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FULL RESEARCH PAPER
Nutrition/obesity (diet, alcohol)

Cardiovascular mortality attributable to dietary risk factors in 54 countries in the WHO European Region from 1990 to 2019: an updated systematic analysis of the Global Burden of Disease Study

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Aims

This study aimed to estimate the association between single dietary risk factors and cardiovascular diseases (CVDs) in the WHO European Region (WHO ER) by age and sex using the data of the Global Burden of Diseases Study (GBD) from 1990 to 2019.

Methods and results

For this purpose, 13 dietary risks and 13 forms of CVDs were included in the study, and the comparative risk assessment framework of the GBD was used to estimate the deaths attributable to them. The study included four regions, with a total of 54 countries. In 2019, 1.55 million (95 % UI, 1.2-1.9 million) people in the WHO ER died from CVDs attributable to sub-optimal diet. Diet-related CVD deaths (DRCDs) accounted for 16.4 % of total deaths and 36.7 % of CVD deaths in 2019. Between 1990 and 2019, there was a DRCDs reduction of 8.1 % and the age-standardized death rate decreased. The deaths were almost equally distributed between women (777 714 deaths) and men (772 519 deaths). The distribution of death numbers between the sexes has changed only slightly over the study period. The largest percentage across the age groups was found in the group 85+ years (32.1 %). Most DRCDs in the WHO ER were caused by a diet low in whole grains (326 755 deaths), followed by a diet low in legumes (232 918 deaths) and a diet high in sodium (193 713 deaths). Overall, 80.3% of deaths were due to ischaemic heart disease, which was the most common cause of death in all countries.

Conclusion

In terms of CVD deaths in the WHO ER, more than every third death is attributable to an unbalanced diet, making the diet one of the most important factors in preventing premature CVD death in the WHO ER.

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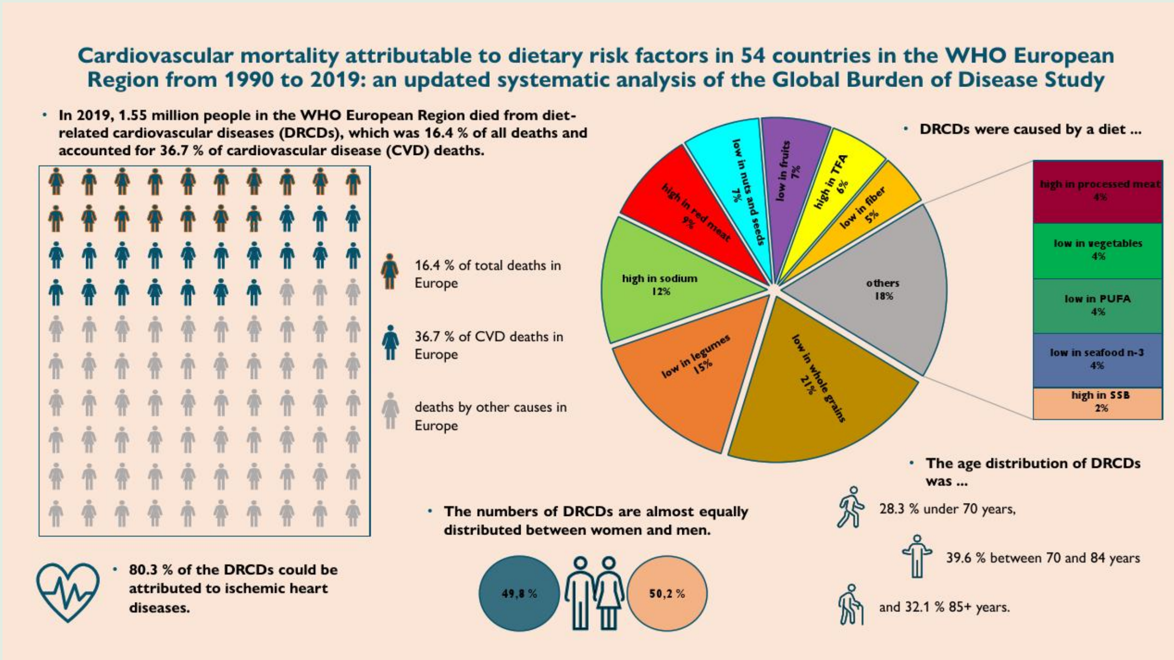
Graphical Abstract



Keywords Global Burden of Disease Study • Nutrition • Dietary risk factors • Cardiovascular diseases • Public health • World Health Organization European Region

Introduction

Non-communicable diseases (NCDs) continue to increase as a part of the health transition and account for the majority of deaths worldwide.[1,2] Cardiovascular diseases (CVDs) are one of the most common diseases in this group, with ischaemic heart disease and stroke accounting for the largest share.[3–6] In 2019, one-third of all deaths worldwide could be attributed to CVDs. In 1990, the proportion was around 26%, with CVDs already being the leading cause of death.[7]

According to the Global Burden of Disease Study (GBD) 2019 iteration, the most important risk factors for all deaths worldwide are high systolic blood pressure, tobacco use and dietary risks.[8] In terms of CVDs, diet-related risk is even the second most important risk factor after high blood pressure.[7] 14.5% of all deaths worldwide in 2019 were due to dietary risks and it ranked third among attributable Level 2 risks of global deaths. In 1990, dietary risks were the fifth most important risk factor.[9]

A healthy diet aims to promote growth and development and to prevent nutrition-related NCDs including CVDs.[10,11] The World Health Organization (WHO) defines a health-promoting diet as follows: eating enough vegetables and fruits, legumes, nuts and whole grains. Besides health effects and adequate intake of essential nutrients this ensures adequate daily intake of dietary fibre. In addition, intakes of free sugars (<10% of total energy intake) and salt (<5 g/day) should be restricted. Instead of saturated fatty acids and trans-fats of all kinds, unsaturated fatty acids including polyunsaturated fatty acids (PUFA) from plant and marine sources should be preferred.[12–16] Even if there are other guidelines, such as national food-based dietary guidelines from individual countries,[17] the recommendations are all quite similar. Non-compliance can be classified as hazardous to health, increasing the risk of certain diseases.[10,18]

This study has the following aims:

- to investigate how many deaths from CVDs in the WHO ER and the associated countries are attributable to dietary risks,
- to analyse the impact of each diet-related risk factor on CVDs in the WHO ER and individual countries between 1990 and 2019, and
- to compare the results with a precedent study[19] covering the period from 1990 to 2016 and to discuss and highlight differences in the underlying comparative risk assessment framework (CRA).

