 (107.30-119.41)	-11%	141.41 (97.10-197.65)	-1%	254.31 (207.98-309.85)	-6%
B.7.2	Drug use disorders	1.90 (1.83-1.97)	8%	87.73 (84.25-91.16)	3%	184.33 (133.03-240.95)	0%	272.06 (219.14-328.21)	1%
B.7.2.1	Opioid use disorders	0.94 (0.90-1.00)	3%	44.96 (43.01-47.99)	-2%	102.46 (71.41-134.19)	-3%	147.42 (116.22-179.04)	-3%
B.7.2.2	Cocaine use disorders	0.03 (0.02-0.03)	2%	1.46 (1.23-1.55)	0%	20.88 (13.84-30.07)	2%	22.35 (15.28-31.49)	2%
B.7.2.3	Amphetamine use disorders	0.07 (0.05-0.07)	8%	3.67 (2.84-3.95)	7%	18.52 (10.80-28.33)	10%	22.19 (14.34-32.25)	9%
B.7.2.4	Cannabis use disorders	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	11.73 (7.43-17.29)	-8%	11.73 (7.43-17.29)	-8%
B.7.2.5	Other drug use disorders	0.87 (0.81-0.91)	14%	37.64 (35.17-39.68)	9%	30.74 (20.67-42.56)	6%	68.38 (58.33-79.94)	7%
B.8	Diabetes and kidney diseases	15.59 (15.15-16.05)	-10%	232.35 (225.84-239.23)	-15%	473.34 (329.47-648.98)	10%	705.69 (561.78-881.37)	0%
B.8.1	Diabetes mellitus	7.93 (7.68-8.17)	-17%	128.85 (124.76-132.74)	-18%	410.41 (277.32-571.10)	13%	539.26 (407.12-699.60)	3%
B.8.1.1	Diabetes mellitus type 1	1.59 (1.19-1.68)	-28%	35.95 (29.76-37.58)	-27%	22.39 (15.15-31.91)	1%	58.34 (49.43-68.47)	-18%
B.8.1.2	Diabetes mellitus type 2	6.34 (6.08-6.83)	-13%	92.90 (88.99-100.24)	-14%	388.02 (261.43-539.65)	14%	480.92 (354.27-632.57)	7%
B.8.2	Chronic kidney disease	7.66 (7.41-7.93)	-2%	103.30 (100.12-106.98)	-11%	62.91 (46.70-79.68)	-3%	166.21 (150.21-183.70)	-8%
B.8.2.1	Chronic kidney disease due to diabetes mellitus type 1	0.30 (0.23-0.39)	-11%	6.41 (5.29-7.80)	-18%	3.21 (2.27-4.27)	-4%	9.62 (7.97-11.56)	-14%
B.8.2.2	Chronic kidney disease due to diabetes mellitus type 2	1.70 (1.41-2.00)	-2%	21.36 (18.20-25.21)	-10%	12.08 (8.84-15.65)	-4%	33.44 (28.58-38.75)	-7%
B.8.2.3	Chronic kidney disease due to hypertension	2.18 (1.84-2.51)	0%	21.96 (18.70-25.11)	-7%	12.04 (8.89-15.48)	-1%	34.00 (29.27-38.89)	-5%
B.8.2.4	Chronic kidney disease due to glomerulonephritis	1.33 (1.10-1.59)	-5%	21.15 (18.45-24.28)	-15%	9.98 (7.08-12.96)	-2%	31.13 (26.79-35.38)	-11%
B.8.2.5	Chronic kidney disease due to other and unspecified causes	2.16 (1.84-2.51)	-1%	32.42 (28.50-36.52)	-11%	25.59 (18.98-32.38)	-3%	58.01 (50.15-66.23)	-8%
B.8.3	Acute glomerulonephritis	0.01 (0.01-0.01)	27%	0.20 (0.19-0.21)	4%	0.02 (0.01-0.03)	-5%	0.22 (0.20-0.23)	3%
B.9	Skin and subcutaneous diseases	0.85 (0.42-1.31)	4%	13.09 (6.69-20.02)	5%	663.99 (447.34-949.64)	2%	677.08 (460.33-963.29)	2%

B.9.1	Dermatitis	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	213.64 (119.53-345.67)	1%	213.64 (119.53-345.67)	1%
B.9.1.1	Atopic dermatitis	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	187.20 (101.37-314.77)	1%	187.20 (101.37-314.77)	1%
B.9.1.2	Contact dermatitis	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	24.94 (16.23-37.00)	0%	24.94 (16.23-37.00)	0%
B.9.1.3	Seborrhoeic dermatitis	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	1.49 (0.85-2.35)	2%	1.49 (0.85-2.35)	2%
B.9.2	Psoriasis	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	137.90 (97.07-181.70)	3%	137.90 (97.07-181.70)	3%
B.9.3	Bacterial skin diseases	0.59 (0.25-0.85)	15%	9.71 (4.39-14.30)	12%	2.64 (1.71-3.97)	2%	12.35 (6.86-17.11)	10%
B.9.3.1	Cellulitis	0.18 (0.06-0.29)	17%	3.21 (1.19-5.00)	16%	1.90 (1.26-2.68)	3%	5.11 (3.01-6.85)	11%
B.9.3.2	Pyoderma	0.41 (0.17-0.58)	14%	6.50 (2.86-9.58)	10%	0.73 (0.30-1.51)	1%	7.23 (3.43-10.44)	9%
B.9.4	Scabies	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	7.26 (4.00-11.87)	-7%	7.26 (4.00-11.87)	-7%
B.9.5	Fungal skin diseases	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	44.23 (17.67-92.43)	0%	44.23 (17.67-92.43)	0%
B.9.6	Viral skin diseases	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	57.93 (36.99-85.78)	0%	57.93 (36.99-85.78)	0%
B.9.7	Acne vulgaris	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	81.76 (49.42-131.49)	13%	81.76 (49.42-131.49)	13%
B.9.8	Alopecia areata	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	9.10 (5.81-13.50)	0%	9.10 (5.81-13.50)	0%
B.9.9	Pruritus	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	8.33 (3.90-15.86)	-2%	8.33 (3.90-15.86)	-2%
B.9.10	Urticaria	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	49.21 (32.70-69.39)	-1%	49.21 (32.70-69.39)	-1%
B.9.11	Decubitus ulcer	0.21 (0.09-0.38)	-19%	2.43 (1.15-4.53)	-15%	3.60 (2.51-4.89)	1%	6.03 (4.43-8.57)	-6%
B.9.12	Other skin and subcutaneous diseases	0.06 (0.03-0.13)	0%	0.95 (0.54-2.08)	-3%	48.38 (23.23-89.46)	3%	49.34 (24.35-90.23)	3%
B.10	Sense organ diseases	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	540.17 (364.13-770.47)	-2%	540.17 (364.13-770.47)	-2%
B.10.1	Blindness and vision impairment	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	183.47 (123.05-263.17)	-3%	183.47 (123.05-263.17)	-3%
B.10.1.1	Glaucoma	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	5.52 (3.58-7.94)	-5%	5.52 (3.58-7.94)	-5%
B.10.1.2	Cataract	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	36.34 (25.21-49.89)	-5%	36.34 (25.21-49.89)	-5%
B.10.1.3	Age-related macular degeneration	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	9.03 (5.90-12.65)	-5%	9.03 (5.90-12.65)	-5%
B.10.1.4	Refraction disorders	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	71.75 (45.14-108.40)	-2%	71.75 (45.14-108.40)	-2%
B.10.1.5	Near vision loss	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	35.41 (16.92-64.60)	-3%	35.41 (16.92-64.60)	-3%
B.10.1.6	Other vision loss	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	25.42 (17.69-34.94)	-4%	25.42 (17.69-34.94)	-4%
B.10.2	Age-related and other hearing loss	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	325.33 (218.83-464.04)	-1%	325.33 (218.83-464.04)	-1%
B.10.3	Other sense organ diseases	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	31.37 (19.42-45.49)	0%	31.37 (19.42-45.49)	0%
B.11	Musculoskeletal disorders	1.18 (1.14-1.23)	-6%	21.44 (20.56-22.35)	-9%	2 163.51 (1 572.50-2 894.98)	0%	2 184.95 (1 593.86-2 915.98)	0%

