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THE BURDEN OF FOODBORNE DISEASES IN THE WHO EUROPEAN REGION



World Health
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REGIONAL OFFICE FOR Europe



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FOODBORNE DISEASES
IN THE WHO EUROPEAN REGION**

Abstract

The first estimates of the global and regional burden of foodborne disease, published by WHO in December 2015, show that the burden is significant throughout the world. This report presents data for the WHO European Region. Every year, more than 23 million people fall ill from eating contaminated food, resulting in 5000 deaths and more than 400 000 disability-adjusted life years. The most frequent causes of foodborne disease are diarrhoeal disease agents, the most common being Norovirus followed by *Campylobacter* spp. Non-typhoidal *Salmonella* spp. are responsible for the majority of deaths. Non-typhoidal *Salmonella* spp. followed by *Campylobacter* spp. cause the highest burden; the parasitic disease toxoplasmosis, which can cause severe damage to unborn children and immunodeficient patients, represents the third highest burden of foodborne disease. These figures indicate the need for strengthened prevention, surveillance and management of foodborne disease in the European Region, including risk communication, awareness-raising and consumer education. Furthermore, the data can be used to guide food safety policy-making and decision-making, including prioritization, at national and regional levels. WHO is committed to working with its Member States and partners to strengthen prevention, detection and management of food safety risks, with the overall aim of lowering the burden of foodborne disease.

Keywords

FOODBORNE DISEASE
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FOREWORD

Food safety is a basic individual right. This is specifically recognized in the United Nations Sustainable Developments Goals, of which goal 2.1 is to, “by 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations including infants, to safe, nutritious and sufficient food all year round”. Foodborne disease has long represented a considerable burden to public health and continues to challenge health systems worldwide. Anyone may catch a foodborne disease, although vulnerable populations such as small children, elderly people, pregnant women, immunocompromised people and those living in poverty or who are food insecure are particular vulnerable. Data suggest that foodborne disease are common throughout the world; however, because of the limitations of surveillance systems, only a small proportion of the actual number of cases is reported. It is assumed that official figures on the incidence of foodborne disease represent only the “tip of the iceberg”. Moreover, little information is available on the *burden* of foodborne disease, which is the impact of these diseases on health in terms of mortality, morbidity and disability. More accurate data on the epidemiology of foodborne diseases and their causative agents and also on their relative impact on health could guide the development and implementation of food safety policies, strengthen the effectiveness and efficiency of food safety systems and thereby better protect consumers.

In December 2015, after an 8-year study, WHO published the first global and regional estimates of the incidence of, mortality from and burden of foodborne disease in terms of disability-adjusted life years (DALYs) due to 31 foodborne hazards. These are the most comprehensive estimates to date on the impact of contaminated food on health and well-being. The information shows that the burden is substantial throughout the world. Globally, foodborne disease results in 33 million DALYs annually. The present report gives an overview of the estimates of the incidence of, mortality from and burden of foodborne disease in the WHO European Region.

In the WHO European Region, it was estimated that more than 23 million people fall ill from eating contaminated food every year, resulting in 4654 deaths and more than 400 000 DALYs. The most frequent causes of foodborne illness are diarrhoeal disease agents, the most common being *Norovirus* followed by *Campylobacter* spp. Non-typhoidal *Salmonella* spp. are responsible for the majority of deaths. In terms of burden, the parasite *Toxoplasma gondii*, which can cause severe damage to unborn children or immunodeficient people, ranks third of all foodborne hazards, after non-typhoidal *Salmonella* spp. and *Campylobacter* spp. These figures highlight the need for strengthened prevention, surveillance and management of foodborne disease in the European Region, including risk communication, awareness-raising and consumer education about food safety. It is to be hoped that the data will help guide food safety policy-making and decision-making, including prioritization, at national and regional levels.

Foodborne diseases are fully preventable, and WHO is committed to working with its Member States and partners to strengthen prevention, surveillance and management of food safety risks with the overall aim of lowering the burden of foodborne disease.

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ABBREVIATIONS AND ACRONYMS

DALY disability-adjusted life year
FERG Foodborne Disease Burden Epidemiology Reference Group
TB tuberculosis
UI uncertainty interval
YLD years lived with disability
YLL years of life lost

SUMMARY

Foodborne diseases are a significant public health concern throughout the world. Unsafe food is not only a threat to health but also plays a fundamental role in the socio-economic development of countries. A variety of bacteria, viruses, parasites and chemical hazards can be transmitted to humans via contaminated food and can cause illness and death. The sources of these hazards and the routes of exposure are diverse, ranging from the environment and primary production at the beginning of the food chain through to domestic handling and food consumption. International trade and travel increase the spread of foodborne disease and contribute to the emergence of new hazards, further challenging prevention, control and surveillance.

The available data on the incidence of foodborne disease represent only the “tip of the iceberg”; the true number of cases is unknown. This gap is due to the limitations of surveillance systems. As not all ill people seek medical care and errors are possible in the diagnosis, classification or notification of cases, foodborne disease may be variously under-ascertained, under-diagnosed and under-reported, resulting inevitably in underestimates of the incidence and burden.

In order to fill this data gap and better understand the real burden of foodborne disease, WHO in 2006 established the Foodborne Disease Burden Epidemiology Reference Group (FERG) to lead an initiative to estimate the global burden of these diseases. The first global and regional estimates of incidence of, mortality from and disease burden in terms of disability-adjusted life years (DALYs) were published in December 2015. These data are the most comprehensive to date on the impact of contaminated food on health and well-being. They provide a conservative perspective of the real burden of 31 selected food-associated hazards, including bacteria, viruses, parasites, toxins and chemicals.

The WHO data show that the global burden of foodborne disease is substantial. It is estimated that more than 600 million globally, or almost one in ten people in the world, fell ill after consuming contaminated food in 2010. Of these, 420 000 people died, including 125 000 children under the age of 5 years. The most frequent causes of foodborne illness were diarrhoeal disease agents, particularly Norovirus and *Campylobacter* spp., and non-typhoidal *Salmonella* spp. were the major causes of deaths. In total, the 31 foodborne hazards caused 33 million DALYs, and 40% of the burden was borne by children under 5 years of age. Diarrhoeal diseases agent were responsible for half the global burden, and non-typhoidal *Salmonella* spp. and enteropathogenic *Escherichia coli* contributed the most.

In the WHO European Region, it was estimated that in 2010 more than 23 million people fell ill from eating contaminated food, resulting in an estimated 4654 deaths. The most frequent causes of foodborne illness were diarrhoeal disease agents, the most common being Norovirus, which caused an estimated 15 million cases, followed by *Campylobacter* spp., which were responsible for almost 5 million cases. Non-typhoidal *Salmonella* spp. were responsible for the majority of deaths, while other major causes of deaths were *Campylobacter* spp., Norovirus, *Listeria monocytogenes* and *Echinococcus multilocularis*. Overall in the European Region, diarrhoeal diseases were responsible for 94% of foodborne illnesses, 63% of deaths and 57% of the burden.

The overall burden of foodborne disease in the European Region in 2010 was estimated to be 413 020 DALYs. Non-typhoidal *Salmonella* spp., *Campylobacter* spp. and *Toxoplasma gondii* caused approximately 107 000, 82 000 and 73 000 DALYs, respectively. Other important contributing hazards were Norovirus (33 000 DALYs), *L. monocytogenes* (15 000 DALYs), dioxin (13 000 DALYs), *Brucella* spp. (12 000 DALYs) and hepatitis A virus (10 000 DALYs).

It is noteworthy that toxoplasmosis, a severe parasitic disease, may be responsible for an estimated 17% of the total foodborne disease burden in the European Region, affecting more than 1 million people annually through the food chain.

These estimates of the burden of foodborne disease globally and in the European Region indicate the importance of preventing and mitigating risks to food safety. The data can help guide the development and implementation of food safety policies and strengthening of food safety systems, which can contribute to consumer protection by lowering the burden of foodborne disease. Furthermore, the estimates provide a comprehensive source of information for countries to use in conducting their own studies and encourage use of evidence-based food safety policy- and decision-making, including setting priorities.

Addressing and tackling foodborne disease is a shared responsibility of all stakeholders along the entire food chain, from production to consumption. Effective, efficient prevention, surveillance and management of foodborne disease rely on intersectoral and interdisciplinary collaboration, cooperation and information-sharing, at national, regional and international levels. Collaboration between governments, the food industry, academia and civil society is essential. Awareness-raising among all stakeholders about food safety risks and how to prevent and reduce them is imperative. Food safety risk communication, including consumer education, is an important part of efforts to tackle foodborne disease.

WHO is committed to working with its Member States and partners in strengthening the prevention, surveillance and management of food safety risks, with the overall aim of lowering the burden of foodborne disease.



INTRODUCTION

Foodborne diseases

Access to safe, sufficient, nutritious food is the right of every individual (1,2) and is essential for good health. Furthermore, a safe food supply supports a country's economy, trade and tourism, contributes to food and nutrition security and stimulates sustainable development. Nevertheless, foodborne diseases occur commonly throughout the world. They comprise a broad range of diseases, usually infectious or toxic, ranging from diarrhoeal diseases to various forms of cancer. They are caused by microorganisms (bacteria, viruses, parasites, fungi, prions) or chemicals, toxins, radioactivity or even physical agents. The prevention and control of these diseases is therefore very complex. While everyone is exposed to foodborne health risks, vulnerable populations, such as small children, the elderly, pregnant women, people who are immunocompromised and people living in poverty or who are food insecure, are the most affected and prone to foodborne diseases.

The effects of these diseases on individuals depend on factors such as their health, nutritional status and age and the virulence of the pathogen. Adverse health effects can result from both acute and chronic exposure and can range from mild and self-limiting (e.g. nausea, vomiting and diarrhoea) to severe (e.g. kidney and liver failure, neurological disorders, reactive arthritis, septicaemia) and may even result in death. *Salmonella* spp., *Campylobacter* spp. and pathogenic *E. coli* are among the most common bacteria that cause foodborne illness. Infection with *Listeria* spp., though less common, is often severe, with a high case-fatality rate. Foodborne parasitic diseases such as those caused by *Taenia solium* and *Echinococcus* spp. are also important public health threats. Illness caused by foodborne viruses is common. Norovirus infections are characterized by nausea, vomiting, watery diarrhoea and abdominal pain, whereas hepatitis A virus can cause liver disease.