Since the publication of Meier *et al.* (2019) and the present study, significant changes have been made to the underlying calculation model, in order to estimate the data as accurately as possible according to the current state of scientific knowledge and to keep the accuracy and significance of the GBD study as high as possible. This new calculation method was not only applied to the data since 2019, but also to all previous years. This has resulted in a fundamental update of the data sets from 1990 and an extension of the study period from 2016. In addition, a new risk factor (a diet high in red meat) was integrated into the GBD data sets. The CVD types were also partially reclassified, though those with less influence within our results.

Finally, informative double-page information sheets have been included in the Supplementary material online, Appendix for each country with key data and changes over the study period.

Methods

In this study, CVD deaths were attributed to the 13 dietary risks of the GBD for the years 1990 to 2019. The data were analysed by age and sex among adults aged 25 years or older and calculated for the 54 countries of the WHO ER and the related regions Western Europe (WE), Central Europe (CE), Eastern Europe (EE), and Central Asia (CA) (see Supplementary material online, Appendix Table I-1). The selection of the countries included and their categorization into the corresponding regions was carried out by the WHO (status 2020). Compared with the GBD 2016 analysis by Meier *et al.*,[19] the analyses now include also Mongolia in CA as well as Monaco and San Marino in WE. Data from the comparative risk assessment (CRA) conceptual framework, developed by Murray and Lopez,[20] were used for this analysis.

Whereas in the GBD CRA framework 15 dietary risk factors are considered, only 13 are relevant for CVDs. Disease-specific endpoints for the influence of the risk factors 'a diet low in milk' and 'a diet low in calcium' are available solely for neoplasms. Since the study of Meier *et al.*,[19] the data now also include the risk factor 'a diet high in red meat'. The remaining risk factors are: a diet low in fibre, fruits, whole grains, legumes, vegetables, nuts and seeds, PUFA and seafood omega-3 fatty acids (seafood *n*–3), as well as a diet high in sodium, processed meat, sugar-sweetened beverages (SSB), and trans fatty acids (TFA).

Moreover, the GBD CRA framework includes the following 13 types of CVDs: ischaemic heart disease, ischaemic stroke, intracerebral haemorrhage, subarachnoid haemorrhage, hypertensive heart disease, cardiomyopathy and myocarditis, atrial fibrillation and flutter, aortic aneurysm, peripheral artery disease, rheumatic heart disease, non-rheumatic valvular heart disease, other cardiovascular and circulatory diseases, and endocarditis.

Not for all of the potential 169 risk-outcome pairs (13 risk factors multiplied by 13 causes of death) data are available that can be linked with sufficient evidence. Thus, there are 38 risk-outcome pairs in this study, which can be found in Supplementary material online, Appendix Table I-2.

Risk factor estimation

The data of the GBD study can be used to estimate the impact of individual risk factors on disease groups and individual diseases. The calculation framework enables the estimation of either deaths, disability-adjusted life years, years of life lost, or years of healthy life lost due to disability as disease endpoints. In the present study, dietary risks were selected as risk factors and regarding cardiovascular deaths. Other death causes affected by dietary risks can be calculated using the GBD framework for neoplasms, diabetes mellitus, and kidney diseases (see Supplementary material online, Appendix Figure I-4).

For each risk estimation, the risks in the GBD are assigned to a hierarchy level. Dietary risks in general are Level 2 factors and belong to the behavioural category (Level 1), while individual factors, such as a diet low in whole grains, are classified as Level 3.[5] Thus, for every Level 3 risk factor, risk-outcome pairs can be defined for which an estimate of the effect size is calculated.

The CRA framework, used as the risk factor estimation tool by GBD, allows quantification of risks or causes and is based on the following components: the metric of burden being assessed (the total number of deaths from each disease endpoint), the exposure level for each risk factor (consumption data), the effect size (relative risk) of the risk factor on each disease endpoint and the theoretical minimum risk level (TMREL).[8] These estimates of relative risks at the population level can also be made for subgroup scenarios, depending on age group, sex, location, and year.[5]

Data on relative risks are retrieved from published studies. For GBD, only studies on risk-outcome pairs are used that meet the World Cancer Research Fund grades of convincing or probable evidence. The relative risk is, therefore, available for each disease endpoint per food group from dose–response meta-analyses of prospective observational studies and partly from randomized controlled trials.[7]

According to this, the burden of a given exposure to risk factors is needed. In the present case consumption data from national and subnational representative nutrition surveys, household budget surveys, Food and Agriculture Organization (FAO) Food balance sheets as well as FAO Supply and Utilization Accounts, U.S. Department of Agriculture Composition Tables, Fresh and Packaged Food Sales Data and 24-h-urinary samples were used. This is followed by the pooling, controlling and adjustment of the data for bias. The exact procedure can be found in the Supplementary material online, Appendix of the GBD study 2019.[8]

The TMREL is defined as the level of risk exposure that minimizes disease risk at the population level. Thus, it is a definition of a safe minimum or maximum daily intake associated with the lowest risk of death for each disease endpoint. In other words, it defines the safe minimum or maximum daily intake of—in the case of this study—food groups for a given population. Failure to meet the risk level can have negative consequences for health.[5,8] *Table 1* shows all the dietary risks, their exposure definition and the associated theoretical minimum risk level (TMERL) that were used in the study.

Modifications were made between the release of the GBD 2017 and GBD 2019 iteration to estimate the data as precisely as possible according to current scientific knowledge and to keep accuracy and significance of the GBD study as high as possible. Consequently, significant changes in the data have been made since the publication by Meier *et al.* (2019) and the present study. Changes can be found, for example, in the following parts of the model: changes in the selection of risk-outcome pairs, in the relative risk as well as in TMREL. For TMREL, the values for all dietary risks except sodium have changed. A detailed presentation of the modifications can be found in Supplementary material online, Appendix Section II.

Uncertainty ratios and uncertainty intervals

The uncertainty ratios (UR) were calculated for both the disease-specific and risk-specific outcomes. It is a dimensionless unit defined as the 95% uncertainty interval (UI) range (95% UI maximum minus 95% UI minimum) divided by the corresponding arithmetic mean of 95% UI maximum and 95% UI minimum. The higher the ratio, the greater the corresponding uncertainty.

Adjusting dietary risk data for multiplicity

The dietary risks are partly not mutually exclusive so that potential overlaps between risks exist. As a result, the individual risks must be adjusted for multiplicity, when calculating the total reduction in disease burden due to all dietary risk factors. All numbers and figures in this study were based on a combined implementation of all risk factors mentioned. More information can be found in the GBD capstone papers.[5,8]

Results

Attributable diet-related cardiovascular diseases deaths in 2019 in the World Health Organization European Region and its countries

In the WHO ER, 1.55 million deaths (95% UI, 1.2–1.9 million) from CVDs in the year 2019 were diet-related CVD deaths (DRCDs) (*Table 2*). These accounted for 16.4% (95% UI, 12.3–21.2%) of total deaths and 36.7% of CVD deaths. Deaths were almost equally distributed between women (777 714 deaths; 95% UI, 607 047–967 079) and men (772 519 deaths; 95% UI, 612 507–951 255). The slightly higher number of deaths among women was also reflected in a higher rate of total deaths (women 26.3%; men 24.8%).