B.11.1	Rheumatoid arthritis	0.33 (0.31-0.41)	-12%	5.56 (5.17-6.59)	-14%	42.81 (28.97-57.16)	3%	48.37 (34.67-62.61)	1%
B.11.2	Osteoarthritis	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	118.40 (59.27-233.56)	2%	118.40 (59.27-233.56)	2%
B.11.3	Low back pain	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	1 342.84 (957.34-1 824.34)	0%	1 342.84 (957.34-1 824.34)	0%
B.11.4	Neck pain	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	425.10 (296.76-589.16)	0%	425.10 (296.76-589.16)	0%
B.11.5	Gout	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	19.01 (12.78-26.35)	1%	19.01 (12.78-26.35)	1%
B.11.6	Other musculoskeletal disorders	0.86 (0.79-0.90)	-4%	15.89 (14.85-16.66)	-7%	215.34 (141.88-307.78)	3%	231.23 (157.65-324.19)	2%
B.12	Other non-communicable diseases	8.53 (7.70-8.93)	-11%	377.45 (347.72-406.61)	-20%	650.58 (445.71-901.27)	-3%	1 028.03 (822.25-1 288.99)	-10%
B.12.1	Congenital birth defects	2.93 (2.50-3.29)	-23%	230.26 (197.24-258.64)	-25%	171.95 (120.87-227.99)	-1%	402.21 (340.61-464.56)	-16%
B.12.1.1	Neural tube defects	0.19 (0.15-0.22)	24%	15.99 (12.30-18.92)	25%	9.33 (6.42-12.49)	-2%	25.32 (20.82-29.88)	13%
B.12.1.2	Congenital heart anomalies	1.10 (0.92-1.23)	-32%	87.15 (72.98-97.93)	-33%	8.55 (4.05-14.33)	3%	95.69 (80.24-107.10)	-31%
B.12.1.3	Orofacial clefts	0.00 (0.00-0.00)	-54%	0.05 (0.04-0.07)	-54%	3.19 (2.10-4.67)	-5%	3.24 (2.15-4.73)	-7%
B.12.1.4	Down syndrome	0.32 (0.24-0.38)	16%	17.56 (13.26-23.06)	12%	6.53 (4.48-9.05)	-1%	24.09 (19.33-29.88)	8%
B.12.1.5	Turner syndrome	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.12 (0.06-0.19)	-1%	0.12 (0.06-0.19)	-1%
B.12.1.6	Klinefelter syndrome	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.03 (0.02-0.06)	2%	0.03 (0.02-0.06)	2%
B.12.1.7	Other chromosomal abnormalities	0.33 (0.19-0.40)	-12%	26.67 (15.20-32.71)	-12%	10.22 (6.72-14.22)	1%	36.89 (25.36-44.25)	-9%
B.12.1.8	Congenital musculoskeletal and limb anomalies	0.07 (0.05-0.10)	-19%	5.76 (4.00-7.84)	-19%	75.85 (50.03-104.27)	-1%	81.61 (56.04-109.52)	-2%
B.12.1.9	Urogenital congenital anomalies	0.08 (0.05-0.10)	-22%	6.54 (3.75-8.10)	-23%	4.52 (2.78-6.85)	0%	11.06 (7.66-13.99)	-15%
B.12.1.10	Digestive congenital anomalies	0.21 (0.16-0.25)	-32%	18.35 (13.75-21.25)	-32%	31.16 (20.74-44.24)	-5%	49.51 (37.92-62.91)	-17%
B.12.1.11	Other congenital birth defects	0.63 (0.56-0.80)	-29%	52.20 (46.05-66.61)	-30%	22.43 (15.10-31.35)	4%	74.63 (63.93-90.23)	-22%
B.12.2	Urinary diseases and male infertility	2.31 (2.24-2.39)	2%	30.94 (29.99-32.10)	-2%	47.93 (31.77-67.54)	1%	78.87 (62.89-98.16)	0%
B.12.2.1	Urinary tract infections	2.06 (1.97-2.13)	3%	26.65 (25.32-27.55)	-1%	1.83 (1.13-2.74)	4%	28.47 (27.09-29.75)	0%
B.12.2.2	Urolithiasis	0.09 (0.07-0.13)	5%	1.45 (1.19-2.09)	2%	3.52 (2.43-4.84)	1%	4.97 (3.73-6.43)	1%
B.12.2.3	Benign prostatic hyperplasia	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	39.17 (25.47-56.01)	3%	39.17 (25.47-56.01)	3%
B.12.2.4	Male infertility	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	1.79 (0.75-3.80)	-6%	1.79 (0.75-3.80)	-6%
B.12.2.5	Other urinary diseases	0.15 (0.13-0.21)	-5%	2.85 (2.44-3.78)	-11%	1.61 (1.11-2.19)	-19%	4.46 (3.77-5.49)	-14%
B.12.3	Gynecological diseases	0.02 (0.02-0.03)	-16%	0.69 (0.64-0.75)	-16%	151.50 (105.86-210.96)	-2%	152.19 (106.52-211.67)	-2%
B.12.3.1	Uterine fibroids	0.01 (0.01-0.01)	-16%	0.31 (0.28-0.36)	-16%	13.74 (7.32-24.02)	-12%	14.04 (7.62-24.31)	-12%
B.12.3.2	Polycystic ovarian syndrome	0.00 (0.00-0.00)	-62%	0.00 (0.00-0.00)	-57%	6.04 (2.65-11.82)	1%	6.04 (2.65-11.82)	1%

B.12.3.3	Female infertility	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	2.02 (0.74-4.46)	7%	2.02 (0.74-4.46)	7%
B.12.3.4	Endometriosis	0.00 (0.00-0.00)	-43%	0.01 (0.00-0.01)	-43%	64.36 (43.15-90.66)	0%	64.37 (43.16-90.67)	0%
B.12.3.5	Genital prolapse	0.00 (0.00-0.00)	-42%	0.03 (0.02-0.04)	-39%	3.92 (1.89-7.38)	-3%	3.95 (1.92-7.42)	-3%
B.12.3.6	Premenstrual syndrome	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	43.59 (27.91-65.08)	-2%	43.59 (27.91-65.08)	-2%
B.12.3.7	Other gynecological diseases	0.01 (0.01-0.02)	-8%	0.33 (0.31-0.38)	-12%	17.83 (11.93-25.81)	-1%	18.17 (12.25-26.12)	-1%
B.12.4	Hemoglobinopathies and hemolytic anemias	0.68 (0.59-0.77)	-15%	13.14 (11.90-15.31)	-18%	13.07 (8.29-20.01)	-16%	26.21 (21.01-33.31)	-17%
B.12.4.1	Thalassemias	0.01 (0.01-0.02)	-16%	0.86 (0.69-1.17)	-18%	0.04 (0.03-0.07)	-7%	0.90 (0.73-1.22)	-17%
B.12.4.2	Thalassemias trait	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	4.00 (2.43-6.08)	-20%	4.00 (2.43-6.08)	-20%
B.12.4.3	Sickle cell disorders	0.04 (0.03-0.05)	-14%	2.45 (2.04-3.36)	-16%	0.25 (0.17-0.35)	-2%	2.70 (2.26-3.59)	-15%
B.12.4.4	Sickle cell trait	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	2.61 (1.57-4.13)	-25%	2.61 (1.57-4.13)	-25%
B.12.4.5	G6PD deficiency	0.06 (0.05-0.07)	-15%	2.36 (2.02-2.74)	-19%	0.09 (0.06-0.13)	-22%	2.45 (2.11-2.82)	-19%
B.12.4.6	G6PD trait	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	-32%	0.00 (0.00-0.00)	-32%
B.12.4.7	Other hemoglobinopathies and hemolytic anemias	0.57 (0.48-0.64)	-16%	7.47 (6.47-8.49)	-19%	6.08 (3.82-9.36)	-9%	13.55 (11.05-16.92)	-14%
B.12.5	Endocrine. metabolic. blood. and immune disorders	2.24 (1.54-2.46)	-1%	72.83 (55.98-83.50)	-5%	31.65 (22.02-44.06)	0%	104.48 (84.12-120.50)	-3%
B.12.6	Oral disorders	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	234.49 (143.68-359.68)	-5%	234.49 (143.68-359.68)	-5%
B.12.6.1	Caries of deciduous teeth	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	2.30 (0.96-4.69)	2%	2.30 (0.96-4.69)	2%
B.12.6.2	Caries of permanent teeth	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	35.86 (15.43-67.88)	-2%	35.86 (15.43-67.88)	-2%
B.12.6.3	Periodontal diseases	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	47.12 (18.59-97.71)	-5%	47.12 (18.59-97.71)	-5%
B.12.6.4	Edentulism and severe tooth loss	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	98.45 (65.91-139.49)	-8%	98.45 (65.91-139.49)	-8%
B.12.6.5	Other oral disorders	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	50.77 (31.72-75.82)	0%	50.77 (31.72-75.82)	0%
B.12.7	Sudden infant death syndrome	0.34 (0.29-0.49)	-25%	29.59 (25.15-42.63)	-25%	0.00 (0.00-0.00)	0%	29.59 (25.15-42.63)	-25%
C	Injuries	28.49 (27.80-29.21)	-21%	1 039.38 (1 013.84-1 065.79)	-27%	1 019.83 (727.38-1 390.90)	1%	2 059.22 (1 769.83-2 426.63)	-15%
C.1	Transport injuries	6.10 (5.93-6.26)	-37%	287.63 (279.50-295.61)	-41%	165.71 (117.06-223.30)	-6%	453.34 (406.13-509.50)	-31%
C.1.1	Road injuries	5.57 (5.42-5.71)	-38%	263.04 (255.74-270.56)	-41%	149.51 (105.56-202.02)	-7%	412.55 (370.30-463.53)	-32%
C.1.1.1	Pedestrian road injuries	1.33 (1.28-1.38)	-42%	53.26 (50.88-55.40)	-46%	26.40 (17.99-36.95)	0%	79.66 (71.35-89.99)	-36%
C.1.1.2	Cyclist road injuries	0.38 (0.37-0.40)	-29%	15.68 (15.03-16.30)	-33%	36.79 (25.34-50.72)	-3%	52.47 (41.01-66.37)	-14%
C.1.1.3	Motorcyclist road injuries	0.92 (0.87-0.97)	-34%	50.30 (47.45-52.75)	-36%	24.08 (16.32-33.16)	-11%	74.38 (66.22-83.53)	-30%

C.1.1.4	Motor vehicle road injuries	2.88 (2.78-3.01)	-38%	141.21 (135.99-148.48)	-41%	55.33 (39.57-74.54)	-12%	196.54 (179.33-217.63)	-35%
C.1.1.5	Other road injuries	0.06 (0.05-0.06)	-40%	2.59 (2.46-2.72)	-42%	6.91 (4.86-9.81)	-3%	9.50 (7.46-12.43)	-18%
C.1.2	Other transport injuries	0.53 (0.51-0.56)	-34%	24.59 (23.54-26.01)	-35%	16.20 (11.46-22.04)	5%	40.79 (36.10-46.60)	-24%
C.2	Unintentional injuries	12.12 (11.79-12.55)	-16%	316.30 (306.98-327.65)	-25%	808.82 (568.78-1 116.48)	3%	1 125.12 (886.42-1 431.39)	-7%
C.2.1	Falls	6.24 (6.02-6.44)	-7%	113.66 (108.94-117.37)	-16%	521.60 (367.44-718.81)	1%	635.26 (482.71-829.49)	-3%
C.2.2	Drowning	1.02 (0.99-1.06)	-29%	48.25 (46.40-50.01)	-33%	0.85 (0.60-1.15)	20%	49.10 (47.22-50.80)	-32%
C.2.3	Fire. heat. and hot substances	0.72 (0.70-0.74)	-26%	22.37 (21.59-23.05)	-31%	28.77 (18.18-43.50)	5%	51.14 (40.50-65.81)	-15%
C.2.4	Poisonings	0.28 (0.27-0.28)	-35%	11.76 (11.42-12.11)	-39%	16.85 (10.74-24.63)	8%	28.61 (22.55-36.24)	-18%
C.2.4.1	Poisoning by carbon monoxide	0.19 (0.19-0.20)	-38%	8.15 (7.89-8.42)	-41%	2.02 (1.35-2.95)	10%	10.17 (9.43-11.14)	-35%
C.2.4.2	Poisoning by other means	0.08 (0.08-0.09)	-27%	3.61 (3.48-3.74)	-32%	14.83 (9.23-22.06)	7%	18.44 (12.88-25.69)	-4%
C.2.5	Exposure to mechanical forces	0.66 (0.63-0.67)	-29%	24.12 (23.08-24.92)	-34%	103.98 (70.77-147.53)	8%	128.10 (95.01-171.65)	-4%
C.2.5.1	Unintentional firearm injuries	0.12 (0.11-0.14)	-28%	4.85 (4.39-5.31)	-32%	3.06 (2.14-4.17)	3%	7.91 (6.83-9.11)	-22%
C.2.5.2	Other exposure to mechanical forces	0.53 (0.51-0.55)	-29%	19.26 (18.39-19.97)	-34%	100.92 (68.58-143.73)	8%	120.19 (87.69-162.86)	-2%
C.2.6	Adverse effects of medical treatment	1.08 (1.00-1.33)	-5%	24.39 (22.54-31.14)	-6%	3.80 (2.36-5.73)	3%	28.18 (25.72-34.67)	-5%
C.2.7	Animal contact	0.07 (0.07-0.07)	-18%	2.50 (2.42-2.59)	-22%	5.59 (3.79-7.82)	-5%	8.09 (6.30-10.31)	-11%
C.2.7.1	Venomous animal contact	0.03 (0.02-0.03)	-18%	0.98 (0.92-1.11)	-21%	3.52 (2.32-5.05)	-5%	4.50 (3.29-6.01)	-9%
C.2.7.2	Non-venomous animal contact	0.04 (0.04-0.04)	-18%	1.52 (1.41-1.60)	-22%	2.07 (1.28-3.17)	-5%	3.59 (2.78-4.73)	-13%
C.2.8	Foreign body	1.38 (1.33-1.42)	-17%	45.53 (43.88-47.42)	-25%	9.46 (6.62-13.15)	6%	54.99 (51.65-58.86)	-21%
C.2.8.1	Pulmonary aspiration and foreign body in airway	1.33 (1.29-1.38)	-17%	43.72 (42.14-45.69)	-25%	2.27 (1.54-3.07)	15%	45.99 (44.32-48.07)	-24%
C.2.8.2	Foreign body in eyes	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	1.93 (0.90-3.35)	6%	1.93 (0.90-3.35)	6%
C.2.8.3	Foreign body in other body part	0.05 (0.04-0.05)	-15%	1.81 (1.48-1.97)	-20%	5.27 (3.70-7.08)	2%	7.08 (5.52-8.86)	-5%
C.2.9	Environmental heat and cold exposure	0.42 (0.41-0.44)	-30%	12.08 (11.70-12.45)	-36%	8.17 (5.69-11.16)	2%	20.25 (17.64-23.28)	-24%
C.2.10	Exposure to forces of nature	0.01 (0.01-0.01)	-58%	0.58 (0.55-0.61)	-60%	0.36 (0.26-0.49)	-12%	0.93 (0.83-1.07)	-49%
C.2.11	Other unintentional injuries	0.24 (0.23-0.25)	-38%	11.05 (10.57-11.49)	-41%	109.41 (73.02-159.10)	8%	120.46 (84.17-170.30)	0%
C.3	Self-harm and interpersonal violence	10.28 (9.91-10.63)	-15%	435.46 (420.46-450.14)	-16%	45.31 (34.54-57.69)	3%	480.76 (462.05-499.27)	-15%
C.3.1	Self-harm	9.37 (9.01-9.70)	-13%	390.61 (376.08-404.90)	-14%	11.22 (7.72-15.16)	-1%	401.83 (386.68-416.87)	-14%
C.3.1.1	Self-harm by firearm	0.66 (0.42-0.93)	-20%	23.36 (14.04-31.61)	-24%	0.04 (0.03-0.05)	-3%	23.39 (14.08-31.65)	-24%
C.3.1.2	Self-harm by other specified means	8.70 (8.34-9.07)	-12%	367.25 (351.95-382.32)	-13%	11.18 (7.69-15.12)	-1%	378.43 (362.61-393.48)	-13%