Chemicals are an important yet less well-understood source of foodborne illness. They include natural compounds such as mycotoxins and marine toxins, environmental contaminants and naturally occurring chemicals in plants, as well as food additives, vitamins, essential oils, pesticides and veterinary drug residues. Several toxic chemicals may be present in the food supply as a result of environmental contamination, agriculture and industrial practices. Heavy metals such as lead, cadmium, arsenic and mercury can accumulate in seafood, shellfish and crustaceans. They can affect health after a single exposure, resulting in acute poisoning, or after long-term exposure, affecting the reproductive and immune systems or causing noncommunicable diseases, such as cancer.

Immune-mediated adverse reactions to food components, such as peanut allergens, manifest as clinical signs and symptoms of variable severity and duration. The use of peanuts and derived products in many processed foods results in frequent inadvertent exposure.

Antimicrobial resistance is a significant public health challenge and a health priority. Antimicrobial resistance is also a food safety issue, as food animals are given antimicrobial agents to prevent disease or, in some places, to promote growth, so that resistant bacteria and resistance genes can pass through the food chain from food animals to humans. Resistance in the foodborne zoonotic bacteria *Salmonella* spp. and *Campylobacter* spp. is linked to use of antimicrobials agents in food animals, and foodborne diseases caused by such resistant bacteria are well documented in humans (3).

Nutrition and food safety are inextricably linked. Foodborne disease and undernourishment create a vicious cycle of worsening health, especially among immunocompromised individuals, young children, the elderly and pregnant women. The presence of co-morbid conditions also

increases the risk for and severity of foodborne disease in these risk groups. Furthermore, where food supplies are insecure, people tend to shift to less healthy diets and consume more “unsafe foods” – in which chemical, microbiological and other hazards pose health risks.

Foodborne disease not only adversely affects people’s health and well-being but also has negative economic consequences for individuals, families, communities, businesses and countries. These diseases place a substantial burden on health-care systems, trade and tourism. The agriculture and food industries are strongly affected by food-associated outbreaks.

Food safety risks increase with globalization and increased travel and trade, and foodborne hazards can easily spread to geographically distant countries and affect the health of people in numerous regions at the same time. Furthermore, the traceability of foods has become vastly more complex, and the ingredients of many processed and ready-to-eat foods may come from countries with different foodborne hazards and risks. Urbanization, changing consumer habits and climate change also affect food safety.

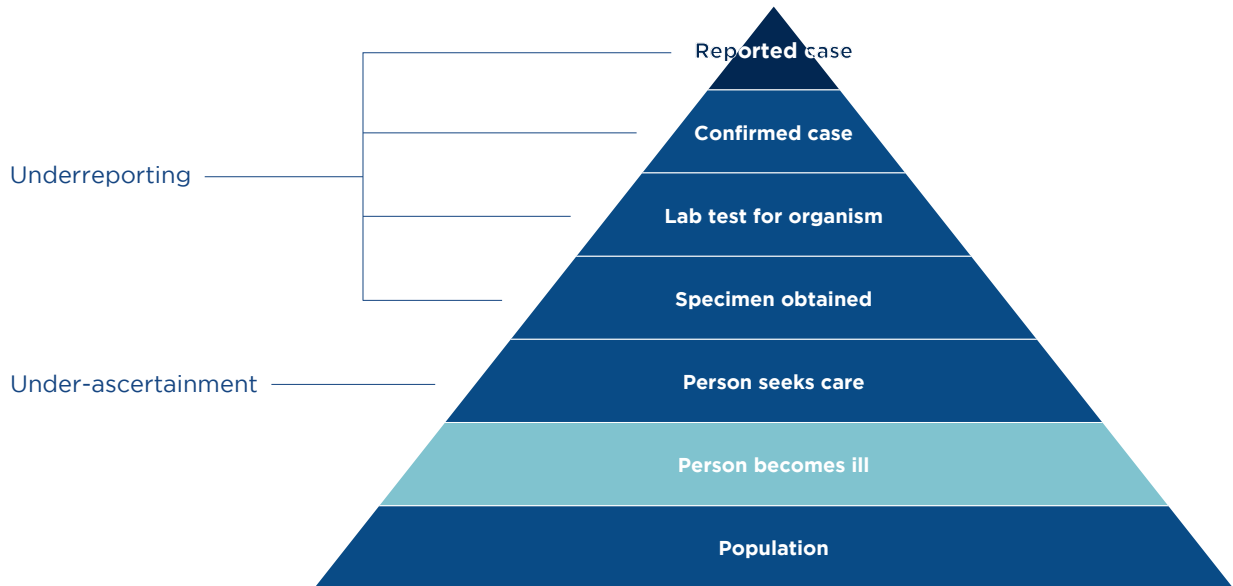
Food can become contaminated at many stages of the food chain, beginning in the environment and primary production, through to manufacture, distribution and retailing and ending with handling and consumption. In principle, all foods can become contaminated and represent a risk to the consumer if they are not produced, processed or handled appropriately.

Effective, efficient prevention and control of foodborne disease rely on food safety systems that are holistic, risk based and address the whole food chain. Surveillance of foodborne disease is an essential component of a modern food safety system, and the data are important for risk assessment, which can guide risk management, including priority-setting and decision-making. Not only the incidence but also mortality due to foodborne disease is important.

The WHO Strategic plan for food safety for 2013–2022, which includes foodborne zoonoses, provides the framework for WHO’s work on food safety. Its overall mission is “to lower the burden of foodborne disease, thereby strengthening the health security and ensuring sustainable development of Member States” (4). The first of the three strategic directions is to “provide the science base for measures along the entire food-chain to decrease foodborne health risks”. Estimates of the burden of foodborne disease at global and regional levels can guide policy- and decision-making in food safety.

The burden of foodborne diseases

Cases of illness and death caused by unsafe food occur daily throughout the world; however, because most cases are not reported, the full burden of foodborne disease is still unknown, although it is thought to be substantial. Fig. 1 depicts a “surveillance pyramid”, in which the tip of the pyramid (or “tip of the iceberg”) represents pathogen-specific cases reported in public health surveillance, whereas the base represents all cases occurring in the country in a given year. Those in between are people who become ill but do not seek medical care (i.e. under-ascertainment) and cases in people who seek medical care but are not diagnosed definitively with a laboratory test and reported (i.e. under-reporting). The lack of accurate data is therefore linked to the extent of underdiagnosis and under-reporting, due mainly to the features of each reporting system and the extent of under-ascertainment. Additionally, for diseases caused by chemical hazards, the association between food and the onset of symptoms is often difficult to establish, as the illness is typically chronic and manifests long after exposure.

Fig. 1. Foodborne disease surveillance pyramid

Source: Brecht Devleesschauwer (Belgian Scientific Institute for Public Health), Brussels.

Many countries lack the necessary surveillance capacity for detecting and responding to cases and outbreaks; therefore, foodborne illness and outbreaks often go undetected. Policy- and decision-makers need access to evidence from health research to allocate resources rationally and improve population health in the most efficient manner (5). In order to increase the efficiency of health policies, more accurate data are required on the epidemiology of diseases and their causative agents and on their relative impact on health.

Quantification of disease burden comprises factors other than just the numbers of cases and fatalities; it includes relevant information on the severity and duration of symptoms and sequelae and, for fatal cases, the age at death, which forms the basis for estimating the number of life years lost (YLL). Information on the burden of foodborne disease can guide the development and implementation of food safety policies and strategies and support setting of priorities, including the hazards to be targeted in national surveillance systems.



WHO INITIATIVE TO ESTIMATE THE GLOBAL BURDEN OF FOODBORNE DISEASES

In 2006, WHO launched an initiative to estimate the global burden of foodborne diseases (6), which provided the strategic framework for the assessment of the burden of foodborne disease and mandated WHO to establish a Foodborne Disease Burden Epidemiology Reference Group (FERG), an advisory group of external experts to conduct the assessments. The FERG consisted of a core or steering group to coordinate and oversee the scientific work and thematic task forces to work in specific areas: enteric diseases, parasitic diseases, chemicals and toxins, source attribution, country studies and computation. Many external experts and advisors were invited to contribute according to their expertise.

The FERG task forces identified 31 foodborne hazards (Annex 1) from an extensive list of possible microbiological and chemical hazards, on the basis of the availability of data and their presumed global impact, in order to estimate the incidence and the probable magnitude of the total burden of foodborne disease. Estimates for a further five hazards, including peanut allergy, could be made only for high-income regions. Chemicals and toxins were chosen on the basis of the severity of potential health effects, the prevalence of exposure and the availability of data. The reference year was 2010.

The outcome, the FERG report (7), presents global and regional estimates of the burden of foodborne disease by cause, age and sex. The present publication presents data for the WHO European Region.

Objectives

The objectives defined at the beginning of the FERG initiative were to:

- ▶ assist countries in strengthening their capacity to assess the burden of foodborne disease;
- ▶ provide estimates of the global burden of foodborne diseases due to a defined list of microbial, parasitic and chemical agents according to age, sex and region;
- ▶ increase awareness and commitment in Member States for implementing food safety standards; and
- ▶ encourage countries to use the results for cost-effective analyses of prevention, intervention and control measures.

Methods

Solid, accurate estimates of burden of disease are required for setting priorities in public health. In order to provide a full picture of the relative impact of different diseases and injuries on human health, it is helpful to combine the impacts of morbidity and mortality in one measure.

Estimating the global burden of foodborne disease is complex and non-linear, requiring a variety of information and data collection. Furthermore, many hazards can be spread not only via food but also from person to person or via water sources, complicating source attribution. The epidemiology of the diseases and environmental and socio-behavioural variables modify the exposure of individuals to hazards. Studying such a variety of illnesses and hazards requires a harmonized, methodological approach to ensure the consistency and comparability of the results. The accuracy of the findings is inherently linked to the quality and availability of the data.

The FERG task forces estimated the incidence and duration of and the mortality rates due to each hazard from systematic reviews of the literature, complemented by other literature sources, surveillance data and expert input. The impact of each disease outcome that could be attributed to primary exposure to each hazard was represented by a disease model.

FERG officially adopted the DALY metric to quantify the global burden of foodborne disease. The DALY is a standard metric commonly used to measure the impact of diseases on population health. The concept of this metric is simple: it represents the years lived with disability (YLD; i.e. decreased quality of life) and YLL due to premature death as a consequence of a given disease or condition, at the individual or population level. One DALY can be thought of as one year of “healthy” life lost, and the burden of disease as a measure of the gap between current health status and an ideal situation in which everyone lives into old age, free of disease and disability (8).

