Chapter 7
The Global Burden of Foodborne Disease

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Abbreviations

DALY	Disability-adjusted life year
FBD	Foodborne diseases
FERG	Foodborne Disease Burden Epidemiology Reference Group
WHO	World Health Organization
YLD	Years lived with disability
YLL	Years of life lost

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7.1 Why Estimate the Global Burden of Foodborne Disease?

Foodborne diseases (FBD) present a constant threat to public health and a significant impediment to socioeconomic development worldwide. At the same time, food safety remains a marginalized policy objective, especially in developing countries. A major obstacle to adequately addressing food safety concerns is the lack of accurate data on the full extent, burden, and cost of FBD. Very few nations have assessed their FBD burden, and information on the global burden of FBD has long been lacking. Several reasons may explain this knowledge gap. Although the potential threat of FBD has long been recognized, epidemiological data on FBD remain scarce, particularly in the developing world. Foodborne outbreaks may go unrecognized if they are not connected to major public health or economic impact. Outbreaks are only the tip of the iceberg; many more infections occur sporadically and often remain unreported. Furthermore, the health effects of FBD are highly complex, reaching far beyond acute gastroenteritis. Indeed, FBD may be caused by numerous microbiological and chemical hazards and lead to a variety of health outcomes and effects on different time scales. Certain diseases that may result from chronic exposure to contaminated food, such as cancer and kidney or liver failure, have multiple causes, and the causal link is difficult to assess for individual cases. When taking a global perspective, the sheer complexity of the problem becomes even more challenging, as the path from food production to food consumption across the globe is highly diverse, and the range of potential contaminants in the food chain is astounding and varies according to food type. Finally, to add to the complexity, food is not the only transmission pathway of many food-related hazards, requiring a clear delineation and quantification of the main transmission routes of food-related hazards. Figure 7.1 shows the complexity of transmission pathways that may exist for a single hazard. It also illustrates the reservoir level and the exposure level as two distinct potential points of attribution, each of which may be relevant depending on where risk management is to be applied (Hald et al. 2016).

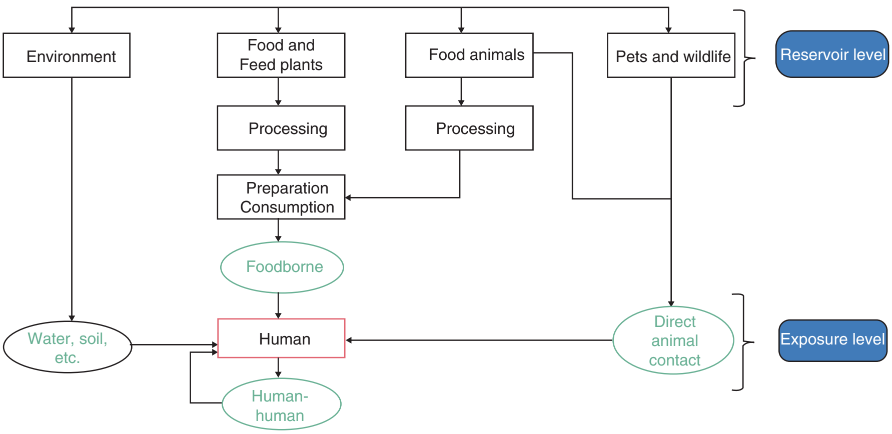

Fig. 7.1 Major transmission routes and points of attribution of human foodborne disease (Hald et al. 2016)

To address these gaps, the World Health Organization (WHO) launched an initiative in 2006 to estimate the global burden of FBD. This initiative was carried forward by the Foodborne Disease Burden Epidemiology Reference Group (FERG), an expert group convened by WHO in 2007. In addition to providing estimates of the global burden of FBD by age, sex, and region, FERG was also tasked with strengthening country capacity to assess FBD burden, encouraging the use of FBD burden estimates to set evidence-informed policies, and increasing awareness and commitment to implement food safety standards. In 2015, FERG published the first-ever estimates of the global and regional burden of FBD (Havelaar et al. 2015; WHO 2015a).

In this chapter, we describe the methodological framework developed by FERG for estimating the global burden of FBD and present the key findings at a global and regional level.