C.3.2	Interpersonal violence	0.90 (0.88-0.93)	-30%	44.25 (42.79-45.69)	-31%	33.09 (25.50-42.06)	4%	77.34 (69.62-86.46)	-19%
C.3.2.1	Physical violence by firearm	0.19 (0.18-0.20)	-31%	9.48 (8.86-10.05)	-33%	1.03 (0.74-1.39)	13%	10.51 (9.83-11.20)	-30%
C.3.2.2	Physical violence by sharp object	0.29 (0.27-0.30)	-30%	13.71 (12.72-14.38)	-32%	2.93 (2.02-4.16)	8%	16.65 (15.28-18.10)	-27%
C.3.2.3	Sexual violence	0.00 (0.00-0.00)	0%	0.00 (0.00-0.00)	0%	11.66 (7.77-17.02)	-3%	11.66 (7.77-17.02)	-3%
C.3.2.4	Physical violence by other means	0.43 (0.41-0.45)	-29%	21.06 (20.24-22.13)	-30%	17.46 (12.05-23.61)	8%	38.53 (33.23-45.26)	-16%
C.3.3	Conflict and terrorism	0.00 (0.00-0.00)	-100%	0.00 (0.00-0.00)	-100%	0.85 (0.56-1.38)	-13%	0.85 (0.56-1.38)	-66%
C.3.4	Executions and police conflict	0.01 (0.01-0.01)	1%	0.60 (0.57-0.62)	-1%	0.15 (0.11-0.22)	16%	0.75 (0.69-0.82)	2%

Supplementary Table 2 – Top 10 causes of age-standardized rates of (A) mortality and (B) DALYs (per 100,000 inhabitants), by sex, in the European Union (28 countries) in 2017.

A - Age-standardized mortality rates (per 100,000 inhabitants) in the EU-28 (2017)

	Male	Female
1	Ischemic heart disease - 103,3 (100,1-108,6)	Ischemic heart disease - 56,3 (54,2-60,0)
2	Tracheal, bronchus, and lung cancer - 43,5 (42,1-45,1)	Alzheimer's disease and other dementias - 37,1 (35,9-38,2)
3	Stroke - 42,4 (41,0-44,5)	Stroke - 33,4 (32,1-35,6)
4	Alzheimer's disease and other dementias - 31,3 (30,4-32,2)	Breast cancer - 17,9 (17,2-18,7)
5	Chronic obstructive pulmonary disease - 25,5 (24,3-26,8)	Tracheal, bronchus, and lung cancer - 16,9 (15,7-18,0)
6	Colon and rectum cancer - 20,7 (19,6-21,6)	Chronic obstructive pulmonary disease - 13,1 (12,5-14,0)
7	Lower respiratory infections - 18,2 (17,6-18,9)	Colon and rectum cancer - 12,4 (11,9-12,9)
8	Prostate cancer - 18,1 (14,3-23,2)	Lower respiratory infections - 10,4 (10,1-10,8)
9	Cirrhosis and other chronic liver diseases - 15,6 (14,8-16,5)	Hypertensive heart disease - 7,9 (3,8-8,7)
10	Self-harm - 15,1 (14,4-15,8)	Pancreatic cancer - 7,7 (7,4-8,1)

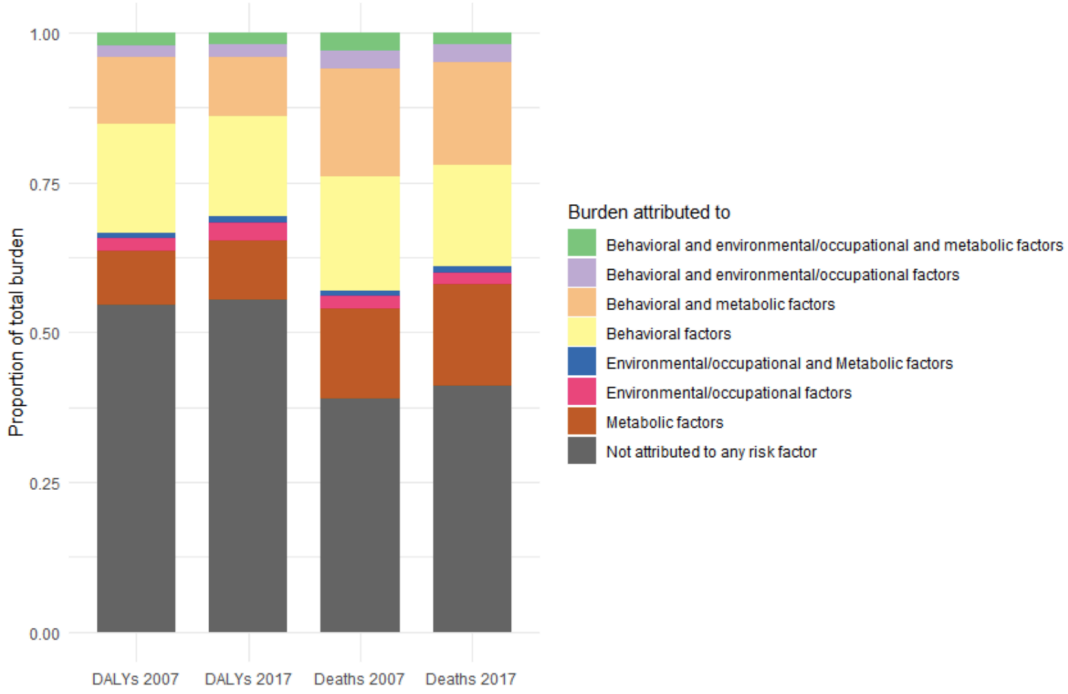
B - Age-standardized DALY rates (per 100,000 inhabitants) in the EU-28 (2017)

	Male	Female
1	Ischemic heart disease - 1749,9 (1691,6-1826,2)	Low back pain - 1444,4 (1030,5-1964,8)
2	Low back pain - 1235,5 (878,4-1675,1)	Headache disorders - 1132,4 (752,2-1605,9)
3	Tracheal, bronchus, and lung cancer - 932,4 (900,4-965,7)	Ischemic heart disease - 737,2 (705,3-777,8)
4	Stroke - 798,5 (746,3-847,6)	Depressive disorders - 691,1 (493,0-944,9)
5	Falls - 757,4 (584,6-975,5)	Anxiety disorders - 613,4 (436,9-816,4)
6	Neonatal disorders - 707,1 (609,9-824,5)	Neonatal disorders - 604,9 (517,0-708,5)
7	Diabetes mellitus - 636,8 (485,4-819,9)	Stroke - 596,8 (550,0-643,9)
8	Self-harm - 629,2 (599,8-658,7)	Falls - 512,6 (379,0-685,1)
9	Headache disorders - 610,5 (405,5-864,1)	Breast cancer - 493,7 (465,7-523,1)
10	Chronic obstructive pulmonary disease - 585,0 (538,4-634,1)	Neck pain - 490,1 (343,7-676,6)

ANNEX 3

Supplementary material of paper 3 "Risk factors and their contribution to population health in the European Union (EU-28) countries in 2007 and 2017".

Supplementary Figure 1 – Proportion of EU-28 (all cause) DALYs and deaths attributable to behavioural, environmental/occupational and metabolic risks and their intersections, in 2007 and 2017.