DALYs aggregate morbidity and disability, expressed as YLD, and mortality, expressed as YLL, into a single figure, calculated as:

$$\text{DALY} = \text{YLD} + \text{YLL}$$

where

YLD = the number of incident cases x average duration until remission or death x disability weight

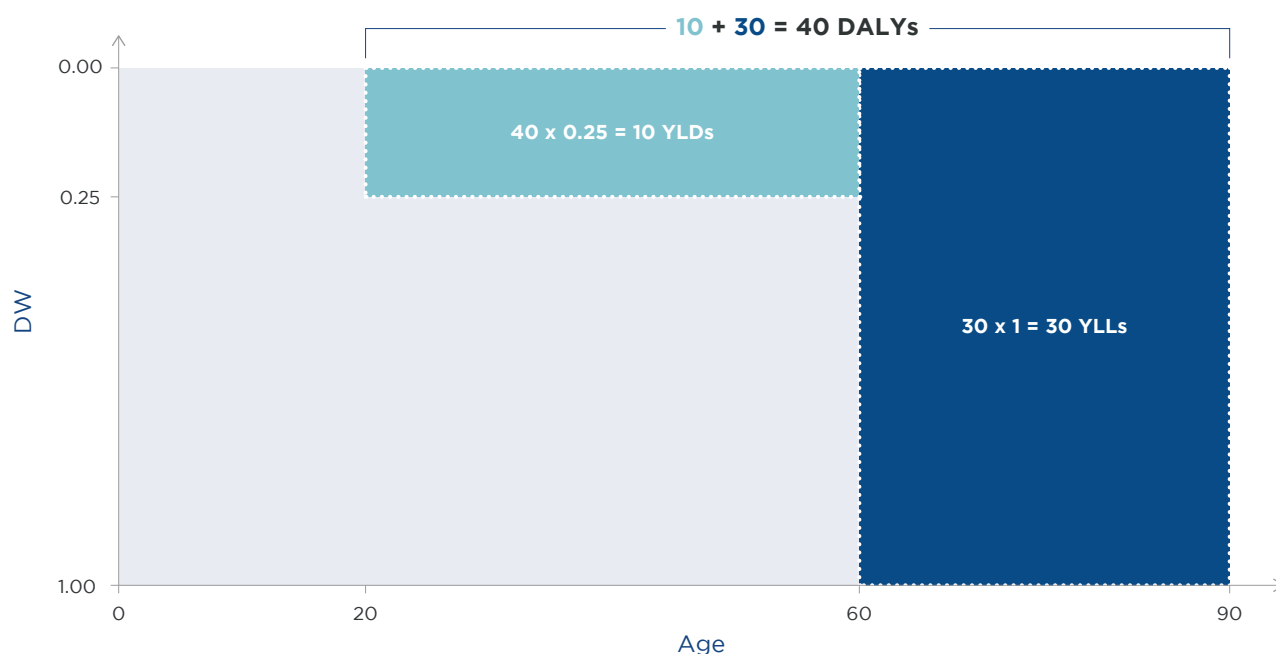
and

YLL = number of deaths x residual life expectancy at the age at death

Disability weight reflects the severity of the disease on a scale of zero (perfect health) to one (death). YLL are strongly influenced by a high mortality rate or death at a young age, whereas YLD are influenced by the number of sequelae, a high disability weight and long duration of disease (9). FERG did not use time-discounting or age-weighting, which were applied in earlier burden estimations.

Fig. 2 presents a theoretical example of calculation of DALYs. An individual is born with perfect health. At age 20 years, a given event (e.g. foodborne disease) decreases his or her quality of life by 25%; thereafter, the person lives in this new health state for another 40 years, at which time he or she dies prematurely. The burden associated with the disease in this individual (total DALYs) is calculated by summing the YLD and the YLL due to premature death.

DALYs were calculated by a hazard- and incidence-based approach, with the reference year set at 2010, in three steps: (i) estimation of incidence of foodborne disease, relevant health states, and associated disability weights; (ii) attribution of foodborne transmission; and (iii) computation of foodborne DALYs. To the extent possible, estimates of country-specific burden were based on national estimates of incidence and mortality. When no national data were available, imputation approaches were used to estimate the missing data and propagate the associated uncertainties.

Fig. 2. Theoretical example of DALYs

To derive estimates of regional source attribution for the hazards investigated, FERG conducted a structured “expert elicitation” by enrolling 72 international experts, who were asked to provide attribution estimates per hazard and sub-region. The criteria used to select the regions for the study were strata of child and adult mortality, where stratum A represented very low child and adult mortality, B low child mortality and very low adult mortality, C low child mortality and high adult mortality, D high child and adult mortality and E high child mortality and very high adult mortality (Annex 2). The responses were weighted by the experts’ performance in a set of seed questions, and aggregated attribution estimates were calculated.

Global estimate of the burden of foodborne diseases

Globally, in 2010, an estimated 600 million, or almost one in ten people in the world, fell ill after consuming food contaminated by any of the 31 foodborne hazards considered (7). Of these, 420 000 people died, including 125 000 children under the age of 5 years. The majority of the 600 million cases (550 million) were caused by diarrhoeal disease agents such as Norovirus (124 million cases) and *Campylobacter* spp. (96 million cases). Frequent causes of invasive infectious illness included hepatitis A virus and the parasites *Ascaris* spp. and *T. gondii*, with 14, 12 and 10 million cases, respectively. The number of deaths due to foodborne diarrhoeal hazards was also very high (approximately 230 000).

The global burden of foodborne disease in 2010 caused by the 31 hazards studied was 33 million DALYs, of the same order as that due to the major infectious diseases HIV/AIDS (92 million DALYs), malaria (55 million DALYs) and tuberculosis (TB) (44 million DALYs). The estimate is also comparable to those for certain other risk factors, such as dietary risk factors (254 million DALYs), poor water and sanitation (211 million DALYs) and air pollution (76 million DALYs).

Diarrhoeal disease agents accounted for 18 million DALYs, or 54% of the burden of foodborne disease, in 2010. Non-typhoidal *Salmonella* spp. alone were responsible for 4 million DALYs, and six other diarrhoeal agents (Norovirus, *Campylobacter* spp., enteropathogenic *E. coli*, enterotoxigenic *E. coli*, *Vibrio cholerae* and *Shigella* spp.) caused a burden of 1–3 million DALYs each. Non-diarrhoeal hazards that contributed substantially to the global burden include *Salmonella* Typhi (*S. enterica* serovar Typhi) 3.7 million DALYs, *T. solium* (2.8 million DALYs), hepatitis A virus (1.4 million DALYs) and *Paragonimus* spp. (1 million DALYs).

Of the group of foodborne chemicals considered, aflatoxin was the most important, responsible for more than 600 000 DALYs in 2010, followed by dioxin, which caused approximately 240 000 DALYs.

Peanut allergy caused approximately 100 000 cases of illness and resulted in 28 deaths in 2010, and the burden was estimated to be 100 000 DALYs. Because of lack of data, the estimates for this hazard were assessed only for three high-income sub-regions (Region of the Americas A, European Region A and Western Pacific Region A).

The FERG report showed considerable differences among regions and hazards. Especially in low- to middle-income countries, there were large differences between children and adults. Although the burden is generally much higher in developing countries, foodborne diseases also have a significant impact in developed countries.



ESTIMATES OF THE BURDEN OF FOODBORNE DISEASES IN THE WHO EUROPEAN REGION

The FERG estimates of the global and regional burdens of foodborne disease show that, even though the WHO European Region has the lowest estimated burden, more than 23 million people fall ill annually and 5000 die from eating contaminated food (7).

The 10 most common causes of foodborne illness are shown in Table 1. Diarrhoeal diseases accounted for the majority of cases, and Norovirus was responsible for the most cases annually, almost 15 million cases, followed by *Campylobacter* spp. with nearly 5 million cases, non-typhoidal *Salmonella* spp. with almost 1.7 million and *T. gondii* with more than 1 million cases. *Giardia* spp., *Cryptosporidium* spp. and Shiga toxin-producing *E. coli* caused more than 485 000, 187 000 and 165 000 illnesses per year, respectively.

Table 1. Leading causes of foodborne illnesses in the WHO European Region by hazard, 2010

RANK	HAZARD	NO. OF CASES	(95% UNCERTAINTY INTERVAL)
1	Norovirus	14 850 045	(5 665 679–29 602 234)
2	<i>Campylobacter</i> spp.	4 687 810	(3 261 443–6 175 655)
3	Non-typhoidal <i>S. enterica</i>	1 683 734	(1 066 414–2 482 159)
4	<i>Toxoplasma gondii</i>	1 068 724	(715 649–1 694 419)
5	<i>Giardia</i> spp.	485 752	(141 334–1 109 206)
6	<i>Cryptosporidium</i> spp.	187 416	(37 598–628 971)
7	Shiga toxin-producing <i>E. coli</i>	165 250	(78 726–254 545)
8	Hepatitis A virus	97 472	(27 613–254 300)
9	<i>Ascaris</i> spp.	71 884	(35 115–103 244)
10	Enteropathogenic <i>E. coli</i>	71 395	(28 333–142 145)
	Peanut allergens*	49 078	(2868–96 214)

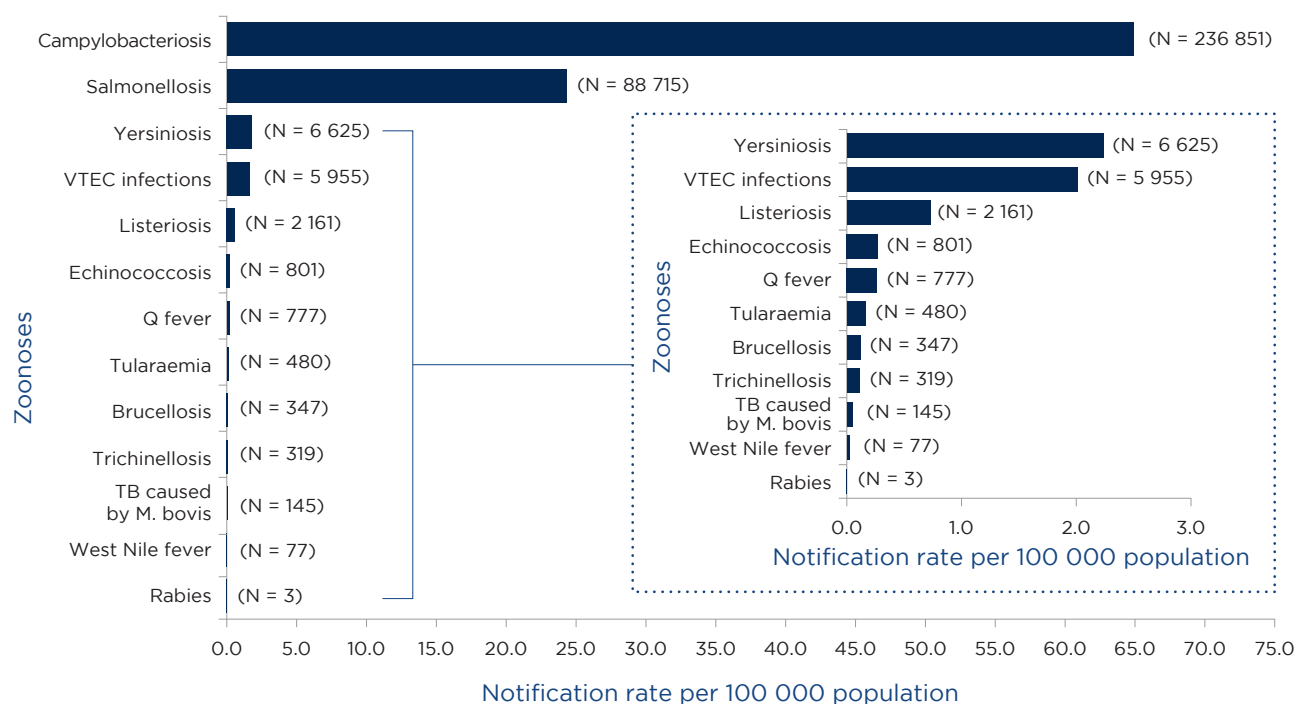
Source: reference (7).