In relation to the total number of deaths in the countries of the WHO ER, DRCDs accounted for the largest share in 2019 in Belarus (28.8%), Ukraine (27.1%), and Turkmenistan (26.5%). The last place was taken by Israel with a share of 6.7%. In terms of total CVD deaths, the countries with the highest DRCD shares in 2019 were Mongolia with 54.7%, Uzbekistan with 50.1% and Turkmenistan with 48.5%. Spain was last with 23.6%. In CE, the proportion of total CVD deaths was highest at 41.3%. The lowest value was found in WE with 30.0%.

The numbers of DRCDs vary among the regions of the WHO ER. In terms of age-standardized death rates, CA tops the list (243 per 100 000). With 40 deaths per 100 000 (10.1 %), WE has the lowest burden in relative numbers and percentage of deaths.

Within EE, Russia showed the highest number of DRCDs in the year 2019 (393 335 deaths), which is also the highest number of deaths in relation to all countries studied. Ukraine, together with Belarus, had the highest age-standardized deaths per 10 000 (250 and 215 per 100 000) and percentages (28.8% respectively, 27.1%). In WE, the highest number of DRCDs were observed in Germany (112 601 deaths). In terms of age-standardized death rates and relative terms, the highest rate was found in Finland (64 per 100 000; 16.4%). Within CE,

Table 1 Dietary risk factors, exposure definitions, and theoretical minimum risk exposure levels used in the present study

Dietary risk factor	Exposure definition	TMREL per person
Diet low in fruits	Average daily consumption of fruit including fresh, frozen, cooked, canned, or dried fruit, excluding fruit juices and salted or pickled fruits	Consumption of fruit 320–325 g per day
Diet low in vegetables	Average daily consumption of vegetables, including fresh, frozen, cooked, canned, or dried vegetables and excluding legumes and salted or pickled vegetables, juices, nuts and seeds, and starchy vegetables such as potatoes or corn	Consumption of vegetables 250–290 g per day
Diet low in legumes	Average daily consumption of legumes and pulses, including fresh, frozen, cooked, canned, or dried	Consumption of legumes 90–100 g per day
Diet low in whole grains	Average daily consumption of whole grains (bran, germ, and endosperm in their natural proportion) from breakfast cereals, bread, rice, pasta, biscuits, muffins, tortillas, pancakes, and other sources	Consumption of whole grains 135–165 g per day
Diet low in nuts and seeds	Average daily consumption of fibre from all sources including fruits, vegetables, grains, legumes, and pulses	Consumption of nuts and seeds 14–18 g per day
Diet low in milk	Average daily consumption of milk including non-fat, low-fat, and full-fat milk, excluding soy milk and other plant derivatives	Consumption of milk 400–520 g per day
Diet high in red meat	Any intake of red meat including beef, pork, lamb, and goat but excluding poultry, fish, eggs, and all processed meats	Consumption of red meat 0 g per day
Diet high in processed meat	Any intake of meat preserved by smoking, curing, salting, or addition of chemical preservatives	Consumption of processed meat 0 g per day
Diet high in SSB	Any intake of beverages with ≥50 kcal per 226.8 g serving, including carbonated beverages, sodas, energy drinks, fruit drinks, but excluding 100% fruit and vegetable juices	Consumption of sugar-sweetened beverages 0 g per day
Diet low in fibre	Average daily intake of fibre from all sources including fruits, vegetables, grains, legumes, and pulses	Consumption of fibre 22–23 g per day
Diet low in calcium	Average daily consumption of calcium from all sources, including milk, yogurt, and cheese	Consumption of calcium 1.05–1.08 g per day
Diet low in seafood *n*–3	Average daily consumption of eicosapentaenoic acid and docosahexaenoic acid	Consumption of seafood omega 3 fatty acids 0.60–0.65 g per day
Diet low in PUFA	Average daily consumption from polyunsaturated fatty acids	Consumption of polyunsaturated fatty acids as 8–12% of total daily energy
Diet high in TFA	Any intake of trans fat from all sources, mainly partially hydrogenated vegetable oils and ruminant products	Consumption of trans fatty acids as 0% of total daily energy
Diet high in sodium	Average 24-h urinary sodium excretion	24-h urinary sodium 1–5 g per day

PUFA, polyunsaturated fatty acids; TFA, trans fatty acids; TMERL, theoretical minimum risk exposure level.

Poland recorded the highest absolute numbers of DRCDs (70 074 deaths). The highest age-standardized death rates and relative percentages were observed in Bulgaria (226 per 100,000; 26,3 %). In CA, Uzbekistan (53,772 deaths) showed the greatest burdens in terms of total deaths and age-standardized death rate (465 per 100,000). Turkmenistan had the highest percentages (26.5 %) related to the total deaths. An overview of the numbers, percentages and deaths per 100 000 in 2019 for all regions and countries can be found in Supplementary material online, Appendix Table I-3.

Changes in the attributable diet-related CVD deaths in the World Health Organization European Region and its countries between 1990 and 2019

Between 1990 and 2019, the numbers of deaths decreased from 1.69 to 1.55 million deaths. The highest absolute number was found in 1995 with nearly 1.9 million deaths. There was a decrease in numbers of DRCDs between 1990 and 2019 in 32 countries and an increase in 22 countries. While the number of deaths decreased by 177 435 in WE (1990: 607 240 deaths; 2019: 429 805 deaths) and 50 247 deaths in CE (1990: 335 032 deaths; 2019: 284 785 deaths), the numbers increased by 42 829 deaths (1990: 602 457 deaths; 2019: 645 286 deaths) in EE and 48 546 deaths (1990: 141 811 deaths; 2019: 190 356 deaths) in CA (*Figure 1*).

The age-standardized death rate decreased in the WHO ER from 212 to 150 deaths between 1990 and 2019, as well as in the individual regions.

The largest decline between 1990 and 2019 was in the United Kingdom (−60 935 deaths). In percentage terms, the largest decrease was in Denmark (−57.6%). The largest increases in numbers between 1990 and 2019 were in Ukraine (+42 356 deaths). In percentage terms, it was Andorra with an increase of 115.4%.