Supplementary Figure 2 – Ranked attributable (all cause) age-standardised death (A) and DALY (B) rates for level 2 risk factors, in EU-28, for years 2007 and 2017. [ARS – age-standardised rate]

A – Age-standardized death rate

Rank	2007 ASR*	2007 Risk	2017 Risk	2017 ASR*
1	108.7	High systolic blood pressure	High systolic blood pressure	85.3
2	102.0	Dietary risks	Tobacco	79.4
3	99.5	Tobacco	Dietary risks	79.2
4	68.7	High fasting plasma glucose	High fasting plasma glucose	60.4
5	56.8	High body-mass index	High body-mass index	48.7
6	52.0	High LDL cholesterol	High LDL cholesterol	39.5
7	43.0	Alcohol use	Alcohol use	34.1
8	27.3	Air pollution	Air pollution	20.4
9	21.3	Impaired kidney function	Impaired kidney function	18.1
10	15.2	Low physical activity	Low physical activity	11.9
11	13.0	Occupational risks	Occupational risks	11.7
12	7.0	Other environmental risks	Other environmental risks	5.4
13	5.2	Child and maternal malnutrition	Drug use	5.1
14	5.0	Drug use	Child and maternal malnutrition	4.0
15	3.1	Unsafe sex	Low bone mineral density	2.7
16	2.9	Low bone mineral density	Unsafe sex	2.4
17	0.2	Unsafe water, sanitation, and handwashing	Unsafe water, sanitation, and handwashing	0.2
18	0.2	Intimate partner violence	Childhood maltreatment	0.1
19	0.1	Childhood maltreatment	Intimate partner violence	0.1

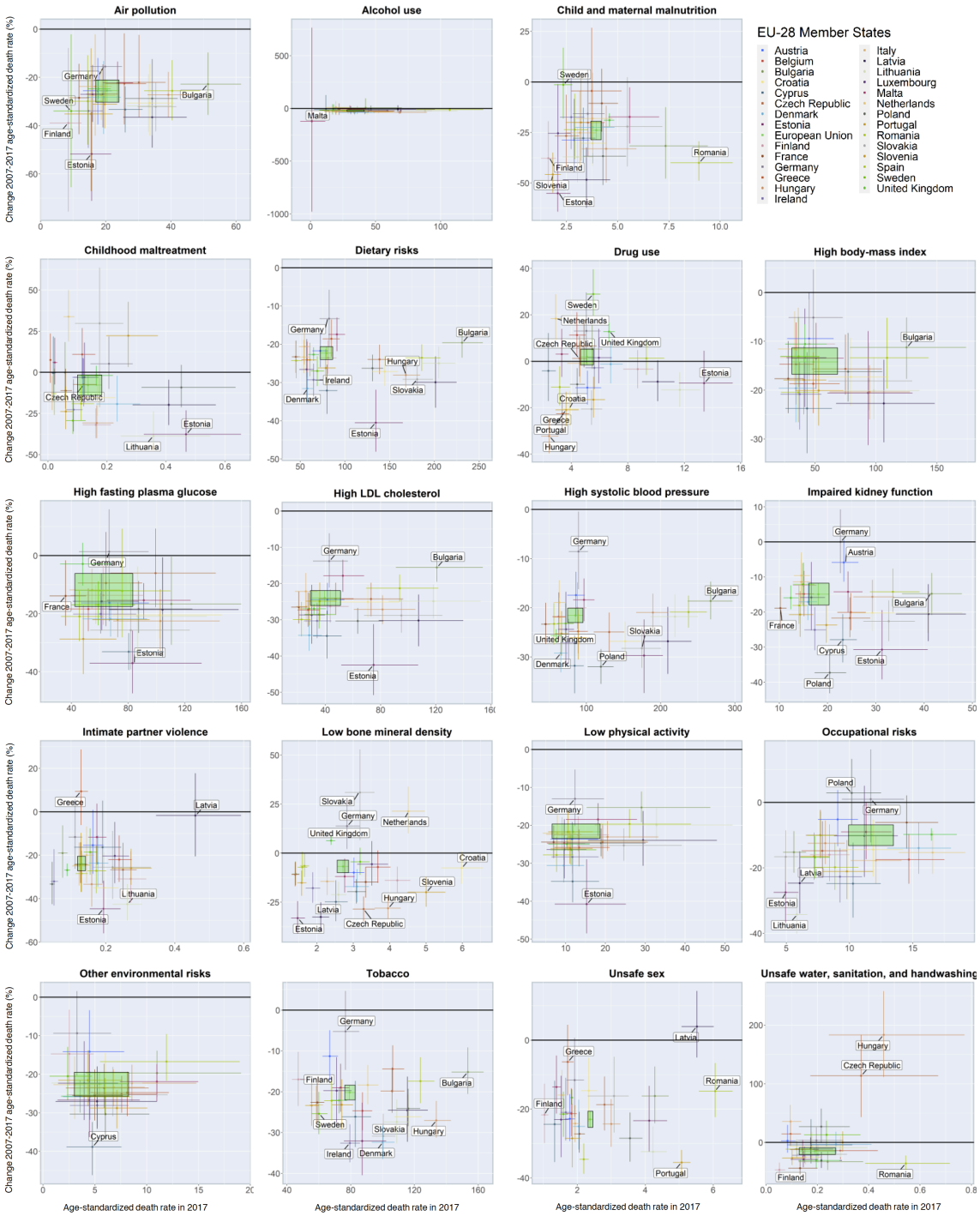
B – Age-standardized DALY rate

Rank	2007 ASR*	2007 Risk	2017 Risk	2017 ASR*
1	2777.8	Tobacco	Tobacco	2269.4
2	2058.2	Dietary risks	Dietary risks	1635.3
3	1969.5	High systolic blood pressure	High systolic blood pressure	1524.9
4	1642.1	Alcohol use	High body-mass index	1460.2
5	1616.5	High body-mass index	High fasting plasma glucose	1337.3
6	1418.8	High fasting plasma glucose	Alcohol use	1333.5
7	959.2	High LDL cholesterol	High LDL cholesterol	714.9
8	701.6	Occupational risks	Occupational risks	668.2
9	682.0	Child and maternal malnutrition	Child and maternal malnutrition	563.0
10	639.0	Air pollution	Air pollution	492.3
11	384.5	Drug use	Drug use	378.2
12	366.7	Impaired kidney function	Impaired kidney function	307.1
13	243.4	Low physical activity	Low physical activity	194.4
14	142.6	Other environmental risks	Low bone mineral density	131.7
15	136.1	Low bone mineral density	Other environmental risks	104.7
16	123.5	Unsafe sex	Unsafe sex	98.5
17	74.0	Childhood maltreatment	Childhood maltreatment	75.9
18	37.4	Intimate partner violence	Intimate partner violence	35.7
19	18.7	Unsafe water, sanitation, and handwashing	Unsafe water, sanitation, and handwashing	14.7

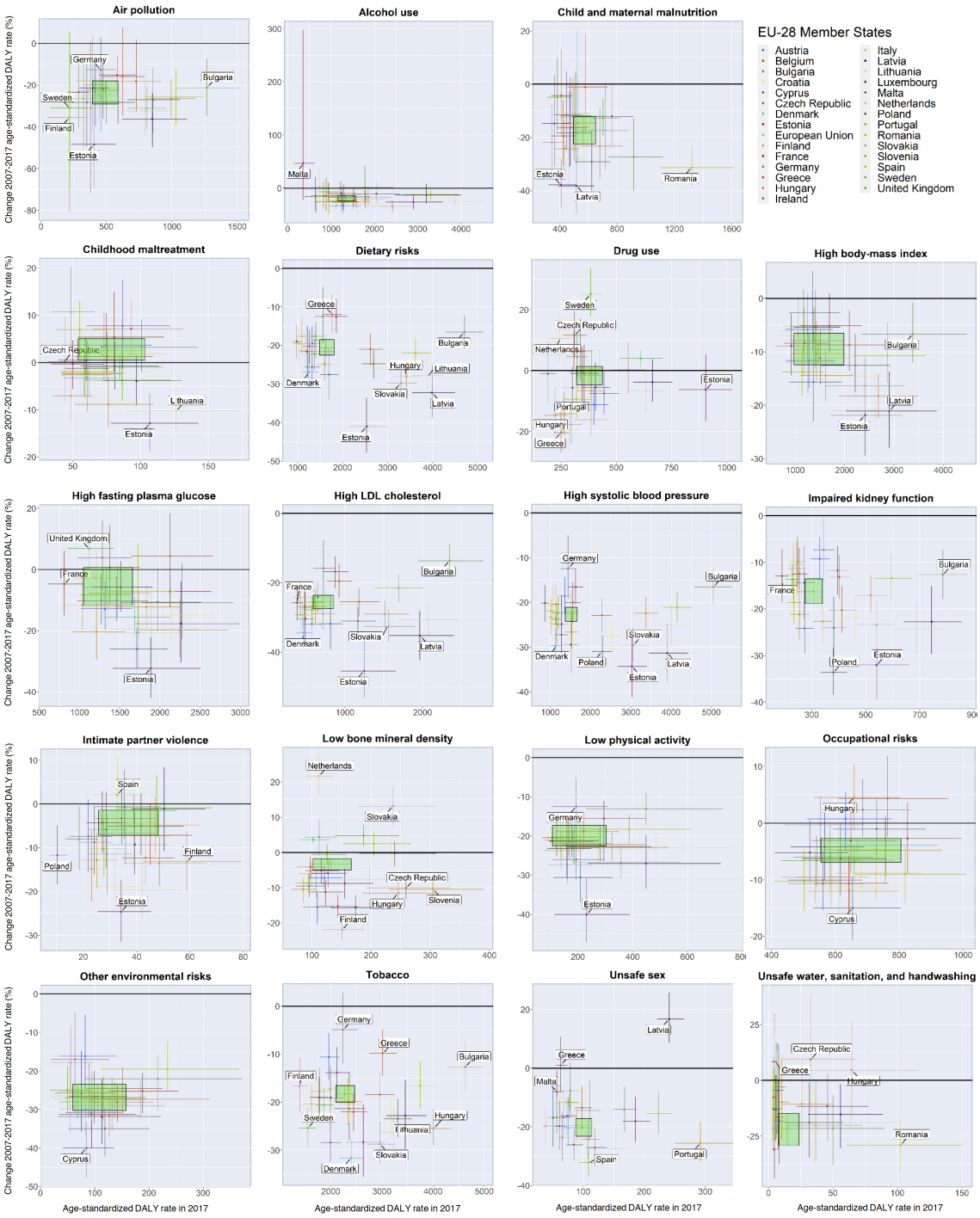
Environmental and occupational risks
Behavioural risks
Metabolic risks