* Only the burden for sub-region European Region A.

In the European Union alone, there were more than 340 000 *reported* cases of zoonoses in 2014 (Fig. 3), which resulted in death in 315 cases (10). *Campylobacteriosis* has been the most commonly reported zoonosis in the European Union since 2005, followed by salmonellosis. These results are in line with the FERG data, as Norovirus infection and toxoplasmosis are not monitored in the European Union.

FERG's ranking of hazards that cause deaths in the European Region (Table 2) shows that non-typhoidal *Salmonella* spp. were the leading cause, with almost 2000 estimated deaths annually, followed by *Campylobacter* spp. (459 deaths), Norovirus (435 deaths) and *L. monocytogenes* (399 deaths).

Table 3 shows the 10 leading causes of the burden of foodborne disease in terms of DALYs. Diarrhoeal disease agents contributed the most to the burden, responsible for 49–68% of the total number of DALYs. Non-typhoidal *Salmonella* spp. (107 000 DALYs), *Campylobacter* spp. (82 000 DALYs) and *T. gondii* (73 000 DALYs) were the three leading causes of the foodborne disease burden, followed by Norovirus (33 000 DALYs). *T. gondii* contributed

Fig. 3. Reported numbers and notification rates of confirmed human zoonoses in the European Union, 2014

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The total number of confirmed cases is indicated in parentheses at the end of each bar, except for West Nile fever, for which the total number of cases is given. VTEC, verocytotoxigenic E. coli; TB, tuberculosis; M. bovis, Mycobacterium bovis.

Table 2. Leading causes of death due to foodborne diseases in the WHO European Region by hazard, 2010

RANK	HAZARD	NO. OF DEATHS	(95% UNCERTAINTY INTERVAL)
1	Non-typhoidal <i>S. enterica</i>	1 854	(1228–2735)
2	<i>Campylobacter</i> spp.	459	(235–847)
3	<i>Norovirus</i>	435	(154–914)
4	<i>Listeria monocytogenes</i>	399	(313–525)
5	<i>Echinococcus multilocularis</i>	239	(98–1708)
6	Hepatitis A virus	195	(56–513)
7	<i>Brucella</i> spp.	191	(58–1491)
8	Aflatoxin	160	(91–294)
9	<i>Mycobacterium bovis</i>	150	(105–237)
10	<i>Echinococcus granulosus</i>	82	(23–233)
	Peanut allergens*	13	(1–26)

Source: reference (7).

* Only the burden for sub-region European Region A.

the most to the foodborne DALYs, with remarkably high estimates in all three sub-regions. Foodborne toxoplasmosis affects more than 1 million people in the Region each year, resulting in 45 deaths due to congenital toxoplasmosis and almost 73 000 DALYs in 2010.

Other main causes of DALYs included *L. monocytogenes*, dioxins, *Brucella* spp., hepatitis A virus, the parasite *Echinococcus multilocularis* and *M. bovis*, which were responsible for 9000–15 000 estimated DALYs each. Dioxins were estimated to have a higher impact in the WHO European Region than in most other regions, with almost 13 000 DALYs (1 DALY per 100 000 population). *Brucella* spp. and *M. bovis* were more relevant in European Region B and C, respectively.

Table 3. Leading causes of disability-adjusted life years (DALYs) due to foodborne diseases in the WHO European Region, by hazard, 2010

RANK	HAZARD	DALYs	(95% UNCERTAINTY INTERVAL)
1	Non-typhoidal <i>S. enterica</i>	106 597	(70 410–158 858)
2	<i>Campylobacter</i> spp.	82 126	(55 413–113 650)
3	<i>Toxoplasma gondii</i>	72 569	(46 120–121 963)
4	Norovirus	33 055	(12 021–68 164)
5	<i>Listeria monocytogenes</i>	14 791	(11 633–19 494)
6	Dioxin	12 834	(8150–168 769)
7	<i>Brucella</i> spp.	12 084	(3766–94 877)
8	Hepatitis A virus	9 522	(3009–24 285)
9	<i>Echinococcus multilocularis</i>	8 937	(3926–74 302)
10	<i>Mycobacterium bovis</i>	8 533	(5977–13 452)
	Peanut allergens*	45 921	(2683–90 026)

Source: reference (7).

* Only the burden for sub-region European Region A.

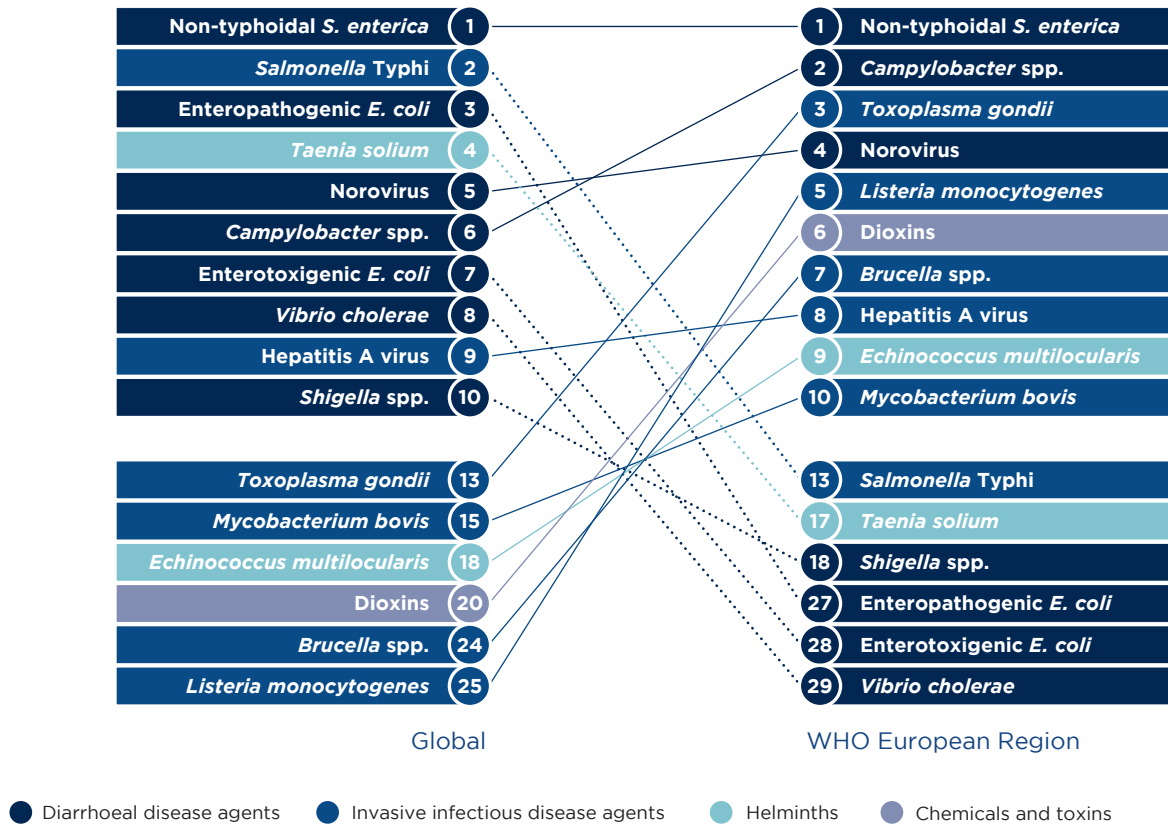
Overall in the European Region, the contribution of YLL to the overall burden estimates was higher for *Salmonella* spp., *Listeria*, hepatitis A virus and *M. bovis* than other hazards, whereas the contribution of YLD was higher for dioxins, *T. gondii* and *Campylobacter* spp.

The estimated DALYs per 100 000 population per year due to chemical hazards were lower in the WHO European Region than in the other regions. Nevertheless, in the A sub-region (including mainly countries in western Europe), the relative contribution of peanut allergens to the DALY estimates was surprisingly high.

The burden of foodborne disease varied widely between and within countries, indicating that aggregated data at national and regional levels may not capture the complexities of disease dynamics; consequently, at-risk populations or areas may be overlooked.

Further analysis of both global and regional estimates shows a markedly different distribution of the burden of foodborne disease. The global ranking of diseases by DALYs is compared with that in the European Region in Fig. 4, showing striking differences: most of the 10 leading contributors to the burden in this Region are invasive infectious diseases, whereas diarrhoeal diseases agents contributed the most in the global ranking. Moreover, apart from non-typhoidal *Salmonella* spp., the 10 leading hazards in the European Region each ranked lower at the global level.

Fig. 4. Leading causes of foodborne disability-adjusted life years (DALYs) at global level and in the WHO European Region estimated for 2010



Source: reference (11).

Solid lines indicate a higher rank in the European Region than globally, while dashed lines indicate a lower rank.

Non-typhoidal *Salmonella* spp.

Salmonella spp. are some of the most important, most widely distributed causes of foodborne illness in humans. Non-typhoidal *S. enterica* (*enterica* serovars other than *S. Typhi* and *S. Paratyphi*) usually cause gastroenteritis. This group of *Salmonella* serovars includes *S. Enteritidis* and *S. Typhimurium*, which are the two most commonly reported serovars of human foodborne *Salmonella* spp. in most parts of the world.