In terms of the share of DRCDs in total deaths, there was an overall decrease of −3.5% between 1990 and 2019. In addition, the share

Table 2 Diet-related cardiovascular disease deaths in the World Health Organization European Region in 2019 due to (a) disease group and (b) food group

	Number of deaths	95%UI lower	95%UI upper	UR
(a) Disease group				
Ischaemic heart disease	1 244 912	1 046 965	1 424 901	0.31
Ischaemic stroke	175 096	120 887	237 763	0.65
Intracerebral haemorrhage	72 963	49 312	99 885	0.68
Hypertensive heart disease	23 902	3498	71 249	0.64
Subarachnoid haemorrhage	16 878	11 691	22 662	1.81
Cardiomyopathy and myocarditis	4523	932	10 682	1.68
Atrial fibrillation and flutter	3094	579	8608	1.75
Other cardiovascular and circulatory diseases	2942	706	6839	1.72
Aortic aneurysm	2171	407	5450	1.81
Non-rheumatic valvular heart disease	1512	278	4296	1.76
Peripheral artery disease	1043	162	3265	1.76
Rheumatic heart disease	672	122	1935	1.63
Endocarditis	524	72	1516	1.82
Sum	**1 550 233**	**1 235 612**	**1 899 052**	**0.42**
(b) Food group				
Diet low in whole grains	325 199	273 093	384 480	0.34
Diet low in legumes	234 123	181 420	291 991	0.47
Diet high in sodium	193 410	139 592	251 494	0.57
Diet high in red meat	138 312	114 437	165 239	0.36
Diet low in nuts and seeds	117 460	99 945	137 567	0.32
Diet low in fruits	105 203	90 308	122 419	0.30
Diet high in TFA	91 160	67 474	116 857	0.54
Diet low in fibre	77 500	64 169	92 541	0.36
Diet high in processed meat	64 753	17 490	97 403	1.23
Diet low in vegetables	57 556	48 609	67 772	0.33
Diet low in PUFA	56 508	39 927	74 336	0.60
Diet low in seafood *n*–3	56 100	49 893	63 544	0.24
Diet high in SSB	32 948	28 238	38 384	0.30
Sum	**1 550 232**	**1 235 612**	**1 899 052**	**0.42**

The higher the ratio the higher is the corresponding uncertainty.
UI, uncertainty interval; UR, uncertainty ratio; TFA, trans fatty acids; PUFA, polyunsaturated fatty acids; SSB, sugar-sweetened beverages.
UR = (95% UI max − 95% UI min)/(95%UI max + 95% UI min/2).

decreased in all regions except CA. The largest decrease between 1990 and 2019 was in Denmark (−10.4%). Proportionally, Turkmenistan saw the largest increase (+8.6%). Overall, there was an increase in share in 11 of the 54 countries.

In terms of total CVD deaths the DRCD proportion decreased in all regions and all countries, with the exception of Kyrgyzstan and Ukraine, where the proportion of total deaths increased slightly between 1990 and 2019. The greatest decrease was found in Estonia (1990: 44.3%; 2019: 32.4%). The above data can be found in detail in the data sheets for the individual regions in Supplementary material online, Appendix Section III.

Distribution of cardiovascular diseases types in 2019 and changes in the impact between 1990 and 2019

About 1.25 million DRCDs (80.3% of all DRCDs) can be attributed to ischaemic heart disease. For ischaemic stroke and intracerebral haemorrhage, values of 175 096 deaths (11.3%) and 72 963 deaths (4.7%), respectively, were found. All other CVDs combined accounted for 57 261 deaths (3.7%).

In all 54 countries and the 4 regions, most DRCDs were due to ischaemic heart disease. Of all deaths, it accounts for between 71.3% (CA) and 83.9% (EE). Ischaemic stroke ranks second in 2 of the 4 regions (WE and EE) and in 48 countries. It ranks third in the other six countries. The third leading cause of death in 2019 was intracerebral haemorrhage. It was second in 6 countries, third in 43 countries, and fourth in 5 countries.

Within the last 20 years, by far the most common cause of DRCDs is ischaemic heart disease, regardless of region and year. However, there are differences in the frequency over the years, for example, the highest number of deaths from ischaemic heart disease was in 2005 (see Supplementary material online, Appendix Figures I-1 and I-2). Between 1990 and 2019, the DRCDs by ischaemic heart disease in WE decreased by −30.8%, while in EE there was an increase of 12.9%. In CE and CA, the DRCDs from ischaemic heart disease increased by 16.95% and 35.0%, respectively, over the last two decades.

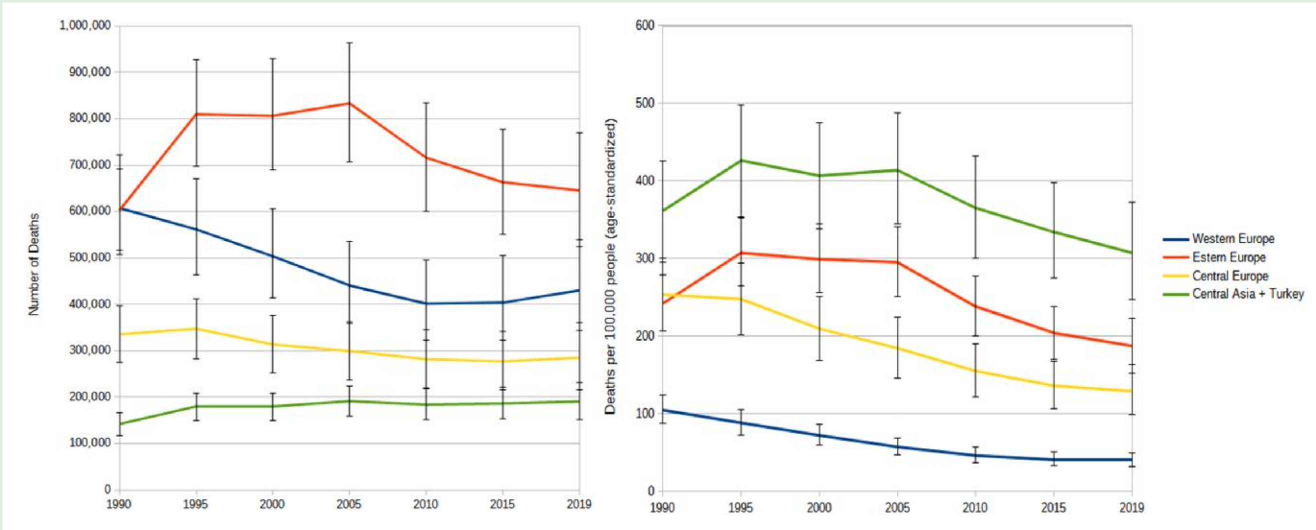


Figure 1 Number of deaths (left) and death rate per 100 000 people (age-standardized) (right) in Central Asia, Central Europe, Eastern Europe, and Western Europe of diet-related cardiovascular disease deaths from 1990 to 2019 (incl. 95% uncertainty interval).