Unchanged order
Ascending order
Descending order

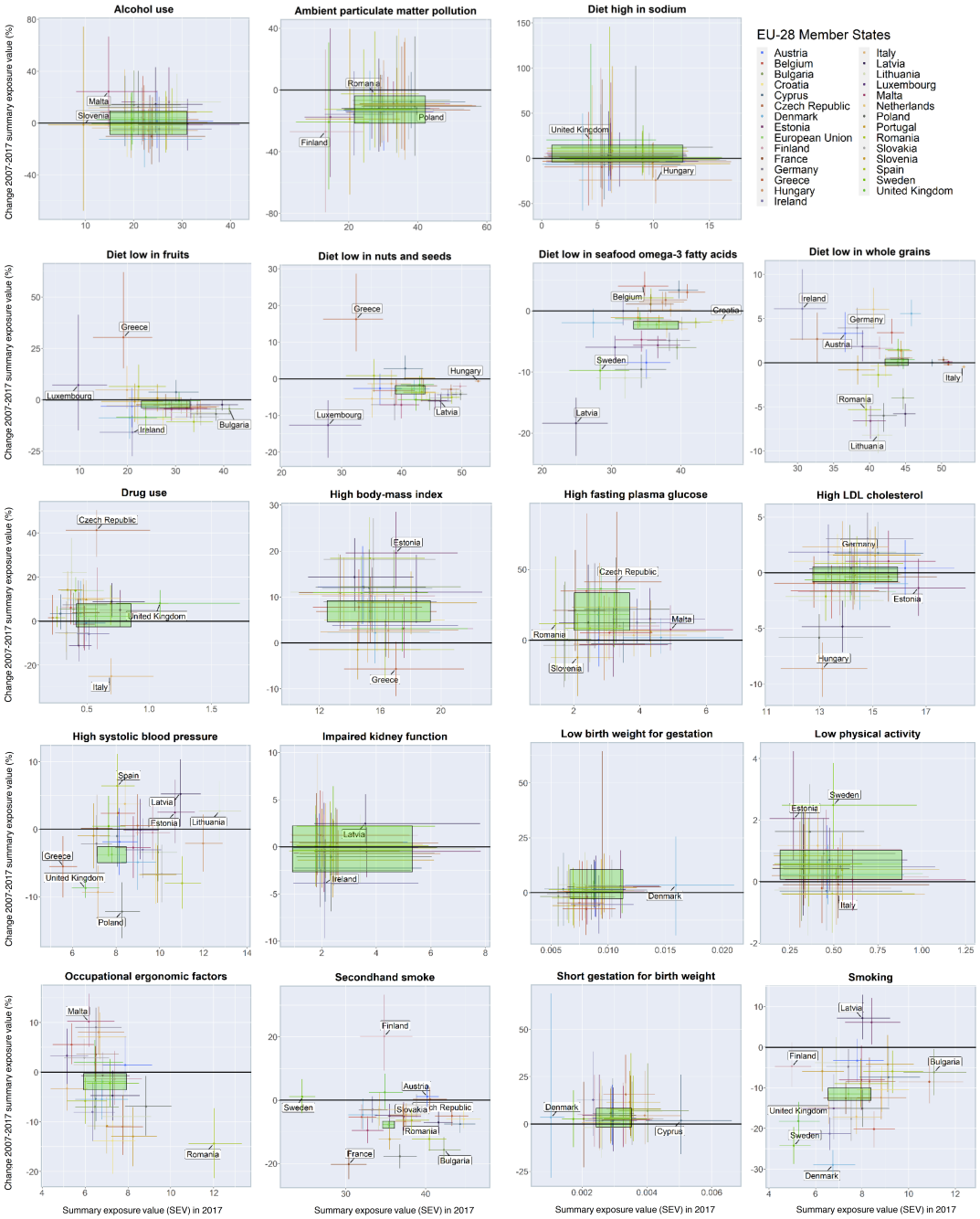
Supplementary Figure 3 – Relationship between the attributable (all cause) age-standardised death rates for level 2 risk factors and their percent 2007-2017 changes, in EU-28. Each dot represents one risk factor and crossed lines the 95% uncertainty intervals.



Supplementary Figure 4 – Relationship between the attributable (all cause) age-standardised DALY rates for level 2 risk factors and their percent 2007-2017 changes, in EU-28; Each dot represents one risk factor and crossed lines the 95% uncertainty intervals.



Supplementary Figure 5 – Relationship between summary exposure values for level 3 risk factors with the highest DALY-rates and their percent 2007-2017 changes, in EU-28. Each dot represents one risk factor and crossed lines the 95% uncertainty intervals. Note: metabolic risks presented for level 2 risk factors and level 3 risk factors 'particulate matter pollution' and 'low birth weight and short gestation' for their level 4 branches, except for "household air pollution from solid fuels" due to its low rate.



ANNEX 4

Supplementary material of paper 4 "Health expectancies in the European Union: same concept, different methods, different results".

Technical appendix

ICC

The Intraclass Correlation (ICC) [1] assesses health expectancy methods estimates reliability by comparing the variability of different health expectancy methods (SPH-HLE and DW-HLE) of the same country to the total variation across all estimates and all countries.

The formula for the ICC is $\frac{s^2(b)}{s^2(b)+s^2(w)}$

where $s^2(w)$ is the pooled variance within countries, and $s^2(b)$ is the variance of the trait between countries. So, s^2 (b) + s^2 (w) is equal to the total variance of estimates--i.e., the variance for all estimates, regardless of whether they are for the same country or not. Hence the interpretation of the ICC as the proportion of total variance accounted for by within-country variation.

An ICC=0 means no reliability between SPH-HLE and DW-HLE and an ICC=1 means perfect reliability between SPH-HLE and DW-HLE.

The ICC was calculated using IBM SPSS Statistics v24.0.

1. Shrout PE, Fleiss JL. Intraclass correlations: Uses in assessing rater reliability. Psychol Bulletin 1979;86:420-427.

IBMD

The sum over all logarithms of possible outcomes of the variable is a valid measure of the amount of information, or uncertainty, contained in a variable. We aim to measure disagreement between measurements obtained by SPH-HLE and DW-HLE. We consider for variable A, a vector A that can take the range of the estimates of health expectancy by SPH-HLE (a_1,…,a_n), and for variable B, a vector B that can take the range of the estimates of health expectancy by DW-HLE (b_1,…,bn),

The intuition behind our definition is that the disagreement between A and B is related to the differences between them, with the minimum reached when A and B are identical. So, it is then natural to consider $\sum_{i=1}^{n} log_2|a_i - b_i|$ the amount of information contained in the differences between SPH-HLE and DW-HLE estimates. By adding 1 to the differences, the behavior of the logarithmic function between 0 and 1 is avoided. The normalized (ranging from 0 to 1) measure is: $\frac{1}{n}\sum_{i=1}^{n} log_2\left(\frac{|a_i-b_i|}{max\{a_i,b_i\}} + 1\right)$.

The IBMD [2] equals 0 when the SPH-HLE and DW-HLE estimates agree, or when there is no disagreement, i.e., when ai = bi. In this case we say that there is no information in the differences between SPH-HLE and DW-HLE estimates. As SPH-HLE and DW-HLE estimates disagree, the amount of information in the differences between estimates increases and the information-based measure of disagreement increases, tending to 1, or, in other words, the distance between the SPH-HLE and DW-HLE estimates increases.

The IBMD was calculated using R v4.0.0 - obs.agree: An R package to assess agreement between observers - https://cran.r-project.org/web/packages/obs.agree/index.html

2. Costa-Santos C, Antunes L, Souto A, Bernardes J. Assessment of Disagreement: A New Information-Based Approach. Ann Epidemiol. 2010 Jul;20(7):555-61.

Bland and Altman limits of agreement

We can summarize the lack of agreement between SPH-HLE and DW-HLE estimates by calculating the mean difference (d) between methods, and the standard deviation of the differences (s). We would expect most of the differences to lie between *d – 1.96s* and *d + 1.96s*. If the differences are Normally distributed (Gaussian), 95% of differences will lie between these limits. If differences within *d +/- 2s (Bland and Altman limits of agreement [3])* would not be

clinically important, we could use the two measurement methods (SPH-HLE and DW-HLE estimates) interchangeably.
The first problem is that in this case the observations are not independent (there are repeated measurements: 7 measurements for each of the 28 countries).
The second problem is that the assumptions of the Bland an Altman limits of agreement are not met (there is a relationship between the differences and the average life expectancy).

We solved the second problem with the solution proposed by Bland and Altman [4,5,6] but instead of using a linear regression we used a linear mixed model for repeated measures due to the first problem.

The linear mixed model was adjusted using IBM SPSS Statistics v24.0 and the plot of differences between SPH-HLE and DW-HLE by the average mean life expectancy was made using Microsoft Excel v16.0.

3. Bland JM, Altman DG. (1986). Statistical methods for assessing agreement between two methods of clinical measurement. Lancet, i, 307-310.

4. https://www-users.york.ac.uk/~mb55/meas/glucose.htm

5. Bland JM, Altman DG. (1999) Measuring agreement in method comparison studies. *Statistical Methods in Medical Research* **8**, 135-160.

6. Martin DD, Shephard MDS, Freeman H, Bulsara MK, Jones TW, Davis EA, Maguire GP. (2005) Point-of-care testing of HbA(1c) and blood glucose in a remote Aboriginal Australian community. *Medical Journal of Australia* **182**: 524-527.

Supplemental File 1 – Original data for healthy life expectancy based on self-perceived health (SPH-HLE) and based on disability weights (DW-HLE) for males and females, between 2010 and 2017, in the European Union countries