Non-typhoidal *Salmonella* spp. are usually transmitted to humans via contaminated food, usually of animal origin, such as eggs, pork and poultry meat and dairy products; however, other foods, in particular fresh produce, can also be implicated in its transmission. Non-typhoidal *Salmonella* spp. usually cause gastroenteritis characterized by acute onset of fever, abdominal pain, diarrhoea, nausea and sometimes vomiting. The onset of symptoms usually begins 12–36 h after ingestion of the bacteria, and the illness usually lasts 2–7 days. Non-typhoidal salmonellosis is usually self-limiting and does not require specific treatment other than oral fluids (11). *Salmonella* spp. infection can, however, cause severe disease, especially in children, the elderly and immunocompromised individuals, and can lead to post-infection complications such as reactive arthritis. In invasive *Salmonella* spp. infections, several organs and systems can be affected, resulting in bacteraemia, meningitis,

osteomyelitis or septic arthritis and sometimes even death. For severe or invasive salmonellosis, treatment with antimicrobial agents is justified, although antimicrobial resistance in *Salmonella* spp. is an increasing problem (3).

According to the FERG estimates, non-typhoidal *Salmonella* spp. are the foodborne hazards that are responsible for the highest annual burden and the largest number of deaths both globally and in the European Region. Globally, non-typhoidal *Salmonella* spp. were estimated to cause approximately 78 million cases of illness, 59 000 deaths and 4 million DALYs per year (7). The numbers were also high in the WHO European Region, where non-typhoidal *Salmonella* spp. occupied the first position in the ranking of DALYs and deaths due to foodborne hazards, causing 107 000 DALYs and 1854 deaths per year. The median rate of DALYs was 8 (95% UI 5–14) DALYs per 100 000 population per year. In addition, non-typhoidal *Salmonella* spp. were estimated to cause 1.7 million cases of illness annually, representing the third most common cause of foodborne illnesses in the Region (7).

In 2014, in the European Union alone, there were over 85 000 *reported* cases of human salmonellosis, with 65 deaths (10). The two most commonly reported *Salmonella* serovars in the European Union are *S. Enteritidis* and *S. Typhi*. The European Food Safety Authority estimated that the overall economic burden of human salmonellosis could be as high as 3 billion annually. A significant downward trend in human salmonellosis in the European Union was noted, which is attributed to joint activities by many actors, including enhanced *Salmonella* spp. control programmes for poultry (12).

***Campylobacter* spp.**

Campylobacter spp. are a major cause of foodborne diarrhoeal illness. *Campylobacter* infection is commonly acquired through consumption of contaminated food such as undercooked poultry and raw milk; contaminated broiler meat is considered the most important source of this hazard to humans.

In most cases of campylobacteriosis, the first symptoms occur 2–5 days after infection. The most common clinical symptoms are diarrhoea (frequently with blood in the faeces), abdominal pain, fever, nausea and/or vomiting. The symptoms typically last 3–6 days. Death from campylobacteriosis is rare and is usually confined to very young or elderly patients or to those with another serious disease such as AIDS. Complications such as bacteraemia, hepatitis, pancreatitis and miscarriage have all been reported at varying frequency. Post-infection complications may include reactive arthritis, which can last for several months, and neurological disorders such as Guillain-Barré syndrome, a form of paralysis that can result in respiratory and severe neurological dysfunction or death in a few cases (13).

According to FERG, in 2010, foodborne *Campylobacter* spp. were responsible for more than 95 million cases of illness and slightly more than 21 000 deaths worldwide. The global burden of this hazard was estimated to be over 2.1 million DALYs per year, consisting mostly of YLL. In the WHO European Region, *Campylobacter* spp. are the second leading hazard in terms of foodborne illness (nearly 4.7 million cases per year), deaths (459 per year) and burden (more than 82 000 DALYs per year). It is undoubtedly a major threat to public health in the Region, where the median was 9 DALYs (95% UI 6–13) per 100 000 population in 2010 (7).

Since 2005, campylobacteriosis has been the most commonly reported foodborne disease in the European Union, with more than 236 000 confirmed cases in 2014. The increasing trend in the incidence of campylobacteriosis in recent years is due partially to improved surveillance systems and diagnosis in several European Union Member States (10).

Prevention consists of control measures at all stages of the food chain to reduce transmission, from the environment to farms through enhanced biosecurity, adequate sewage and faeces disposal systems, hygienic slaughtering and application of good food handling practices, including avoidance of cross-contamination and ensuring proper heat-treatment of poultry products.

Toxoplasma gondii

T. gondii is a protozoal parasite that is distributed globally. All warm-blooded animals, including humans, can become infected. Most infections in humans are asymptomatic; the clinical manifestations range from very mild fever or lymph node swelling to very severe neurological symptoms and fatal cases in immunocompromised patients. Asymptomatic infections can develop into ocular disorders, with visual problems later in life, such as acquired chorioretinitis. Other syndromes are increasingly being associated with acquired toxoplasmosis, including epilepsy, schizophrenia and psychosomatic disorders (14).

Primary *T. gondii* infection in a pregnant woman can have severe consequences for her unborn child. The symptoms depend on the time of infection in pregnancy. Early on, it can result in fetal death and spontaneous abortion, neurological and neurocognitive deficits and chorioretinitis (15). Later in pregnancy, an infection may be asymptomatic and therefore go unnoticed and untreated but with neurocognitive disorders and chorioretinitis later in life for a child born at term.

T. gondii is an important foodborne pathogen. It has a complex life cycle. Felids such as domestic cats are the definitive hosts, in which sexual replication occurs in the intestines after infection by eating e.g. infected mice. Oocysts are shed in the faeces, and infective oocysts can remain infectious in the environment for up to 18 months after sporulation. Meat-producing animals can become infected by oral uptake of infectious oocysts, and tissue cysts can be found in muscles and organs of all livestock exposed to oocysts. Humans can become infected by consuming raw vegetables, fruit, water or meat contaminated with oocysts. A European multicentre study of pregnant women showed that 30–60% of infections were attributable to food. FERG experts attributed 49% of infections to food (16).

The seropositivity rate for *T. gondii* in human populations ranges from < 10% to ≤ 90% (15). Human surveillance is, however, lacking in most countries. Country policies on toxoplasmosis screening differ, and European studies on congenital toxoplasmosis do not provide a homogeneous picture of the general status of the illness (17). In The Netherlands, the human seroprevalence decreased from 43% in 1996 to 26% in 2006 (18), which might be associated with the decrease in seroprevalence in livestock due to more intensive animal husbandry, especially of pigs and poultry.

Globally, congenital and acquired foodborne toxoplasmosis affected more than 10 million people in 2010, resulting in an estimated global burden of 829 000 DALYs. Foodborne toxoplasmosis in the European Region affected more than 1 million people, resulting in 73 000

DALYs. The burden of foodborne toxoplasmosis was remarkably high in all three European sub-regions. In the European Region as a whole, the median rate of foodborne illness per 100 000, defined as the number of new cases of acquired toxoplasmosis in 2010, and the estimated DALYs were 119 (95% UI, 79–188) and 6 (95% UI, 4–10), respectively, and the figures for congenital toxoplasmosis were 0.3 (95% UI, 0.2–0.7) and 2 (95% UI, 1–3), respectively (19).

T. gondii-attributable congenital and acquired disease contributed the most to the estimated DALYs among all parasitic hazards and ranked third for the disease burden of all foodborne hazards in the WHO European Region in 2010. A high disease burden of toxoplasmosis was also estimated in 2009 in The Netherlands, where a comparative study of 14 foodborne pathogens showed that the DALYs due to toxoplasmosis (3620), summed for acquired (1350) and congenital toxoplasmosis (2210), were the highest due to all foodborne pathogens, followed by those due to *Campylobacter* (3250) (20).

In Europe, the high burden of toxoplasmosis is not paid the same attention with regard to risk management as are salmonellosis and campylobacteriosis. Better understanding is required of the transmission of *T. gondii* to humans in Europe and its relative importance, such as whether most infections are acquired in the environment or from meat or fresh produce and the types of meat most often implicated. Country or regional source attribution models should be developed. A source attribution study based on quantitative risk assessment conducted in The Netherlands of the relative contributions of different meats to toxoplasmosis indicated that beef was responsible for more than 50% of human infections associated with meat (21). The results suggest that the prevalence of *T. gondii* infection in cattle, the quantity of beef consumed, cooking methods and eating raw or undercooked beef products explain the relatively high contribution of this meat source.

As both the prevalence and the burden of toxoplasmosis are high in the European Region, evidence-based measures should be applied. Communication and awareness-raising are important to prevent infections in pregnant women. Other measures could be improving surveillance in human and meat-producing animal populations and controlling *T. gondii* infections in meat-producing animals or meat products at risk (22).

Norovirus

One of the most common causes of gastroenteritis in humans globally is human Norovirus and specifically genogroup 2 Noroviruses. The symptoms include diarrhoea, vomiting (including projectile vomiting) and stomach ache. The virus can be transmitted to humans by ingestion of contaminated food or water and, directly, from person to person, resulting in infection and disease in a relatively large proportion of exposed individuals. Immunity is of limited duration and is strain- or genotype-specific, with little or no protection conferred across genogroups.

Although there is no commercially available vaccine at present, human challenge studies based mainly on the production of virus-like particles or P particle subunits in expression systems have demonstrated safety, immunogenicity and efficacy. There is no specific therapy; common rehydration is advised (23).

The FERG estimates (7) show that, worldwide, Norovirus is associated with approximately 20% of all foodborne illness due to diarrhoeal disease hazards (125 million per year), with a significant burden of disease in all regions. Globally, foodborne Norovirus causes 2.5 million

DALYs (95% UI, 1.2–5.5 million). It is the most common cause of diarrhoeal disease in all age and risk groups, with the most severe outcomes in young children and elderly people. Norovirus infection is the sixth most common cause of diarrhoeal death in children under the age of 5 years and the second most common cause of death due to diarrhoea in children over 5 years of age, with similar patterns across WHO regions. 99% of approximately 35 000 annual deaths due to norovirus occur in middle- and low-income settings.

The FERG data for the WHO European Region (7) indicate that Norovirus is the most common cause of foodborne illness, with nearly 15 million estimated new cases in 2010. The relatively low case-fatality ratio places Norovirus as the third leading cause of foodborne deaths, with an estimated 435 deaths in 2010, and the fourth leading cause of the foodborne disease burden, with an estimated 33 000 DALYs (or approximately 14% of all DALYs due to diarrhoeal disease agents). There were approximately 1.6 million cases of illness in children under 5 years, resulting in 48 deaths and 5000 DALYs. The burden of Norovirus was distributed homogeneously across the European Region, with 3–4 DALYs per 100 000 in all sub-regions.