7.2 Methodological Framework for WHO Estimates of the Global Burden of Foodborne Disease

FERG established five task forces focusing on groups of hazards (chemical, enteric, parasitic) or aspects of the methodology (source attribution, computation). The work of task force members was augmented by additional support from external resource advisors. The computational task force was responsible for integrating the work of the other task forces on DALY inputs and implementing FERG's methodological framework to generate DALY estimates (Fig. 7.2). This framework was structured around five distinct components leading to estimates of the global burden of FBD for the year 2010, expressed as disability-adjusted life years (DALYs): disease models and epidemiological data, imputation model, disability weights, probabilistic burden assessment, and source attribution.

In a first step, the hazard-specific task forces commissioned systematic reviews and other studies to provide the baseline epidemiological data needed to calculate burden estimates. This was done for 31 foodborne hazards that were chosen by each task force from a comprehensive list of hazards, taking into account presumed significance for the global burden of FBD and data availability. These 31 hazards included 11 diarrheal disease agents, 7 invasive disease agents, 10 helminths, and 3 chemicals and toxins (Table 7.1). For five hazards, including four bacterial toxins and one allergen, the data were found insufficient to generate global estimates, and burden estimates were presented for high-income regions only.

The epidemiological data were used to define and parameterize so-called disease models or outcome trees. These are schematic representations of the health states that are causally associated with the specific hazard. As a result, the burden of a foodborne hazard could be defined and quantified as the burden resulting from all related health states, including acute illness, chronic sequelae, and death. Across all considered hazards, 75 distinct health states were identified, highlighting the diverse nature of the health impact of FBD (Table 7.1). Where needed, the disease

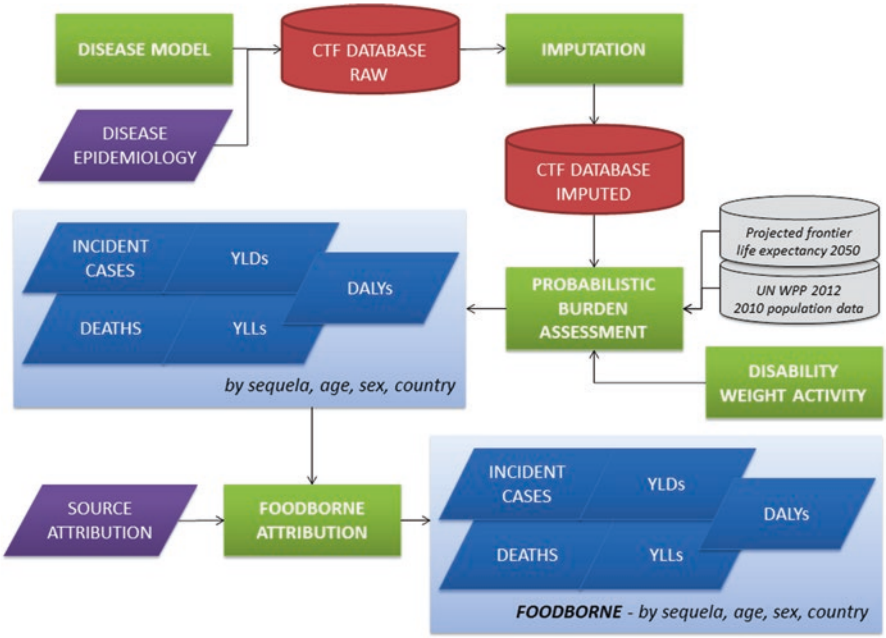

Fig. 7.2 Computational task force workflow (Devleesschauwer et al. 2015)

model further included an underestimation factor to correct the incidence data for underreporting and underascertainment (Gibbons et al. 2014). Finally, all retrieved information was compiled in a standardized spreadsheet database.

Even though all efforts were made to retrieve the best available epidemiological estimates, many data gaps remained, particularly for some of the world's most populous countries such as China, India, and Indonesia. FERG used statistical models to estimate these missing data from the available data and to quantify the associated uncertainties on a regional basis (Ezzati et al. 2002). Motivated by a strive for parsimony and transparency, a hierarchical Bayesian lognormal random effects model was adopted as the default model for imputing missing country-level incidence data (McDonald et al. 2015). After fitting this model to the available data, incidence values for countries with no data for a particular hazard were imputed based on the resulting posterior predictive distributions. For countries in a region where at least one of the other countries had data, the incidence was imputed as multiple random draws from a lognormal distribution reflecting a "random" country within the concerned region, with the uncertainty interval describing the variability within regions. For countries in a region where none of the countries had data, the incidence was imputed as multiple random draws from a lognormal distribution reflecting a "random" country within a "random" region, with the uncertainty interval describing the variability between and within regions. Of the 14 hazards to which

