PHASE 1, STEPS 1 AND 2: COLLECTION AND SUMMARY OF DATA ON THE EUROPE-WIDE IMPACT OF DIET-RESPONSIVE NON-COMMUNICABLE DISEASES

Content

Summary

See pages 43-45 for interim summary but interim conclusions recommend the following diet-responsive non-communicable diseases be taken forward in this project are:

Ischaemic heart disease
Stroke (ischaemic and haemorrhagic)
Colo-rectal cancer
Type 2 diabetes mellitus
Alzheimer's disease and other dementias

1. Introduction

Non-communicable diseases (NCD) are those diseases that are not transmissible directly between individuals. They include most cardiovascular diseases, most cancers, diabetes, Alzheimer's disease and their impact can be both chronic or acute. NCDs are the greatest cause of death globally and according to the World Health Organisation (WHO) they caused 68% of deaths in 2012, a notable rise from 60% in 2000. NCDs are also responsible for a major part of health care costs and the European Commission (EC) has estimated that cardiovascular diseases (CVD) cost EU health care systems €217 billion in 2015 with €37 billion and €39 billion related to ischaemic heart disease (IHD) and stroke respectively. Moreover, NCDs also lead to indirect costs such as productivity losses and costs of home care which the EC estimated to be €195 billion with the majority (€80 million) related to IHD. Many NCDs are the result of lifestyle issues notably limited exercise and poor diets.

The purpose of the Phase 1, step 1 part of the current project is to assess the contribution of NCDs to European ill health and mortality and crucially to identify NCDs that are responsive to dietary change.

2. Methods

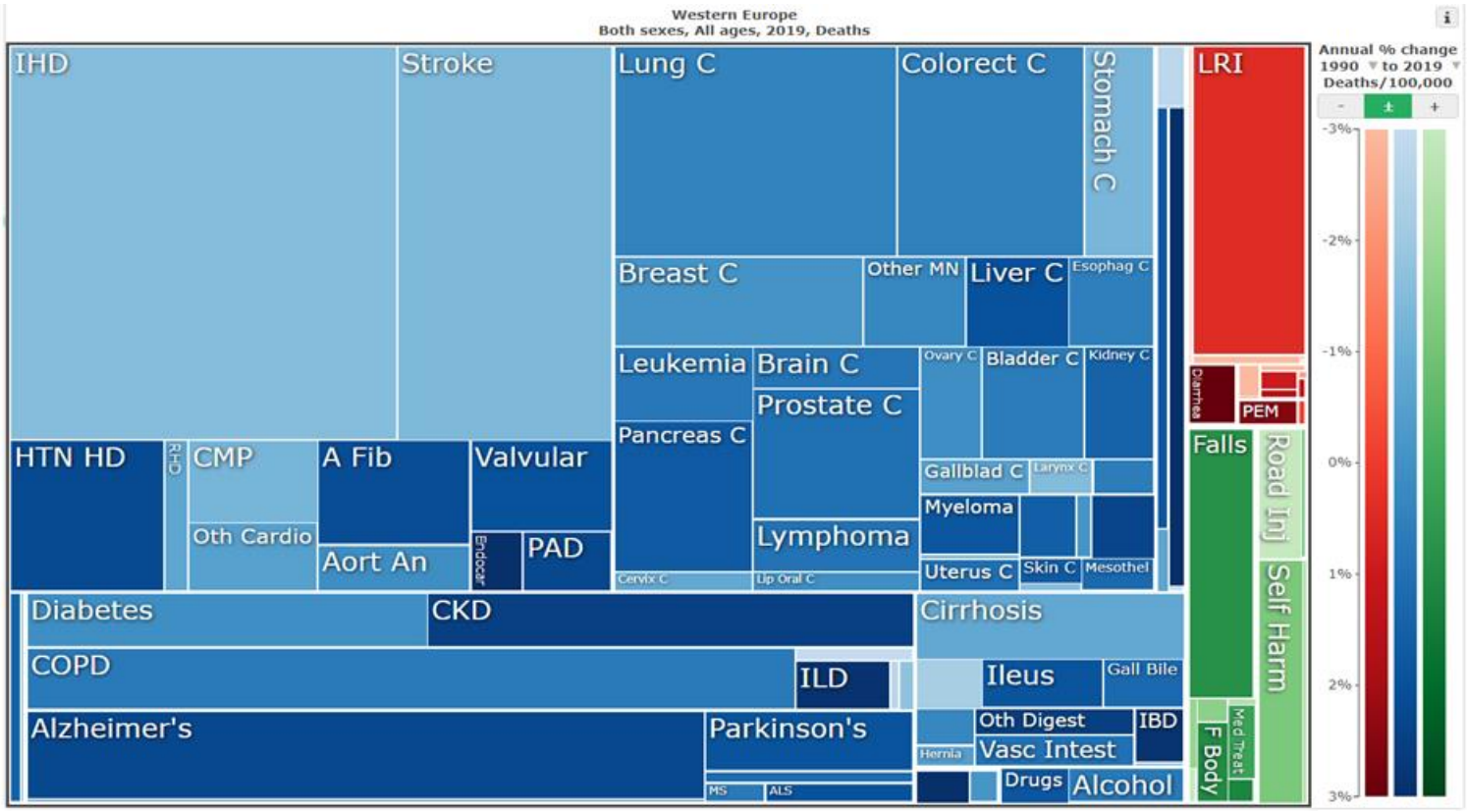
Whilst there are a range of approaches for assessing disease impacts the current work will concentrate on Europe and follow a hierarchical approach:

1. Assess the relative contribution of all diseases to all-cause mortality. This will begin at a European population level and for key diet-responsive NCDs progress through the assessment at country level according to sex.
2. For the key diet-responsive NCDs, assess relative trends in age-standardised prevalence over the period 1990-2019 for European countries.
3. For important metabolic and dietary risk factors, assess relative trends in summary exposure value (a measure of a population's exposure to a risk factor) over the period 1990-2019 according to European countries.
4. Assess the impact of key NCDs on disability-adjusted life years (DALYs) over the period 1990-2019 and health care costs.
5. Undertake a reflection on diet-responsive NCDs to assess their relative impact and related importance.
6. Summarise the evidence and give recommendations.

The primary source of disease data used was the Global Burden of Disease (GBD) database (1). This is managed by the Institute for Health Metrics and Evaluation at the University of Washington and is highly regarded with comprehensive data at regional and global levels. Some outputs from this source were compared with those from others, notably Eurostat.

3. Results

For ease of interpretation the results are presented primarily as figures although most of the data behind the figures are available in Supplementary Material.



Cardiovascular conditions	Full name
IHD	Ischaemic heart disease
HTN HD	Hypertensive heart disease
CMP	Cardiomyopathy and myocarditis
A Fib	Atrial fibrillation and flutter
Aort An	Aortic aneurysm
RHD	Rheumatic heart disease
Valvular	Valvular heart disease
PAD	Peripheral artery disease
Endo car	Endocarditis
Cancer	**Full name**
Colorect C	Colorectal cancer

Figure 1. Relative disease contribution to all-cause mortality Western Europe, all ages, both sexes

3.1 Causes of mortality

Figure 1 gives an overview of the relative contribution of diseases to all-cause mortality in Western Europe. The aggregated percentage contribution of disease groups to all-cause mortality based on the data relating to Figure 1 are given in Table 1 together with comparison of similar information in the Eurostat data (2).

Table 1. Aggregated percentage contribution of disease groups to all-cause mortality

Eurostat data for 2017	**2017**		**GBD data for EU 2019**	**2019**
Causes of death (%)	**%**		**Causes of death (%)**	**%**
Circulatory diseases	36.7		Cardiovascular diseases	34.1
Cancer	25.0		Neoplasms	30.8
Respiratory diseases	7.9		Neurological disorders	6.7
External causes of death	4.7		Digestive diseases	5.1
Diseases of the digestive system	4.2		Chronic respiratory diseases	4.7
Diseases of the nervous system	4.2		Diabetes and kidney diseases	4.1
Mental and behavioural disorders	3.9		Respiratory infections and tuberculosis	3.2
Endocrine, nutritional and metabolic diseases	3.2		Other non-communicable diseases	1.96
All remaining causes of death	10.2		Other cardiovascular and circulatory diseases	0.86
			All remaining causes of death	8.5
All causes of death (A00-Y89) excluding S00-T98	**100**		All causes of death (A00-Y89) excluding S00-T98	**100**

The two sets of data have good agreement on the major contributions of CVD and cancers, but the more recent and detailed GBD values indicate a greater contribution of neurological disorders and as noted in Figure 1, this is predominantly Alzheimer's disease. GBD data also show the major contribution of hypertension to deaths from IHD (51.9%), stroke (46.1%), hypertensive heart disease (100%) and chronic kidney disease (69.1%).

Figure 2 shows the all-cause mortality data per 100,000 according to cause, country and sex. The predominance of CVD is notable and followed by cancers is in line with the above, but the wide variability between countries is notable with Iceland and Ireland being the lowest and Bulgaria being the highest by a considerable margin. It is also noted that the five highest countries are all from more eastern parts of the EU.

Deaths per 100,000 from CVD are examined in further detail according to CVD type, country and sex in Figure 3. This shows a general predominance of IHD and a substantial range of data among countries with the eastern EU countries having substantially greater mortality from CVD with Bulgaria having the highest values and an approximately equal contribution from IHD and stroke most notably in females.

Deaths per 100,000 from type 2 diabetes are shown in Figure 4 according to country and sex in Figure 4. This again shows substantial variation between countries with highest being Portuguese females, and the lowest Iceland. It should be noted that there is concern in the UK at least (3), that because CVD are often a result of diabetes, CVD are often the recorded death, and so it is possible that the data underestimates the contribution of type 2 diabetes substantially.

It is noted above that neurological diseases and particularly Alzheimer's disease is now the third most common cause of death in Western Europe. Figure 5 examines deaths due to neurological diseases further according to disease type, country and sex. The large predominance of Alzheimer's disease is very noticeable as is the higher death rate in females than males.

References

1 VizHub - GBD Results (healthdata.org)
2 Data - Health - Eurostat (europa.eu)
3 Deaths due to diabetes underestimated - Diabetes

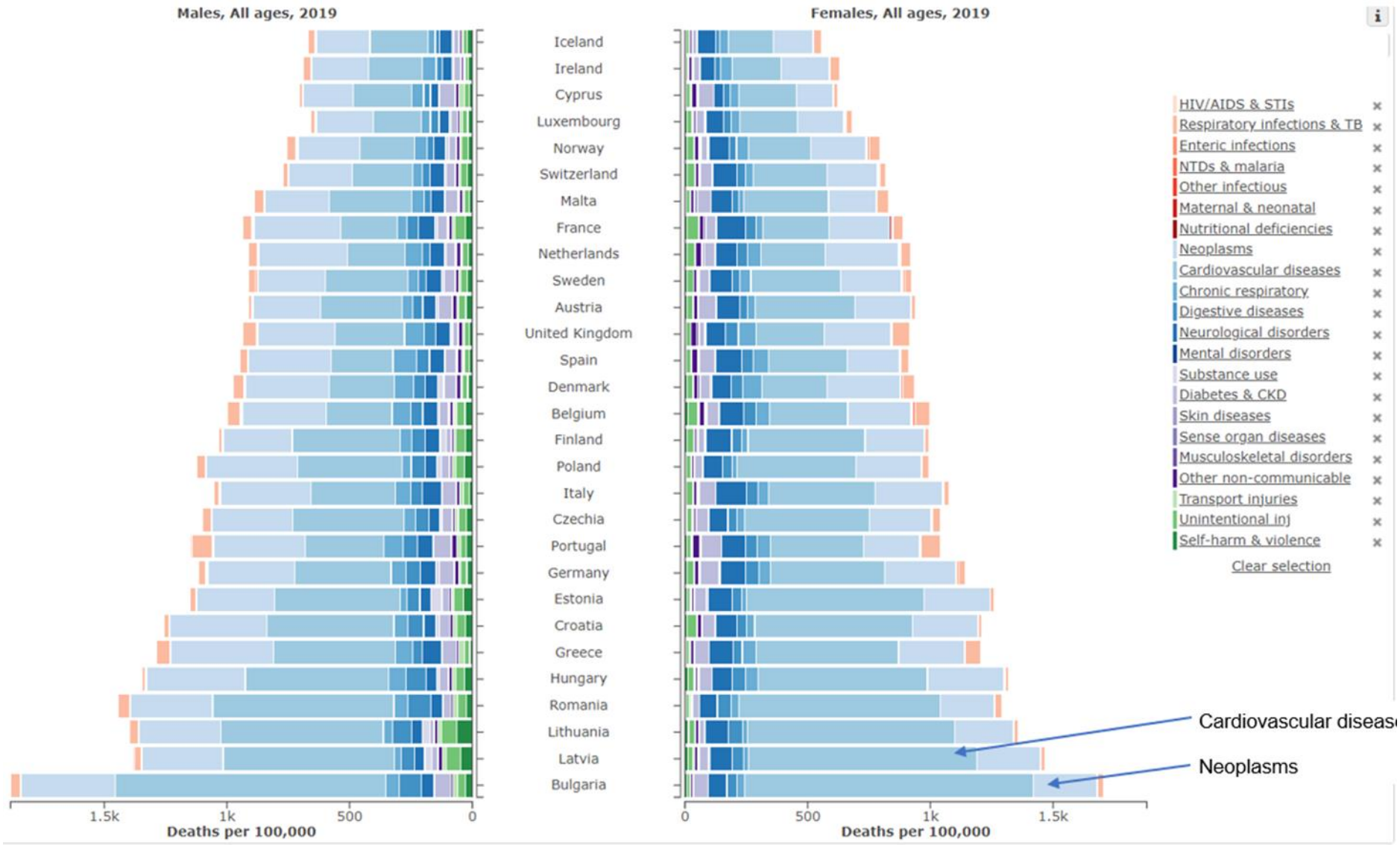


Figure 2. All-cause mortality per 100,000: Western Europe, by cause, country and sex

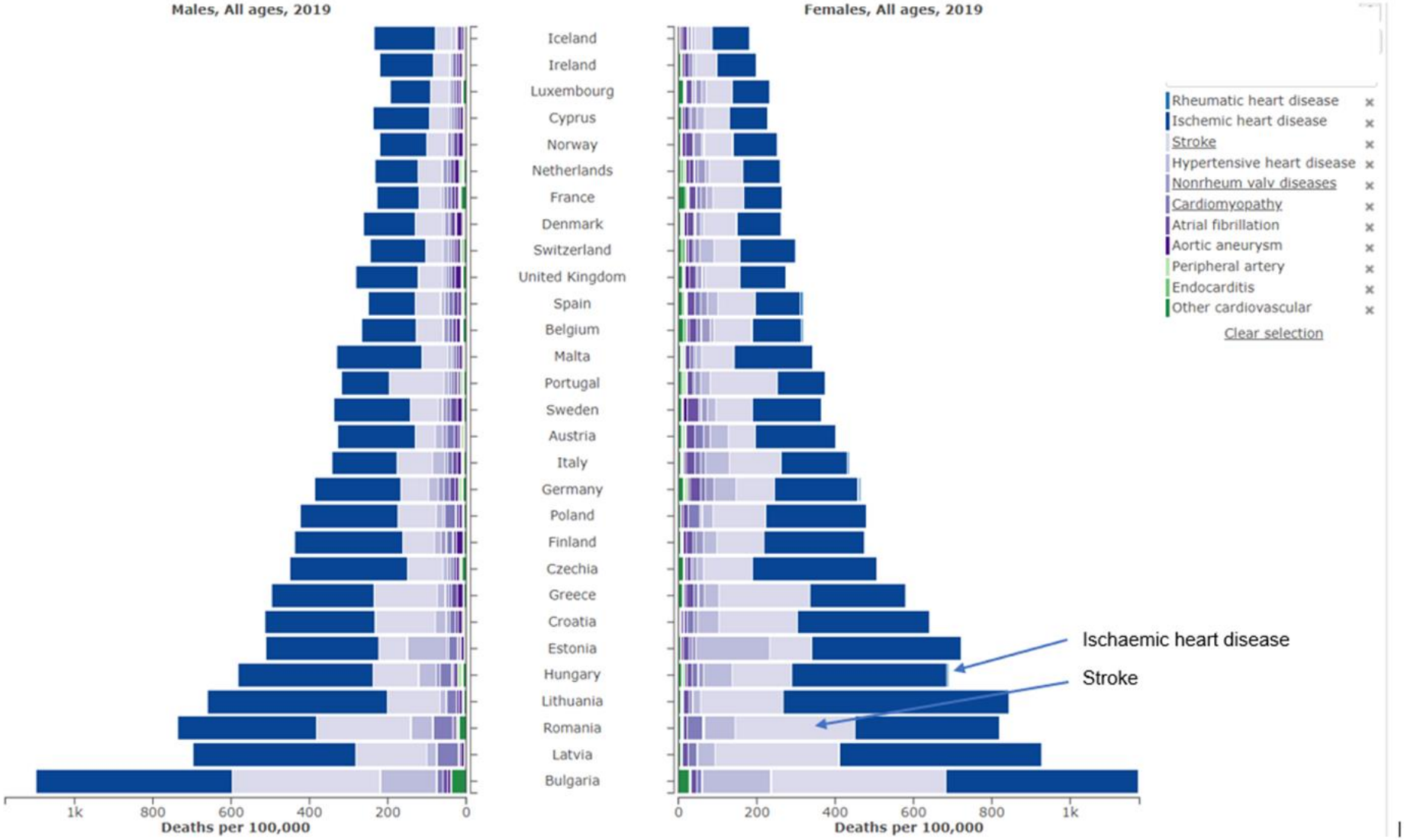


Figure 3. Cardiovascular disease mortality per 100,000: Western Europe, by CVD type, country and sex

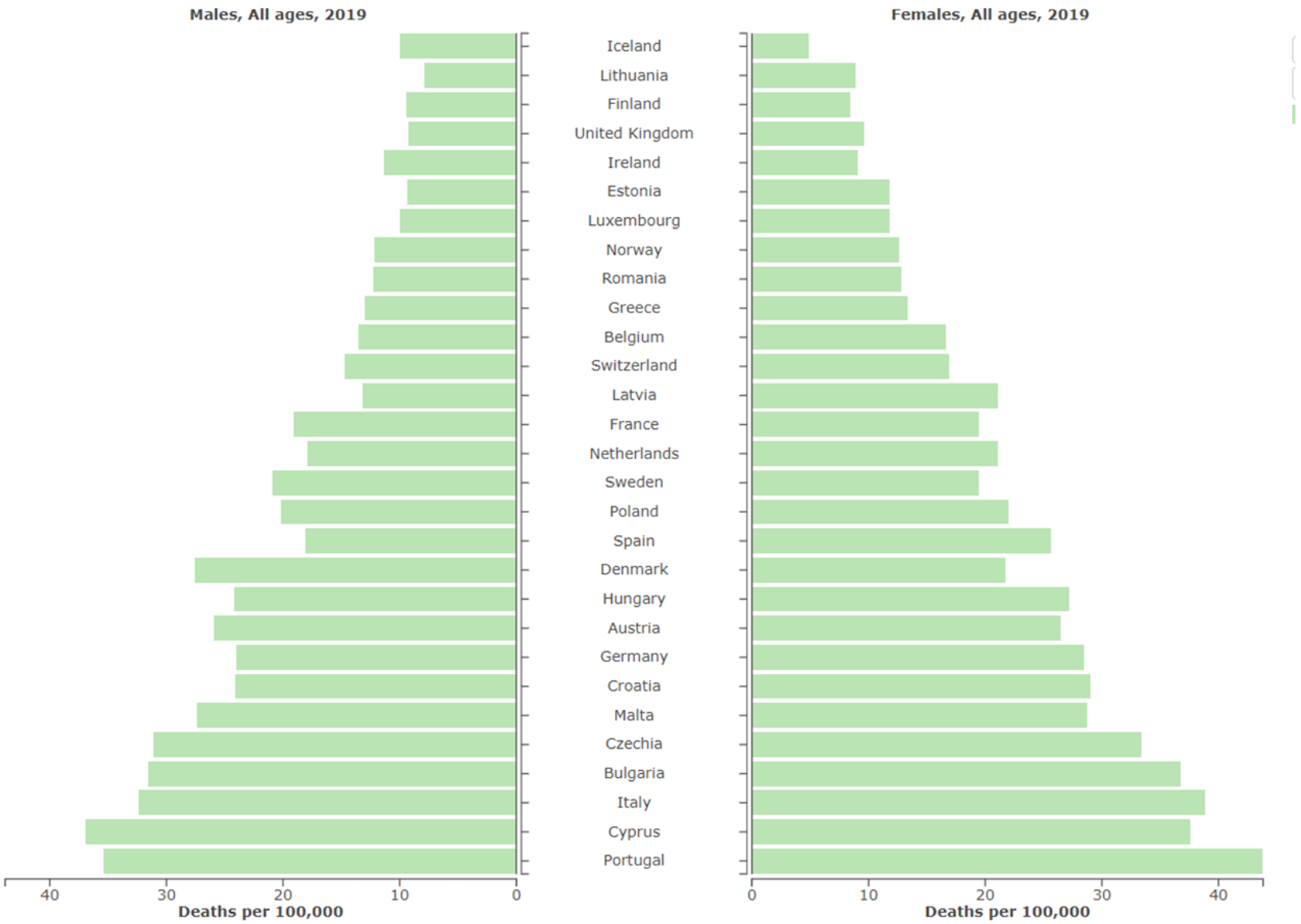


Figure 4. Mortality related to type 2 diabetes per 100,000: Western Europe, by country and sex