***Brucella* spp.**

Brucellosis is a foodborne zoonosis caused by *Brucella* spp. The most common route of infection in humans is consumption of contaminated unpasteurized or raw milk and dairy products. The clinical signs and symptoms of brucellosis are nonspecific and can include fever, headaches, fatigue, sweating and muscle and joint pain. Chronic infection is characterized by recurrent appearance of symptoms, severe arthritis, chronic fatigue, neurological disorders, depression and even death. Recovery from the infection usually occurs within a few weeks up to several months.

Brucellosis is endemic in many Mediterranean and eastern countries in the European Region, including the Balkans and Central Asia. In 2014, 347 confirmed cases of brucellosis were reported in the European Union, and more than half the cases were hospitalized. The highest notification rates and the majority of autochthonous cases were reported from Mediterranean countries in which cattle, sheep and goats are not officially brucellosis-free. Major gaps in the available data for eastern Europe and Central Asia limit understanding of the real distribution of brucellosis (24).

According to the FERG estimates (7), foodborne brucellosis was responsible for nearly 400 000 cases of illness worldwide in 2010, resulting in nearly 2000 deaths and 125 000 DALYs. The European Region's burden was more than 12 000 DALYs per year, and the hazard is listed seventh in the ranking of DALYs by foodborne causative agents. The median rate of DALYs due to *Brucella* spp. was highest in European Region B (4 DALYs per 100 000 population per year), followed by sub-regions C (0.8 DALYs per 100 000 population per year) and A (0.3 DALYs per 100 000 population per year). The global estimated median rate per 100 000 population for 2010 was 2 DALYs.

Many countries in the European Region have made efforts to control and eradicate *Brucella* spp. from their animal populations, with successful results, especially in European Union countries. Owing to the peculiarities of this pathogen and to different production systems and epidemiological and socioeconomic situations, it is difficult to eradicate this agent from animal populations, especially in countries with limited resources. In addition, as many brucellosis-endemic countries have weak surveillance systems, the available data might provide an underestimate of the true impact of this disease (25).

Mycobacterium bovis

TB is one of the most devastating human infectious diseases, with worldwide distribution. While human TB is caused mainly by *M. tuberculosis*, zoonotic transmission of *M. bovis*, the principal agent of zoonotic TB, from animals to humans is well described. Cattle are considered to be the true hosts of *M. bovis*, but the disease has also been reported in many other domesticated and non-domesticated animals. People can become infected with *M. bovis* by eating or drinking contaminated and unpasteurized dairy products or through close contact with infected animals. Not all people infected with *M. bovis* exhibit symptoms, and only a few infected individuals develop TB. The symptoms depend on the system or organs affected and the primary site of infection (pulmonary or extrapulmonary), but they can include fever, weight loss, cough, abdominal pain and diarrhoea. Some evidence suggests that there are more cases than previously thought of zoonotic and extrapulmonary TB than of pulmonary TB caused by *M. tuberculosis*. This may be due in part to improved diagnostic capacity for both zoonotic and extrapulmonary TB in recent years and better awareness among health care workers in affected settings. The suggested underestimation of extrapulmonary and zoonotic TB has implications for treatment and care, from both a clinical and a public health perspective.

The occurrence of zoonotic TB depends strongly on the presence of the disease in animal populations in each country and region. People in close contact with infected animals are at higher risk (26). Thus, control of *M. bovis* in animal populations and the food chain is essential for prevention of infection in humans. The public health relevance of zoonotic TB is considerable in developing countries where control measures for TB in animal population are limited and milk is not routinely pasteurized. Because of lack of data, under-diagnosis and, consequently, under-reporting of TB cases, the occurrence of *M. bovis* infections and their contribution to the overall prevalence of TB cannot be fully assessed in many countries and regions.

In the European Union in 2014, 145 cases of human TB due to *M. bovis* were reported (70). The median proportion of zoonotic TB among all bacteriologically confirmed cases of human TB was reported to be 0.4% (0–21.1%) (26).

According to the FERG estimates (7), *M. bovis* is the tenth leading cause of the foodborne disease burden in the European Region, where it is responsible for more than 8500 DALYs per year. It caused an estimated 150 deaths in 2010, ranking ninth among the causes of deaths due to foodborne hazards. The median rate of DALYs by European sub-region was highest in sub-region C (3 DALYs per 100 000 population), followed by sub-regions B (0.6 DALYs per 100 000 population) and A (0.06 DALYs per 100 000 population). The global median rate of DALYs per 100 000 population reached 3.68 in 2010. These data show that, although *M. bovis* does not cause a large number of human infections, its impact on health should not go unnoticed, and prevention and control of *M. bovis* in the food chain should be strengthened.

Listeria monocytogenes

Listeriosis is an important foodborne disease caused by the ubiquitous bacterium *L. monocytogenes*. Unlike most other foodborne pathogens, *L. monocytogenes* can grow in food at fairly low moisture, a high salt concentration and at refrigeration temperatures. The ability to persist and multiply in the food environment makes *L. monocytogenes* especially difficult to control.

Listeriosis occurs mainly in risk groups such as pregnant women, elderly people, immunocompromised people, fetuses and neonates. Healthy people infected with *L. monocytogenes* may experience febrile gastroenteritis, which is usually mild and self-limiting. Mainly in patients with impaired cell-mediated immunity, *L. monocytogenes* can lead to severe illness, including severe sepsis, meningitis or encephalitis and therefore have lifelong consequences and even death. Infection during pregnancy can result in spontaneous abortion, stillbirth or preterm birth (27).

Most cases of listeriosis are sporadic, but outbreaks may occur. In general, the incidence is relatively low, but the hospitalization and fatality rates are high. According to the FERG estimates (7), listeriosis resulted in more than 14 000 cases of illness, over 3170 deaths and over 118 000 DALYs globally in 2010. The proportion of perinatal cases was approximately 20%. In the European Region, listeriosis caused an estimated 1781 cases of illness, 399 deaths and almost 15 000 DALYs in 2010. Listeriosis was the fourth leading foodborne hazard in terms of deaths and the fifth in terms of DALYs. Throughout the European Region, the median rates of DALYs due to *L. monocytogenes* infection were 0.3–3.0 per 100 000 population, which were comparable to the estimates for the other regions (1–3 DALYs) (7,27).

In the European Union, 2161 confirmed human cases of listeriosis were reported in 2014, and a statistically significant increasing trend in cases of listeriosis was observed between 2008 and 2014 (10). The case fatality rate in 2014 was 15% of the 1401 confirmed cases with known outcome.

The above figures illustrate the public health impact of listeriosis in the European Region. The resistance of *L. monocytogenes* to diverse environmental conditions, its tenacity in the industrial environment and its ability to grow and survive at low temperatures and for prolonged periods make this bacterium a critical public health problem. The high risk for *Listeria* infection is related to the consumption of processed and ready-to-eat foods in settings in which vulnerable population groups, such as the elderly, are served (28).

Hepatitis A virus

Hepatitis A virus is an important cause of sporadic disease and outbreaks worldwide. Symptoms of hepatitis A range from mild to severe and can include fever, malaise, loss of appetite, diarrhoea, nausea, abdominal discomfort, dark-coloured urine and jaundice. Adults have symptoms of illness more often than children, and the severity increases with age. The incubation time is usually 2–4 weeks.

Hepatitis A virus is transmitted through the faecal–oral route, and people are infected by consuming contaminated food or water, by contact with an infected person or by touching contaminated surfaces. The virus retains its infectivity in the environment and is resistant to freezing and drying, so that food and water are efficient vehicles if they are not appropriately heated before consumption. Many kinds of food have been implicated in hepatitis A outbreaks, including bivalve shellfish such as oysters and mussels, raw fruit and vegetables and prepared foods. Of particular concern are infected food workers, who can pass the virus to others by handling food, for instance in food service establishments or while picking berries. Fruit and vegetables can also be contaminated with hepatitis A virus when faecally contaminated water is used for irrigation, including re-use of wastewater, or washing. Several recent outbreaks of hepatitis A infection have been associated with berries, including frozen berries, on the international market.

In Europe, a gradient of intermediate to very low endemicity can be seen, from the south-east, including Central Asia, to the north-west. Hepatitis A virus infection in childhood results in life-long immunity. With a lower incidence of infection, childhood infections occur less frequently. In countries with a low incidence, hepatitis A can be introduced by travellers returning from endemic regions and through food imported from these regions and spread by secondary infection. Consequently, a gradually increasing proportion of the adult population is becoming susceptible. Hepatitis A virus strains are strongly linked to their original endemic geographical region.

Proper water and sanitation infrastructure and the application of hygiene measures along the food chain are crucial for the prevention and control of hepatitis A virus infections. Vaccination is efficient. In 2016, the WHO Regional Committee for Europe adopted an action plan for the health sector response to viral hepatitis in the Region (29).

Hepatitis A virus infects approximately 120 million people per year globally (30). According to the FERG estimates, in 2010, foodborne hepatitis A virus infection resulted in approximately 14 million (4–39 million) cases of illness, resulting in 28 000 (7000–77 000) deaths and 1.4 million (0.4–3.7 million) DALYs (7). With respect to DALYs, hepatitis A virus was among the 10 leading foodborne hazards, globally as well as in the European Region. In the Region, foodborne hepatitis A virus was responsible for nearly 100 000 cases of illness (28 000–250 000), which resulted in 195 (56–513) deaths and 9500 (3000–24 000) DALYs. FERG estimated a higher incidence in European sub-region C (15/100 000), followed by sub-regions B (11/100 000) and A (8/100 000). The estimated mortality rates were more consistent by sub-region, at 0.02–0.03 deaths per 100 000, resulting in DALYs of 0.8–1 per 100 000 population across sub-regions.

Echinococcus multilocularis

Echinococcosis can be caused by the larval stage of tapeworm species belonging to the genus *Echinococcus*. Human infection can result after ingestion of eggs shed by the definitive canid hosts. In the European Region, two *Echinococcus* species occur: *E. granulosus*, the causative agent of cystic echinococcosis, with the dog as the main definitive host, and *E. multilocularis*, the causative agent of alveolar echinococcosis, for which wild canids such as the red fox are the main definitive hosts.