Table 7.1 Hazards and associated health states considered by the Foodborne Disease Burden Epidemiology Reference Group for quantifying the global burden of foodborne disease

Hazards	Health states
Diarrheal disease agents	
Viruses	
Norovirus	Diarrheal disease
Bacteria	
Campylobacter spp.	Diarrheal disease, Guillain-Barré syndrome
Enteropathogenic *E. coli*	Diarrheal disease
Enterotoxigenic *E. coli*	Diarrheal disease
Shiga toxin-producing *E. coli*	Diarrheal disease, hemolytic uremic syndrome, end-stage renal disease
Non-typhoidal *S. enterica*	Diarrheal disease, invasive salmonellosis
Shigella spp.	Diarrheal disease
Vibrio cholerae	Diarrheal disease
Protozoa	
Cryptosporidium spp.	Diarrheal disease
Entamoeba histolytica	Diarrheal disease
Giardia spp.	Diarrheal disease
Invasive infectious disease agents	
Viruses	
Hepatitis A virus	Hepatitis
Bacteria	
Brucella spp.	Acute brucellosis, chronic brucellosis, orchitis
Listeria monocytogenes	*Perinatal*: sepsis, central nervous system infection, neurological sequelae
	Acquired: sepsis, central nervous system infection, neurological sequelae
Mycobacterium bovis	Tuberculosis
Salmonella Paratyphi	Paratyphoid fever, liver abscesses, and cysts
Salmonella Typhi	Typhoid fever, liver abscesses, and cysts
Protozoa	
Toxoplasma gondii	*Congenital*: intracranial calcification, hydrocephalus, chorioretinitis early in life, chorioretinitis later in life, CNS abnormalities
	Acquired: chorioretinitis, acute illness, post-acute illness
Enteric intoxications	
Bacillus cereus[a]	Acute intoxication
Clostridium botulinum[a]	Moderate/mild botulism, severe botulism

(continued)

Table 7.1 (continued)

Hazards	Health states
Clostridium perfringens[a]	Acute intoxication
Staphylococcus aureus[a]	Acute intoxication
Helminths	
Cestodes	
Echinococcus granulosus	*Cases seeking treatment*: pulmonary cystic echinococcosis, hepatic cystic echinococcosis, central nervous system cystic echinococcosis
	Cases not seeking treatment: pulmonary cystic echinococcosis, hepatic cystic echinococcosis, central nervous system cystic echinococcosis
Echinococcus multilocularis	Alveolar echinococcosis
Taenia solium	Epilepsy, treated, seizure-free; epilepsy, treated, with recent seizures; epilepsy, severe; epilepsy, untreated
Nematodes	
Ascaris spp.	Ascariasis infestation, mild abdominopelvic problems due to ascariasis, severe wasting due to ascariasis
Trichinella spp.	Acute clinical trichinellosis
Trematodes	
Clonorchis sinensis	Abdominopelvic problems due to heavy clonorchiosis
Fasciola spp.	Abdominopelvic problems due to heavy fasciolosis
Intestinal flukes[b]	Abdominopelvic problems due to heavy intestinal fluke infections
Opisthorchis spp.	Abdominopelvic problems due to heavy opisthorchiasis
Paragonimus spp.	Central nervous system problems due to heavy paragonimiasis, pulmonary problems due to heavy paragonimiasis
Chemicals and toxins	
Aflatoxin	Hepatocellular carcinoma, diagnosis and primary therapy; hepatocellular carcinoma, metastatic; hepatocellular carcinoma, terminal phase with medication; hepatocellular carcinoma, terminal phase without medication
Cyanide in cassava	Konzo
Dioxin	Hypothyroid due to prenatal exposure, hypothyroid due postnatal exposure, male infertility
Peanut allergens[a]	Living with peanut-induced allergy

Adapted from Havelaar et al. (2015)

[a]Excluded from global burden assessments

[b]Includes *Echinostoma* spp., *Fasciolopsis buski*, *Heterophyes* spp., *Metagonimus* spp., and other foodborne intestinal trematode species (depending on data availability)

the random effects imputation model was applied, the Southeast Asian and Latin American regions were the ones for which most often no data could be identified. At a country level, at least one hazard had to be imputed for each country, while Cambodia had the highest number of data gaps, i.e., ten hazards with no data (Devleesschauwer et al. 2015). Figure 7.3 plots the number of data gaps per country.