Distribution of dietary risks in 2019 and changes in the impact between 1990 and 2019

Focusing on the food and nutrient groups, the largest impact on DRCDs in the WHO ER was found for a diet low in whole grains (325 199 deaths, 21.0% of the total DRCDs burden), a diet low in legumes (234 123 deaths; 15.1%), and diet high in sodium (193 410 deaths; 12.5%). All other groups had an attributable fraction smaller than 10% in each case. The smallest proportion was found for diet high in SSB (32 948 deaths; 2.1%) (*Table 2* and *Figure 2*).

A diet low in whole grains could be identified as the main factor in three of the four regions. The exception is CE, where this was the second most important factor. In was also the main risk factor in 36 of the 54 countries in 2019, the second most important risk factor in 17 countries and ranked third only once. A diet low in legumes was the second most important risk factor in three of the four regions with the exception of CE (32 of 54 countries) and the main risk factor in four countries. A diet high in red meat was ranked third on average but was found to be ranked from first to ninth in the different countries. A diet high in sodium is on average only ranked fourth among the risk factors but is ranked first in all countries in CE as well as in the region itself. The factor diet high in SSB had the least influence in three of the four regions. In CA, a diet low in vegetables ranked last.

Between 1990 and 2019, there were no greater changes in the ranking of the risk factors in the WHO ER (*Figure 3*). The order of the most influential factors has also not changed significantly in the regions over the last two decades, in terms of absolute death rates.

Differences between sexes and age groups in 2019

The distribution of cases among age groups varies from region to region. For 2019, the proportions of age and sex groups for WHO ER and by region can be found in Supplementary material online, Table I-4 in the Supplementary material online, Appendix.

Focusing the numbers of DRCDs in whole studied WHO ER, in 2019 the percentages of women are slightly higher with 50.2%. This distribution has changed slightly over the period under study. In 1990, the proportion of women was 50.8%, then fell to 48.9% by 2005 and has since risen again. A higher proportion of women are also found in EE, where women make up 53.0% of the cases. In all other regions, the share of men is predominant. While in WE and CE men account for 51.5% and 50.6% of cases, respectively, in CA it is 54.6% (see Supplementary material online, Appendix Table I-5–I-9).

Up to the age group 70–74 years, the proportion of DRCDs by men predominates in the entire WHO ER, after which the proportion of women exceeds (*Figure 4* and Supplementary material online, Table I-4). This is also the case in EE and CA. This turning point is reached in CE after the age group of 75–79 years, in WE it reached even after 80–84 years. In 1990, this point was still after the 70–74 age group in CE, after 60–64 in EE, after 65–69 in CA, and after 75–79 in WE. Thus, this turning point has shifted back one age group on average, except in EE where it is even two age groups. Most DRCDs in all regions and among both sexes are recorded in the 85+ age group. These accounted for a third of all DRCDs in 2019 (32.1%). Approximately another third is in the age range 70–84 years (39.6%), and the remaining third (28.3%) is distributed among all age groups under 70 years (*Figure 5*).

The 85+ age group accounts for 21% of DRCDs among men and 43% among women. For men, the age group under 60 years accounts for another fifth of deaths. For women, the group accounts for only 5% of deaths. The remaining 51% of deaths are distributed between the ages of 60 and 84 for women. For men it is even 60% (*Figure 4* and Supplementary material online, Table I-4).

Effects of changes in the comparative risk assessment in GBD between 2017 and 2019

Modifications were made between the release of the GBD 2017 and GBD 2019 iteration. The most recent comparable data available for both papers is for the year 2010 and is shown in Supplementary material online, Table II-5 in the Supplementary material online, Appendix. As a main result of the changes in the CRA, the values between 2017 and 2019 have become smaller in direct comparison.