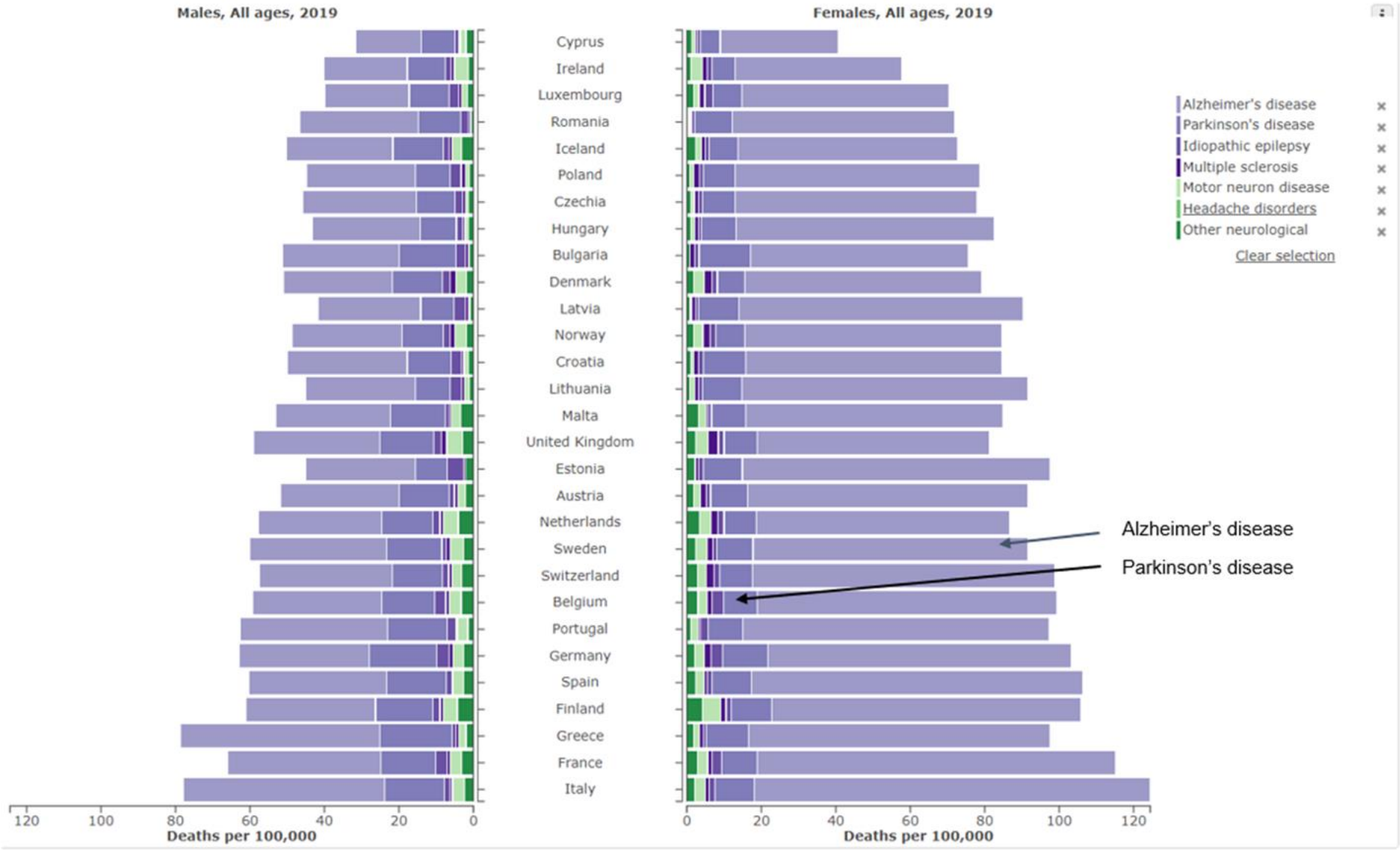


Figure 5. Mortality related to neurological diseases per 100,000: Western Europe, by country and sex

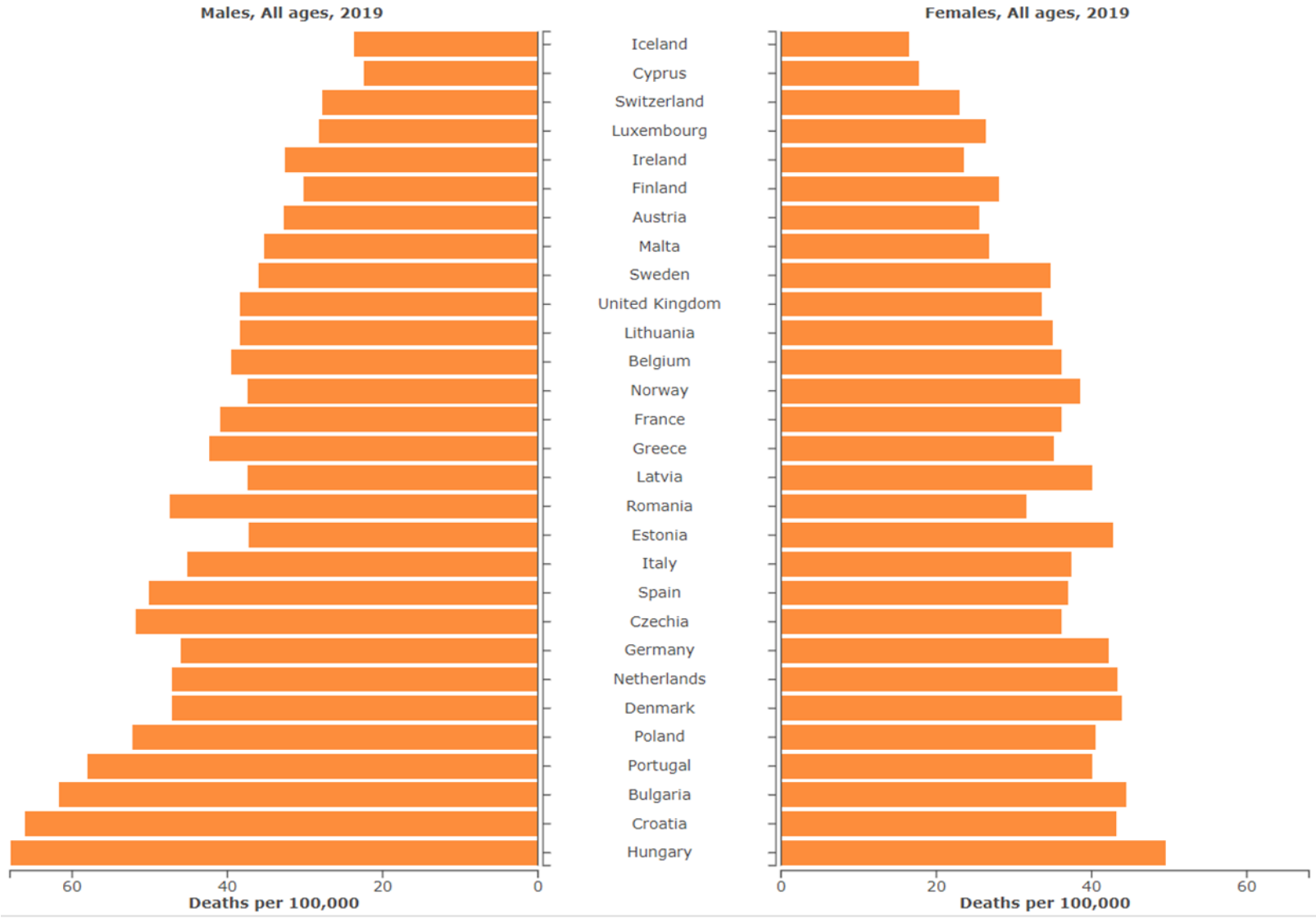


Figure 6. Mortality caused by colorectal cancer per 100,000: Western Europe by country and sex.

Colorectal cancer is the second largest cause of death from cancer (see figure 2), although unlike some cancers, it affects both females and males (see figure 6). Colorectal cancer is known to have a relationship with diet (Section 4.5). There is considerable variation between countries with Iceland having the lowest death rate with Bulgaria, Croatia and Hungary being the highest three. Overall, males seem to have a greater death rate than females.

3.2 Trend in disease prevalence

Prevalence is a measure of the frequency of a disease or health condition in a population at a particular point in time (point prevalence) or over a specified period of time (period prevalence) and the disease may, or may not, lead to death. Prevalence differs from incidence in that prevalence includes all cases, both new and pre-existing, in the population at the specified time, whereas incidence is limited to new cases only. Prevalence is a good measure of the amount of a chronic disease in a population which can help in the estimation of resources needed to reduce the disease, including cost. The data in this section show the trend in prevalence from 1990 to 2019 (i.e. period prevalence) of the same potentially diet-responsive NCDs as examined for mortality. The data are also age standardised, an important technique for comparing populations which may have different age structures.

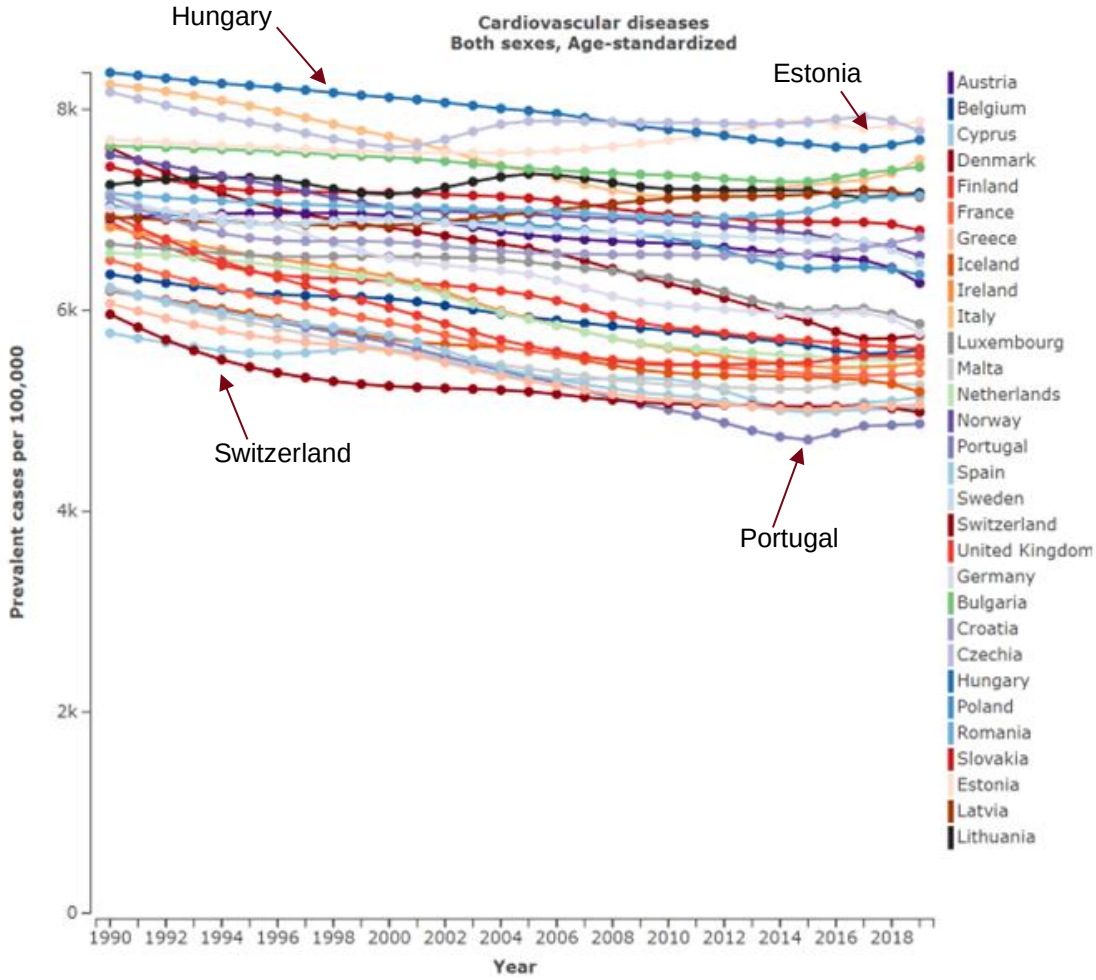


Figure 7. Age standardised prevalence of cardiovascular for both sexes 1990-2019 per 100,000: Western Europe by country.

Although the range of up to about 200,000 cases is seen between countries with the highest and lowest prevalence of cardiovascular diseases (Figure 7), the overall trends are downward in agreement the trends in deaths from IHD and stroke (not shown). However, despite the welcome trends, CVD still remains the greatest cause of death by a substantial margin.

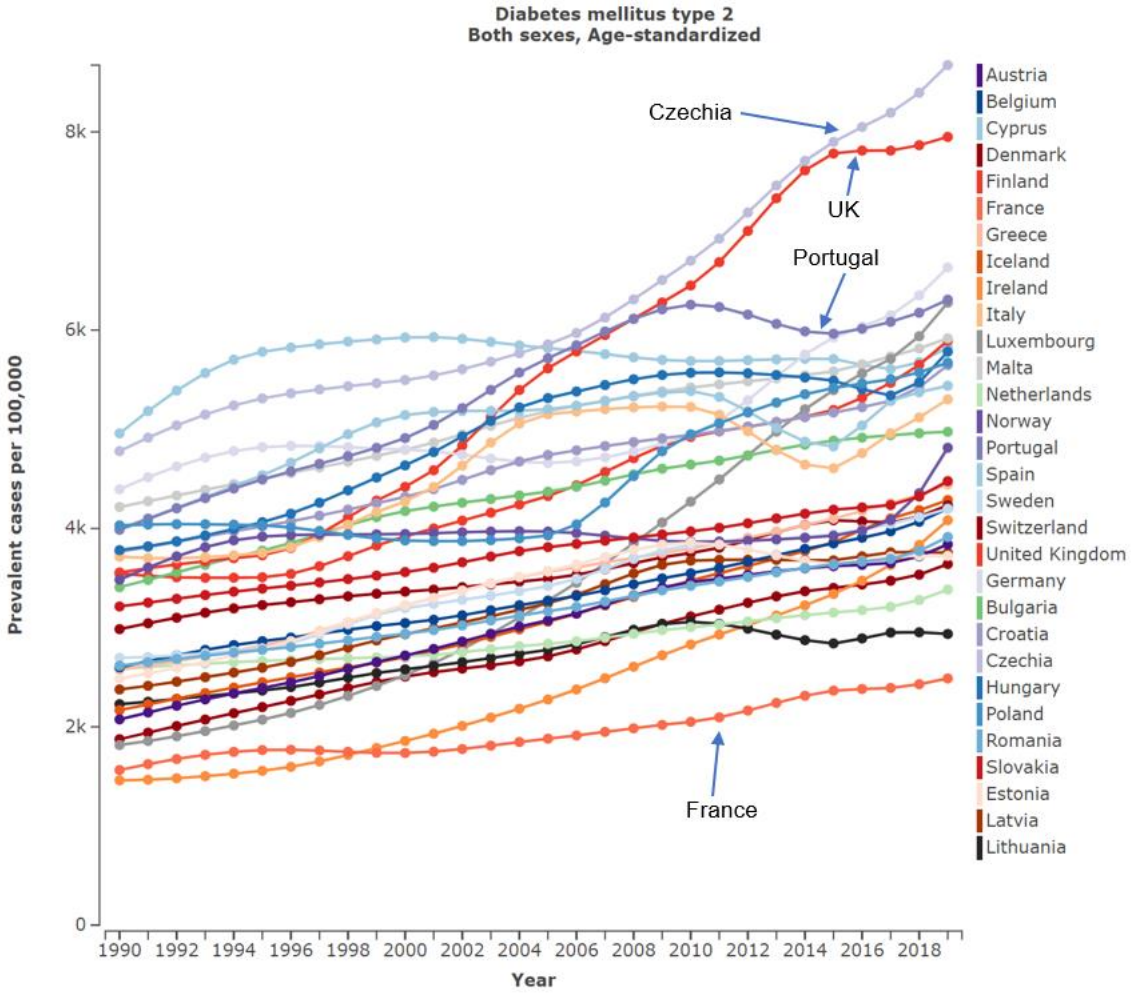


Figure 8. Age standardised prevalence of type 2 diabetes for both sexes 1990-2019 per 100,000: Western Europe by country.

The trends in the prevalence of type 2 diabetes (Figure 8) are concerning, increasing in almost all countries. There is clearly very substantial variation between countries with the two having the most rapid rate of increase and highest terminal prevalence being Czechia and the United Kingdom. France has the lowest prevalence and a slow increase. These trends are not reflected in the trend in mortality from type 2 diabetes (not shown), potentially because of the certification of death issue noted earlier (section 3.1). This also shows the benefit of examining prevalence in addition to mortality.

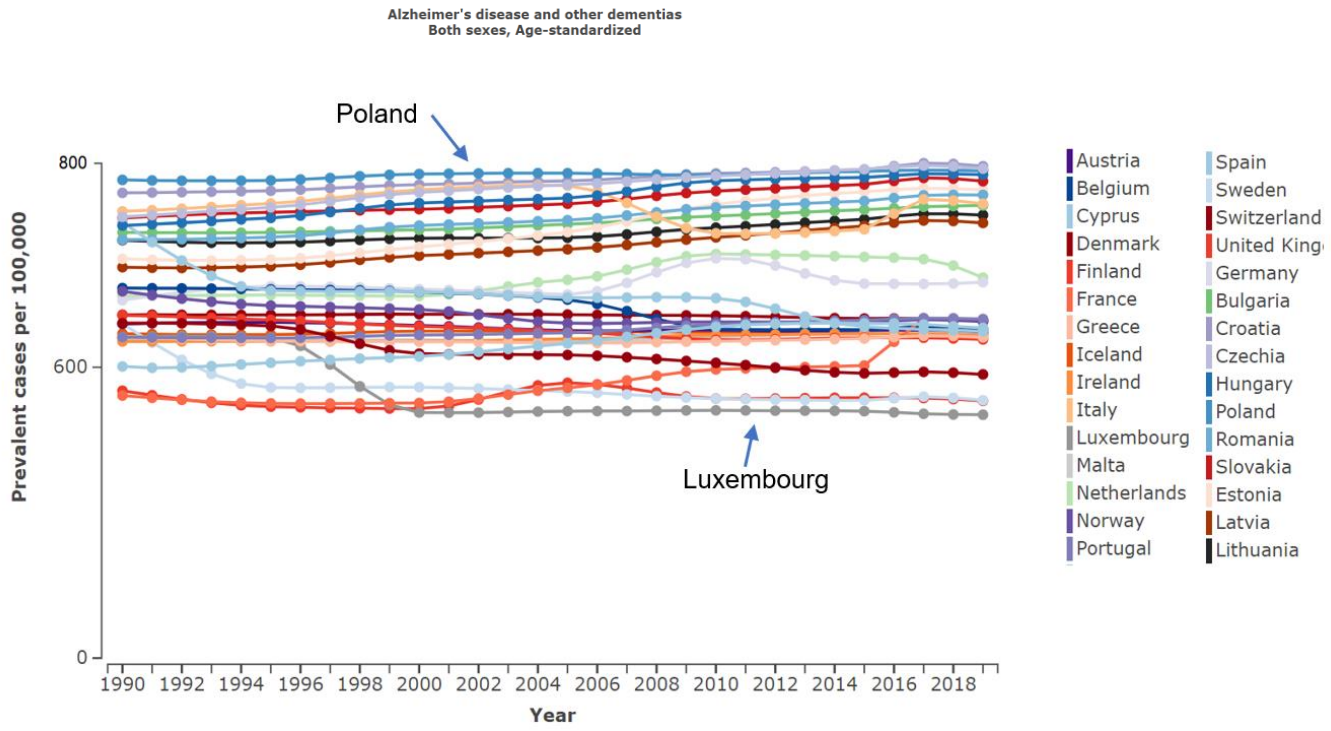


Figure 9. Age standardised prevalence of Alzheimer's disease and other dementias for both sexes 1990-2019 per 100,000: Western Europe by country.