Health expectancy based on self-perceived health (SPH-HLE), years

	Male								Female							
	2010	2011	2012	2013	2014	2015	2016	2017	2010	2011	2012	2013	2014	2015	2016	2017
EU-28	71,4	71,5	71,5	71,9	72,2	72,2	73,1	73,4	74,9	74,9	74,7	75,1	75,5	75,5	76,3	76,7
Austria	72,1	72,2	72,6	72,8	73,7	73,1	73,9	74,4	75,4	75,5	76,1	76,1	76,3	76,7	77,5	77,0
Belgium	72,5	72,3	72,6	73,3	73,4	73,6	73,9	74,4	75,4	75,3	75,9	75,8	76,2	75,1	76,2	76,6
Bulgaria	65,0	65,5	65,7	66,0	65,4	65,7	66,4	66,4	69,0	69,5	70,2	70,9	70,1	70,0	71,3	71,3
Croatia	61,3	62,6	63,0	63,1	63,6	64,0	65,1	64,9	65,0	65,0	65,6	66,9	66,6	67,0	67,7	68,7
Cyprus	72,4	73,0	73,5	74,2	75,9	75,2	76,7	76,1	74,6	74,1	75,8	76,3	77,7	77,6	79,8	79,3
Czech Republic	67,8	68,3	68,4	68,6	69,6	70,0	69,8	70,0	71,5	71,5	71,7	72,2	73,4	73,3	73,6	74,3
Denmark	72,7	72,9	73,9	74,3	74,3	74,7	74,2	74,3	75,1	75,6	76,4	76,5	77,0	76,8	77,0	77,2
Estonia	63,9	63,5	63,3	64,6	64,0	65,5	65,9	67,0	70,3	69,6	69,9	70,1	71,3	71,7	72,6	72,8
Finland	72,1	72,5	73,6	74,0	74,1	74,9	74,8	75,5	77,8	78,1	78,6	78,8	79,2	80,2	79,4	80,3
France	72,6	73,2	73,3	73,4	74,1	74,2	74,3	74,1	77,1	77,6	77,8	78,1	78,4	78,9	78,8	78,7
Germany	72,9	72,7	72,9	73,6	73,6	73,1	73,6	73,6	76,3	76,7	76,3	76,6	77,5	77,0	77,0	77,1
Greece	71,5	72,5	72,6	72,4	72,1	72,2	72,7	72,7	75,2	76,0	75,4	74,9	75,1	75,2	75,4	75,5
Hungary	62,7	63,7	63,9	64,6	64,9	64,6	66,4	66,5	66,7	66,8	67,0	67,9	67,9	68,0	70,0	70,0
Ireland	76,4	76,4	76,3	76,3	76,5	76,7	77,3	78,1	80,1	80,5	80,8	79,9	79,8	80,1	80,5	80,8
Italy	74,1	72,3	72,5	72,8	73,3	73,0	76,6	77,6	76,3	74,0	74,4	74,7	75,4	75,0	78,8	80,2
Latvia	60,2	60,8	61,9	61,9	61,6	62,9	63,0	62,6	65,9	66,4	68,6	67,6	68,0	68,5	69,2	68,6
Lithuania	60,1	59,9	60,3	61,3	61,7	62,8	62,2	65,1	65,9	65,3	65,3	66,5	67,7	68,3	69,4	69,6
Luxembourg	72,5	73,3	74,0	74,9	74,1	74,6	73,9	73,6	76,7	76,3	77,0	75,9	77,5	76,7	74,7	75,7
Malta	76,7	75,7	76,4	76,9	77,1	77,0	78,0	76,9	79,1	78,4	79,1	79,7	81,0	80,5	81,3	80,3
Netherlands	75,9	76,1	76,1	76,6	76,8	76,9	77,1	77,6	79,0	78,6	78,5	79,0	79,2	79,1	79,3	79,5
Poland	63,6	64,0	64,3	64,9	65,8	65,7	66,5	66,3	68,2	69,0	69,2	69,9	70,7	70,7	71,3	71,3
Portugal	65,7	67,3	67,9	68,1	68,2	68,5	69,8	70,5	65,4	68,2	68,4	68,1	68,7	69,3	70,8	71,6
Romania	65,7	66,4	66,1	67,1	67,0	67,6	68,6	68,4	70,2	70,1	70,1	71,0	71,5	72,0	73,4	73,4
Slovakia	64,0	64,7	65,1	65,8	66,2	65,8	66,6	67,0	67,1	67,5	68,7	69,3	69,1	69,2	70,1	70,9
Slovenia	68,2	68,6	69,3	70,0	70,9	70,6	71,7	72,1	71,3	71,9	72,5	74,2	74,1	73,7	75,6	75,6
Spain	74,1	74,6	74,2	74,7	75,2	75,5	76,2	76,3	77,1	78,0	77,5	77,7	77,9	78,5	79,4	80,2
Sweden	76,8	76,7	76,7	77,7	77,5	78,0	77,7	77,3	78,7	79,4	79,7	79,9	80,3	80,0	78,9	79,2
United Kingdom	74,6	75,2	73,8	73,4	73,4	73,8	73,9	75,0	78,5	78,7	76,2	77,0	76,9	76,7	76,4	77,5

Health expectancy based on disability weights (DW-HLE), years

	Male								Female							
	2010	2011	2012	2013	2014	2015	2016	2017	2010	2011	2012	2013	2014	2015	2016	2017
EU-28	67,0	67,2	67,4	67,6	67,8	67,8	67,9	68,0	70,6	70,7	70,8	70,9	71,1	71,0	71,1	71,2
Austria	67,6	68,0	68,2	68,3	68,6	68,7	69,0	69,1	70,9	70,9	71,1	71,3	71,3	71,5	71,6	71,7
Belgium	67,1	67,2	67,2	67,5	67,8	68,0	68,2	68,3	69,9	69,9	70,1	70,1	70,5	70,5	70,7	70,9
Bulgaria	61,5	61,7	61,9	62,1	62,0	62,2	62,2	62,2	66,8	67,1	67,4	67,6	67,3	67,5	67,6	67,7
Croatia	63,4	63,7	63,8	64,4	64,3	64,3	64,7	64,9	68,7	68,9	69,2	69,3	69,3	69,1	69,7	69,9
Cyprus	67,5	67,8	68,1	68,3	68,4	68,6	68,7	68,8	71,3	71,6	71,9	72,1	72,3	72,4	72,6	72,8
Czech Republic	64,0	64,1	64,3	64,5	64,8	64,9	65,0	65,1	68,9	69,0	69,1	69,2	69,5	69,5	69,5	69,6
Denmark	67,4	67,9	68,2	68,3	68,5	68,7	68,7	68,6	69,7	70,0	70,2	70,5	70,7	70,7	70,7	70,6
Estonia	61,6	61,8	61,9	62,7	62,7	63,3	63,6	63,8	68,9	69,1	69,2	69,3	69,5	69,8	69,8	70,0
Finland	66,5	66,8	67,1	67,4	67,7	68,1	68,0	68,0	70,6	70,8	70,8	71,0	71,2	71,4	71,5	71,5
France	68,6	68,8	69,1	69,3	69,6	69,6	69,9	70,0	72,6	72,7	72,8	73,0	73,2	73,3	73,4	73,4
Germany	68,1	68,3	68,4	68,3	68,5	68,3	68,2	68,3	70,8	70,9	71,0	70,9	71,1	70,9	70,8	70,8
Greece	68,1	68,1	68,2	68,5	68,6	68,3	68,5	68,6	70,7	70,8	70,8	71,1	71,3	71,3	71,3	71,3
Hungary	61,2	61,6	61,8	62,3	62,4	62,2	62,8	63,1	67,0	67,1	67,2	67,5	67,7	67,4	68,0	68,3
Ireland	68,2	68,3	68,5	68,7	68,9	69,2	69,4	69,4	70,8	70,7	70,7	70,9	71,1	71,1	71,2	71,3
Italy	69,5	69,6	69,7	69,9	70,2	70,2	70,5	70,6	72,3	72,3	72,4	72,5	72,7	72,6	72,8	73,0
Latvia	59,2	59,7	59,9	60,1	60,3	60,7	60,8	60,9	66,7	67,0	67,4	67,2	67,6	67,8	67,8	68,0
Lithuania	58,8	59,2	59,4	59,4	59,9	60,1	60,2	60,4	67,2	67,3	67,5	67,6	67,9	67,8	68,0	68,1
Luxembourg	68,2	68,4	68,5	68,8	68,8	68,9	68,9	69,0	69,8	69,9	70,0	70,1	70,1	70,2	70,4	70,4
Malta	68,2	68,5	68,6	68,8	69,0	69,0	68,7	68,7	70,7	70,7	70,8	70,9	71,0	70,9	70,9	70,9
Netherlands	68,6	68,8	68,9	69,1	69,4	69,4	69,5	69,6	70,5	70,4	70,5	70,7	70,8	70,8	70,7	70,7
Poland	62,3	62,5	62,6	62,9	63,3	63,3	63,5	63,7	69,0	69,1	69,1	69,3	69,5	69,6	69,8	69,9
Portugal	67,3	67,5	67,8	68,0	68,3	68,6	68,6	68,6	70,6	70,8	71,0	71,2	71,4	71,6	71,6	71,6
Romania	60,7	61,5	61,5	61,8	61,8	61,9	61,9	61,9	66,5	66,9	67,0	67,1	67,2	67,4	67,5	67,6
Slovakia	61,9	62,2	62,4	62,8	62,9	62,9	63,4	63,7	68,2	68,3	68,5	68,6	68,7	68,6	68,8	68,9
Slovenia	64,7	65,1	65,3	65,5	66,1	65,9	66,1	66,3	70,0	70,1	70,2	70,4	70,8	70,9	71,1	71,2
Spain	69,4	69,6	69,8	70,1	70,2	70,1	70,4	70,5	73,0	73,0	73,2	73,3	73,4	73,3	73,5	73,6
Sweden	69,3	69,5	69,8	69,9	70,0	70,0	70,2	70,4	71,0	71,0	71,0	71,0	71,2	71,4	71,4	71,4
United Kingdom	68,0	68,3	68,5	68,5	68,6	68,5	68,5	68,5	69,9	70,1	70,1	70,1	70,2	70,1	70,0	70,0

Life expectancy – European Commission (EC-LE), years

	Male								Female							
	2010	2011	2012	2013	2014	2015	2016	2017	2010	2011	2012	2013	2014	2015	2016	2017
EU-28	**76,9**	**77,3**	**77,4**	**77,7**	**78,1**	**77,9**	**78,2**	**78,3**	**82,8**	**83,1**	**83,0**	**83,3**	**83,6**	**83,3**	**83,7**	**83,6**
Austria	77,8	78,3	78,4	78,6	79,1	78,8	79,3	79,4	83,5	83,8	83,6	83,8	84,0	83,7	84,1	84,0
Belgium	77,5	78,0	77,8	78,1	78,8	78,7	79,0	79,2	83,0	83,3	83,1	83,2	83,9	83,4	84,0	83,9
Bulgaria	70,3	70,7	70,9	71,3	71,1	71,2	71,3	71,4	77,4	77,8	77,9	78,6	78,0	78,2	78,5	78,4
Croatia	73,4	73,8	73,9	74,5	74,7	74,4	75,0	74,9	79,9	80,4	80,6	81,0	81,0	80,5	81,3	81,0
Cyprus	79,2	79,3	78,9	80,1	80,3	79,9	80,5	80,2	83,9	83,1	83,4	85,0	84,3	83,7	84,9	84,2
Czech Republic	74,5	74,8	75,1	75,2	75,8	75,7	76,1	76,1	80,9	81,1	81,2	81,3	82,0	81,6	82,1	82,0
Denmark	77,2	77,8	78,1	78,3	78,7	78,8	79,0	79,2	81,4	81,9	82,1	82,4	82,8	82,7	82,8	83,1
Estonia	70,9	71,4	71,4	72,8	72,4	73,2	73,3	73,8	80,8	81,3	81,5	81,7	81,9	82,2	82,2	82,6
Finland	76,9	77,3	77,7	78,0	78,4	78,7	78,6	78,9	83,5	83,8	83,7	84,1	84,1	84,4	84,4	84,5
France	78,2	78,7	78,7	79,0	79,5	79,2	79,5	79,6	85,3	85,7	85,4	85,6	86,1	85,6	85,8	85,7
Germany	78,0	77,9	78,1	78,1	78,7	78,3	78,6	78,7	83,0	83,1	83,1	83,0	83,6	83,1	83,5	83,4