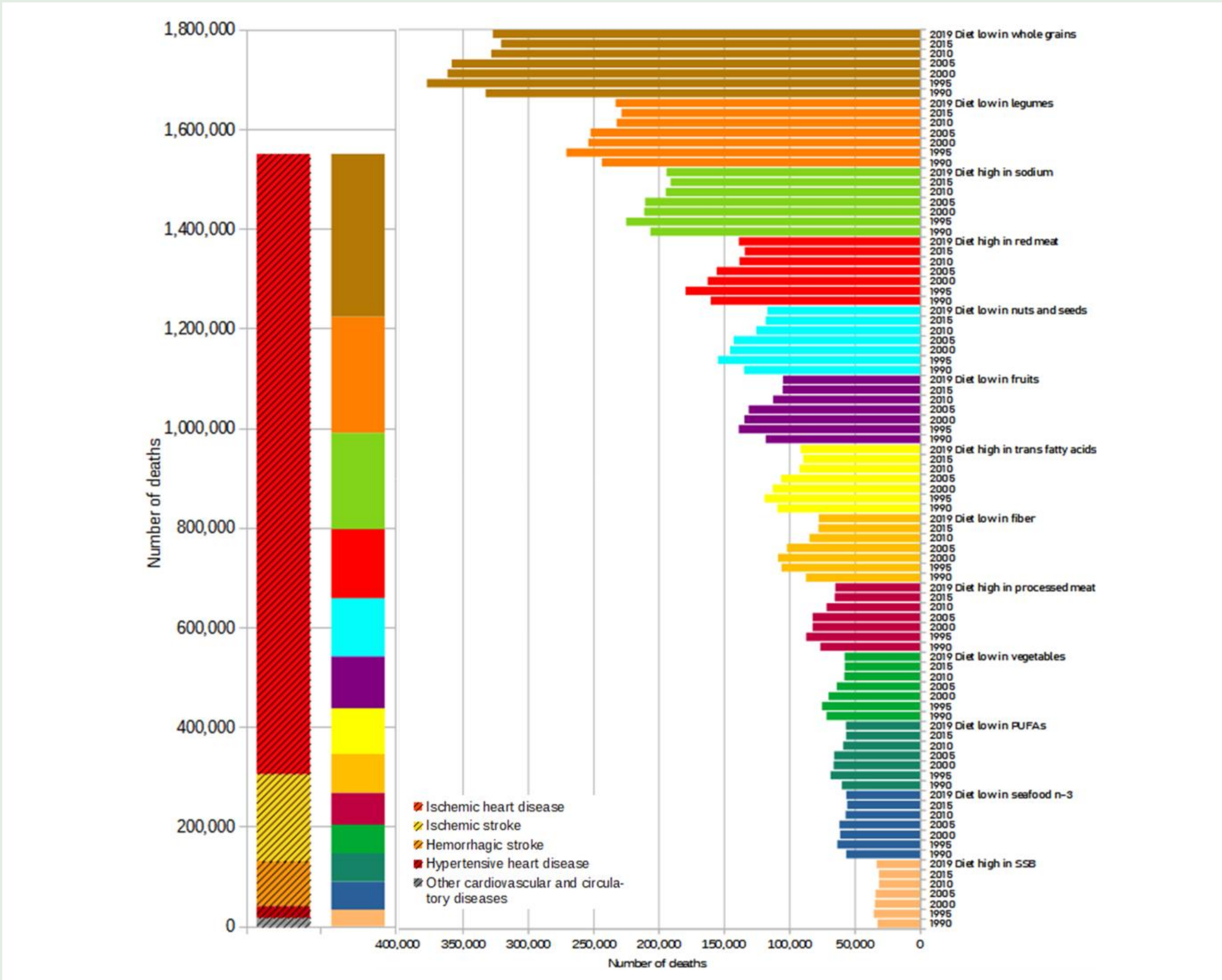


Figure 2 Diet-related cardiovascular disease deaths 2019 cardiovascular disease (right) and food group-specific (left), and diet-related cardiovascular disease deaths from 1990 to 2019 in the World Health Organization European Region.

A comparison of the main results of Meier *et al.* (2019) for the year 2016 and the present work reveals the following differences:

- At 2.1 million deaths, the former way of calculating deaths exceeded the current 2019 results; also the percentage of total DRCDs was higher at 22.4% compared with the current results (16.4%).
- In 2016, EE and CA had the highest burden of age-standardized death rates per 100 000 deaths, which could be confirmed here. It has also not changed that, in terms of absolute deaths, the highest value was found in EE, and the lowest in CA. Western Europe continues to have the smallest burden in percentages of deaths and age-standardized death rates per 100 000.
- Israel continues to have the lowest percentage of DRCDs in the total number of deaths (2016: 9.8%; 2019: 6.7%). While Ukraine was still in first place in the study for 2016, with a value of 38.2%, it slipped to second place in this study with 27.1%. Belarus now has this position with 28.8%.
- With focus on CVD types, ischaemic heart disease was identified as the main cause of death (2016: 84%) in both analyses.

With regard to food and nutrient groups, Meier *et al.* (2019) observed the following ranking: first a diet low in whole grains with 20.4%, followed by a diet low in nuts and seeds 16.2%, and a diet low in fruits 12.5%.

A direct comparison of the values from 2016 and the values from 2019 is of course possible only to a limited extent due to the outlined changes. As a result of the change in the calculation method, the total DRCDs has decreased. In addition, the share of dietary risks has also changed. All values have become smaller. However, the picture has also become more differentiated due to the additional risk a diet high in red meat.

Discussion and limitations

With every sixth death in the WHO ER, DRCDs occupies a comparatively high position. In terms of total CVD deaths, even more than every third death is attributable to diet. Globally, dietary risks are responsible for 22% of all deaths.[21] This makes the diet one of the most important factors in the field of disease prevention and health promotion. Dietary factors have a major impact on health in Europe and are also a modifiable factor. Improving dietary habits, along with other behavioural risks, is one of the most effective ways to prevent premature death in the

	Low in fiber	Low in fruits	Low in legumes	Low in nuts and seeds	High in processed meat	Low in PUFA	High in red meat	Low in seafood n-3 FA	High in sodium	High in SSB	High in TFA	Low in vegeta-bles	Low in whole grains
1990	8	6	2	5	9	11	4	12	3	13	7	10	1
1995	8	6	2	5	9	11	4	12	3	13	7	10	1
2000	8	6	2	5	9	11	4	12	3	13	7	10	1
2005	8	6	2	5	9	10	4	12	3	13	7	11	1
2010	8	6	2	5	9	10	4	12	3	13	7	11	1
2015	8	6	2	5	9	11	4	12	3	13	7	10	1
2019	8	6	2	5	9	11	4	12	3	13	7	10	1

	Ischemic heart disease	Ischemic stroke	Intracerebral haemorrhage	Subarachnoid haemorrhage	Hypertensive heart disease	Cardiomyo-pathy & myocarditis	Atrial fibrillation & flutter	Aortic aneurysm	Peripheral artery disease	Rheumatic heart disease	Non-rheumatic valvular heart disease	Other cardio-vascular & circulatory diseases	Endocarditis
1990	1	2	3	5	4	7	8	6	10	11	12	9	13
1995	1	2	3	5	4	7	8	6	9	11	12	10	13
2000	1	2	3	5	4	6	8	7	9	11	12	10	13
2005	1	2	3	4	5	6	8	7	9	10	12	11	13
2010	1	2	3	4	5	6	8	7	9	10	11	12	13
2015	1	2	3	4	5	6	8	7	9	10	11	12	13
2019	1	2	3	4	5	6	7	8	9	10	11	12	13

Figure 3 Heat map of numbers of death by dietary risks (above) and cardiovascular disease deaths (below) from 1990 to 2019 in the World Health Organization European Region (ranked from highest numbers by death to lowest).