There is clearly substantial variation (maximum 213 cases per 100,000 in 2019) in age-standardised prevalence of Alzheimer's disease and other dementias between countries (Figure 9), and whilst for some (e.g. Switzerland, UK, Malta, Iceland, Ireland, Poland, Austria) prevalence rate has not changed substantially between 1990 and 2019, some others show a steady increase (e.g. Bulgaria, Croatia, Cyprus, Estonia, Hungary, Latvia, Romania, Slovakia) and decrease (e.g. Denmark, Finland, Norway, Spain, Sweden). In addition, some countries show substantial changes in age-standardised prevalence during the examination period with increases (e.g., Germany from 2005, France from 2000 and again from 2015) and decreases (e.g., Belgium from 2005, Italy from 2005 with a rise from 2015).

Figure 10 shows the trends in age-standardised prevalence of colorectal cancer. With few exceptions the trends are upward with many by a substantial amount (e.g., Estonia, Spain, Portugal, The Netherlands, Bulgaria, Romania). Austria has the most consistent decline from 1996 after a small rise from 1990 to 1995.

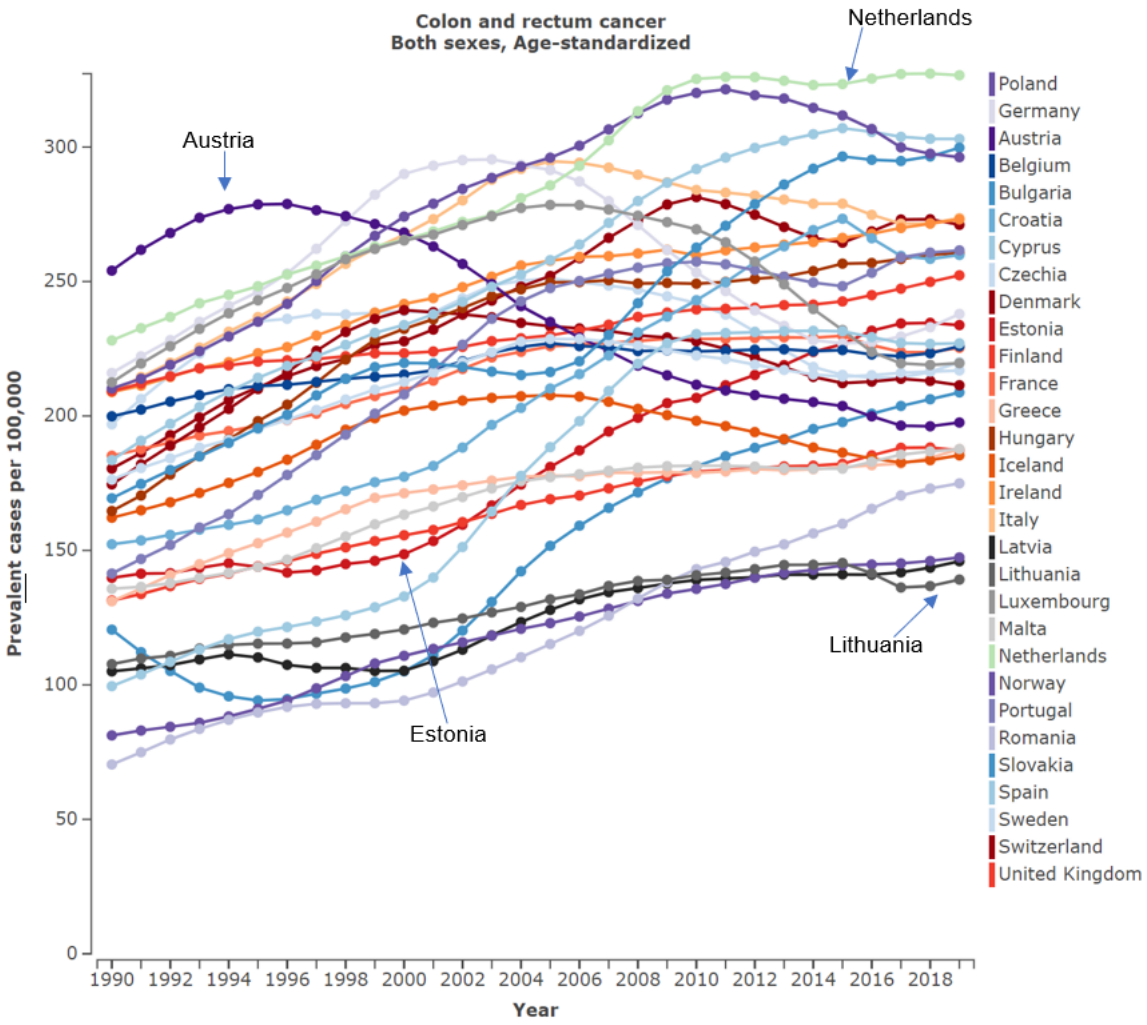


Figure 10. Age standardised prevalence of colorectal cancer for both sexes 1990-2019 per 100,000: Western Europe by country.

3.3 Exposure values

3.3.1 I*n vivo* summary exposure values

A summary exposure value (SEV) is a measure of a population's exposure to a risk factor that considers the extent of exposure by risk level and the severity of that risk's contribution to disease burden. SEV would have the value zero when no excess risk for a population exists and the value one when the population is at the highest level of risk. In this report SEV values are expressed on a scale from 0% to 100% to emphasise that it is risk-weighted prevalence.

Key *in vivo* metabolic risk factors for CVD are hypertension and high adiposity and for type 2 diabetes elevated fasting blood glucose concentration and high adiposity. Accordingly, the trends in age standardised SEV values from 1990 to 2019 are examined for high body mass index (BMI), systolic hypertension and elevated fasting blood glucose.

Figure 11 shows the SEV trend for high BMI. Although the overall exposure is relatively low, almost every country shows a substantial rise over the period with the highest values seem for Estonia and Hungary. Figure 12 gives the SEV trend for high systolic blood pressure which shows substantial variation among countries

with perhaps the most marked decline in the UK, Finland, and Hungary. Figure 13 gives the SEV trend for high fasting plasma glucose which has increased over the period in almost all countries. The SEV trend for plasma glucose broadly matches the increasing prevalence of type 2 diabetes seen in Figure 8 with both showing the highest values in the UK and Czechia and the lowest in France.

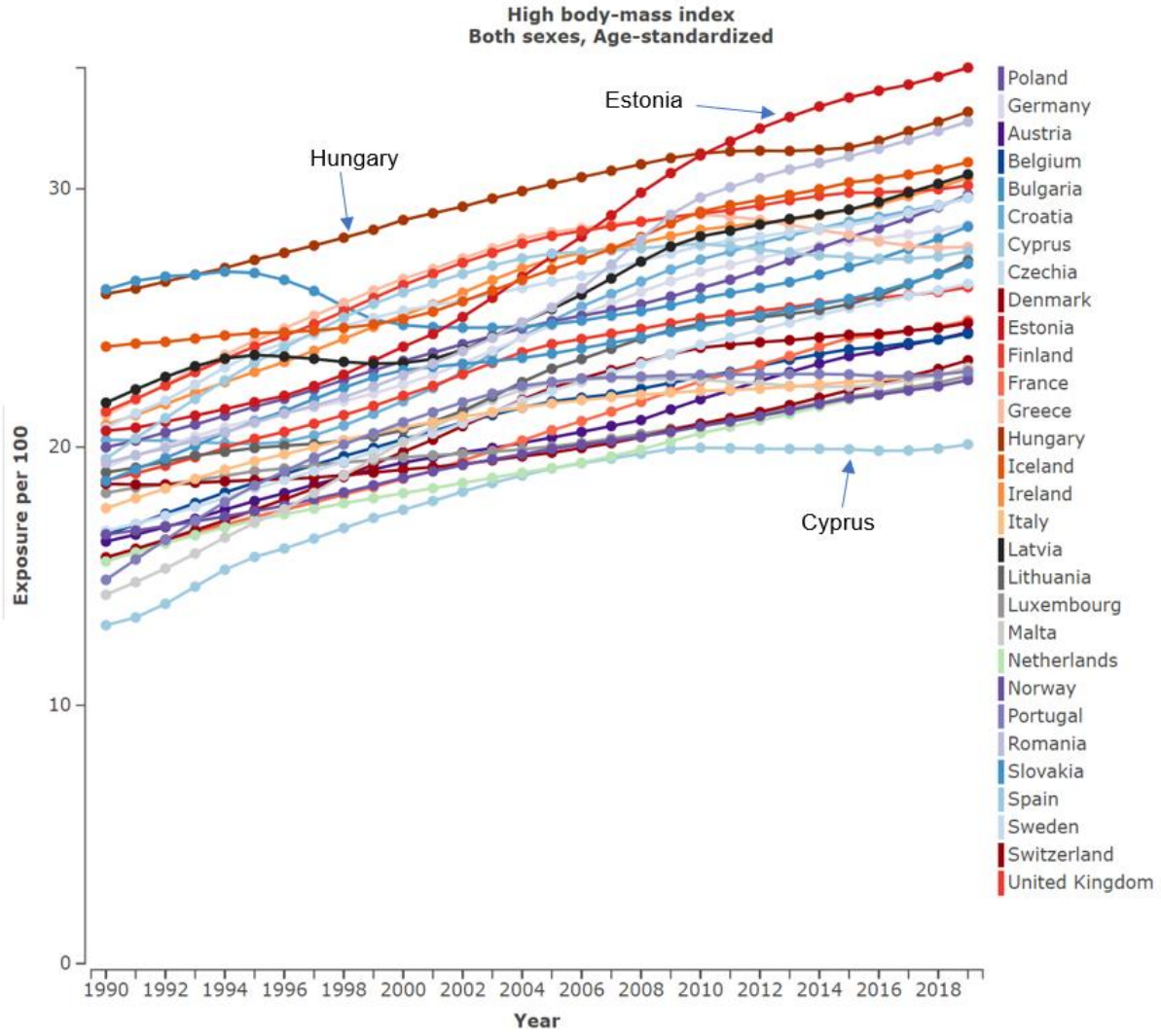


Figure 11. Age standardised summary exposure value (%) of high body mass index for both sexes 1990-2019, Western Europe by country.

The increasing SEV values for BMI (Figure 11) and plasma glucose (Figure 13) are concerning and represent substantial risk factors, especially for type 2 diabetes although it should be noted that the values for BMI (> 23.0 kg/m^2) and fasting plasma glucose (>5.3 mmol/L) used in this analysis to represent high values are conservative and would include some values which would often be classed as normal. Similarly, high systolic blood pressure (Figure 12) was taken to be >115 mm Hg which again could include some normal values. Nevertheless, the upward trend in high systolic blood pressure in a number of countries is concerning although a number have substantial reductions and it would be valuable to understand the reasons for these contrasting trends.

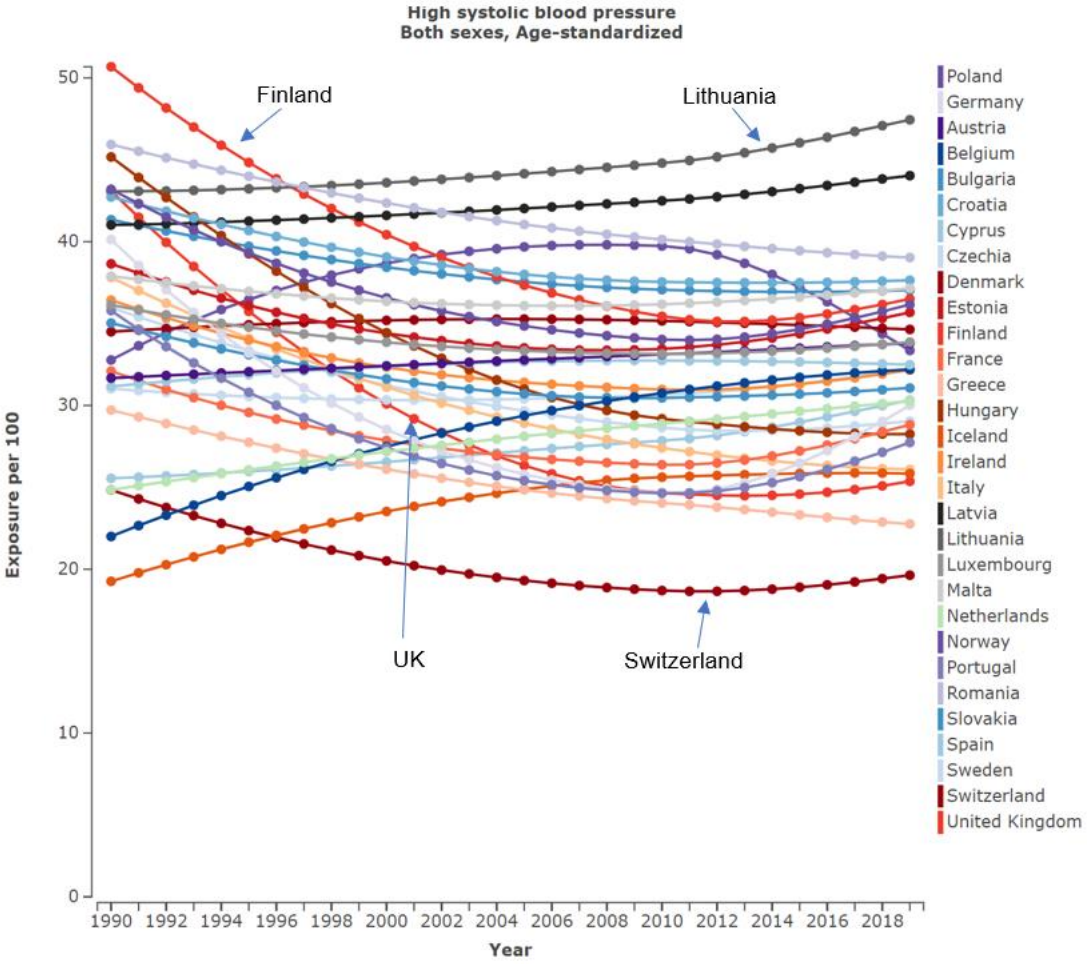


Figure 12. Age standardised summary exposure value (%) of high systolic blood pressure for both sexes 1990-2019, Western Europe by country.

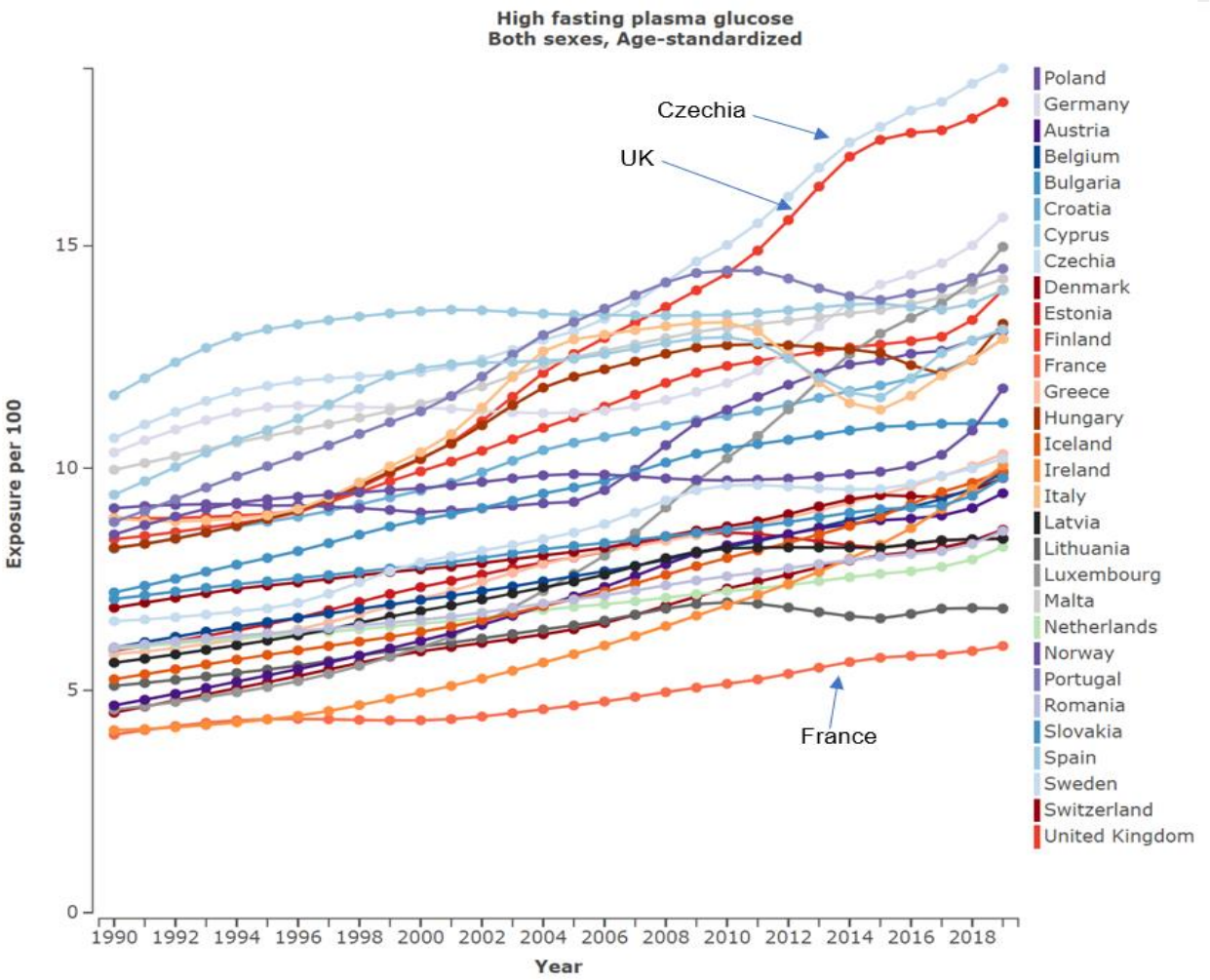


Figure 13. Age standardised summary exposure value (%) of high fasting plasma glucose concentration for both sexes 1990-2019, Western Europe by country

3.3.2 Exposure to dietary risk factors

A number of dietary factors are recognised risk factors for particular NCDs. This section will examine some associations for which the evidence is consistent, notably industrial *trans* fatty acids and ischaemic heart disease, high sodium intakes (which increase blood pressure) and stroke, high intakes of processed meat and colorectal cancer and low intakes of calcium and dietary fibre and colorectal cancer. For these associations, the 1990-2019 trends in disability-adjusted life years (DALYs, see Section 3.4) attributable to the dietary risk factors are examined. DALYs are used as a proxy for prevalence for which appropriate data are not available.

Figure 14 shows the trends in DALYs associated with high intakes of *trans* fatty acids. It is assumed that these data represent exposure primarily to dietary *trans* fatty acids of industrial origin, probably from hydrogenation of unsaturated fats for use in food manufacture. There are also so-called natural *trans* fatty acids in foods of ruminant animal origin (e.g. milk) but the evidence to date suggests these are not a risk to health and in any case are consumed in very small amounts. Most western Europe countries have vigorously reduced the amounts of industrial *trans* fatty acids in foods over the last 30 years together with having strict limits on *trans* fatty acid intake in dietary guidelines, typically a maximum of 1-2% of total energy intake. As shown in Figure 14, whilst the impact of *trans* fatty acids on ischaemic heart disease has generally reduced in all countries over the 30-year period there remains a number that appear to still have relatively high intakes. These are notably the Baltic states with Latvia having the highest values. This picture very much agrees with the mortality map attributable to high diet *trans* fatty acids published by the European Commission in 2019 (Diet high in trans fatty acids - Mortality map | Knowledge for policy (europa.eu)) although it should be noted that the data source was the same as that for Figure 14. Given the consistent evidence of risk from industrial *trans* fatty acids, a key recommendation of this report is that effort is increased to reduce *trans* fatty acid intake in the Baltic and eastern EU member states.