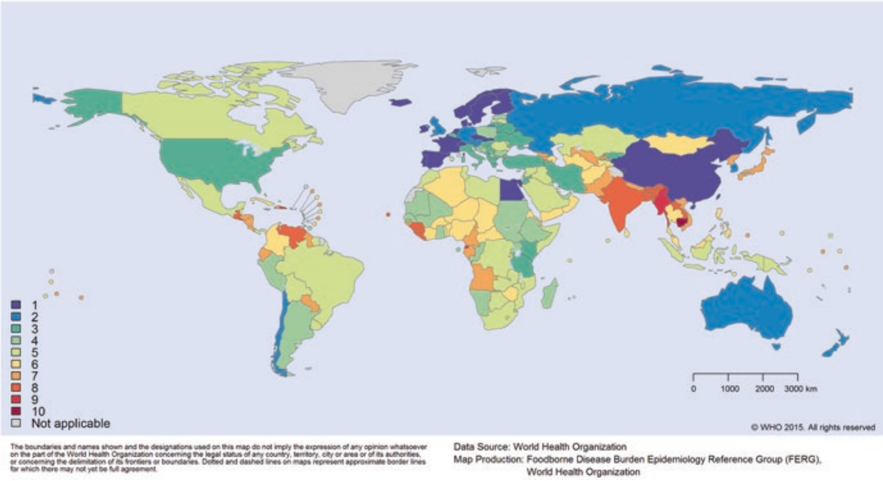

Fig. 7.3 Number of hazards requiring imputation per country (Devleesschauwer et al. 2015)

In a next step, the retrieved and imputed epidemiological data were translated into DALYs. DALYs combine years lived with disability (YLD) and years of life lost (YLL) due to premature mortality into a single estimate of healthy life-years lost. FERG used an incidence perspective for calculating YLDs, which defines YLDs as the product of the number of incident cases and the duration and severity of the health state. The estimates thus reflect the future health losses due to foodborne infections acquired in 2010. Compared to a prevalence perspective, which is for instance used in the recent iterations of the Global Burden of Disease study (2016), the incidence perspective was deemed to be more sensitive to current epidemiological trends and more consistent with the estimation of YLLs. To quantify the severity of health states, FERG adopted the disability weights used in the WHO Global Health Estimates. These, in turn, were largely based on the disability weights developed for the Global Burden of Disease 2010 study, which were based on population health equivalence and pairwise comparison surveys conducted face to face in Bangladesh, Indonesia, Peru, and Tanzania, telephone-based in the United States, and an open access web-based survey (Salomon et al. 2012). To estimate the YLLs due to premature mortality, FERG used as residual life expectancy table the highest United Nations projected life expectancy for 2050, with a life expectancy at birth of 92 years for both sexes. In line with current practice, age weighting and time discounting were not applied.

Many foodborne hazards are not exclusively transmitted by food; therefore, a separate effort was set up for the attribution of exposure to different sources, including food, the environment, and direct contact between humans or with animals. As many data are lacking for attribution, it was decided to apply structured expert elicitation to provide a consistent set of estimates. The global expert elicitation study involved 73 experts and 11 elicitors and was one of the largest, if not the largest study, of this kind ever undertaken (Hald et al. 2016). Due to the study constraints (remote elicitation instead of face-to-face meetings), individual experts' accuracies, elicited based on calibration questions, were generally lower than in other structured expert judgment studies. However, performance-based weighting, a key characteristic of Cooke's classical model, increased informativeness while retaining accuracy at acceptable levels (Aspinall et al. 2016).

All calculations were performed in a probabilistic framework, in which parameter, imputation and attribution uncertainties were propagated to the final foodborne DALY estimates by Monte Carlo simulation. The resulting uncertainty distributions were summarized by their median and 95% uncertainty interval. Estimates were presented per hazard, outcome, and age group (< or ≥5 years). Due to the limitations in data availability, FERG decided to present its estimates on a regional level only, even though all calculations were performed on a national level. The regional estimates are considered more robust as they build on data from several countries in most regions. It should however be noted that the regional estimates do not reflect the diversity of risks between countries in a region, or even within a country.