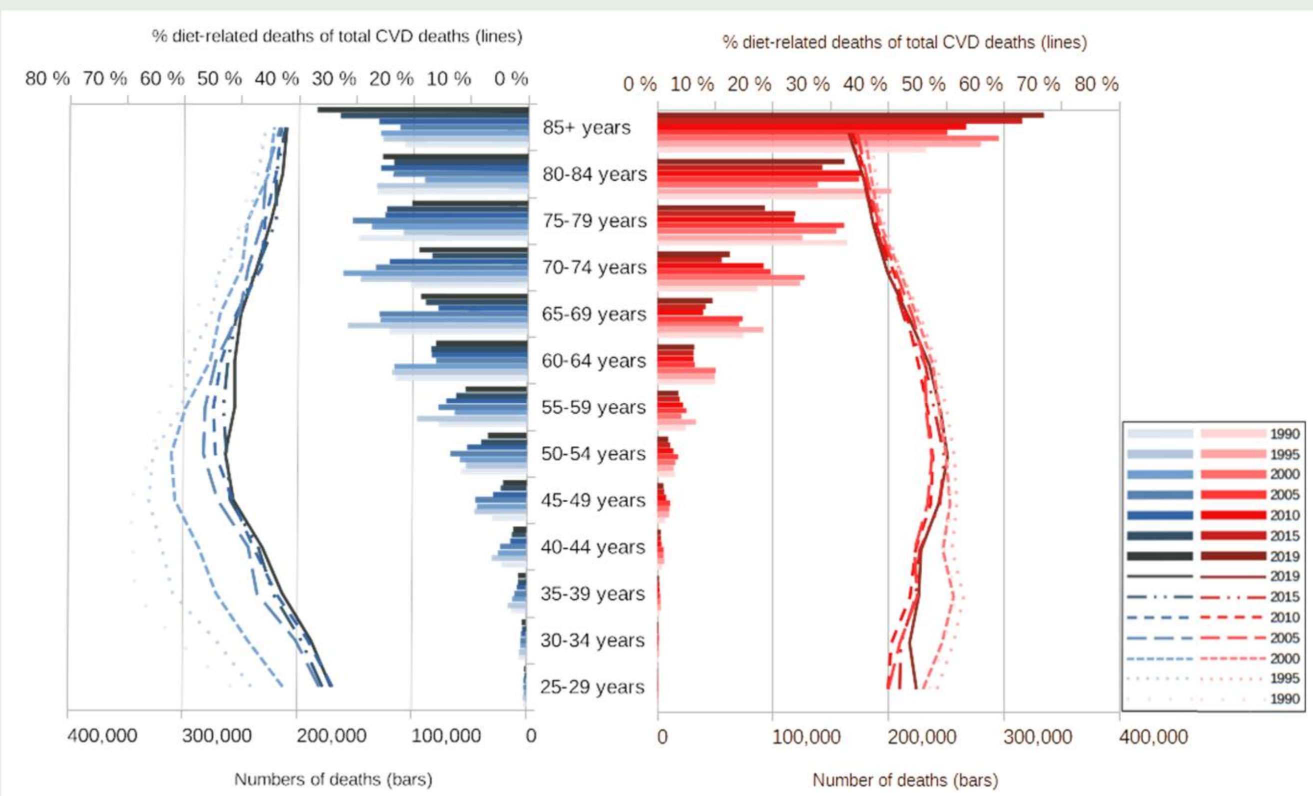


Figure 4 Age- and sex-specific mortality of diet-related cardiovascular disease deaths (bars) and share of diet-related on total cardiovascular disease deaths (lines).

WHO ER. In terms of the behavioural risk factors (low physical activity, tobacco smoking, alcohol and drug use) included in GBD 2019, diet has the largest impact.[8,21]

A reduction in DRCDs, both in absolute and relative terms, was observed in the WHO ER during the study period, while the numbers of diet-related deaths are increasing worldwide.[21] The latter, however, is

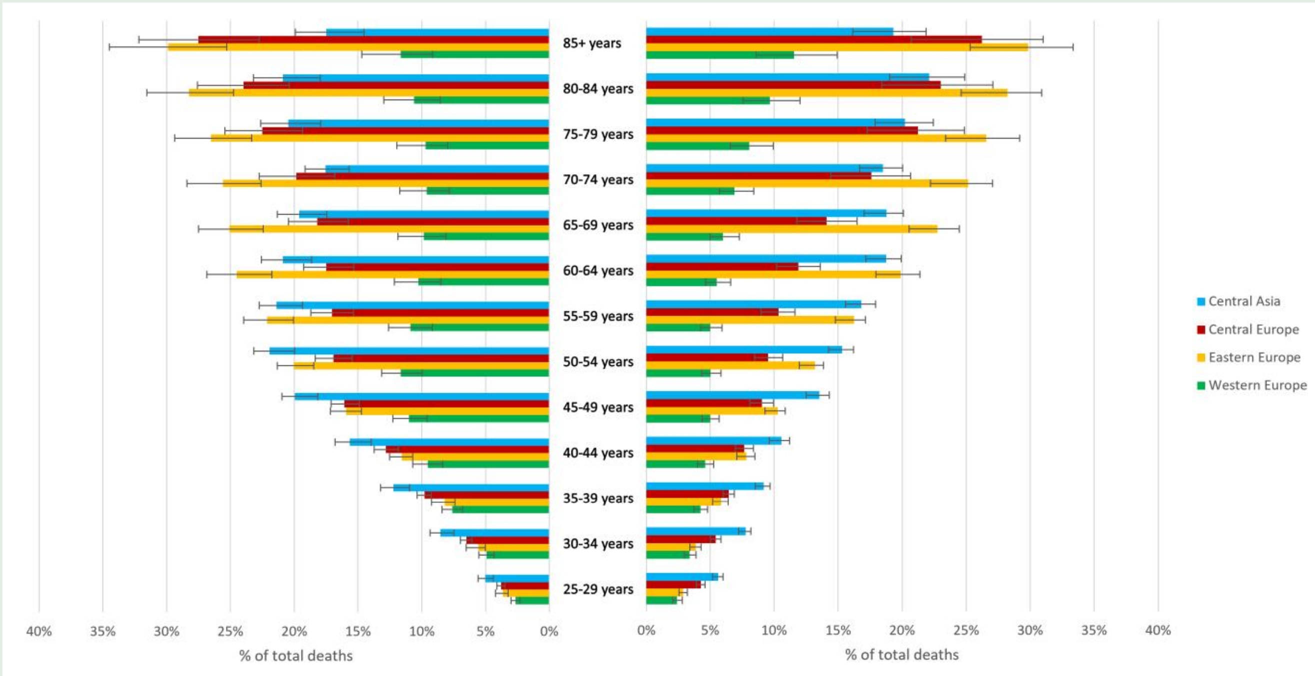


Figure 5 Attributable fraction of diet-related cardiovascular disease deaths due to sex and age group in 2019, male (left), female (right) (incl. 95% uncertainty interval).

partly due to rising population numbers worldwide and population aging.[5,7,21] If these effects are excluded, the age-standardized attributable death rates show a significant decrease, both globally and in the WHO ER.

The results of the dietary risks are thus comparable to global trends in relation to all deaths. There, sodium is in first place, followed by whole grains. If all deaths are considered, the influence of sodium increases strongly worldwide. However, if one looks only at deaths due to CVDs (without neoplasm and other causes), a diet low in whole grains is also the number one risk factor worldwide.[21] Nevertheless, a reduction in salt intake remains an important factor for the prevention of diet-related diseases and was therefore also included in the WHO global target on NCDs as 'A 30% relative reduction in mean population intake of salt/sodium'.[22,23]

It is important to optimize the salt, sugar and fat contents of foods and to reduce the intake of (ultra)-processed foods. At the same time, there should be a further focus on increasing the consumption of health-promoting foods, as this could have an even greater impact, as the rankings of the individual dietary risks show. Although the problems are similar all over the world, it is important to look at each country and its region individually to see which measures work best and where specific dietary problems are.

Trends in DRCD death rates have emerged over the last two decades, especially with regard to the development of death rates as well as individual developments within countries. The release of the GBD data from 2020 and later will show whether these trends will continue as shown in the recent study. However, the data presented here provide a comprehensive overview, as they reflect the last year before the onset of the severe acute respiratory syndrome coronavirus type 2, Corona virus pandemic.