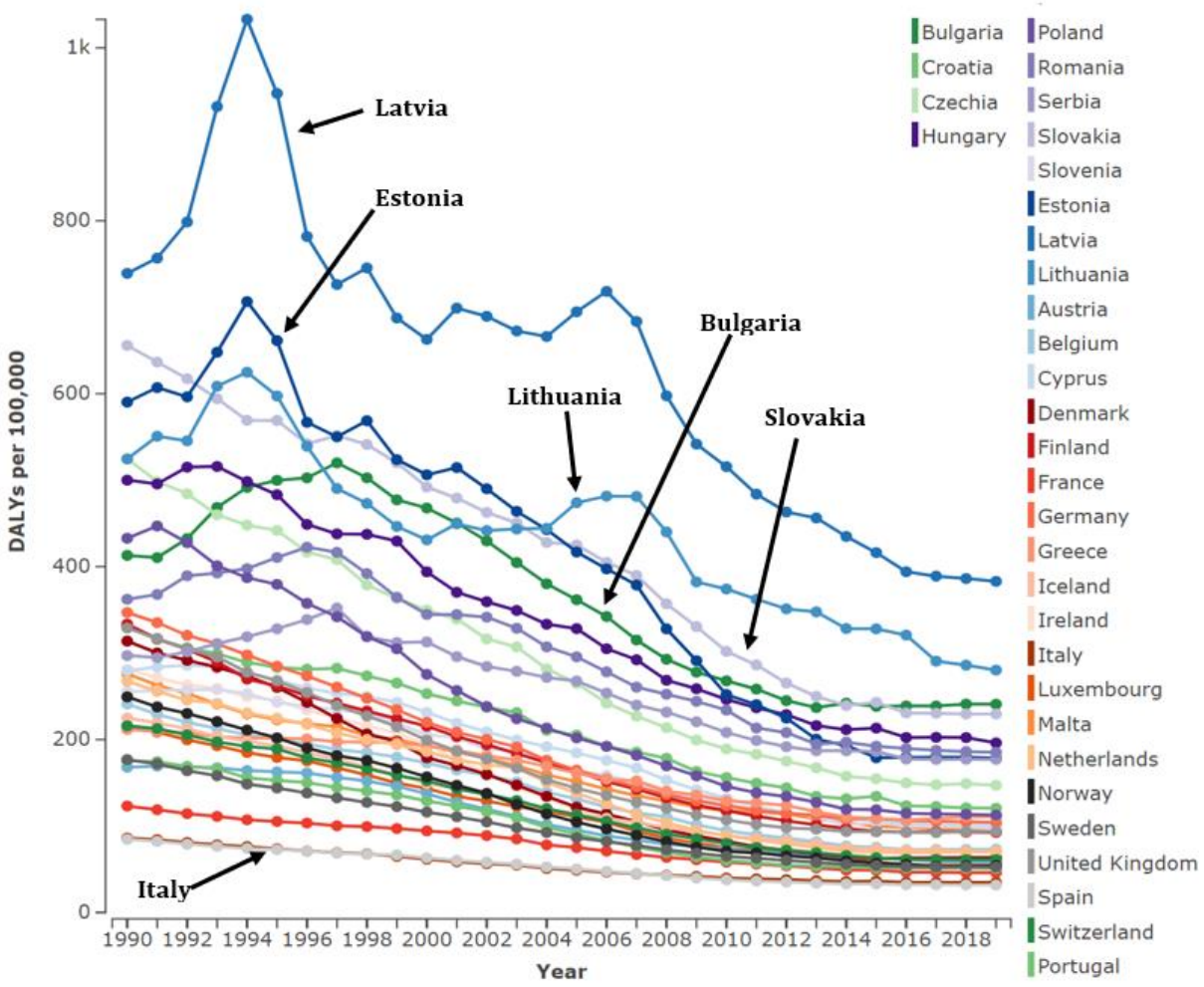


Figure 14. Trends in DALYs resulting from ischaemic heart disease attributable to diets high in *trans* fatty acids. Both sexes, age standardised.

Figure 15 shows the trends on impact of DALYs related to stroke attributed to high sodium intake. Hypertension is the major risk factor for stroke and increased sodium intake (mostly as sodium chloride) is associated with increased blood pressure. Many western European countries have been running campaigns to reduce sodium chloride intake to typically no more than 6g/day (2.4 g sodium/day). Whilst most countries have reduced the impact of high sodium diets over the last 30 years several eastern European countries still have substantial impacts, particularly noticeable for Bulgaria. Clearly there should be more effort to reduce the impact of sodium (chloride) in diets, experience elsewhere suggests greatest intakes arise from manufactured foods rather than from table salt.

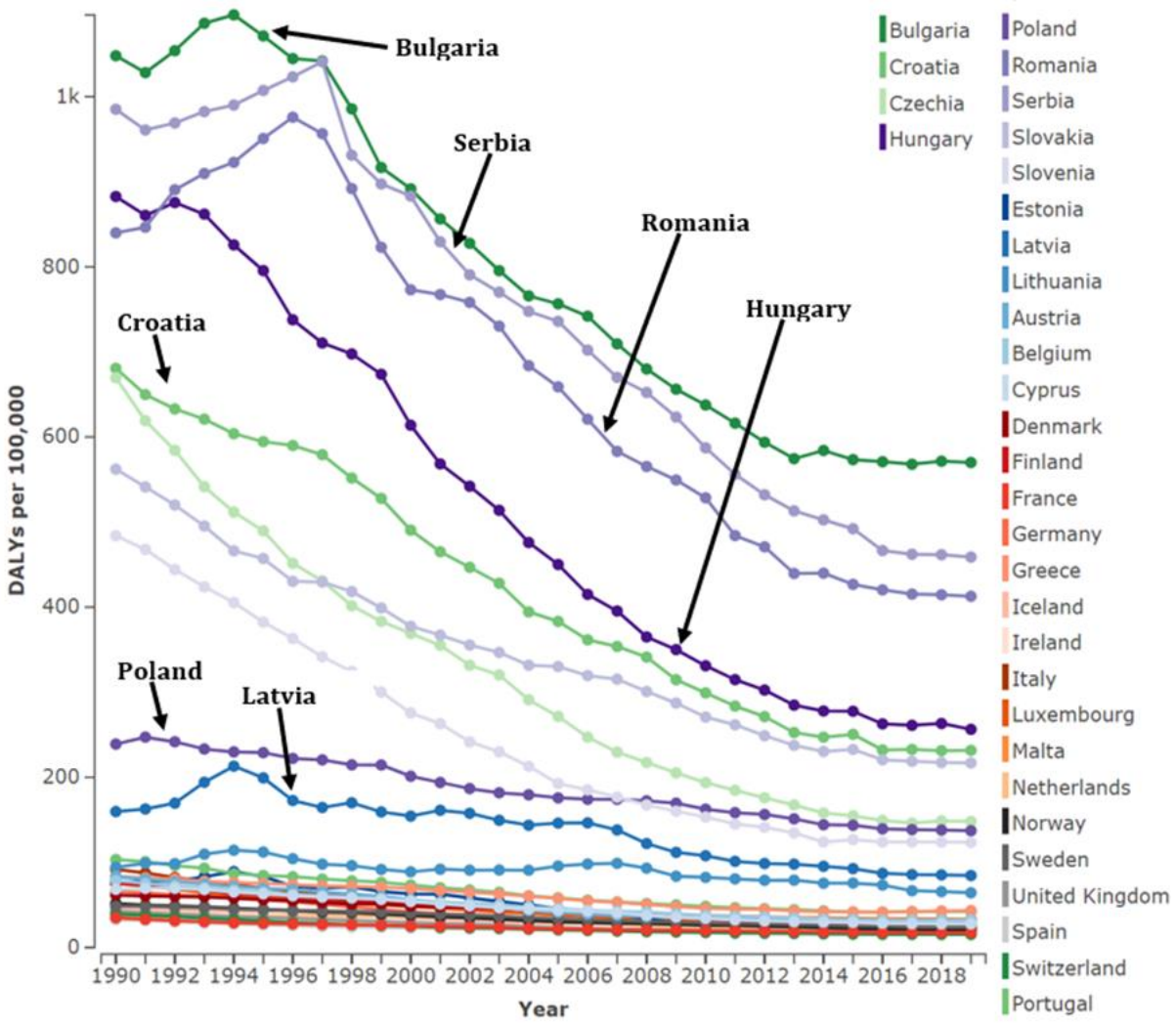


Figure 15. Trends in DALYs resulting from stroke attributable to diets high in sodium. Both sexes, age standardised.

Figures 16, 17 and 18 show the DALYs for colorectal cancer attributed to diets low in calcium, high in processed meat and low in dietary fibre respectively. There is a very large variation in impacts between countries but as noted for other conditions, the impact of concerning diets is substantially higher in the eastern European and Baltic states. This is perhaps particularly noticeable for diets low in calcium and dietary fibre. Low calcium intake is often linked to low milk/dairy intake foods which are themselves associated with reduced risk of colorectal cancer in the World Cancer Research Fund reviews of evidence. Overall, these data strongly suggest that considerable effort is needed to reduce the dietary risks seen in these parts of the EU in particular.

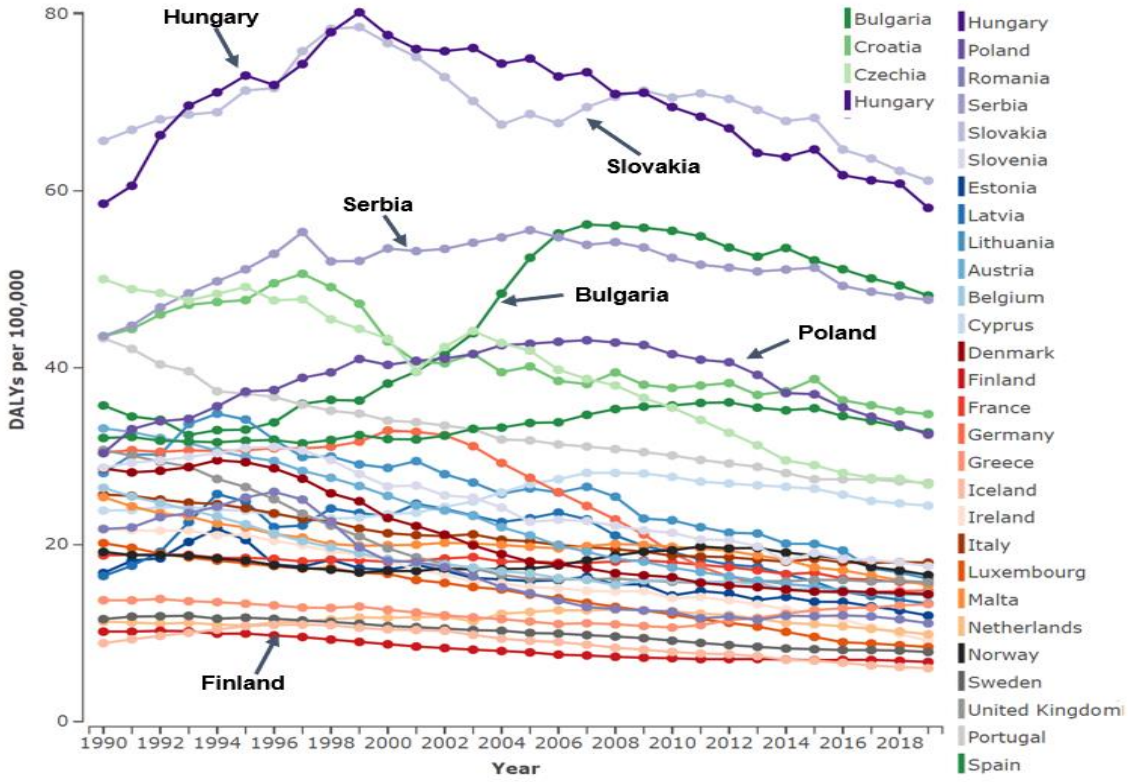


Figure 16. Trends in DALYs resulting from colorectal cancer attributable to low calcium diets. Both sexes, age standardised.

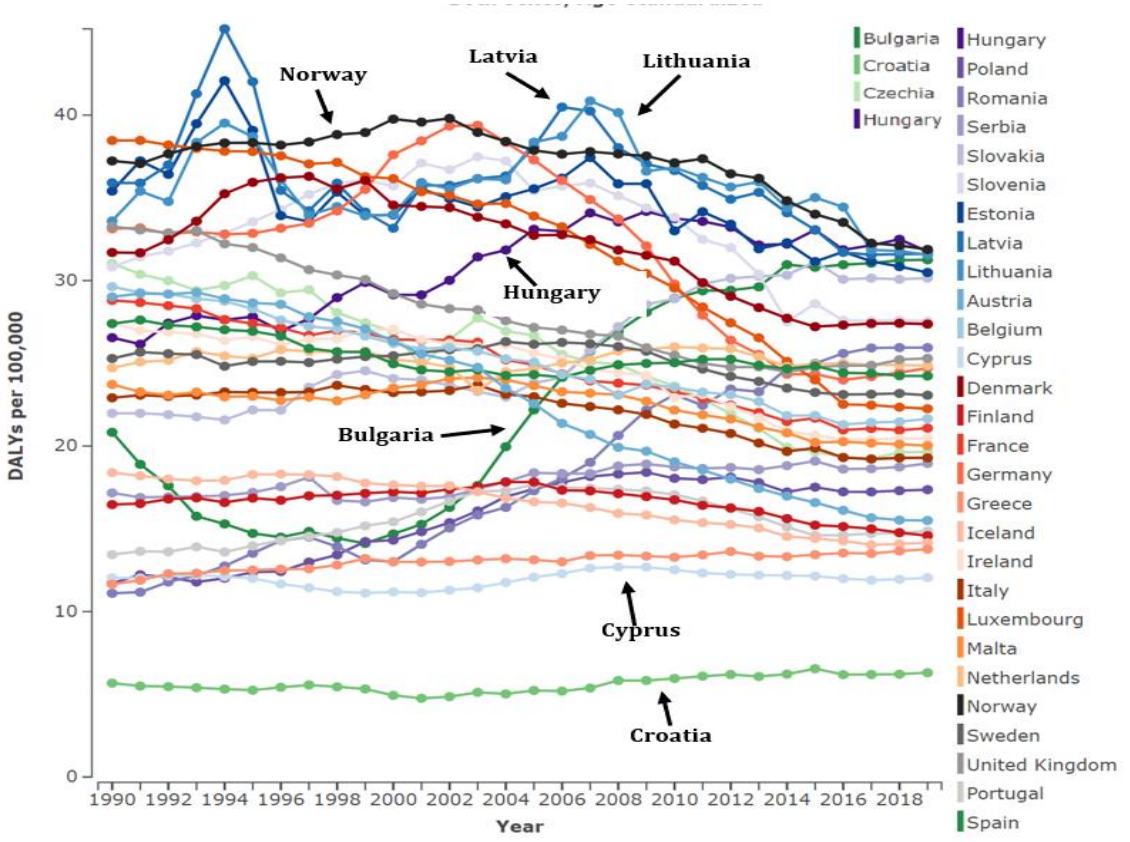


Figure 17. Trend in DALYs resulting from colorectal cancer attributable to diets high in processed meat. Both sexes, age standardised.

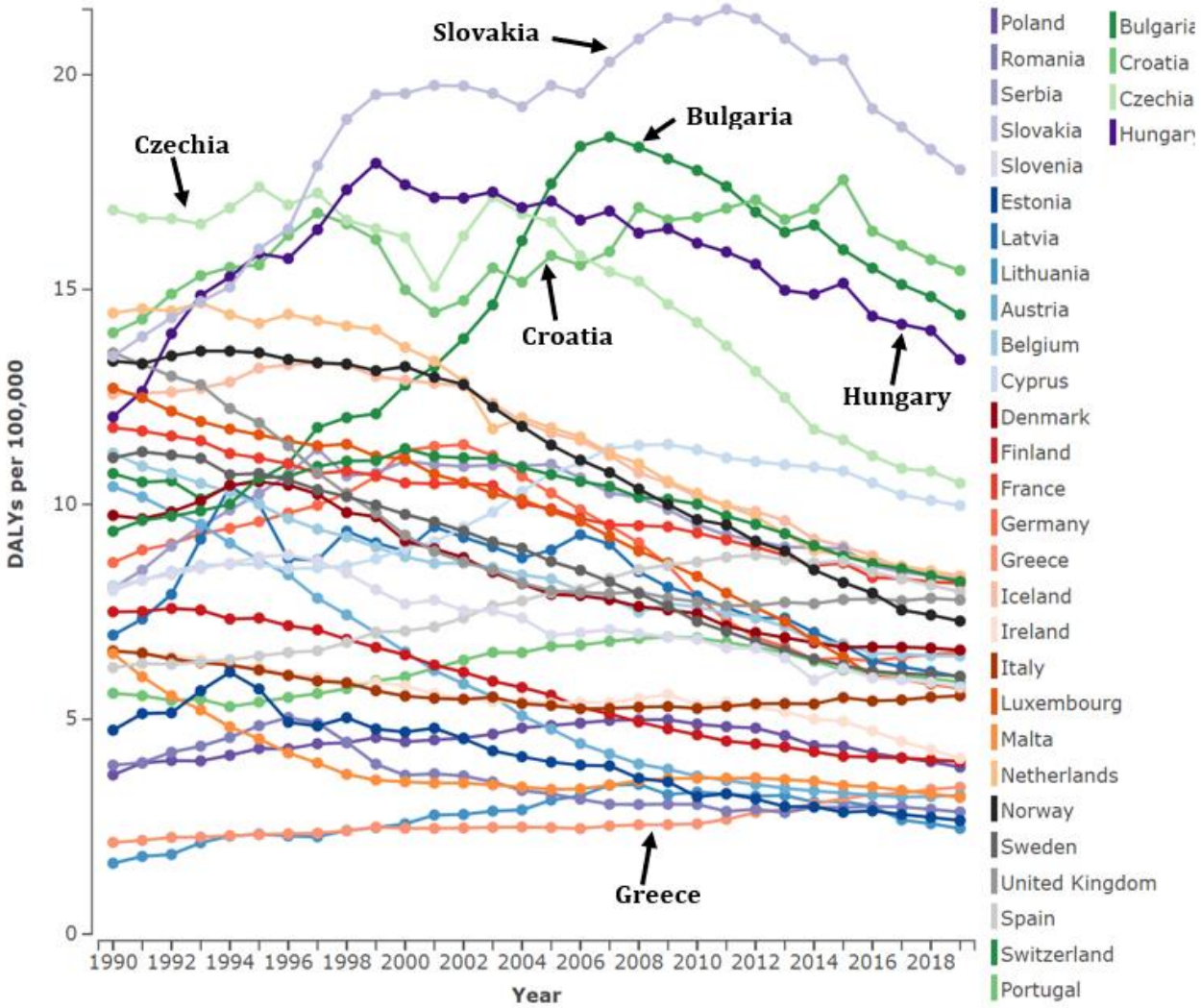


Figure 18. Trend in DALYs resulting from colorectal cancer attributable to diets low in fibre. Both sexes, age standardised.

3.4 Disability-adjusted life years (DALYs)

DALYs are disability-adjusted life years. These are a good measure of overall disease burden expressed as the number of years lost to ill-health, disability or early death. It is often used to compare the overall health and life expectancy of different countries. DALYs are given for the same conditions as for prevalence and for the trend from 1990 to 2019. The data on DALYs are not age standardised.