7.3 Global Estimates and Regional Comparisons of the Global Burden of Foodborne Disease

FERG estimated that in 2010, the 31 considered hazards caused 600 million foodborne illnesses, implying that roughly one out of every 10 people in the world would suffer from FBD annually. These illnesses were estimated to lead to 420,000 deaths and 33 million DALYs, making the global burden of FBD comparable to those of the major infectious diseases, HIV/AIDS, malaria, and tuberculosis (WHO 2015b) and comparable to certain other risk factors such as dietary risk factors, unimproved water and sanitation, and air pollution (GBD 2015 DALYs and HALE Collaborators 2016). Diarrheal disease agents accounted for more than 90% of all foodborne illnesses, but just over half of all foodborne deaths and DALYs – reflecting the fact that many diarrheal episodes are relatively benign (Table 7.2).

Table 7.2 Global burden of foodborne disease, 2010, by broad hazard groups

Hazard group	Foodborne illnesses (millions)	Foodborne deaths (thousands)	Foodborne disability-adjusted life years (millions)
All	600	420	33
Diarrheal disease agents	549	230	18
Invasive infectious disease agents	36	117	8
Helminths	13	45	6
Chemicals	0.2	19	0.9

Adapted from Havelaar et al. (2015)

Table 7.3 Major foodborne hazards contributing to the global burden of foodborne disease

#	Hazard	Estimate
Foodborne illnesses		
1	Norovirus	124,803,946
2	*Campylobacter* spp.	95,613,970
3	ETEC	86,502,735
4	NTS	78,707,591
5	*Shigella* spp.	51,014,050
6	*Giardia* spp.	28,236,123
7	*Entamoeba histolytica*	28,023,571
8	EPEC	23,797,284
9	Hepatitis A virus	13,709,836
10	*Ascaris* spp.	12,280,767
Foodborne deaths		
1	NTS	59,153
2	*Salmonella Typhi*	52,472
3	EPEC	37,077
4	Norovirus	34,929
5	*Taenia solium*	28,114
6	Hepatitis A virus	27,731
7	ETEC	26,170
8	*Vibrio cholerae*	24,649
9	*Campylobacter* spp.	21,374
10	Aflatoxin	19,455
Foodborne disability-adjusted life years		
1	NTS	4,067,929
2	*Salmonella Typhi*	3,720,565
3	EPEC	2,938,407
4	*Taenia solium*	2,788,426
5	Norovirus	2,496,078
6	*Campylobacter* spp.	2,141,926
7	ETEC	2,084,229
8	*Vibrio cholerae*	1,722,312
9	Hepatitis A virus	1,353,767
10	*Shigella* spp.	1,237,103

Adapted from Havelaar et al. (2015)
NTS non-typhoidal *Salmonella enterica*, *EPEC* enteropathogenic *Escherichia coli*, *ETEC* enterotoxigenic *Escherichia coli*

Table 7.3 shows the ten major foodborne hazards contributing to the global foodborne illnesses, deaths, and DALYs. The majority of foodborne illnesses were caused by norovirus and other diarrheal disease agents, while non-typhoidal *Salmonella enterica* was the major cause of foodborne deaths and DALYs. The three included chemicals and toxins resulted in nearly 1 million foodborne DALYs, a non-negligible share of the overall FBD burden. However, as there are many more

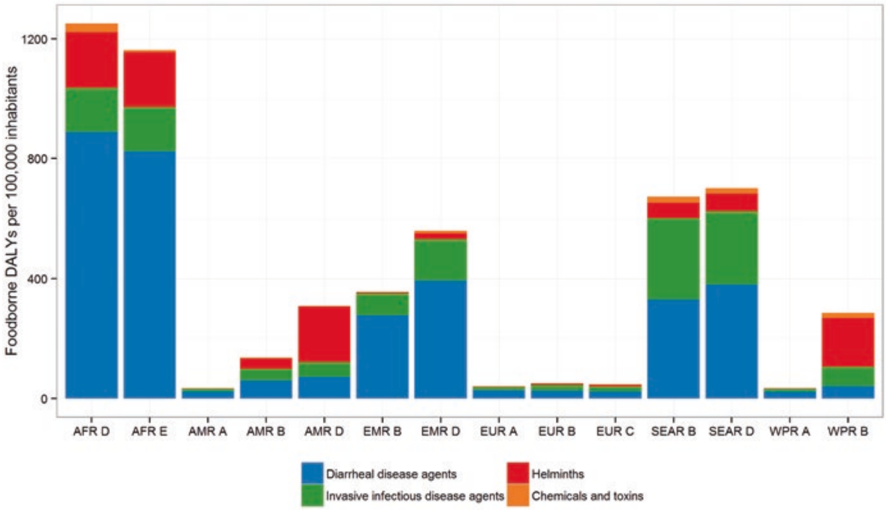

Fig. 7.4 Foodborne disability-adjusted life years (DALYs) by region, 2010 (Havelaar et al. 2015). *AFR* African Region, *AMR* Region of the Americas, *EMR* Eastern Mediterranean Region, *EUR* European Region, *SEAR* Southeast Asian Region, *WPR* Western Pacific Region; Strata A–E further subdivide the regions from low to high child and adult mortality, as documented by Ezzati et al. (2002)

chemical food contaminants beyond those included, the true disease burden of chemical foodborne hazards is expected to be considerably larger.