In summary, the greatest impact on reducing DRCDs could be achieved by changing eating habits with a focus on the following three factors: (i) 'a diet low in whole grains', (ii) 'a diet low in legumes', and (iii) 'a diet high in salt'. These are the major risk factors for the WHO ER as a whole and for most countries in this region. Together, these factors account for 48% of the DRCDs in the WHO ER. At the national level, however, other risk factors could play a greater individual role. Which groups should be focused on can be viewed individually for each country in the data sheets. Due to our results, targeted strategies development based on the needs of the respective countries can be developed.

In terms of Germany, emphasizing more legumes and plant-based foods in general in the new food-based dietary guidelines is, therefore, an important step towards improving population health and prevention of metabolic diseases.[24] However, if the knowledge gained here is applied to the guidelines for communal catering provided by the German Nutrition Society,[25–27] the recommendations of one portion of whole grain products or legumes per 5-day week in the lunch menu should be adapted and increased accordingly.

In many CE countries, the attention should be paid on reducing salt in the population's diet, as this risk factor accounts for a particularly high proportion of DRCDs here. Due to partly similar regional circumstances and possibly comparable consumption habits, the exchange of experiences made with target-oriented strategies is recommended.

Limitations by data

Since 2016, one additional dietary risk has been added to the estimation. However, the potential influence of other risk factors cannot be excluded. The influence of milk and dairy products (especially fermented milk products) on the estimates of cardiovascular risks is still unclear, as is the influence of calcium. These two factors are already taken into account for other diseases in the GBD data.[8] However, they have not yet been included in the underlying data for the 2019 estimates. Other factors have also not yet been taken into account, where an influence on cardiovascular health cannot be ruled out. These could include processed and ultra-processed foods, fermented milk products, phosphorous, and potassium, for example.[28] The existing dietary data comes from various sources, so that the data varies in type and level of uncertainty. The way in which the resulting uncertainties are dealt with as been described elsewhere[7,21] and cannot be influenced for the present study. Limitations with regard to data collection and calculations were described in the Capstone papers and also in Meier *et al.*[8]

Even though the results were differentiated for age groups, the group under 25 years could not be considered, as no data for dietary risks are available for this age group in the GBD study dataset.

It must be mentioned that for many diet-CVD pairs (risk-outcome pairs) there are no values available in the GBD data. Data are available for all dietary risks in relation to ischaemic heart disease. Only for the risk factor a diet high in sodium a value is available for each type of CVD. For seven dietary risks only risk factors for ischaemic heart disease are currently implemented in the CRA framework. For a diet high in whole grains, the outcome ischaemic stroke is implemented besides ischaemic heart disease. For the remaining four dietary factors there are risk factors for ischaemic stroke, intracerebral haemorrhage, subarachnoid haemorrhage and ischaemic heart disease implemented (see Supplementary material online, Appendix Table I-2).

The results of the regions and individual countries depend on the quality and quantity, as well as the actuality, of the corresponding health data collected in the individual countries.[29] These external factors therefore also have a limiting effect on this paper. Even more detailed results of the individual countries and the associated regions would also be provided by surveys on a sub-national level, as is already done in the UK or Poland, for example.[30,31]

Only risk-outcome pairs were included in the GBD study that have grades of convincing or probable evidence. Depending on the diet risk, different numbers of studies were used. Data entry for the dietary risk factor analysis ranged from 10 (legumes, trans fats) to 116 (fruit) studies, depending on the risk factor.[8] So far, the calculations of diet risk factors have increasingly been based on observational studies. However, in order to achieve a higher level of evidence, a larger number of randomized controlled trials would be required to shed more light on the relationships.

Necessary changes to minimize dietary risks

To promote and plan accurate public health measures to reduce the burden of NCDs, an interdisciplinary approach is necessary. It requires a mixture of methods, as well as to involve all relevant sectors and stakeholders.[23,32–34] The diet-related disease burden shown here results as a consequence of behavioural risks from earlier phases of life of the individuals. It is therefore not sufficient to target the group with the highest burden alone for activities to reduce burden, but to preventively reduce risk factors over the entire life course.[23,35,36]

One approach is to learn health-promoting behaviours at a young age and to live under health-promoting conditions. People must be empowered to make self-determined informed decisions in favour of their health. At the same time, a health-promoting environment is required.[23,32] In addition to the family environment, this includes, above all, settings of communal catering, such as day-care centres (pre-school) and schools. Subsequently, this also applies to the food on offer in public canteens in further education establishments, such as vocational schools, at universities, at or near the workplace, as well as in healthcare facilities, and elderly homes. These places offer the possibility to experience this independently of social status and health knowledge of the individual and the social environment.[34,37] For this purpose, government regulations are important, such as the legally binding to quality standards in communal catering, as, for example, provided by the German Nutrition Society,[25–27,38,39] as an possible public health strategy (see also[40,41]). In addition, there are other interventions and instruments at the local, regional, national, and international level ranging from low forcing approaches, such as nudging and food labelling, to market regulatory measures and legal regulations.[33,34,37,42,43]

At the same time, regular representative surveys on the dietary behaviour of the population as well as continuous monitoring of CVD are important to obtain up-to-date data from countries.[6] Dietary behaviour is influenced by various factors (individual factors such as socioeconomic status and personal preferences, environmental influences, social and cultural factors, and economy).[32,33,42] Nutrition surveys should therefore include both individual dietary factors and consumption patterns as a whole.

To achieve a healthy society and environment, there must be a shift towards a varied, plant-based diet with a high proportion of fresh food instead of highly processed products. Animal products, as well as those with high energy density and salt or sugar content or unfavourable fats, should barely feature in the daily menu.

Conclusion

With one in six deaths in the WHO ER, CVD due to suboptimal diet is a prominent cardiovascular risk factor. In terms of total CVD deaths, more than every third death is attributable to diet. This makes diet, along with other behavioural risks, one of the most important factors in preventing premature death in the WHO ER. Improving dietary habits is one of the most effective means of prevention and health promotion. A combination of preventive measures for different population groups as well as health promotion in various areas of public life is required. The preventive potential of a healthy diet for cardiovascular health and other NCDs has been demonstrated here.

Supplementary material

Supplementary material is available at *European Journal of Preventive Cardiology*.

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Author's contribution

S.L. and T.M. critically revised the manuscript and were in charge of conceptualizing the work. T.P. was involved in the conception, carried out the formal analysis, and drafted the manuscript. The project administration was led by S.L. and supported by T.M. T.M. led the methodological approach, supported by T.P. and S.L. All the authors gave final approval and agreed to be accountable for all the aspects of work ensuring integrity and accuracy.

Ethic statement

All Authors align with the GATHER statement.

Conflict of interest: Please refer to the documents 'ICMJE Disclosure Form'.

Data availability

The data underlying this article were provided by the Institute for Health Metrics and Evaluation as part of the Global Burden of Disease Study.

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