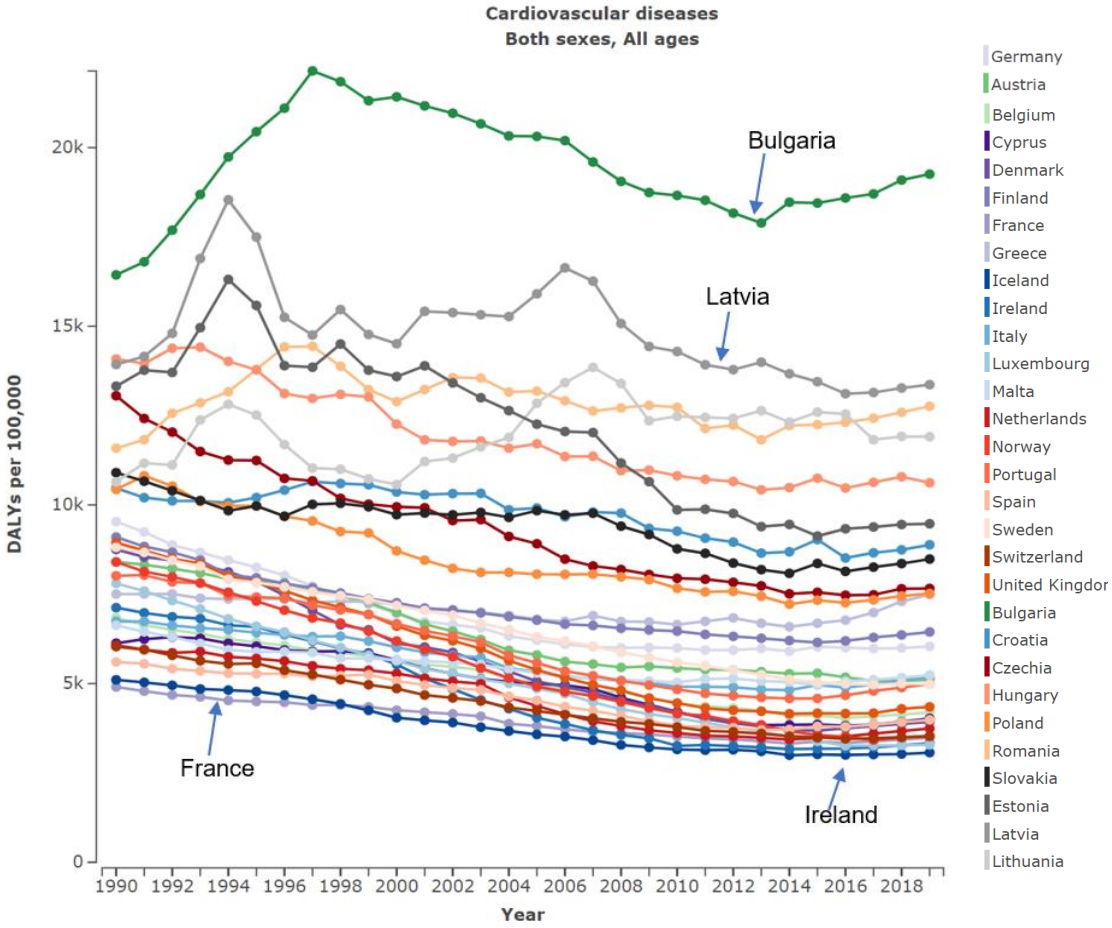


Figure 19. Trend in Disability-Adjusted Life Years resulting from cardiovascular diseases 1990-2019, Western Europe by country

The trend in DALYs for CVD (Figure 19) are broadly downward in agreement with the prevalence data (Figure 7) but with a large variation between countries with Bulgaria being consistently higher than elsewhere. Bulgaria also had the highest mortality for CVD (Figure 3). DALYs for type 2 diabetes (Figure 20) have a generally upward trend notably by Czechia leading to the highest terminal value with Bulgaria second. There is also an upward trend for DALYs related to Alzheimer's disease (Figure 21) with Italy recording the greatest terminal number. Figure 22 shows the trend in DALYs for colorectal cancer with very substantial variation between countries. Many countries had an increasing upward trend, notably Bulgaria and a few downward, notably Austria.

Overall, the approximate range in DALYs (per 100,000 of population) in 2019 between countries indicate 400-20,000 for CVD, 500-1,500 for type 2 diabetes, 400-1,000 for Alzheimer's disease and 300-1,100 for colorectal cancer. This confirms the overwhelming impact of CVD on disability adjusted life years which is likely be reflected in the direct and indirect costs of treatment etc. (see section 6)

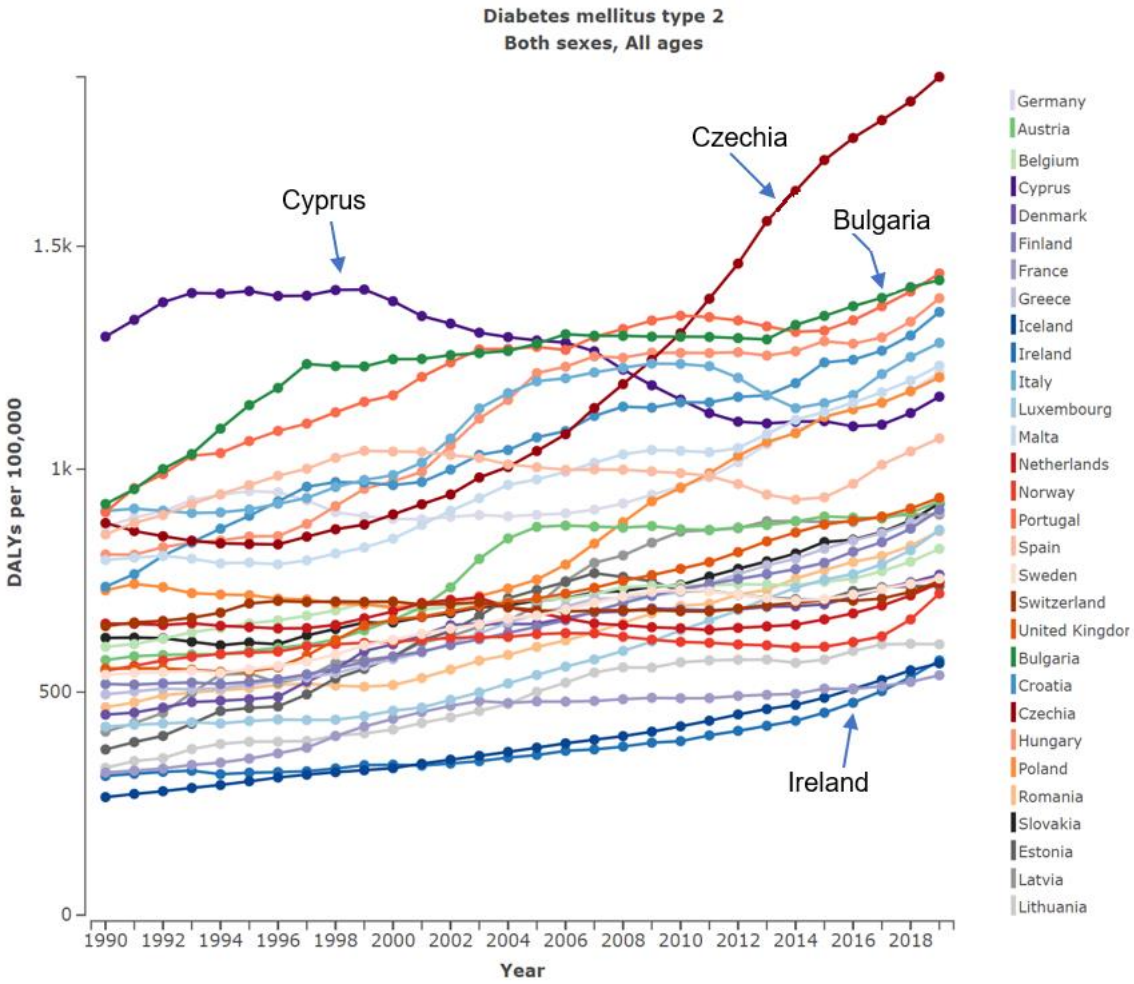


Figure 20. Trend in Disability-Adjusted Life Years resulting from type 2 diabetes 1990-2019, Western Europe by country

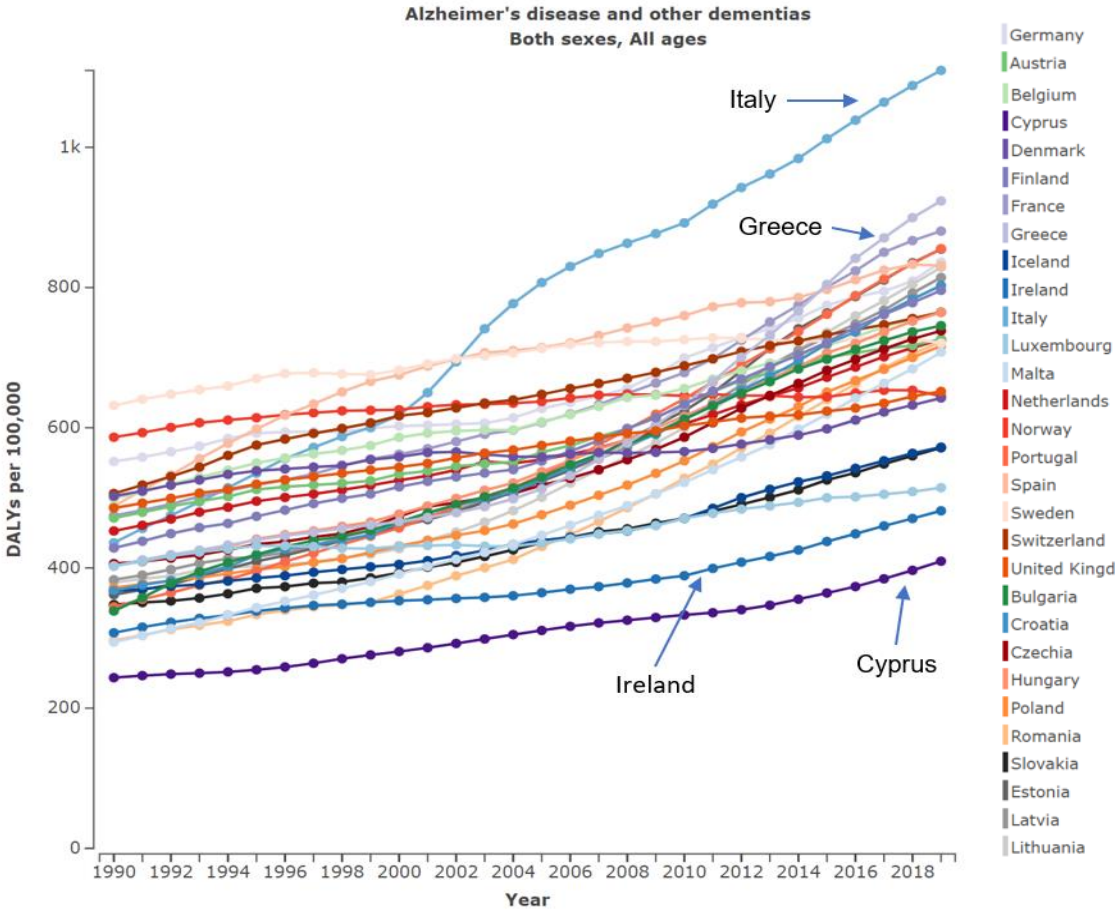


Figure 21. Trend in Disability-Adjusted Life Years resulting from Alzheimer's disease and other dementias 1990-2019, Western Europe by country

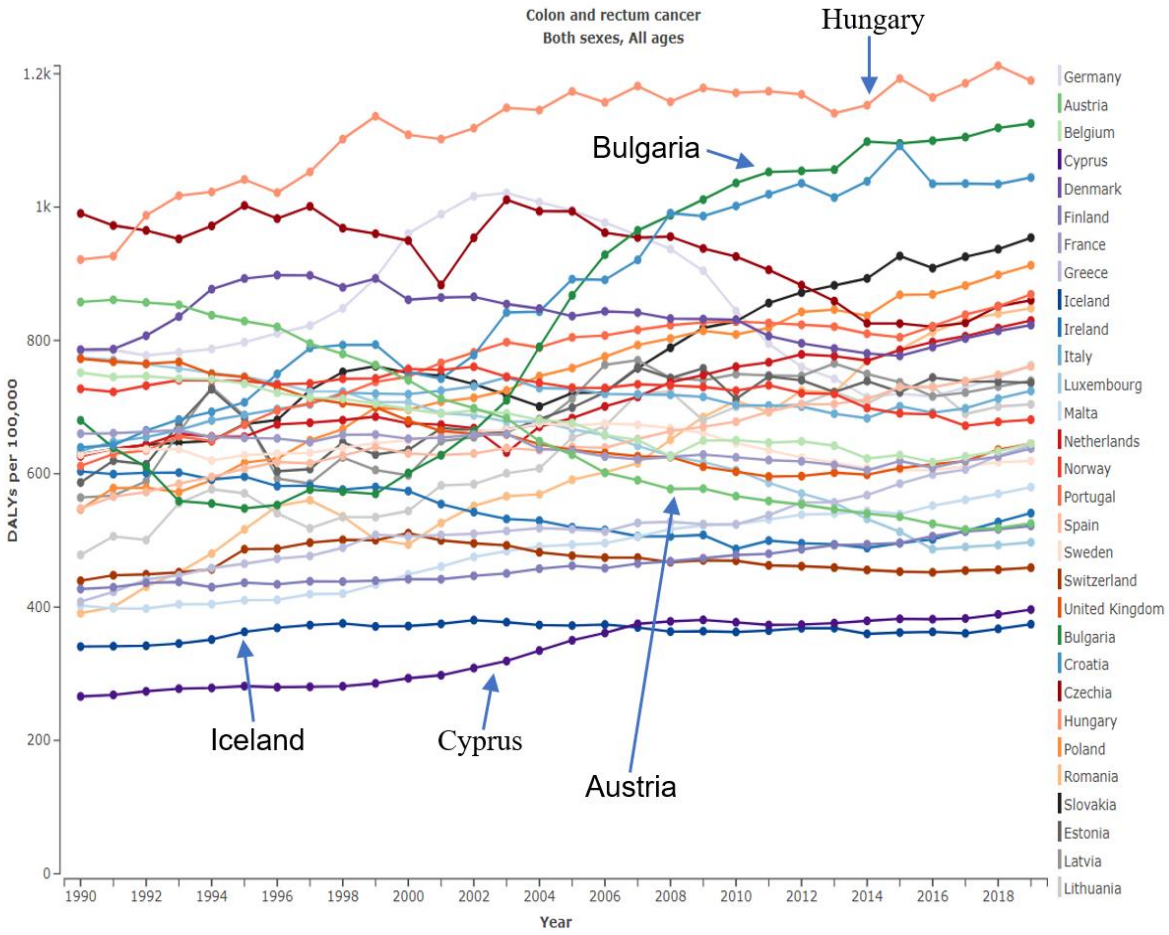


Figure 22. Trend in Disability-Adjusted Life Years resulting from colorectal cancer 1990-2019, Western Europe by country

4. Reflections of diet-responsive NCDs

Although the important diet-responsive NCDs have been identified in the foregoing, this section aims to give further details on the nature of the diet-responsiveness with references to published evidence. In addition, evidence on the relationship between diet and mental health is explored.

4.1 Ischaemic heart disease and diet

Background

Ischaemic heart disease describes the narrowing or complete blockage of the coronary arteries due to atherosclerotic plaques, caused by a build-up of cholesterol and other fats within and on the surface of arteries. Both non-modifiable (e.g., sex, ethnicity) and modifiable lifestyle risk factors (e.g., smoking, diet, excessive amounts of alcohol, increased body weight, high blood cholesterol, high blood pressure and diabetes) can contribute to atherosclerosis development.

Treatment and prevention of ischaemic heart disease include lifestyle changes. Diet is known as one of the most important modifiable risk factors in the prevention and risk reduction of ischaemic heart disease and in the following paragraphs the relationship between ischaemic heart disease and diet quality will be briefly discussed.

Nutrients

The Seven Countries Study, performed in the 1950's, was the first to illustrate the associations between dietary fats and ischaemic heart disease reporting a strong positive relationships between ischaemic heart disease mortality and intake of saturated fatty acids, dietary cholesterol and latterly trans fatty acids (1). Some antioxidant vitamins were also shown to be associated with lower ischaemic heart disease (2).

Food groups

In relation to food groups, the most consistent evidence is available for fruit and vegetable intakes and ischaemic heart disease risk. In the EPIC study, higher intakes of fruit and vegetables were associated with lower risk of ischaemic heart disease (3). Similarly, a meta-analysis reported that fish intake was related to lower ischaemic heart disease incidence and mortality (4). Moreover, Hu et al. reported that higher consumption of total whole grains were significantly associated with lower ischaemic heart disease risk using data from The Nurses' Health and Health Professionals Follow up study (5). In terms of alcohol consumption, most meta-analyses show a J-shaped relationship between average alcohol consumption and ischaemic heart disease with lifetime abstainers showing a higher risk compared to current 'moderate' drinkers and then an uptake of the risk curve to similar or higher risks compared to those seen for heavier drinkers (6).

Dietary patterns

Analysis of 27 years of data from global burden of disease database covering 137 countries showed that the Mediterranean diet may have a preventative effect on ischaemic heart disease (7). Similarly following a DASH diet was found to reduce ischaemic heart disease incidence (8).

References

1. Kromhout D, Menotti A, Bloemberg B, Aravanis C, Blackburn H, Buzina R, Dontas AS, Fidanza F, Giampaoli S, Jansen A, et al. Dietary saturated and trans fatty acids and cholesterol and 25-year mortality from coronary heart disease: the Seven Countries Study. *Prev Med*. 1995;24(3):308-15.

2. Bhupathiraju SN, Tucker KL. Coronary heart disease prevention: nutrients, foods, and dietary patterns. *Clin Chim Acta*. 2011;412(17-18):1493-514.
3. Perez-Cornago A, Crowe FL, Appleby PN, Bradbury KE, Wood AM, Jakobsen MU, Johnson L, Sacerdote C, Steur M, Weiderpass E, et al. Plant foods, dietary fibre and risk of ischaemic heart disease in the European Prospective Investigation into Cancer and Nutrition (EPIC) cohort. *International journal of epidemiology*. 2020;50(1):212-22.
4. Zhang B, Xiong K, Cai J, Ma A. Fish Consumption and Coronary Heart Disease: A Meta-Analysis. *Nutrients*. 2020;12(8).
5. Hu Y, Willett WC, Manson JAE, Rosner B, Hu FB, Sun Q. Intake of whole grain foods and risk of coronary heart disease in US men and women. *BMC Med*. 2022;20(1):192.
6. Roerecke M. Alcohol's Impact on the Cardiovascular System. *Nutrients*. 2021;13(10):3419.
7. Sezaki A, Imai T, Miyamoto K, Kawase F, Shirai Y, Abe C, Sanada M, Inden A, Kato T, Suzuki N, et al. Global relationship between Mediterranean diet and the incidence and mortality of ischaemic heart disease. *European Journal of Public Health*. 2021;31(3):608-12.
8. Chiavaroli L, Viguiliouk E, Nishi SK, Blanco Mejia S, Rahelić D, Kahleová H, Salas-Salvadó J, Kendall CW, Sievenpiper JL. DASH Dietary Pattern and Cardiometabolic Outcomes: An Umbrella Review of Systematic Reviews and Meta-Analyses. *Nutrients*. 2019;11(2).

4.2 Stroke and diet

Background

Stroke occurs due to a decrease in blood supply to the brain or a blockage of the carotid arteries (ischaemic) or when a blood vessel in the brain bursts (haemorrhagic). Blockages typically form in areas where the arteries have been narrowed over time by fatty deposits known as atherosclerotic plaques and are due to a thrombose (blood clot). Modifiable risk factors for this disease include smoking, high blood pressure, obesity, high circulating cholesterol concentrations and excessive alcohol intake. Diet is recognised as a key stroke prevention option as diet quality impacts on blood pressure, body weight and circulating lipid concentrations. In line with this, a review by Rees et al. (1) estimated that dietary interventions can reduce stroke risk by 19%.

Nutrients

Supplementation of some antioxidant vitamins can prevent stroke (2). Evidence also exists for the association between excess salt intake and a greater incidence of stroke (3) with intervention studies, such as DASH showing significant reduction in blood pressure the greatest risk factor for stroke. Similarly, higher potassium consumption was associated with reduced risk of stroke (4). Another key nutrient related to risk from stroke is dietary fibre with an estimated 7 g/day increased intake associated with decreased stroke risk (5).

Food groups

Consumption of more than five servings of fruits and vegetable/day has been associated with lower stroke risk compared to those who consume less than three servings of fruits and vegetable (6). Moreover, high red and processed meat consumption was associated with increased stroke risk (7, 8). In contrary, evidence suggests that there is an association between fish consumption and stroke prevention (9). There is also increasing evidence that consumption of three or more cups of black/green tea a day compared with less than a cup/day is associated with lower stroke risk (10). Furthermore, in The Nurses' Health Study, higher consumption of sugar-sweetened and low-calorie drinks were associated with higher stroke risk (11). It is also known that some milk proteins, whey protein in particular, can lead to a reduction in blood pressure (12), a benefit since high blood pressure is a major risk factor for stroke.

Dietary patterns

Adherence to both a DASH or Mediterranean diet is associated with a reduced stroke risk, whereas a Western diet is associated with an increased stroke risk (13). Similarly, in The Nurses' Health study a Western dietary pattern (high in saturated fatty acids, processed grains and simple sugars) was associated with higher stroke incidence whereas a diet high in fruit, vegetables, whole grains, legumes and fish was associated with a decrease in stroke incidence (14).