E. multilocularis is endemic in some regions of central Europe and large regions of the Russian Federation and adjacent countries (31). Human cases of alveolar echinococcosis occur throughout the European Region, but, as there are no official reporting and surveillance systems for *E. multilocularis* in most European countries, the true epidemiological distribution of this hazard is still unknown (32). Alveolar echinococcosis is one of the most severe parasitic zoonoses in Europe, and, without treatment, the case fatality ratio is high (14).

Alveolar echinococcosis is endemic in Austria, eastern France, southern Germany and Switzerland, with a prevalence of 50–60% in the fox population. *E. multilocularis* is spreading in foxes and is now also present in other regions of Europe. Moreover, other wild canids, such as the raccoon dog, are also becoming good definitive hosts for the parasite, contributing to further spread. *E. multilocularis* is thus an emerging parasite in Europe, with increasing numbers of human cases reported in well-known endemic regions such as Austria (33) and Switzerland (34) and also in north-eastern Europe, such as the Baltic States (35), Kyrgyzstan (36) and Poland (37); human cases are also now being reported in north-western Europe, such as in The Netherlands (38).

Foodborne transmission of *E. multilocularis* can be due to contamination of fresh produce or water containing embryonated eggs of the parasites. Other transmission routes include direct contact with soil or faeces containing eggs or with the fur of infected animals. The relative importance of the different transmission routes is difficult to determine because of the long incubation period (5–15 years), although risk factors have been identified, such as having an agricultural occupation or a kitchen garden (39). In the FERG report (9), the proportion of cases due to foodborne transmission was estimated by experts to be 48%.

Globally, more than 8000 new cases of foodborne alveolar echinococcosis occur each year, with a total disease burden of more than 300 000 DALYs (7); of these, 90% occur in China, especially in Tibetan communities (14,19), where the main definitive host is the dog. In the European Region, foodborne alveolar echinococcosis is estimated to cause 667 new cases per year, resulting in 239 deaths and almost 9000 DALYs; *E. multilocularis* thus ranks ninth among foodborne disease burdens. Little attention is being paid in Europe to reducing the disease burden, and more human cases might occur in the future (40).

In the European Union in 2014, 806 cases of echinococcosis were reported, of which 801 were confirmed in a laboratory (10). Species information was provided for 521 cases; *E. granulosus* accounted for 439 cases and *E. multilocularis* for 82 cases.

Escherichia coli

E. coli is a common bacterium in the gastrointestinal tracts of humans and other warm-blooded animals and is part of the normal bacterial flora. Most strains of *E. coli* are harmless; however, some strains can cause illness and even severe foodborne disease. *E. coli* are categorized into groups according to their virulence mechanism. Diarrhoeogenic *E. coli* groups include amongst others enteropathogenic *E. coli*, enterotoxigenic *E. coli* and Shiga toxin-producing *E. coli* (also known as verotoxin-producing *E. coli*).

Shiga toxin-producing *E. coli* can cause severe foodborne disease, especially in young children and elderly people. Infection may manifest as haemorrhagic enteric disease (bloody diarrhoea) and sometimes haemolytic uraemic syndrome and death. Cattle and other ruminants are the natural reservoirs of Shiga toxin-producing *E. coli*, which is part of their normal intestinal flora. *E. coli* O157 is the most commonly reported serogroup, but other serogroups, such as O26, O103, O145, O91, O146 and O111, can also cause human infection.

People can become infected with diarrhoeogenic *E. coli* by consuming or handling contaminated food or water or by contact with infected animals. Person-to-person transmission is also possible. Foods typically associated with Shiga toxin-producing *E. coli* include raw milk and dairy products, undercooked ground meat products and fresh produce. Foodborne outbreaks of Shiga toxin-producing *E. coli*, sometimes with international ramifications, are being reported increasingly, more and more of which are associated with fresh produce.

According to the FERG estimates (7), globally in 2010, enterotoxigenic *E. coli* were the group of *E. coli* that caused the most cases of foodborne illness (86 million cases), followed by enteropathogenic *E. coli* (23 million cases) and Shiga toxin-producing *E. coli* (1.2 million cases). The annual burden of DALYs due to enterotoxigenic, enteropathogenic and Shiga toxin-producing *E. coli* was 2.1 million, 2.9 million and 12 953, respectively (41).

In the WHO European Region, Shiga toxin-producing *E. coli* caused more than 150 000 cases of illness per year, representing the seventh of the ten most common causes of illness. Enteropathogenic *E. coli* was in tenth place in terms of the causes of illness, with approximately 72 000 human cases per year. The annual burden of Shiga toxin-producing, enteropathogenic and enterotoxigenic *E. coli* in the WHO European Region was estimated to be 1000, 46 and 35 DALYs, respectively (7); none was among the 10 leading foodborne hazards in terms of burden or deaths.

In the European Union in 2014, there were 5955 confirmed and reported cases of Shiga toxin-producing *E. coli* infections, with 7 deaths. The most commonly reported Shiga toxin-producing *E. coli* serogroup in the European Union is O157, although its proportion relative to other serogroups appears to be decreasing (10).

Chemicals and toxins

Aflatoxins are fungal metabolites produced by a small number of *Aspergillus* species, particularly *A. flavus* and *A. parasiticus*. Aflatoxins B1 and B2 produced by *A. flavus* and aflatoxins G1 and G2 produced by *A. parasiticus* can occur naturally in foods. The secondary metabolites M1 and M2 of B1 and B2 aflatoxins can be found in foods, such as milk and milk products, and also in food crops (maize, peanuts and oilseeds) and other contaminated plant products in tropical and subtropical regions. Aflatoxins are responsible for acute poisoning, hepatocellular carcinoma, growth impairment in children and immunosuppression (42).

Cassava is a tropical root crop that contains cyanogenic compounds in its edible parts and can cause acute cyanide poisoning or other illnesses, such as konzo. Konzo is found mainly in rural areas of tropical regions and is associated with extreme poverty. It is characterized by irreversible spastic paraparesis with abrupt onset and exaggerated bilateral knee and ankle jerks.

Dioxins are mainly by-products of industrial processes, but they can also result from natural events, such as volcanic eruptions and forest fires. Humans are most commonly exposed by eating contaminated foods, such as meat, fish and dairy products. Short-term exposure to high levels of dioxins can result in skin lesions and altered liver function. Long-term exposure has been associated with impairment of the immune system, the developing nervous system, the endocrine system and reproductive function.

Peanut (*Arachis hypogaea*) allergy is a life-long disease related to the consumption of peanuts or their products. The onset of this disease manifests very early in life, before 18 years of age (median age, 5 years). Clinical signs of peanut allergy are usually very short-lived. They can affect various organs and systems, and the symptoms vary from mild (skin and subcutaneous involvement only) to moderate (respiratory, gastrointestinal and cardiovascular disorders) and severe (cyanosis, hypotension, confusion, collapse). Peanut allergy is one of the most common causes of severe food-induced anaphylaxis, which, on rare occasions, is fatal. In Europe, the prevalence of peanut allergy is 0.1–1.8%, depending on age and country of origin (43).

The chemical hazards considered by FERG were shown to have a substantial impact on the global burden of foodborne disease. In 2010, aflatoxin, dioxin and cassava cyanide caused more than 200 000 cases of illness, nearly 20 000 deaths and 1 million DALYs (7). In the WHO European Region, the greatest share of the disease burden due to chemicals is attributed to

dioxin, which was responsible for almost 13 000 DALYs and was therefore the sixth leading foodborne hazard for disease burden. The next greatest contributor to the burden of foodborne disease among chemical hazards is aflatoxin. Although the burden of peanut allergens was estimated only for European sub-region A, it was considerable.

Peanut allergens and dioxin were the main contributors to the burden of YLD, whereas aflatoxin and cassava cyanide contributed most to YLL. The difference is due to the higher fatality rates associated with aflatoxin and cassava cyanide poisoning; dioxin poisoning, although it affects more individuals, is associated with fewer deaths. Peanut-induced anaphylaxis may lead to death, but the burden of morbidity is particularly high, as affected individuals face a lifelong burden.

These findings draw attention to the substantial impact that these chemical hazards have on the global and regional burden of foodborne disease. More information is needed on this group of hazards; data gaps are a large obstacle to making estimates, yet the lack of reported information and cases is formidable.



DISCUSSION

The FERG report (7) provides the first global and regional estimates of foodborne disease incidence, mortality and disease burden in terms of DALYs and are the most comprehensive to date on the impact of contaminated food on health and well-being. The data provide a conservative perspective of the real burden of 31 selected food-associated bacteria, viruses, parasites, toxins and chemicals. It should be noted that the negative economic consequences of foodborne diseases on health-care systems, agriculture, food industries, trade and tourism are not captured by DALY estimates. Furthermore, antimicrobial resistance was not addressed in the FERG study, although resistance to antimicrobials is common in *Salmonella* spp. and *Campylobacter* spp. (3), adding to the health burden caused by these foodborne pathogens.

The estimates of foodborne disease in the European Region are the first of their kind, and they show that the overall burden of these diseases on health is substantial. Their importance, summarized in rankings of illness, death and DALYs by hazard, were found to differ widely. The main hazards for illness are those that cause diarrhoeal diseases. In the ranking of DALYs, only 3 of the 10 leading hazards are the causative agents of diarrhoeal diseases, but the distribution of hazards is very heterogeneous; half are bacteria, one is a chemical, two are parasites, and two are viruses. Interestingly, the hazards that contribute most to foodborne illness in the European Region are not necessarily ranked high in terms of foodborne deaths or DALYs. This discrepancy suggests that some diseases are recognizable from the large number of human cases and therefore attract more attention from public health authorities, while others are less common but cause a significant yet under-appreciated health burden in the population. Consideration of the severity and duration of the symptoms caused by hazards, as well as the case fatality ratio and age at death, shifts the perception of foodborne disease and the relative importance of the major causes.

Comparison of global and European Region rankings reveals major differences in the burden of foodborne disease. For instance, apart from non-typhoidal *Salmonella* spp., the 10 leading foodborne causes of DALYs in the European Region are hazards that are systematically ranked lower at global level. The burden in the European Region is dominated by invasive infectious diseases, while that at global level is dominated by diarrhoeal diseases. These findings highlight the importance and pertinence of estimates at regional and lower levels. Renewed effort is warranted to prevent and control invasive foodborne diseases, such as toxoplasmosis, listeriosis and brucellosis, and also dioxin poisoning in the Region.

The FERG report provides strikingly high estimates for the incidence and burden of toxoplasmosis in the European Region, which should be called to the attention of regional and national health and food safety authorities. Although the incidence and burden of toxoplasmosis rank close to those of diseases caused by *Salmonella* and *Campylobacter* spp., no measures are currently taken in the food chain to reduce the risk. In most countries, preventive measures are limited to communication to women of child-bearing age.