Greece	78,0	78,0	78,0	78,7	78,8	78,5	78,9	78,8	83,3	83,6	83,4	84,0	84,1	83,7	84,0	83,9
Hungary	70,7	71,2	71,6	72,2	72,3	72,3	72,6	72,5	78,6	78,7	78,7	79,1	79,4	79,0	79,7	79,3
Ireland	78,5	78,6	78,7	78,9	79,3	79,6	79,8	80,4	83,1	83,0	83,1	83,1	83,5	83,4	83,6	84,0
Italy	79,5	79,7	79,8	80,3	80,7	80,3	81,0	80,8	84,7	84,8	84,8	85,2	85,6	84,9	85,6	85,2
Latvia	67,9	68,6	68,9	69,3	69,1	69,7	69,8	69,8	78,0	78,8	78,9	78,9	79,4	79,5	79,6	79,7
Lithuania	67,6	68,1	68,4	68,5	69,2	69,2	69,5	70,7	78,9	79,3	79,6	79,6	80,1	79,7	80,1	80,5
Luxembourg	77,9	78,5	79,1	79,8	79,4	80,0	80,1	79,9	83,5	83,6	83,8	83,9	85,2	84,7	85,4	84,4
Malta	79,3	78,6	78,6	79,6	79,9	79,8	80,6	80,2	83,6	83,0	83,0	84,0	84,3	84,1	84,4	84,6
Netherlands	78,9	79,4	79,3	79,5	80,0	79,9	80,0	80,2	83,0	83,1	83,0	83,2	83,5	83,2	83,2	83,4
Poland	72,2	72,5	72,6	73,0	73,7	73,5	73,9	73,9	80,7	81,1	81,1	81,2	81,7	81,6	82,0	81,8
Portugal	76,8	77,3	77,3	77,6	78,0	78,1	78,1	78,4	83,2	83,8	83,6	84,0	84,4	84,3	84,3	84,6
Romania	70,0	70,8	70,9	71,6	71,3	71,4	71,6	71,7	77,7	78,2	78,1	78,7	78,7	78,6	79,0	79,1
Slovakia	71,8	72,3	72,5	72,9	73,3	73,1	73,8	73,8	79,3	79,8	79,9	80,1	80,5	80,2	80,7	80,7
Slovenia	76,4	76,8	77,1	77,2	78,2	77,8	78,2	78,2	83,1	83,3	83,3	83,6	84,1	83,9	84,3	84,0
Spain	79,2	79,5	79,5	80,2	80,4	80,1	80,5	80,6	85,5	85,6	85,5	86,1	86,2	85,7	86,3	86,1
Sweden	79,6	79,9	79,9	80,2	80,4	80,4	80,6	80,8	83,6	83,8	83,6	83,8	84,2	84,1	84,1	84,1
United Kingdom	78,6	79,0	79,1	79,2	79,5	79,2	79,4	79,5	82,6	83,0	82,8	82,9	83,2	82,8	83,0	83,1

Life expectancy – Institute for Health Metrics and Evaluation (IHME-LE), years

	Male								Female							
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
EU-28	76,8	77,2	77,4	77,6	77,9	77,8	78,0	78,1	82,6	82,7	82,9	83,0	83,2	83,2	83,3	83,4
Austria	77,8	78,2	78,4	78,6	78,9	79,0	79,3	79,4	83,3	83,2	83,5	83,7	83,8	83,9	84,0	84,0
Belgium	77,4	77,6	77,6	78,0	78,4	78,5	78,8	78,9	82,6	82,7	82,9	82,9	83,4	83,3	83,6	83,8
Bulgaria	70,4	70,7	71,0	71,3	71,0	71,4	71,4	71,3	77,4	77,7	78,1	78,4	78,0	78,3	78,5	78,6
Croatia	73,5	73,8	74,0	74,7	74,7	74,6	75,1	75,4	79,9	80,2	80,5	80,8	80,8	80,5	81,3	81,6
Cyprus	76,9	77,3	77,7	77,9	78,1	78,3	78,4	78,5	83,5	83,9	84,3	84,6	84,7	84,9	85,1	85,2
Czech Republic	74,5	74,8	75,1	75,4	75,8	75,9	76,1	76,3	80,8	81,0	81,1	81,3	81,7	81,8	81,8	82,0
Denmark	77,2	77,7	78,1	78,3	78,6	78,9	78,9	78,8	81,4	81,8	82,1	82,4	82,7	82,8	82,7	82,7
Estonia	70,9	71,1	71,3	72,3	72,3	73,1	73,5	73,7	80,7	80,9	81,1	81,2	81,6	81,8	81,9	82,1
Finland	76,9	77,3	77,7	78,0	78,4	78,8	78,7	78,6	83,4	83,6	83,6	83,8	84,1	84,3	84,3	84,3
France	78,1	78,4	78,7	79,0	79,4	79,4	79,7	79,8	84,6	84,8	84,9	85,1	85,4	85,5	85,7	85,7
Germany	77,9	78,2	78,3	78,3	78,5	78,3	78,1	78,3	82,8	82,9	83,1	83,0	83,2	83,0	82,9	83,0
Greece	77,8	77,8	77,8	78,3	78,4	78,1	78,3	78,4	82,8	82,9	82,9	83,2	83,5	83,6	83,6	83,6
Hungary	70,7	71,2	71,5	72,1	72,3	71,9	72,8	73,2	78,4	78,5	78,7	79,0	79,3	78,9	79,8	80,2
Ireland	78,5	78,6	78,8	79,1	79,4	79,8	80,0	80,0	82,9	82,9	82,9	83,1	83,4	83,3	83,6	83,7
Italy	79,4	79,5	79,7	80,0	80,3	80,2	80,7	80,8	84,4	84,4	84,5	84,8	85,0	84,8	85,1	85,3
Latvia	68,0	68,7	69,0	69,2	69,5	69,9	70,1	70,2	78,0	78,5	78,9	78,7	79,3	79,5	79,6	79,9
Lithuania	67,6	68,2	68,5	68,5	69,1	69,4	69,5	69,6	78,9	79,1	79,3	79,4	79,8	79,7	80,0	80,2
Luxembourg	79,0	79,3	79,5	79,8	79,9	79,9	80,0	80,0	82,4	82,6	82,7	82,8	82,8	82,9	83,2	83,3
Malta	78,1	78,6	78,8	79,1	79,3	79,3	79,0	78,9	82,6	82,7	82,8	83,0	83,1	83,0	83,0	83,0
Netherlands	78,7	79,1	79,1	79,4	79,7	79,7	79,8	79,9	82,7	82,7	82,8	83,1	83,2	83,2	83,0	83,1
Poland	72,2	72,5	72,7	73,1	73,7	73,6	73,8	74,1	80,6	80,8	80,8	81,1	81,4	81,4	81,7	81,8
Portugal	76,9	77,3	77,6	77,8	78,2	78,5	78,6	78,5	83,0	83,3	83,6	83,9	84,1	84,4	84,3	84,2
Romania	70,0	70,9	71,0	71,4	71,4	71,6	71,6	71,6	77,5	78,1	78,2	78,4	78,5	78,7	78,9	79,0
Slovakia	71,8	72,2	72,5	73,0	73,1	73,1	73,8	74,1	79,3	79,5	79,8	80,0	80,3	80,1	80,4	80,6
Slovenia	76,1	76,6	76,8	77,1	77,8	77,6	77,8	77,9	82,7	82,9	83,0	83,2	83,8	83,9	84,1	84,2
Spain	78,9	79,2	79,3	79,8	79,9	79,8	80,1	80,2	85,0	85,0	85,2	85,4	85,5	85,4	85,7	85,8
Sweden	79,4	79,6	80,0	80,1	80,3	80,3	80,6	80,8	83,6	83,6	83,6	83,7	83,9	84,1	84,1	84,2
United Kingdom	78,4	78,8	79,1	79,0	79,2	79,1	79,1	79,2	82,4	82,6	82,7	82,7	82,9	82,8	82,7	82,7

Proportion of life spent in good health – European Commission (EC-%GH), %

	Male								Female							
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
EU-28	92,8	92,5	92,4	92,5	92,4	92,7	93,5	93,7	90,5	90,1	90,0	90,2	90,3	90,6	91,2	91,7
Austria	92,7	92,2	92,6	92,6	93,2	92,8	93,2	93,7	90,3	90,1	91,0	90,8	90,8	91,6	92,2	91,7
Belgium	93,5	92,7	93,3	93,9	93,1	93,5	93,5	93,9	90,8	90,4	91,3	91,1	90,8	90,0	90,7	91,3
Bulgaria	92,5	92,6	92,7	92,6	92,0	92,3	93,1	93,0	89,1	89,3	90,1	90,2	89,9	89,5	90,8	90,9
Croatia	83,5	84,8	85,3	84,7	85,1	86,0	86,8	86,6	81,4	80,8	81,4	82,6	82,2	83,2	83,3	84,8
Cyprus	91,4	92,1	93,2	92,6	94,5	94,1	95,3	94,9	88,9	89,2	90,9	89,8	92,2	92,7	94,0	94,2
Czech Republic	91,0	91,3	91,1	91,2	91,8	92,5	91,7	92,0	88,4	88,2	88,3	88,8	89,5	89,8	89,6	90,6
Denmark	94,2	93,7	94,6	94,9	94,4	94,8	93,9	93,8	92,3	92,3	93,1	92,8	93,0	92,9	93,0	92,9
Estonia	90,1	88,9	88,7	88,7	88,4	89,5	89,9	90,8	87,0	85,6	85,8	85,8	87,1	87,2	88,3	88,1
Finland	93,8	93,8	94,7	94,9	94,5	95,2	95,2	95,7	93,2	93,2	93,9	93,7	94,2	95,0	94,1	95,0
France	92,8	93,0	93,1	92,9	93,2	93,7	93,5	93,1	90,4	90,5	91,1	91,2	91,1	92,2	91,8	91,8
Germany	93,5	93,3	93,3	94,2	93,5	93,4	93,6	93,5	91,9	92,3	91,8	92,3	92,7	92,7	92,2	92,4
Greece	91,7	92,9	93,1	92,0	91,5	92,0	92,1	92,3	90,3	90,9	90,4	89,2	89,3	89,8	89,8	90,0
Hungary	88,7	89,5	89,2	89,5	89,8	89,3	91,5	91,7	84,9	84,9	85,1	85,8	85,5	86,1	87,8	88,3
Ireland	97,3	97,2	97,0	96,7	96,5	96,4	96,9	97,1	96,4	97,0	97,2	96,1	95,6	96,0	96,3	96,2
Italy	93,2	90,7	90,9	90,7	90,8	90,9	94,6	96,0	90,1	87,3	87,7	87,7	88,1	88,3	92,1	94,1
Latvia	88,7	88,6	89,8	89,3	89,1	90,2	90,3	89,7	84,5	84,3	86,9	85,7	85,6	86,2	86,9	86,1
Lithuania	88,9	88,0	88,2	89,5	89,2	90,8	89,5	92,1	83,5	82,3	82,0	83,5	84,5	85,7	86,6	86,5
Luxembourg	93,1	93,4	93,6	93,9	93,3	93,3	92,3	92,1	91,9	91,3	91,9	90,5	91,0	90,6	87,5	89,7
Malta	96,7	96,3	97,2	96,6	96,5	96,5	96,8	95,9	94,6	94,5	95,3	94,9	96,1	95,7	96,3	94,9
Netherlands	96,2	95,8	96,0	96,4	96,0	96,2	96,4	96,8	95,2	94,6	94,6	95,0	94,9	95,1	95,3	95,3
Poland	88,1	88,3	88,6	88,9	89,3	89,4	90,0	89,7	84,5	85,1	85,3	86,1	86,5	86,6	87,0	87,2
Portugal	85,5	87,1	87,8	87,8	87,4	87,7	89,4	89,9	78,6	81,4	81,8	81,1	81,4	82,2	84,0	84,6
Romania	93,9	93,8	93,2	93,7	94,0	94,7	95,8	95,4	90,3	89,6	89,8	90,2	90,9	91,6	92,9	92,8
Slovakia	89,1	89,5	89,8	90,3	90,3	90,0	90,2	90,8	84,6	84,6	86,0	86,5	85,8	86,3	86,9	87,9
Slovenia	89,3	89,3	89,9	90,7	90,7	90,7	91,7	92,2	85,8	86,3	87,0	88,8	88,1	87,8	89,7	90,0
Spain	93,6	93,8	93,3	93,1	93,5	94,3	94,7	94,7	90,2	91,1	90,6	90,2	90,4	91,6	92,0	93,1
Sweden	96,5	96,0	96,0	96,9	96,4	97,0	96,4	95,7	94,1	94,7	95,3	95,3	95,4	95,1	93,8	94,2
United Kingdom	94,9	95,2	93,3	92,7	92,3	93,2	93,1	94,3	95,0	94,8	92,0	92,9	92,4	92,6	92,0	93,3