References

1. Rees K, Dyakova M, Ward K, Thorogood M, Brunner E. Dietary advice for reducing cardiovascular risk. *Cochrane Database Syst Rev*. 2013(3).
2. Bjelakovic G, Nikolova D, Gluud LL, Simonetti RG, Gluud C. Mortality in randomized trials of antioxidant supplements for primary and secondary prevention: systematic review and meta-analysis. *Jama*. 2007;297(8):842-57.
3. Frohlich ED. The salt conundrum: a hypothesis. *Hypertension*. 2007;50(1):161-6.
4. D'Elia L, Barba G, Cappuccio FP, Strazzullo P. Potassium intake, stroke, and cardiovascular disease a meta-analysis of prospective studies. *J Am Coll Cardiol*. 2011;57(10):1210-9.
5. Threapleton DE, Greenwood DC, Evans CEL, Cleghorn CL, Nykjaer C, Woodhead C, Cade JE, Gale CP, Burley VJ. Dietary Fiber Intake and Risk of First Stroke. *Stroke*. 2013;44(5):1360-8.
6. Sauvaget C, Nagano J, Allen N, Kodama K. Vegetable and fruit intake and stroke mortality in the Hiroshima/Nagasaki Life Span Study. *Stroke*. 2003;34(10):2355-60.
7. Chen GC, Lv DB, Pang Z, Liu QF. Red and processed meat consumption and risk of stroke: a meta-analysis of prospective cohort studies. *Eur J Clin Nutr*. 2013;67(1):91-5.
8. Kim K, Hyeon J, Lee SA, Kwon SO, Lee H, Keum N, Lee JK, Park SM. Role of Total, Red, Processed, and White Meat Consumption in Stroke Incidence and Mortality: A Systematic Review and Meta-Analysis of Prospective Cohort Studies. *J Am Heart Assoc*. 2017;6(9).
9. Chowdhury R, Stevens S, Gorman D, Pan A, Warnakula S, Chowdhury S, Ward H, Johnson L, Crowe F, Hu FB, et al. Association between fish consumption, long chain omega 3 fatty acids, and risk of cerebrovascular disease: systematic review and meta-analysis. *BMJ : British Medical Journal*. 2012;345:e6698.
10. Hooper L, Kroon PA, Rimm EB, Cohn JS, Harvey I, Le Cornu KA, Ryder JJ, Hall WL, Cassidy A. Flavonoids, flavonoid-rich foods, and cardiovascular risk: a meta-analysis of randomized controlled trials. *Am J Clin Nutr*. 2008;88(1):38-50.
11. Bernstein AM, de Koning L, Flint AJ, Rexrode KM, Willett WC. Soda consumption and the risk of stroke in men and women. *Am J Clin Nutr*. 2012;95(5):1190-9.
12. Fekete, Á. A., Giromini, C., Chatzidiakou, Y., Givens, D. I., Lovegrove, J. A. (2016) Whey protein lowers blood pressure and improves endothelial function and lipid biomarkers in adults with prehypertension and mild hypertension: results from the chronic Whey2Go randomized controlled trial. *Am J Clin Nut* 104:1534-154.
13. Sherzai A, Heim LT, Boothby C, Sherzai AD. Stroke, food groups, and dietary patterns: a systematic review. *Nutr Rev*. 2012;70(8):423-35.
14 Fung TT, Stampfer MJ, Manson JE, Rexrode KM, Willett WC, Hu FB. Prospective Study of Major Dietary Patterns and Stroke Risk in Women. *Stroke*. 2004;35(9):2014-9.

4.3 Hypertensive heart disease and diet

Background

Hypertensive heart disease refers to heart conditions caused by hypertension. It results in the heart working under increased pressure which can lead to heart failure, thickening of the heart muscle, coronary artery disease, and other aspects of ischaemic heart disease. Hypertensive heart disease is the leading cause of death from hypertension. However, since hypertension is a key risk factor for other serious conditions including haemorrhagic stroke in particular, this section examines the overall effects of hypertension and how diet can influence it (1).

In most countries and regions of the world, high blood pressure is the number one preventable cause of CVD mortality and disease burden. According to the Framingham Heart Study, those with hypertension (defined as SBP 160 mmHg or DBP 95 mmHg) have a higher risk of developing coronary heart disease than those with SBP 140 mmHg and DBP 90 mmHg. According to the study, people with high-normal blood pressure—defined as SBP between 130 and 139 mmHg and DBP between 85 and 89 mmHg—have a higher chance of developing CVD than those with optimal blood pressure (2). One billion adults worldwide are predicted to have hypertension, which affects between 25 and 30 percent of the adult population and its prevalence is expected to rise. The availability and consumption of a Westernised diet, adoption of a sedentary lifestyle that leads to obesity, and growing age in the population are factors that are to blame for the predicted increase in the prevalence of hypertension worldwide (3,4). In the following paragraphs, the impact of diet on hypertensive heart disease will be briefly discussed.

Nutritional factors for the management and prevention of hypertension

Numerous randomised clinical trials have demonstrated that lowering blood pressure with anti-hypertensive agents increases event-free survival of patients with hypertension. While modifying food and lifestyle habits is equally important to managing hypertension, anti-hypertensive medication remains a staple of treatment for those with the condition. Adopting a balanced diet and lifestyle is crucial for those who are hypertension-free and plays a crucial role in improving blood pressure control for those who already have the condition. Dietary and lifestyle changes are frequently advised for people with hypertension as an initial strategy or as a supplement to antihypertensive medication to manage blood pressure and enhance the cardiovascular risk profile.

Dietary patterns

The Dietary Approaches to Stop Hypertension (DASH)-based diets are frequently suggested. A diet high in fruits, vegetables, and low-fat dairy products, as well as a reduction in saturated and total fat, define the DASH-type diet (6). Reduced salt consumption has previously been advised for the management and prevention of hypertension. Although there is sufficient evidence linking dietary salt intake to blood pressure, a number of contradictory studies have recently been published (7), adding to the debate over whether there is a connection, whether lowering salt intake reduces cardiovascular events and death, and what the "ideal" level of salt intake is for lowering blood pressure, cardiovascular events, and death.

The Mediterranean diet is similar to DASH, however, is normally higher in fat, especially monounsaturated fatty acids from olive oil, seeds and nuts. In the PREDIMED study, compared to low fat, following a Mediterranean diet with extra-virgin olive oil or nuts reduced systolic blood pressure (-0.38 and -0.26 mm Hg, respectively) (8).

Micronutrients

Some medical professionals advise increasing potassium consumption since it is linked to reduce blood pressure. Although the appropriate potassium intake is unknown, 4.7 g (or 120 mmol) of potassium per day

has been suggested (9). For blood pressure control, the American Society of Hypertension recommend reducing sodium intake to a goal of <2300 mg/day (10).

Other dietary factors

Alcohol consumption should be kept to no more than two drinks per day for males and one drink per day for women (Half pint of ordinary beer, small glass of wine, or single measure of distilled spirits are considered one alcoholic drink). A healthy body weight should also be maintained in addition to these dietary considerations because it lowers blood pressure and the risk of cardiovascular disease. Obesity is a serious issue in both industrialised and developing nations. While 45% of adults living in the EU had a normal weight in 2019, 53% were considered as overweight (36% pre-obese and 17% obese). It has been proven through a number of randomised experiments that losing weight lowers blood pressure.

References

1. Zhou B, Perel P, Mensah GA, Ezzati M. Global epidemiology, health burden and effective interventions for elevated blood pressure and hypertension. Nat Rev Cardiol.18, 785-802 (2021).
2. Kannel, W. B., Dawber, T. R., Kagan, A., Revotskie, N. & Stokes, J., 3rd. Factors of risk in the development of coronary heart disease–six-year follow- up experience. The Framingham Study. Ann. Intern. Med. 55, 33–50 (1961).
3. Shimbo, D. Dietary and lifestyle factors in hypertension. J Hum Hypertens 30, 571–572 (2016).
4. Bundy, J. D. et al. Systolic blood pressure reduction and risk of cardiovascular disease and mortality: a systematic review and network meta- analysis. JAMA Cardiol. 2, 775–781 (2017).
5. Migliaccio, S., Brasacchio, C., Pivari, F. et al. What is the best diet for cardiovascular wellness? A comparison of different nutritional models. Int J Obes Supp 10, 50–61 (2020).
6. Elliott P, Muller DC, Schneider-Luftman D et al., I. Estimated 24-Hour Urinary Sodium Excretion and Incident Cardiovascular Disease and Mortality Among 398 628 Individuals in UK Biobank. Hypertension 76(3):683-691 (2020).
7. Estruch R, Martínez-González MA, Corella D, Salas-Salvadó J, Ruiz-Gutiérrez V, Covas MI, Fiol M, Gómez-Gracia E, López-Sabater MC, Vinyoles E, Arós F, Conde M, Lahoz C, Lapetra J, Sáez G, Ros E; PREDIMED Study Investigators. Effects of a Mediterranean-style diet on cardiovascular risk factors: a randomized trial. Ann Intern Med. (2006) Jul 4;145(1):1-11. Erratum in: Ann Intern Med. 2018 Aug 21;169(4):270-271. PMID: 16818923.
8. Burnier M. Should we eat more potassium to better control blood pressure in hypertension? Nephrol Dial Transplant 34(2):184-193 (2019).
9. Gunn JP, Barron JL, Bowman BA, Merritt RK, Cogswell ME, Angell SY, Bauer UE, Frieden TR. Sodium reduction is a public health priority: reflections on the Institute of Medicine's report, sodium intake in populations: assessment of evidence. Am J Hypertens 26(10):1178-80 (2013).

4.4 Type 2 diabetes and diet

Background

Type 2 diabetes mellitus (T2DM) is a complex and chronic illness, characterised by hyperglycaemia, and accounts for 90–95% of all diabetes. T2DM encompasses individuals who have relative (rather than absolute) insulin deficiency and have peripheral insulin resistance (1). Most, but not all, patients with type 2 diabetes have overweight or obesity. Excess weight itself causes some degree of insulin resistance. Ongoing diabetes self-management education and support are critical to preventing acute complications and reducing the risk of long-term complications. Significant evidence exists that supports a range of interventions to improve diabetes outcomes (2, 3). As shown earlier, the prevalence of T2DM has increased substantially in most

European countries over the last 30 years. For example, in the UK, age-standardised prevalence has risen from 3,556 per 100,1000 in 1990, to 7949 per 100,000 in 2019, one of the most rapid increases in Europe.

Nutritional factors, the responsiveness of T2DM to diets

Nutrition therapy plays an integral role in overall diabetes management and each person with diabetes should be actively engaged in education, self-management, and treatment planning with his or her health care team, including the collaborative development of an individualised eating plan. An personalised medical nutrition therapy programme is needed to achieve treatment goals, provided by a registered dietitian or nutritionist, which is recommended for all people with T2DM and prediabetes. For all patients with overweight or obesity among patients with T2DM, behavioural modification to achieve and maintain a minimum weight loss of 5% is recommended (4).

Eating patterns and macronutrient distribution

There is no ideal macronutrient pattern for people with diabetes; meal plans should be individualised while keeping total energy and metabolic goals in mind. Moreover, a variety of eating patterns can be considered for the management of T2DM and to prevent diabetes in individuals with prediabetes (5,6). The only indication that has demonstrated the most evidence for improving glycaemia in patients with T2DM is the reduction of the overall carbohydrate intake and may be applied in a variety of eating patterns that meet individual needs and preferences (7,8).

Carbohydrates

Carbohydrate intake should emphasise nutrient-dense carbohydrate sources that are high in fibre (at least 14g fibre per 1,000 kcal) and minimally processed. Eating plans should emphasise non starchy vegetables, fruits, and whole grains, as well as dairy products, with minimal added sugars (9,10). People with diabetes and those at risk are advised to replace sugar-sweetened beverages (including fruit juices) with water as much as possible in order to control glycaemia and weight and reduce their risk of cardiovascular disease and fatty liver and should minimise the consumption of foods with added sugar that have the capacity to displace healthier, more nutrient-dense food choices (11).

Protein

There is no evidence that adjusting the daily protein intake (typically 1–1.5 g/kg body wt/day or 15–20% total energy) will improve health, and research is inconclusive regarding the ideal amount of dietary protein to optimise either glycaemic management or CVD risk. Therefore, protein intake goals should be personalised based on current eating patterns (12, 13).

Dietary fat

The ideal amount of dietary fat for individuals with diabetes is controversial. New evidence suggests that there is not an ideal percentage of energy from fat for people with or at risk for diabetes and that macronutrient distribution should be individualised according to the patient's eating patterns, preferences, and metabolic goals (14). The type of fats consumed is more important than total amount of fat (15,16). An eating plan emphasising elements of a Mediterranean-style eating pattern rich in monounsaturated and polyunsaturated fats and also foods rich in long-chain n-3 fatty acids (EPA and DHA) such as fatty fish and nuts and seeds (ALA) is recommended to prevent or treat cardiovascular diseases associated with T2DM (17).

Micronutrients and herbal supplements

There is no clear evidence that dietary supplementation with vitamins, minerals (such as chromium and vitamin D), herbs, or spices (such as cinnamon or aloe vera) can improve outcomes in people with diabetes who do not have underlying deficiencies, and they are not generally recommended for glycaemic control (7).

Other issues

Adults with diabetes who drink alcohol should do so in moderation (no more than one drink per day for adult women and no more than two drinks per day for adult men). Sodium consumption should be limited to <2,300 mg/day. The use of non-nutritive sweeteners as a replacement for sugar-sweetened products may reduce overall energy and carbohydrate intake as long as there is not a compensatory increase of energy intake from other sources (9).

Relevant references

1. Standard of Medical care in diabetes – 2022, Diabetes Care, January 2022 Volume 45, Supplement 1130-158-159-160-161------166, 167, 168, 118-119-120-121-153.
2. Evert AB, Dennison M, Gardner CD, et al. Nutrition therapy for adults with diabetes or prediabetes: a consensus report. Diabetes Care 2019;42:731–754.
3. Briggs Early K, Stanley K. Position of the Academy of Nutrition and Dietetics: the role of medical nutrition therapy and registered dietitian nutritionists in the prevention and treatment of prediabetes and type 2 diabetes. J Acad Nutr Die 2018;118:343–353.
4. Estruch R, Ros E, Salas-Salvad o J, et al.; PREDIMED Study Investigators. Primary prevention of cardiovascular disease with a Mediterranean diet supplemented with extravirgin olive oil or nuts. N Engl JMed 2018;378:e34.
5. Delahanty LM, Nathan DM, Lachin JM, et al.; Diabetes Control and Complications Trial/Epidemiology of Diabetes. Association of diet with glycated hemoglobin during intensive treatment of type 1 diabetes in the Diabetes Control and Complications Trial. Am J Clin Nutr 2009;89:518–524.
6. Zafar MI, Mills KE, Zheng J, et al. Low glycemic index diets as an intervention for diabetes: a systematic review and meta-analysis. Am J Clin Nutr 2019;110:891–902.
7. Wheeler ML, Dunbar SA, Jaacks LM, et al. Macronutrients, food groups, and eating patterns in the management of diabetes: a systematic review of the literature, 2010. Diabetes Care 2012;35:434–445.
8. Tuttle KR, Bakris GL, Bilous RW, et al. Diabetic kidney disease: a report from an ADA consensus conference. Diabetes Care 2014;37:2864–2883.
9. Bosch J, Gerstein HC, Dagenais GR, et al.; ORIGIN Trial Investigators. n-3 fatty acids and cardiovascular outcomes in patients with dysglycemia. N Engl J Med 2012;367:309–318.
10. Shai I, Schwarzfuchs D, Henkin Y, et al.; Dietary Intervention Randomized Controlled Trial (DIRECT) Group. Weight loss with a low carbohydrate, Mediterranean, or low-fat diet. N Engl J Med 2008;359:229–241.
11. Brunerova L, Smejkalova V, Potockova J, Andel M. A comparison of the influence of a high-fat diet enriched in monounsaturated fatty acids and conventional diet on weight loss and metabolic parameters in obese non-diabetic and type 2 diabetic patients. Diabet Med 2007;24:533–540.
12. Bloomfield HE, Koeller E, Greer N, MacDonald R, Kane R, Wilt TJ. Effects on health outcomes of a Mediterranean Diet with no restriction on fat intake: a systematic review and meta-analysis. Ann Intern Med 2016;165:491–500.
13. Sacks FM, Lichtenstein AH, Wu JHY, et al.; American Heart Association. Dietary fats and cardiovascular disease: a presidential advisory from the American Heart Association. Circulation 2017;136:e1–e23.
14. Ros E. Dietary cis-monounsaturated fatty acids and metabolic control in type 2 diabetes. Am J Clin Nutr 2003;78(Suppl.):617S–625S.
15. Forouhi NG, Imamura F, Sharp SJ, et al. Association of plasma phospholipid n-3 and n-6 polyunsaturated fatty acids with type 2 diabetes: the EPIC-InterAct case-cohort study. PLoS Med 2016;13:e1002094.

16. Wang DD, Li Y, Chiuve SE, et al. Association of specific dietary fats with total and cause specific mortality. JAMA Intern Med 2016;176:1134–1145.
17. Brehm BJ, Lattin BL, Summer SS, et al. One year comparison of a high-monounsaturated fat diet with a high-carbohydrate diet in type 2 diabetes. Diabetes Care 2009;32:215–220.

4.5 Colorectal cancer and diet

Background

The colon is the lower part of the intestinal tract and extends from the caecum to the rectum. The colon contains a very large population of many types of bacteria, which have potentially important functions. These include the fermentation of unabsorbed carbohydrates (non-starch polysaccharides and resistant starch) resulting in the production of short chain fatty acids that influence the health of the colonic mucosa.

Approximately 95 per cent of colorectal cancers (CRC) are adenocarcinomas and the World Cancer Research Fund (WCRF) in collaboration with the American Institute for Cancer Research (AICR) regularly reviews the evidence on the relationship between diet (and other factors) and this type of CRC. In the most recent review (1) a range of dietary factors which influence the risk and development of CRC are explored. Overall, the WCRF/AICR concluded that there is probable evidence that consumption of whole grains, dietary fibre, dairy products and calcium supplements protect against CRC. They also say that consumption of red meat is probably a cause of CRC and that there is convincing evidence that processed meat and body fatness causes CRC. Some aspects of these dietary factors are summarised below.

Dietary fibre/whole grains

In terms of the influence of dietary fibre on CRC (2) there are indications of a negative association, i.e. increased fibre intake is associated with reduced risk. This is likely due to influences mediated by the gut microbiota as well as a mildly laxative effect of fibre (allowing less time for carcinogens or tumour promoters to accumulate). Gut microbes are adept at carbohydrate metabolism, with the production of benign metabolites such as organic acids. One in particular, butyrate, has been suggested to be a fuel for normal colonocyte function but can stimulate apoptosis when cells grow quickly - thereby having anti-tumour potential. As such, fibres that stimulate butyrate are likely to be preferred types in terms of CRC protection. These would include starchy carbohydrates from whole grains. As a related aside, genera seen as traditionally health promoting and the usual targets for pro/prebiotics (bifidobacteria, lactobacilli) cannot manufacture butyrate. As such, we need a better understanding of other positive groups and how to stimulate those. A further facet is that more saccharolytic metabolism in the gut decreases proteolysis. In contract to the former, the latter produces metabolites that have toxic potential (e.g., ammonia, amines, phenolics) some linked to CRC. In support of this, most incidences of CRC arise in the distal colon which is a more proteolytic environment than the proximal area. As such, targeting fibres to the left side on the large intestine holds much research promise.

Dairy products

A recent review of mainly WCRF/AICR evidence on dairy foods and cancer risk (3) concluded that the association between dairy and CRC was consistent for dairy products, milk, cheese, and dietary calcium showing a decreased risk of CRC with increased consumption although the evidence for cheese was less strong than other dairy food exposures. No evidence concerning exposures to butter, yoghurt, ice cream, and fermented milk was available. There is some evidence that the calcium in dairy foods contributes to the reducing CRC risk.

Red and Processed meat

A recent review of evidence mainly from WCRF/AICR (4) and Farvid et al. (5) on the association of red and processed meat on CRC risk concluded that recent findings provide further evidence on the association between red and processed meat and colorectal cancers with the conclusion that processed meat is a greater risk to CRC than red meat. However, it remains uncertain how the variability in the many meat types and their methods of processing around the world differ in the impact on cancer. There is evidence that cooking meat at high temperatures can result in the formation of heterocyclic amines and polycyclic aromatic hydrocarbons both of which have been linked with CRC development. Also, haem iron in red meat and processed red meat may be involved in the cancer initiation by stimulating N-nitroso compounds.

Other dietary factors

WCRF/AICR (1) also examined evidence suggesting some decreased CRC risk was associated with foods containing vitamin C, fish, vitamin D and multivitamin supplements. It was concluded that the evidence was limited but suggestive.

References

1. World Cancer Research Fund/American Institute for Cancer Research (2018) Diet, Nutrition, Physical Activity and Colorectal Cancer, Continuous Update Project Expert Report. Summary available at: Colorectal cancer | What causes colorectal cancer? | WCRF International
2. Louis P, Hold GL & Flint H (2014) The gut microbiota, bacterial metabolites and colorectal cancer. Nat. Rev. Microbiol. 12: 661-672.
3. Givens DI (2020) Dairy foods and the risk of cancer. In *Milk and Dairy Foods: Their Functionality in Human Health and Disease* [Ed D I Givens] Elsevier/Academic Press Cambridge, MA.
4. Giromini C and Givens D I (2022) Benefits and risks associated with meat consumption during key life processes and in relation to the risk of chronic diseases. Foods 11: 2063.
5. Farvid, M.S et al. Consumption of red meat and processed meat and cancer incidence: A systematic review and meta-analysis of prospective studies. Eur. J. Epidemiol. 2021, 36, 937–951.