The FERG estimates show that, although the incidence of listeriosis is relatively low, it represents a considerable health burden in the European Region. Therefore, preventive measures in the food industry and awareness-raising among vulnerable population groups are required to reduce the risk.

The incidence of brucellosis and echinococcosis is in general low in the European Region, but these diseases still represent a major burden. These diseases are under-diagnosed in many countries due to the lack of availability of diagnostic tests and limited awareness of the diseases by health practitioners (44). Control of neglected zoonotic diseases has been hampered by

competing priorities, a low political profile, suspected under-reporting and recognition that the control of these diseases is complex. The factors that favour these diseases are often suboptimal sanitation, poverty and deficient health systems (45).

Assessment of the burden of diseases due to chemical hazards continues to be a challenge, and it is likely to be underestimated. As the health effects of some chemicals may be observed several years after exposure, assessments face methodological challenges. In addition, data are lacking, particularly from low- to middle-income countries, and understanding of the impact of these hazards in the food chain is limited. More information on the incidence and evidence of foodborne transmission, chronic sequelae and mortality due to chemical hazards would advance studies of the burden of foodborne disease.

Food allergy is a growing problem, estimated to affect 1–3% of adults and 4–6% of children worldwide. The prevalence of these illnesses is uncertain, even in developed countries, partly because of a scarcity of studies for some regions and the use of a variety of methods (43). Peanut allergy occurs early in life and is life-long, implying constant attention of allergic individuals to information about the ingredients of the foods they eat. The estimated burden of this hazard in sub-region A of the European Region was surprisingly high. Food control authorities recommend improved labelling of foods and explicit warnings to help consumers avoid common causes of adverse reactions.

Non-typhoidal *Salmonella* spp. are the greatest foodborne hazards in terms of health burden in the European Region. A generally decreasing trend in the number of reported cases of salmonellosis has been achieved in many countries of the European Union, owing partly to efficient control programmes in the animal and food industries and particularly poultry-raising (10). The FERG report reveals an interesting finding: even though non-typhoid *Salmonella* spp. are in third place in the ranking of hazards that cause illness in the European Region, they are the leading hazard in terms of foodborne DALYs. An overall reduction in the burden of foodborne salmonellosis will require maintenance of the decreasing trend in exposure to this hazard via the food chain.

The FERG estimates have some limitations because of missing data and under-reporting, particularly in low- to middle-income countries. In the absence of adequate information on exposure to chemical hazards, the FERG experts could estimate the burden represented by only four chemical contaminants. Further understanding of foodborne disease and of the proportion of the diseases that are foodborne is required to obtain more accurate estimates. Better understanding of the real burden of foodborne disease is important for evidence-based food safety policy- and decision-making. The DALY estimates illustrate the burden of foodborne disease in the European Region as they represent a comparison of the relative impact of different diseases on populations. This approach is relevant for prioritization in food safety management and for preparing target-specific policies on foodborne disease.

The FERG estimates provide a comprehensive source of information to encourage and guide countries in conducting their own studies on the burden of foodborne disease, and WHO has made available a tool for this purpose.¹ Such studies allow countries to analyse the burden of disease associated with food contamination and to describe the epidemiology of foodborne disease. Furthermore, they encourage use of evidence-based information in food safety policy- and decision-making, including setting priorities, and in risk communication and awareness-raising about food safety, ultimately preventing foodborne disease at both national and regional levels.

¹ https://extranet.who.int/sree/Reports?op=vs&path=/WHO_HQ_Reports/G36/PROD/EXT/FoodborneDiseaseBurden



CONCLUSIONS

The WHO estimates of the global burden of foodborne disease show a significant burden, globally as well as throughout Europe. In the European Region, millions of people fall ill and thousands die every year as a result of eating unsafe food. The estimates of foodborne disease in the Region are unique, and they show that the overall health burden is substantial. The global estimates show that, while the pattern of distribution of foodborne hazards and diseases varies widely among the WHO regions, *Salmonella* spp., *Campylobacter* spp., Norovirus and hepatitis A virus are important, common foodborne hazards. In the European Region, an emerging area of concern is the burden due to the foodborne parasites *T. gondii* and *E. multilocularis*, the bacterium *L. monocytogenes*, dioxins and peanut allergy. Despite progress made in tackling these diseases during past years, they represent a large but often unquantified burden. Food allergies are an increasing concern in the Region, representing a risk for public health.

The WHO initiative to estimate the global and regional burdens of foodborne disease was an important step for food safety. The FERG report represents a comprehensive source of information to better understand the situation of foodborne diseases, globally as well as in the different WHO regions. Furthermore, it provides encouragement and guidance to countries in conducting national studies of the burden of foodborne disease. The FERG estimates emphasize the importance of strengthened prevention, surveillance and management of foodborne disease in the European Region, including risk communication, awareness-raising and consumer education on food safety. For example, the unexpectedly high estimates of some foodborne hazards may increase awareness about certain neglected foodborne disease, such as toxoplasmosis. The FERG estimates encourage application of evidence-based food safety policy-making and decision-making, including setting priorities, at national and regional levels to protect consumers from foodborne risks and thereby ultimately decrease the burden of foodborne disease.

Addressing food safety challenges is the responsibility of all stakeholders along the food chain, from production to consumption. Effective, efficient prevention, surveillance and management of foodborne disease rely on intersectoral, interdisciplinary collaboration, cooperation and information-sharing at national, regional and international levels. Collaboration between governments, the food industry, academia and civil society is essential. All stakeholders should be made aware of food safety risks and how to prevent and reduce them, and risk communication, including education of consumers, is an essential part of the efforts to reduce the burden of foodborne disease.

WHO is committed to working with its Member States and partners to strengthen the prevention, surveillance and management of food safety risks, with the overall aim of lowering the burden of foodborne disease.



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ANNEX 1. Hazards included in the study

HAZARD		
DIARRHOEAL DISEASE AGENTS	Viruses	Norovirus
	Bacteria	<i>Campylobacter</i> spp., Enteropathogenic <i>Escherichia coli</i> , enterotoxigenic <i>E. coli</i> , Shiga-toxin producing <i>E. coli</i> , Non-typhoidal <i>Salmonella</i> spp., <i>Shigella</i> spp., <i>Vibrio cholerae</i>
	Protozoa	<i>Cryptosporidium</i> spp., <i>Entamoeba histolytica</i> , <i>Giardia</i> spp.
INVASIVE INFECTIOUS DISEASE AGENTS	Viruses	Hepatitis A virus
	Bacteria	<i>Brucella</i> spp., <i>Listeria monocytogenes</i> , <i>Mycobacterium bovis</i> , <i>Salmonella</i> Typhi, <i>S. Paratyphi</i>
	Protozoa	<i>Toxoplasma gondii</i>
HELMINTHS	Cestodes	<i>Echinococcus granulosus</i> , <i>E. multilocularis</i> , <i>Taenia solium</i>
	Nematodes	<i>Ascaris</i> spp., <i>Trichinella</i> spp.
	Trematodes	<i>Clonorchis sinensis</i> , <i>Fasciola</i> spp., <i>Opisthorchis</i> spp., <i>Paragonimus</i> spp., intestinal flukes
CHEMICALS AND TOXINS		Aflatoxins, cassava cyanide, dioxins

ANNEX 2.

Categorization of sub-regions in WHO regions

SUB-REGION	WHO MEMBER STATES
AFRICAN REGION D	Algeria, Angola, Benin, Burkina Faso, Cameroon, Cabo Verde, Chad, Comoros, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Madagascar, Mali, Mauritania, Mauritius, Niger, Nigeria, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Togo
AFRICAN REGION E	Botswana, Burundi, Central African Republic, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Eritrea, Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Uganda, United Republic of Tanzania, Zambia, Zimbabwe
REGION OF THE AMERICAS A	Canada, Cuba, United States of America
REGION OF THE AMERICAS B	Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, El Salvador, Grenada, Guyana, Honduras, Jamaica, Mexico, Panama, Paraguay, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela (Bolivarian Republic of)
REGION OF THE AMERICAS D	Bolivia (Plurinational State of), Ecuador, Guatemala, Haiti, Nicaragua, Peru
EASTERN MEDITERRANEAN REGION B	Bahrain, Iran (Islamic Republic of), Jordan, Kuwait, Lebanon, Libya, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, United Arab Emirates
EASTERN MEDITERRANEAN REGION D	Afghanistan, Djibouti, Egypt, Iraq, Morocco, Pakistan, Somalia, South Sudana ^a , Sudan, Yemen
EUROPEAN REGION A	Andorra, Austria, Belgium, Croatia, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, San Marino, Slovenia, Spain, Sweden, Switzerland, United Kingdom of Great Britain and Northern Ireland
EUROPEAN REGION B	Albania, Armenia, Azerbaijan, Bosnia and Herzegovina, Bulgaria, Georgia, Kyrgyzstan, Montenegro, Poland, Romania, Serbia, Slovakia, Tajikistan, The Former Yugoslav Republic of Macedonia, Turkey, Turkmenistan, Uzbekistan
EUROPEAN REGION C	Belarus, Estonia, Hungary, Kazakhstan, Latvia, Lithuania, Republic of Moldova, Russian Federation, Ukraine
SOUTH-EAST ASIA REGION B	Indonesia, Sri Lanka, Thailand
SOUTH-EAST ASIA REGION D	Bangladesh, Bhutan, Democratic People's Republic of Korea, India, Maldives, Myanmar, Nepal, Timor-Leste
WESTERN PACIFIC REGION A	Australia, Brunei Darussalam, Japan, New Zealand, Singapore
WESTERN PACIFIC REGION B	Cambodia, China, Cook Islands, Fiji, Kiribati, Lao People's Democratic Republic, Malaysia, Marshall Islands, Micronesia (Federated States of), Mongolia, Nauru, Niue, Palau, Papua New Guinea, Philippines, Republic of Korea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu, Viet Nam

^a South Sudan was assigned to the WHO African Region in May 2013. As this study covers only periods before that date, estimates for South Sudan were included in those for the WHO Eastern Mediterranean Region.

The subregions are defined on the basis of child and adult mortality as described by Ezzati et al. (7). Stratum A, very low child and adult mortality; stratum B, low child mortality and very low adult mortality; stratum C, low child mortality and high adult mortality; stratum D, high child and adult mortality; and stratum E, high child mortality and very high adult mortality. The term “sub-region” here and in the text does not refer to an official grouping of WHO Member States, and the “sub-regions” are not related to the six official WHO regions.

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