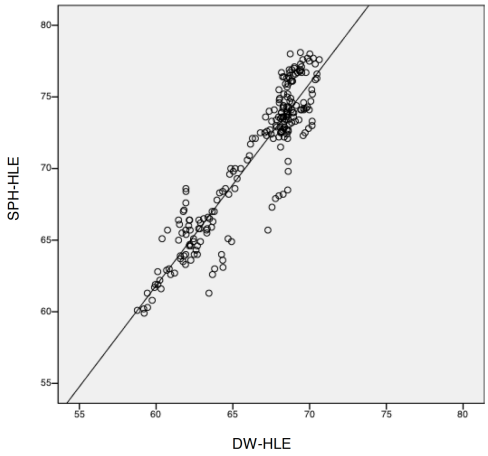
Proportion of life spent in good health – Institute for Health Metrics and Evaluation (IHME-%GH), %

	Male								Female							
	2010	2011	2012	2013	2014	2015	2016	2017	2010	2011	2012	2013	2014	2015	2016	2017
EU-28	87,2	87,2	87,1	87,1	87,0	87,1	87,0	87,0	85,5	85,5	85,4	85,4	85,4	85,4	85,3	85,3
Austria	87,0	86,9	86,9	86,9	86,9	87,0	87,0	87,1	85,2	85,2	85,2	85,2	85,2	85,2	85,2	85,3
Belgium	86,6	86,6	86,6	86,6	86,5	86,6	86,5	86,6	84,6	84,6	84,6	84,6	84,5	84,6	84,6	84,6
Bulgaria	87,3	87,3	87,2	87,2	87,2	87,1	87,1	87,1	86,4	86,3	86,3	86,2	86,3	86,2	86,2	86,2
Croatia	86,3	86,3	86,2	86,1	86,1	86,2	86,1	86,1	86,0	86,0	85,9	85,8	85,8	85,8	85,7	85,6
Cyprus	87,7	87,7	87,6	87,6	87,6	87,6	87,6	87,7	85,4	85,4	85,3	85,3	85,3	85,3	85,3	85,4
Czech Republic	85,8	85,8	85,7	85,6	85,5	85,5	85,4	85,4	85,2	85,2	85,2	85,1	85,0	85,0	85,0	85,0
Denmark	87,4	87,3	87,2	87,2	87,1	87,1	87,1	87,0	85,7	85,6	85,6	85,5	85,5	85,5	85,4	85,4
Estonia	86,9	86,8	86,8	86,7	86,7	86,6	86,6	86,6	85,4	85,4	85,3	85,3	85,3	85,2	85,2	85,2

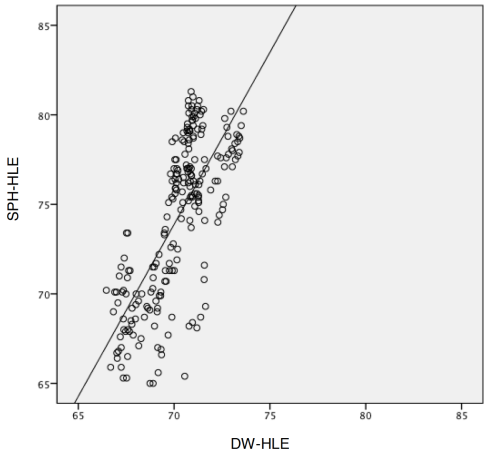
Finland	86,4	86,4	86,4	86,4	86,4	86,4	86,5	86,6	84,6	84,6	84,7	84,7	84,7	84,7	84,8	84,9
France	87,9	87,8	87,8	87,8	87,7	87,7	87,7	87,7	85,8	85,8	85,8	85,7	85,7	85,7	85,6	85,7
Germany	87,4	87,3	87,3	87,3	87,2	87,3	87,3	87,2	85,5	85,5	85,5	85,4	85,4	85,4	85,4	85,3
Greece	87,6	87,6	87,6	87,5	87,4	87,5	87,5	87,5	85,5	85,5	85,5	85,4	85,3	85,3	85,3	85,3
Hungary	86,6	86,5	86,5	86,4	86,3	86,4	86,3	86,2	85,5	85,5	85,4	85,4	85,3	85,4	85,2	85,2
Ireland	87,0	87,0	86,9	86,9	86,9	86,8	86,8	86,7	85,3	85,3	85,4	85,3	85,3	85,3	85,2	85,2
Italy	87,5	87,5	87,5	87,4	87,4	87,4	87,4	87,4	85,6	85,6	85,6	85,6	85,6	85,6	85,6	85,5
Latvia	87,0	86,9	86,9	86,9	86,8	86,8	86,8	86,9	85,5	85,4	85,3	85,3	85,2	85,2	85,2	85,1
Lithuania	86,9	86,8	86,8	86,8	86,7	86,7	86,7	86,7	85,2	85,2	85,1	85,1	85,0	85,0	85,0	85,0
Luxembourg	86,2	86,2	86,2	86,1	86,1	86,1	86,1	86,1	84,7	84,7	84,7	84,6	84,6	84,6	84,6	84,6
Malta	87,2	87,1	87,1	87,0	87,0	87,0	87,0	87,0	85,6	85,5	85,5	85,5	85,4	85,4	85,4	85,4
Netherlands	87,1	87,1	87,1	87,1	87,0	87,0	87,0	87,1	85,2	85,2	85,1	85,1	85,1	85,1	85,1	85,1
Poland	86,2	86,2	86,1	86,1	86,0	86,0	86,0	86,0	85,6	85,5	85,5	85,5	85,4	85,4	85,4	85,4
Portugal	87,5	87,4	87,4	87,4	87,3	87,3	87,3	87,4	85,0	84,9	84,9	84,9	84,9	84,9	84,9	85,0
Romania	86,8	86,6	86,6	86,5	86,6	86,5	86,6	86,6	85,8	85,7	85,7	85,6	85,6	85,6	85,6	85,6
Slovakia	86,2	86,2	86,1	86,0	86,0	86,0	85,9	85,9	85,9	85,8	85,8	85,7	85,6	85,6	85,6	85,5
Slovenia	85,1	85,0	85,0	85,0	84,9	85,0	85,0	85,1	84,6	84,6	84,6	84,6	84,5	84,5	84,5	84,5
Spain	88,0	87,9	87,9	87,9	87,9	87,9	87,9	87,9	85,9	85,9	85,9	85,9	85,8	85,9	85,8	85,8
Sweden	87,3	87,3	87,2	87,2	87,2	87,1	87,1	87,1	84,9	84,9	84,9	84,9	84,9	84,8	84,9	84,9
United Kingdom	86,8	86,7	86,7	86,7	86,6	86,6	86,6	86,6	84,9	84,8	84,8	84,8	84,7	84,7	84,7	84,7

Supplemental File 2 – Scatter plots between between health expectancy, life expectancy and proportion of life spent in good health methods, by sex and by year, for EU28 countries between 2010 and 2017.

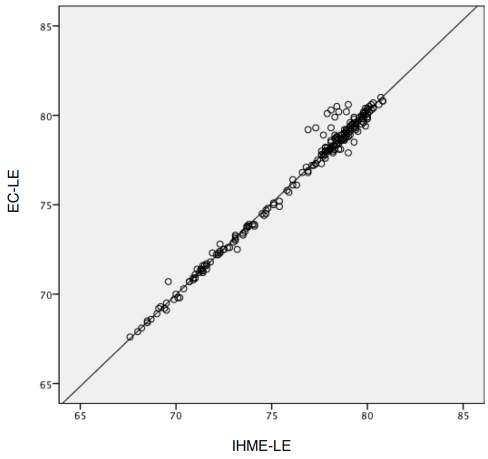
A – Healthy expectancy (males)



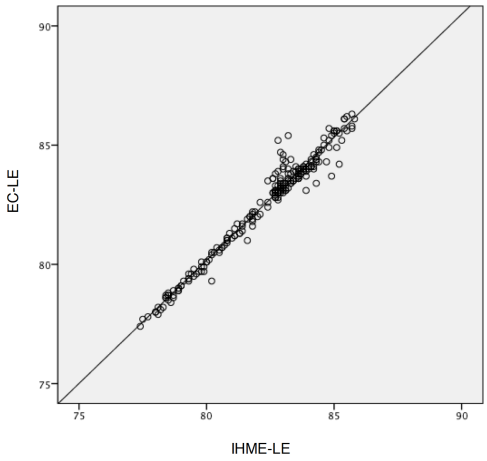
B – Healthy expectancy (females)



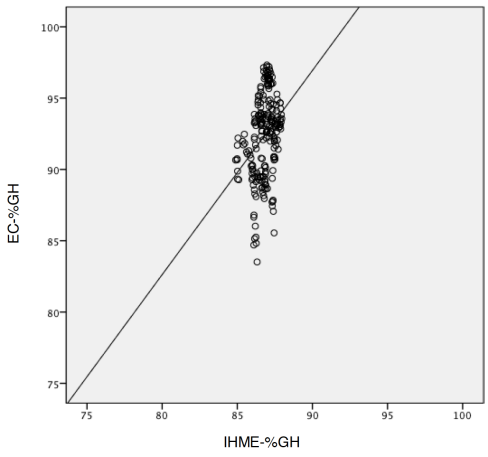
C – Life expectancy (males)



D – Life expectancy (females)



E – Proportion of life spent in good health (males)



F – Proportion of life spent in good health (females)