4.6 Alzheimer's disease, dementias, mental health and diet

4.6.1 Relationship between Diet & Dementia and Alzheimer's Disease

Summary

Cognitive impairment is associated with reduced quality of life, increased risk of hospitalisation, inability to live independently, and increased health care costs; therefore, identification of modifiable risk factors for prevention and delay of cognitive decline is of increasing importance. There is a growing body of research and interest in the relationship between diet and cognitive function. Preventing or delaying the onset or progression of dementia through dietary interventions could have a significant impact on public health, and several studies have identified several diets and/or nutrients associated with reduced risk of cognitive impairment and decline.

Overview of literature review

We conducted a rapid literature review focusing on meta-analysis and review papers from 2012 until now using keywords Alzheimer's disease*AND*diet, Dementia*AND*Diet, Fruits and Vegetables*AND*Alzheimer's disease, Fruits, and Vegetables*AND*Dementia, ADD: Whole grains to understand how diet impacts the occurrence of dementia and Alzheimer's disease.

Focus on Alzheimer's Disease

The evidence from two recent meta-analysis indicates that dietary factors may mitigate the risk of developing Alzheimer's disease. For example, the ratio of reduced risk for Alzheimer's disease was 0.74 when consuming a diet higher in fruits and vegetables, from an overall sample size of 21,175 participants across 6 cohort studies (1). Similarly, adherence to a Mediterranean diet, which is also high in fruits and vegetables, was reported to reduce the risk of Alzheimer's disease by a slightly higher risk ratio of 0.89, from a sample size of 12,458 across 11 studies (2). Therefore, evidence from the highest quality reviews (meta-analyses) supports the suggestion that dietary factors, specifically consumption of healthy foods such as fruits and vegetables may reduce risk of developing Alzheimer's disease. This is supported by the findings from several other systematic reviews all of which indicate an association between either the Mediterranean diet or a fruit and vegetable-rich diet and lower risk of AZ disease (3, 4, 5, 6, 7, 8, 9). Interestingly, there is also some recent evidence that dietary interventions (e.g., a high fat, low carbohydrate diet) for those already diagnosed with Alzheimer's disease may help the ongoing management of the disease and the associated symptoms (10).

Focus on Dementia

Similarly, to Alzheimer's disease, the highest quality evidence from meta-analyses indicates that higher fruit and vegetable consumption is associated with a lower risk of developing Dementia, with a risk ratio of 0.8. This is also supported by systematic reviews indicating that fruit and vegetables (11,12) and the Mediterranean diet (13, 14, 15) can reduce the likelihood of developing Dementia. Interestingly a recent meta-analysis also showed that the risk of Dementia and Alzheimer's disease was reduced by 0.79 following regular supplementation with Vitamin E (16). In summary, the evidence points to the suggestion that diet is a modifiable risk factor for the development of clinical defined neurodegenerative conditions such as Alzheimer's Disease and Dementia.

Limitations

Self-reported dietary data can be biased by many factors such as age, gender, socioeconomic status, and education; yet there is limited research on the impact of cognitive function on the integrity of self-reported dietary data. Cognitive function itself may bias diet assessment methods, subsequently obscuring the evaluation of the nutrition cognition relationship.

To date, many studies have focused on the associations between individuals' current dietary patterns or their consumption of specific macronutrients and the associations with dementia prevalence. However, it is unknown whether a healthy change in diet (e.g., increasing the intake of beneficial food items while decreasing the intake of unhealthy food items) is associated with later risk of dementia. Given the pathological process underlying Alzheimer's disease and other dementias may start many years in advance of any noticeable symptoms, it is likely that a healthy diet in middle age is critical to delay or prevent the onset of dementia; once symptoms have become noticeable, adjustments to diet may have limited efficacy to delay ongoing pathology.

It is noteworthy that growing literature indicates that cardiovascular disease and its risk factors are associated with increased risk of dementia and Alzheimer's disease, and its precursor, cognitive decline. Thus, dietary modifications which decrease vascular disease might also hold promise for reducing the burden of dementia, Alzheimer's disease and cognitive decline.

References

1. Wu, L., Sun, D., & Tan, Y. (2017). Intake of fruit and vegetables and the incident risk of cognitive disorders: a systematic review and meta-analysis of cohort studies. The journal of nutrition, health & aging, 21(10), 1284-1290.
2. García-Casares, N., Gallego Fuentes, P., Barbancho, M. Á., López-Gigosos, R., García-Rodríguez, A., & Gutiérrez-Bedmar, M. (2021). Alzheimer's Disease, Mild Cognitive Impairment and Mediterranean Diet. A Systematic Review and Dose-Response Meta-Analysis. Journal of Clinical Medicine, 10(20), 4642.
3. Hu, N., Yu, J. T., Tan, L., Wang, Y. L., Sun, L., & Tan, L. (2013). Nutrition and the risk of Alzheimer's disease. BioMed research international, 2013.
4. Morris, M. C., Tangney, C. C., Wang, Y., Sacks, F. M., Bennett, D. A., & Aggarwal, N. T. (2015). MIND diet associated with reduced incidence of Alzheimer's disease. Alzheimer's & Dementia, 11(9), 1007-1014.
5. Yusufov, M., Weyandt, L. L., & Piryatinsky, I. (2017). Alzheimer's disease and diet: a systematic review. The International journal of neuroscience, 127(2), 161–175. https://doi.org/10.3109/00207454.2016.1155572
6. Hartman, R. E., & Ross, D. M. (2018). Effects and mechanisms of actions of phytochemicals on Alzheimer's disease neuropathology. Frontiers in Bioscience-Elite, 10(2), 300-333.
7. Román, G. C., Jackson, R. E., Gadhia, R., Román, A. N., & Reis, J. (2019). Mediterranean diet: The role of long-chain ω-3 fatty acids in fish; polyphenols in fruits, vegetables, cereals, coffee, tea, cacao and wine; probiotics and vitamins in prevention of stroke, age-related cognitive decline, and Alzheimer disease. Revue neurologique, 175(10), 724-741
8. Samadi, M., Moradi, S., Moradinazar, M., Mostafai, R., & Pasdar, Y. (2019). Dietary pattern in relation to the risk of Alzheimer's disease: a systematic review. Neurological Sciences, 40(10), 2031-2043.
9. Chu, C. Q., Yu, L. L., Qi, G. Y., Mi, Y. S., Wu, W. Q., Lee, Y. K., & Chen, W. (2022). Can dietary patterns prevent cognitive impairment and reduce Alzheimer's disease risk: exploring the underlying mechanisms of effects. *Neuroscience & Biobehavioral Reviews,* 104556.
10. Hersant, H., & Grossberg, G. (2022). The Ketogenic Diet and Alzheimer's Disease. The journal of nutrition, health & aging, 1-9.
11. Boeing, H., Bechthold, A., Bub, A., Ellinger, S., Haller, D., Kroke, A., ... & Watzl, B. (2012). Critical review: vegetables and fruit in the prevention of chronic diseases. European Journal of Nutrition, 51(6), 637-663.
12. Loef, M., & Walach, H. (2012). Fruit, vegetables and prevention of cognitive decline or dementia: a systematic review of cohort studies. The journal of nutrition, health & aging, 16(7), 626-630.
13. Cao, L., Tan, L., Wang, H., Jiang, T., Zhu, X., Lu, H., Tan, M., & Yu, J. (2016). Dietary Patterns and Risk of Dementia: a Systematic Review and Meta-Analysis of Cohort Studies. Molecular Neurobiology, 53(9), 6144-6154. https://doi.org/10.1007/s12035-015-9516-4
14. Petersson, S. D., & Philippou, E. (2016). Mediterranean diet, cognitive function, and dementia: a systematic review of the evidence. Advances in Nutrition, 7(5), 889-904.
15. Marchand, N. E., & Jensen, M. K. (2018). The role of dietary and lifestyle factors in maintaining cognitive health. American Journal of Lifestyle Medicine, 12(4), 268-285.
16. Zhao R, Han X, Zhang H, Liu J, Zhang M, Zhao W, Jiang S, Li R, Cai H, You H. Association of vitamin E intake in diet and supplements with risk of dementia: A meta-analysis. Front Aging Neurosci. 2022 Aug 1;14:955878. doi: 10.3389/fnagi.2022.955878. PMID: 35978949; PMCID: PMC9376618.

4.6.2 Relationship between Diet & Mental Health

Summary

Mental health problems are associated with impaired quality of life and increased health care costs, especially when consistent or recurring; therefore, identification of modifiable risk factors for prevention and delay of mental health problems is of increasing importance. There is a growing body of research and interest in the relationship between diet and various mental health disorders, especially mood disorders such anxiety and depression. Emerging evidence points to a positive association between a healthy diet (e.g., Mediterranean diet) and improved mood, and thus reduced symptoms of depression and anxiety.

Overview of literature review

We conducted a rapid literature review focusing on meta-analysis and review papers from 2012 until now using the search terms Mental health*AND*diet, Depression*AND*Diet, eating disorders*AND*diet, and Anxiety*AND*Diet in order to understand how diet impacts mental health acknowledging that mental health is broader than above mentioned diagnosis.

In what follows, we summarise the evidence for an association between diet and mental health; we describe whether evidence supports an association between mental health and diets. In general, various studies and meta-analysis support an association between a healthy diet and good mental health. For instance, in a large scale, cross-sectional, and prospective study in Japan (~10,000 participants), Choda et al. (1) describe an association between less intake of vegetables, protein, calcium, saturated fatty acid, and vitamin D and negative general mental health as reported in questionnaires. Importantly, dairy and calcium products were the most consistent and strongest predictor of positive mental health across their cross-sectional and prospective data analyses.

This association between a healthy diet and positive mental health also extends to children and adolescents where relationships between unhealthy dietary patterns and poorer mental health have been found (2, 3). For instance, Antonopoulou et al. (4) summarised most of the available studies and concluded that poorer students' health status was associated with lower adherence to a Mediterranean diet. Higher adherence to a Mediterranean diet, in contrast, was positively associated with lower depression risk. Finally, a higher perceived stress score was associated with lower fruit and vegetables intake.

Looking more specifically into anxiety, Kris-Etherton et al. (5) reviewed the evidence surrounding the role of diet in preventing and managing anxiety. They concluded that adherence to policy recommendations regarding food intake and diet requirements can have a positive impact on the prevention and treatment of anxiety and depression.

Related to this, several reviews have summarised the evidence on an association between diet and depression. For instance, Khalid et al., (3) describe in their review that two main approaches have been used to examine this relationship. First, several studies have investigated the impact of individual nutrients such as n-3 fatty acids, vitamins such as B_{12}, and minerals such as Zn, Se and Fe, in addition to studies testing the effect of supplements containing more than one nutrient. Second, other approaches have tested the effects of the whole diet and eating patterns on mood. In correlational epidemiological studies of adults, an 'unhealthy' and 'Westernised' diet was associated with an increased likelihood of mental disorders and psychiatric distress, whereas a 'healthy' or 'good-quality' diet was associated with better mental health. A recent review article by Glabska et al. (6) confirms these findings. They reviewed 61 studies studying depression but also quality of life etc.. They concluded that high total intake of fruits and vegetables, and some of their specific subgroups including berries, citrus, and green leafy vegetables, may promote higher levels of optimism and self-efficacy, as well as reduce the level of psychological distress, ambiguity, and cancer fatalism, and protect against depressive symptoms.

Moderating factors and role of age:

Given the development of the brain during childhood and adolescence, and the emergence of depression during adolescence, the impact of diet on mental health may plausibly be greater during this period than later in life (3). The impact of diet on mental health in older adults has also been studied. In particular, reduction in folate, omega-3 intakes and an increased consumption of energy-dense food have been discussed to be the factors leading late-life depression and poor mental health (7).

Limitations

It is important to notice that the direction of causality is difficult to determine in some of these findings. For instance, depression will impact people's appetite and hunger and will lower their motivation and capability to pursue a healthy diet. Similarly, anxiety might cause people to neglect their diet as they become preoccupied by their anxiety-related concerns.

Further, various factors might represent confounds when looking at these associations, for instance, factors such as socio-economic status, household income and educational levels also influence dietary choice (3).

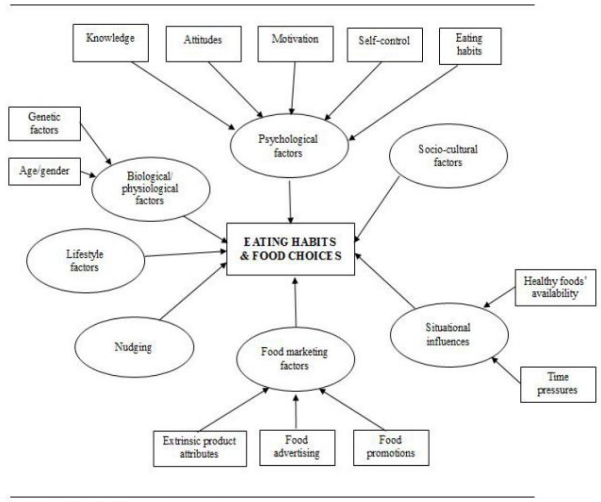
References

1. Choda, N., Wakai, K., Naito, M., Imaeda, N., Goto, C., Maruyama, K., ... & Hamajima, N. (2020). Associations between diet and mental health using the 12-item General Health Questionnaire: cross-sectional and prospective analyses from the Japan Multi-Institutional Collaborative Cohort Study. Nutrition journal, 19(1), 1-14.
2. O'Neil, A., Quirk, S. E., Housden, S., Brennan, S. L., Williams, L. J., Pasco, J. A., ... & Jacka, F. N. (2014). Relationship between diet and mental health in children and adolescents: a systematic review. American journal of public health, 104(10), e31-e42.
3. Khalid S, Williams CM, Reynolds SA. Is there an association between diet and depression in children and adolescents? A systematic review. Br J Nutr. 2016 Dec;116(12):2097-2108. doi: 10.1017/S0007114516004359. Epub 2017 Jan 17. PMID: 28093091.
4. Antonopoulou, M., Mantzorou, M., Serdari, A., Bonotis, K., Vasios, G., Pavlidou, E., ... & Giaginis, C. (2020). Evaluating Mediterranean diet adherence in university student populations: Does this dietary pattern affect students' academic performance and mental health?. *The International Journal of Health Planning and Management, 35*(1), 5-21.
5. Kris-Etherton, P. M., Petersen, K. S., Hibbeln, J. R., Hurley, D., Kolick, V., Peoples, S., ... & Woodward-Lopez, G. (2021). Nutrition and behavioral health disorders: depression and anxiety. Nutrition reviews, 79(3), 247-260.
6. Głąbska, D., Guzek, D., Groele, B., & Gutkowska, K. (2020). Fruit and vegetable intake and mental health in adults: a systematic review. *Nutrients, 12*(1), 115.
7. Payne ME. Nutrition and late-life depression: etiological considerations. Aging health. 2010;6(1):133-143

5. Environmental drivers of food choice

As previously mentioned, various factors such as emotional states in mental health disorders will not only be influenced by diet but will also impact food choice of consumers. In this context, it is important to consider the various drivers of food choice, as shown below, adapted from Koester et al. (1)

Figure 1. Key drivers of eating habits and food choices



Source: Adapted from Köster (2009)

Eating behaviour is affected by environmental factors. This is often referred to as the "choice architecture" in which choices occur – this can be the physical environment (how products or food service environments are laid out), the information environment (how information is described – e.g. 90% fat free rather than 10% fat – or organised), and the social environment (the real or perceived social norms around the decision maker). (2) This choice architecture can have an impact on food choices as they are often fast decisions made with little conscious processing. In order to help change behaviours like this, "nudging" can be an effective strategy (2). Nudging can be defined as an umbrella term in which changes to behaviour are facilitated by changing aspects of the physical, informational or social environment. It aims to shift people's behaviours in a predictable way (3,4), and can do so without expressly forbidding any options. In their systematic review and metanalysis Arno and Thomas (5) concluded that nudge strategies increased (on average 15.3%) healthy food choices. Similarly, in a systematic review and metanalysis it was reported that over 80% of the reviewed research showed positive results of nudging approach on healthy food choices (4).

For example, the layout of food choice environments has been shown to have an impact on choice. For example, products that are presented at eye level or next to the till have been shown to draw more attention (4, 6). Vandenbroele et al. (4), discuss how, not just what the information that is presented on food labels is, but also how that information is presented can affect people's choices. Simple interventions such as changing the size and colour of plates can also have an impact on the amount of food consumed (7).

Sensory characteristics such as vision (i.e. packaging), taste (i.e. tasting samples in store), sounds (i.e. music in store), haptics (i.e. trying a product in store) and olfaction (i.e. smell in the environment) has also been shown to affect consumer choices (4).

5.1 Social drivers of food choice

Eating behaviour is profoundly affected by social factors (8). Social factors can impact food choice via various ways.

Firstly, **interpersonal social factors** impact eating pattern on the micro-level. For instance, family practices, rules and structure around mealtimes play a role in individuals eating habits (9). A large body of evidence indicates that family practices such as making healthy food available, serving healthy food, having frequent family meals and creating expectation for meal times is associated with higher diet quality, better weight status, lower risk of mental health problems and disordered eating and improved general wellbeing (10,,11,12,13, 14, 15). Furthermore, easy access to unhealthy foods during childhood is associated with development of unhealthier dietary pattern development during adolescents and adulthood. Cross-sectional studies reveal that discordance in food parenting practices was associated with children's snacking behaviour and adolescents unhealthy weight control behaviours and consumption of fast food (16, 17). The literature emphasized that parents influence the food preferences of their children (restriction of food experience, modelling, parenting practices and parenting styles), children affect parents, and friends affect each other's food choices (18).

Secondly**, social influence** is another factor that influences eating in interpersonal settings on the micro level but also on the macro level via organisational or societal influences. Social influence models of food intake describe how people directly adapt their food intake to that of their social group, defined at the level of nationality or ethnicity, peer group, family and friendship grouping depending on context. This extends to the perceived standards or the social eating norm of what constitutes as an appropriate amount and type of food, for members of a social group (19). People conform to others' eating because they consider the amount eaten by others as an indicator of how much food one can or should consume or because of affiliation motives. Both observational and correlational studies show that people adapt their intake to that of their eating companion, and that those who are eating together converge upon an eating norm (e.g., 19,20, 21).

Social facilitation of eating describes an increase in food intake when people eat together as compared to when they eat alone. A comprehensive review of diary, observational and experimental studies show that social facilitation occurs as people who are to eat in groups select more food especially with friends (22). One study showed participants eat more when eating with familiar people compared to those who ate with strangers (20). In a related vein, impression management refers to the assumption that people are motivated to present themselves in a favourable light. When someone chooses to eat in a variety of contexts, they can provide others with information about themselves. Therefore, people can modify their eating behaviour as a means of creating an impression of themselves in the eyes of their companion. A review of studies on impression management demonstrated that eating companions influence people more eager to suppress their intake to convey a good impression (23). Concerns about appearance or self-expression motives and social pressures to eat healthily can drive healthy but also unhealthy eating patterns (24). For instance, social norms to indulge might prevent people from eating healthily when these motivations are stronger in a choice situation (24, 25, 26,). In line with this reasoning, obstructing social norms or missing opportunities to implement healthy eating are predictors of intentions to not eat healthily and actual eating patterns (27).

Social Media is another social factor that may influence the eating behaviour of an individual. A systematic review of qualitative studies primarily on university students concluded that social media engagements and exposure to image related content has a negative impact of BMI and food choices in young adults who are vulnerable to social media influence. The risk increased with constant viewing of idyllic images of celebrities, peer, food, fitness, and fashion, in addition to participation in negative behaviours such as body fat discussions, reassurance seeking and comparisons of appearance (28). However due to its exponential growth social media can be used by nutrition and health professionals, government, and other health organisations to leverage social media to reinforce healthy diet and behaviours.

References

1. Köster, E.P., 2009. Diversity in the determinants of food choice: A psychological perspective. Food Quality and Preference, 20(2), pp.70-82.
2. Thaler, R. H., & Sunstein, C. R., Nudge. Penguin. 2009.
3. Vecchio R, Cavallo C. Increasing healthy food choices through nudges: A systematic review. *Food Quality and Preference*. 2019;78:103714.
4. Vandenbroele J, Vermeir I, Geuens M, Slabbinck H, Van Kerckhove A. Nudging to get our food choices on a sustainable track. *Proc Nutr Soc*. 2020;79(1):133-46.
5. Arno A, Thomas S. The efficacy of nudge theory strategies in influencing adult dietary behaviour: a systematic review and meta-analysis. *BMC Public Health*. 2016;16(1):676.
6. Ensaff H. A nudge in the right direction: the role of food choice architecture in changing populations' diets. *Proc Nutr Soc*. 2021;80(2):195-206.
7. Spence, C. (2018). Background colour & its impact on food perception & behaviour. *Food Quality and Preference, 68*, 156–166
8. Rozin, P., 2006. The integration of biological, social, cultural and psychological influences on food choice. Frontiers in Nutritional Science, 3, p.19.
9. Patrick, H. and Nicklas, T.A., 2005. A review of family and social determinants of children's eating patterns and diet quality. Journal of the American College of Nutrition, 24(2), pp.83-92.
10. Hammons, A.J. and Fiese, B.H., 2011. Is frequency of shared family meals related to the nutritional health of children and adolescents?. Pediatrics, 127(6), pp.e1565-e1574.
11. Utter, J., Scragg, R., Schaaf, D. and Mhurchu, C.N., 2008. Relationships between frequency of family meals, BMI and nutritional aspects of the home food environment among New Zealand adolescents. International Journal of Behavioral Nutrition and Physical Activity, 5(1), pp.1-7.
12. Loth, K.A., MacLehose, R.F., Larson, N., Berge, J.M. and Neumark-Sztainer, D., 2016. Food availability, modeling and restriction: How are these different aspects of the family eating environment related to adolescent dietary intake?. Appetite, 96, pp.80-86.
13. Berge, J.M., MacLehose, R.F., Loth, K.A., Eisenberg, M.E., Fulkerson, J.A. and Neumark-Sztainer, D., 2015. Parent-adolescent conversations about eating, physical activity and weight: prevalence across sociodemographic characteristics and associations with adolescent weight and weight-related behaviors. Journal of Behavioral Medicine, 38(1), pp.122-135.
14. Eisenberg, M.E., Olson, R.E., Neumark-Sztainer, D., Story, M. and Bearinger, L.H., 2004. Correlations between family meals and psychosocial well-being among adolescents. Archives of Pediatrics & Adolescent Medicine, 158(8), pp.792-796.
15. Utter, J., Denny, S., Robinson, E., Fleming, T., Ameratunga, S. and Grant, S., 2013. Family meals among New Zealand young people: relationships with eating behaviors and body mass index. Journal of Nutrition Education and Behavior, 45(1), pp.3-11.
16. Berge, J.M., MacLehose, R.F., Larson, N., Laska, M. and Neumark-Sztainer, D., 2016. Family food preparation and its effects on adolescent dietary quality and eating patterns. Journal of Adolescent Health, 59(5), pp.530-536.
17. Gevers, D.W., Kremers, S.P., De Vries, N.K. and Van Assema, P., 2015. Patterns of food parenting practices and children's intake of energy-dense snack foods. Nutrients, 7(6), pp.4093-4106.
18. Guidetti, M. and Cavazza, N., 2010. De gustibus: l'influenza sociale nella costruzione dei repertori alimentari. Psicologia Sociale, (3), pp.359-386.
19. Higgs, S., 2015. Social norms and their influence on eating behaviours. Appetite, 86, pp.38-44.
20. Salvy, S.J., Romero, N., Paluch, R. and Epstein, L.H., 2007. Peer influence on pre-adolescent girls' snack intake: effects of weight status. Appetite, 49(1), pp.177-182.
21. Salvy, S.J., Vartanian, L.R., Coelho, J.S., Jarrin, D. and Pliner, P.P., 2008. The role of familiarity on modeling of eating and food consumption in children. Appetite, 50(2-3), pp.514-518.
22. Herman, C.P., 2015. The social facilitation of eating. A review. Appetite, 86, pp.61-73.

23. Vartanian, L.R., 2015. Impression management and food intake. Current directions in research. Appetite, 86, pp.74-80.
24. Munt, A.E., Partridge, S.R. and Allman-Farinelli, M., 2017. The barriers and enablers of healthy eating among young adults: A missing piece of the obesity puzzle: A scoping review. Obesity Reviews, 18(1), pp.1-17.
25. Kelly, B., Freeman, B., King, L., Chapman, K., Baur, L.A. and Gill, T., 2016. The normative power of food promotions: Australian children's attachments to unhealthy food brands. Public Health Nutrition, 19(16), pp.2940-2948.
26. Mann, T., Tomiyama, A.J. and Ward, A., 2015. Promoting public health in the context of the "obesity epidemic" : False starts and promising new directions. Perspectives on Psychological Science, 10(6), pp.706-710.
27. McDermott, M.S., Oliver, M., Simnadis, T., Beck, E.J., Coltman, T., Iverson, D., Caputi, P. and Sharma, R., 2015. The Theory of Planned Behaviour and dietary patterns: A systematic review and meta-analysis. Preventive Medicine, 81, pp.150-156.
28. Rounsefell, K., Gibson, S., McLean, S., Blair, M., Molenaar, A., Brennan, L., Truby, H. and McCaffrey, T.A., 2020. Social media, body image and food choices in healthy young adults: A mixed methods systematic review. Nutrition & Dietetics, 77(1), pp.19-40.

6. Direct and indirect financial costs of NCDs

Direct financial costs are the expenses that are directly connected to patient diagnosis, treatment and hospital care whereas indirect financial costs refer to the economic loss associated with a given disease. Indirect costs include the value of decreased or lost productivity and income. Table 2 aims to give details on the direct and indirect financial costs of NCDs identified in this report, although both costs were not available for all NCDs. It is also notable that costs may reflect the prevalence of a condition, the size of the population and/or the amount a country is willing to spend on a condition and may reflect the country's wealth. In this section a summary table is presented.

Table 2. Direct and indirect costs of NCDs in Europe

Country	Cardiovascular diseases		Colon cancer	Dementia	Type 2 diabetes
	Direct cost (€ M/year)	Indirect cost (€ M/year)	Direct cost (€ M/year)	Total cost (€ M/year)	Total cost €/diabetic/year
Austria	2,522	2,218	176	1,697	5,364
Belgium	2,421	2,247	232	1,360	5,110
Bulgaria	344	605	22.4	-	1,774
Croatia	242	535	16.6	-	1,064
Cyprus	-	-	6.2	-	2,047
Czechia	1,481	1,300	76.4	1,744	1,563
Denmark	962	1,193	145	734	5,631
Estonia	178	311	6.8	163	1,415
Finland	1,999	925	51.7		3,849
France	15,495	8,407	1,214	16,831	4,955
Germany	28,306	29,201	1,302	32,607	4,692
Greece	1,948	1,242	65.9		1,692
Hungary	1,512	1,059	52.6		1,260
Iceland	-	-	4.8	-	6,531
Ireland	857	951	80.5	-	6,729
Italy	15,708	12,507	730	13,710	2,906
Latvia	130	338	7.6	-	1,068
Lithuania	226	411	13.8	-	1,251
Luxemburg	162	96	15.8	-	8,137
Malta	48	63	5.3	-	2,414
Netherlands	5,527	3,426	393	-	5,487
Norway	-	-	146	-	9,242
Poland	4,352	4,315	153	-	941
Portugal	1,174	1,654	70.3	-	1,836
Romania	1,274	1,560	52.1	-	1,232
Slovakia	657	615	29.8	-	1,497
Slovenia	247	294	16.3	656	2,111
Spain	9,243	7,607	365	8,269	2,704
Sweden	1,664	1,824	125	726	6,776
United Kingdom	12,348	14,318	497	-	5,360
Switzerland	-	-	295	-	12,153
EU	-	-	19,100* (11,600**)	-	-

*direct costs, **indirect costs, -no data available

References

1. Centre for Economics and Business Research (CEBR). The economic cost of cardiovascular disease from 2014-2020 in six European economies. 2014; https://www.cebr.com/wp-content/uploads/2015/08/Short-Report-18.08.14.pdf%0Ahttp://www.cebr.com/reports/the-rising-cost-of-cvd/. [9 August 2018]
2. Czech M, Opolski G, Zdrojewski T, et al. The costs of heart failure in POL from the public payer's perspective. Polish programme assessing diagnostic procedures, treatment and costs in patients with heart failure in randomly selected outpatient clinics and hospitals at different levels of car. Kardiol Pol. 2013;71(3):224-232.
3. Esposti LD, Degli Esposti, Buda, Saragoni, Sturani A. Glycemic control and diabetes-related health care costs in type 2 diabetes; retrospective analysis based on clinical and administrative databases. Clin Outcomes Res. 2013:193.
4. Eurostat. HEDIC: Health Expenditures by Diseases and Conditions. Luxembourg: 2016; Report No. KS-TC-16-008.
5. Foo J, Landis SH, Maskell J, et al. Continuing to confront COPD international patient survey: Economic impact of COPD in 12 countries. PLoS One. 2016;11(4):1-15.
6. Gibson GJ, Loddenkemper R, Sibille Y, Lundbäck B. The economic burden of lung disease. In: Gibson GJ, Loddenkemper R, Sibille Y, Lundbäck B, eds. The European Lung White Book: Respiratory Health and Disease in Europe. Sheffield: European Respiratory Society; 2013:16-27.
7. Hanly P, Soerjomataram I, Sharp L. Measuring the societal burden of cancer: The cost of lost productivity due to premature cancer-related mortality in Europe. BMC Cancer. 2014;14(224):E136-E145.
8. International Diabetes Federation (IDF). IDF Diabetes Atlas. 2017; http://diabetesatlas.org/resources/2017-atlas.html. [9 August 2018]
9. Jacobs E, Hoyer A, Brinks R, Icks A, Kuß O, Rathmann W. Healthcare costs of Type 2 diabetes in DEU. Diabet Med. 2017;34(6):855-861.
10. Jönsson B, Hofmarcher T, Lindgren P, Wilking N. The cost and burden of cancer in the EU 1995-2014. Eur J Cancer. 2016;66:162-170.
11. Kanavos P, Aardweg S Van Den, Schurer W. Diabetes Expenditure, Burden of Disease and Management in 5 EU Countries. LSE Heal. 2012; http://eprints.lse.ac.GBR/54896/1/__libfile_REPOSITORY_Content_LSE Health and Social Care_Jan 2012_LSEDiabetesReport26Jan2012.pdf. [9 August 2018]
12. Köster I, Huppertz E, Hauner H, Schubert I. Costs of Diabetes Mellitus (CoDiM) in DEU, direct per-capita costs of managing hyperglycaemia and diabetes complications in 2010 compared to 2001. Exp Clin Endocrinol Diabetes. 2014;122(9):510–516.
13. Lisspers K, Larsson K, Johansson G, et al. Economic burden of COPD in a Swedish cohort: The ARCTIC study. Int J COPD. 2018;13:275-285.
14. Luengo-Fernandez R, Leal J, Gray A, Sullivan R. Economic burden of cancer across the EU: a population-based cost analysis. Lancet Oncol. 2013;2045(13):1-10.
15. Łyszczarz B, Nojszewska E. Productivity losses and public finance burden attributable to breast cancer in POL, 2010-2014. BMC Cancer. 2017;17(1):1-13.
16. Marcellusi A, Viti R, Mecozzi A, Mennini FS. The direct and indirect cost of diabetes in ITA: a prevalence probabilistic approach. Eur J Heal Econ. 2016;17(2):139-147.
17. Marcellusi A, Viti R, Sciattella P, et al. Economic aspects in the management of diabetes in ITA. BMJ Open Diabetes Res Care. 2016;4(1).
18. Mata-Cases M, Casajuana M, Franch-Nadal J, et al. Direct medical costs attributable to type 2 diabetes mellitus: a population-based study in Catalonia, ESP. Eur J Heal Econ. 2016;17(8):1001-1010.

19. McLean S, Hoogendoorn M, Hoogenveen RT, et al. Projecting the COPD population and costs in England and Scotland: 2011 to 2030. Sci Rep. 2016;6:1-10.
20. Nuhoho S, Vietri J, Worbes-Cerezo M. Increased cost of illness among European patients with type 2 diabetes treated with insulin. Curr Med Res Opin. 2017;33(1):47-54.
21. Pagano E, De Rosa M, Rossi E, et al. The relative burden of diabetes complications on healthcare costs: The population-based CINECA-SID ARNO Diabetes Observatory. Nutr Metab Cardiovasc Dis. 2016;26(10):944-950.
22. Peters ML, Huisman EL, Schoonen M, Wolffenbuttel BHR. The current total economic burden of diabetes mellitus in NLD. Neth J Med. 2017;75(7):281-297.
23. Pil L, Hoorens I, Vossaert K, et al. Burden of skin cancer in BEL and cost-effectiveness of primary prevention by reducing ultraviolet exposure. Prev Med (Baltim). 2016;93:177-182.
24. Ulrich S, Holle R, Wacker M, et al. Cost burden of type 2 diabetes in DEU: Results from the population-based KORA studies. BMJ Open. 2016;6(11).
25. Vallejo-Torres L, Morris S, Kinge JM, Poirier V, Verne J. Measuring current and future cost of skin cancer in England. J Public Heal (United Kingdom). 2014;36(1):140-148.
26. van Boven JFM, Vegter S, van der Molen T, Postma MJ. COPD in the Working Age Population: The Economic Impact on Both Patients and Government. COPD J Chronic Obstr Pulm Dis. 2013;10(6):629-639.
27. Waldeyer R, Brinks R, Rathmann W, Giani G, Icks A. Projection of the burden of type 2 diabetes mellitus in DEU: A demographic modelling approach to estimate the direct medical excess costs from 2010 to 2040. Diabet Med. 2013;30(8):999-1008.
28. Wilkins E, Wilson L, Wickramasinghe K, et al. European Cardiovascular Disease Statistics 2017 edition. 2017:192. https://www.bhf.org.GBR/informationsupport/publications/statistics/european-cardiovascular-disease-statistics-2017. [9 August 2018]
29. https://diabetesatlas.org/idfawp/resource-files/2021/07/IDF_Atlas_10th_Edition_2021.pdf
30. Hofmarcher, T., Lindgren, P., Wilking, N., & Jönsson, B. (2020). The cost of cancer in Europe 2018. European journal of cancer (Oxford, England : 1990), 129, 41–49. https://doi.org/10.1016/j.ejca.2020.01.011
31. European Cardiovascular Disease Statistics 2017
32. Jönsson L. The personal economic burden of dementia in Europe. Lancet Reg Health Eur. 2022 Jul 25;20:100472. doi: 10.1016/j.lanepe.2022.100472. PMID: 35910037; PMCID: PMC9326307.
33. Meijer, E., Casanova, M., Kim, H., Llena-Nozal, A., & Lee, J. (2022). Economic costs of dementia in 11 countries in Europe: Estimates from nationally representative cohorts of a panel study. The Lancet regional health. Europe, 20, 100445. https://doi.org/10.1016/j.lanepe.2022.100445
34. Henderson, R. H., French, D., Maughan, T., Adams, R., Allemani, C., Minicozzi, P., Coleman, M. P., McFerran, E., Sullivan, R., & Lawler, M. (2021). The economic burden of colorectal cancer across Europe: a population-based cost-of-illness study. *The Lancet Gastroenterology & Hepatology*. https://doi.org/10.1016/S2468-1253(21)00147-3
35. Vekic B, Dragojevic-Simic V, Jakovljevic M, et al. Medical Cost of Colorectal Cancer Services in Serbia Between 2014 and 2017: National Data Report. Front Pharmacol. 2019;10:526. Published 2019 May 15. doi:10.3389/fphar.2019.00526
36. Digestive cancers Europe IHE report- https://ihe.se/wp-content/uploads/2020/10/IHE-Report-2020_6_.pdf
37. Kanavos P., van den Aardweg S. and Schurer W (2012). Diabetes expenditure, burden of disease and management in 5 EU countries. https://www.lse.ac.uk/business/consulting/assets/documents/diabetes-expenditure-burden-of-disease-and-management-in-5-eu-countries.pdf

38. Alzheimer's society annual report overview 2020/21 https://www.alzheimers.org.uk/sites/default/files/202110/alzheimers_society_annual_report_2021.pdf
39. Jönsson, B., & CODE-2 Advisory Board (2002). Revealing the cost of Type II diabetes in Europe. Diabetologia, 45(7), S5–S12. https://doi.org/10.1007/s00125-002-0858-x
40. https://www.diabetesatlas.org/upload/resources/material/20200302_133351_IDFATLAS9e-final-web.pdf

7. Overall summary

In this report we have summarised the impact of diet-responsive NCD mortality and morbidity in European countries. The research that is now available shows that varied degrees of NCDs have always been present in Europe. According to GBD data, NCDs account for an estimated 91.08% (4.9 million) of all deaths and 87.55% of all Disability-Adjusted Life Years (DALYs) in the EU. Unhealthy diet, tobacco use, excess alcohol consumption and lack of physical activity have been identified as the main risk factors for NCDs in Europe. According to GBD, in 2019, 950,000 deaths and over 16 million DALYs can be attributed to unhealthy diets. To summarise the findings from the available data;

- CVDs remain largest cause of death by far (34%) 71% of which is IHD plus stroke
- CVDs mortality is reducing somewhat together with prevalence and DALYs
- CVDs are associated with the highest DALYs of all diet-responsive NCDs
- The impact of dietary *trans* fatty acids and sodium on CVD remain a concern particularly in the Baltic and eastern EU states

- ➢ Cancers are the 2nd largest cause of death (31%) with colorectal cancer 13% of total, 6th overall
- ➢ Colorectal cancer prevalence is rising in most countries.
- ➢ Dietary factors such as low dietary fibre intake need more attention to reduce the rise in colorectal cancer

- ❖ Neurological disorders are the 3rd largest cause of death (6.7%) of which ~90% is Alzheimer's disease.
- ❖ Alzheimer's disease prevalence is fairly stable overall, but DALYs attributable are increasing in most countries.
- ❖ Alzheimer's disease prevalence is higher in women.

- ▪ T2D has apparently relatively low mortality rate but there is concern about CVD cause of death registration.
- ▪ T2D prevalence and attributable DALYs are rising substantially in most countries.

- Very substantial variations in diet-responsive NCDs between countries
- Mid and eastern EU countries, particularly Bulgaria has highest ACM and CVD and CRC mortality rates.
- Women have a greater death rate from Alzheimer's disease than men but men tend to have greater CRC mortality than women.

As mentioned previously, high-income countries have seen dramatic drops in CVD, however it still remains the largest cause of death. The reasons behind the reduction in CVD prevalence are likely complex and include both broad economic and infrastructure growth and particular health system initiatives aimed at prevention and treatment. The large and globally inequitable burden of NCDs should motivate the use of the individual and population-based interventions discussed in this report to reverse rising trends and accelerate declines,

even though overall economic and health development over the ensuing decades may replicate these successes elsewhere.

Indeed, numerous interventions and strategies can lower the risk of NCD among the general population. Effective population-based interventions include raising the accessibility and affordability of fresh fruits and vegetables through pricing and targeted subsidies for low-income families, decreasing the sodium content of packaged and prepared foods and staples like bread by influencing food reformulation and regulatory and voluntary mechanisms, and increasing the accessibility and availability of dietary salt substitutes. That means, creating a health-enabling environment is one of the ways to tackle NCDs. It is expected that in an obesogenic environment, the predictable outcome is overweight/obesity whereas a physical activity friendly environment enhances physical activity. In addition, creating food environments where healthy food is available and affordable is important. Collaboration between global, regional, national, and local governments, several government agencies, and professionals in health promotion and disease prevention is essential for the success of these efforts. An implementation investigation is required to determine which interventions and techniques at the individual and population levels are most effective and sustainable in each environment, as well as any unintended consequences. Studies in low- and middle-income nations are particularly needed to find and assess efficient population-level interventions in environments with constrained resources for individuals, families, and governments, with poor infrastructure, and in various social contexts.

8. Conclusions

NCDs are the leading causes of death worldwide. There are policies to tackle NCDs, however they remain the largest cause of deaths in Europe. Deaths at early age or living long term with NCDs and disabilities has socioeconomic consequences. If the NCD epidemic is not controlled, mortality from NCDs is predicted to increase. It has been known that NCD mortality can be prevented by dealing with key modifiable risk factors. Unhealthy diets, being overweight/obese are the top modifiable risk factors in Europe, which contribute to NCDs such as CVD, Type 2 diabetes and some cancers. Therefore, based on knowledge of the conditions and the evidence presented in Section 4, their contribution to European illness, morbidity and no doubt financial costs the following diet-responsive NCDs will be targeted in this project.

- Ischaemic heart disease
- Stroke (ischaemic and haemorrhagic)
- Colo-rectal cancer
- Type 2 diabetes mellitus
- Alzheimer's disease and other dementias

9. Supplementary data

The numerical data relating to most of the figures presented are available in an Excel file.