Figure 7.4 shows the estimated DALY rates per 100,000 person-years for the 14 considered regions, with a breakdown by four broad hazard groups, i.e., diarrheal disease agents, invasive infectious disease agents, helminths, and chemicals and toxins. There were considerable variations in disease burden across regions, confirming the close link between FBD and development. Indeed, while making up 41% of the world population, individuals living in low-income regions suffered from 53% of all foodborne illnesses, succumbed to 75% of all foodborne deaths, and bore 72% of the global foodborne DALYs. Specifically, the African regions were most affected (more than 1000 foodborne DALYs per 100,000 person-years), followed by the Southeast Asian regions (700 foodborne DALYs per 100,000 person-years). The European regions and the high-income American and Western Pacific regions on the other hand had the lowest foodborne disease burden, with 30–50 foodborne DALYs per 100,000 person-years. High-income countries have been largely successful in controlling foodborne deaths, partly by reducing exposure to hazards with high case-fatality rates but also because of better healthcare systems, leading to, e.g., much lower case-fatality rates for diarrheal disease. In contrast with these accomplishments, high-income countries have been less successful in controlling the incidence of FBD, which is only three- to four-folds lower than the global average (Table 7.4).

The pattern of contributing hazards also showed marked differences across regions. Bacterial agents were the dominant pathogens in most regions, i.e., non-typhoidal *S. enterica* in the African and European regions, *Salmonella Typhi* in

Table 7.4 Burden of foodborne disease in high-income regions, 2010

Metric (per 100,000)	Global average	AMR A (North America)	EUR A (Western Europe)	WPR A (Australia, New Zealand, Japan)
Incidence	8729	2577	2431	2798
Deaths	6	0.4	0.5	0.4
DALYs	477	35	41	36

Adapted from Havelaar et al. (2015)

Southeast Asian regions, and *Campylobacter* spp. in the eastern Mediterranean regions and the high-income American and Western Pacific regions. Parasites were the dominant pathogens in the remaining regions, i.e., the pork tapeworm (*Taenia solium*) in the middle- and low-income American regions and the lung fluke (*Paragonimus* spp.) in the middle-income Western Pacific region. Peanut allergy was a significant contributor to the foodborne disease burden in high-income regions, but data limitations did not allow generating estimates for other regions. Despite these differences, diseases caused by non-typhoidal *S. enterica*, *Campylobacter* spp., and *Toxoplasma gondii* were found to be a public health concern across the world.

Infants and young children are at particular risk of contracting and dying from common food-related diseases due to their immature immune system and their lack of protective immunity due to few past exposures. Even though children under the age of 5 make up only 9% of the world population, FERG estimated that they suffered from 38% of all foodborne illnesses, succumbed to 30% of all foodborne deaths, and bore 40% of global foodborne DALYs. The important contribution of children to the burden of FBD explains for a large part the relatively high burden of FBD in the African and Southeast Asian regions. Furthermore, at a global level, pre- and perinatal infections accounted for 21% of the burden of *Listeria monocytogenes* and for 32% of the burden of *Toxoplasma gondii*.

7.4 Discussion

The FERG estimates provide the first-ever comprehensive picture of the substantial global burden of FBD and address the lack of data to support food safety policy making. The estimates highlight significant differences between low- and high-income regions, suggesting that FBD are largely preventable by currently available methods. The WHO works with governments and stakeholders to implement effective food safety systems, which require preventive, risk-based and enabling methods, instead of reactive and repressive ones. These systems need to be complemented by effective laboratory-based surveillance networks at country, regional, and global levels, in order to monitor progress and detect emerging risks. In resource-poor settings, however, implementation of effective food safety systems may not receive sufficient priority. There is therefore an urgent need to develop cost-effective food

Fig. 7.5 World Health Organization's Five Keys to Safer Food (http://www.who.int/foodsafety/areas_work/food-hygiene/5keys/en/)

hygiene interventions that can be implemented in such settings. High-income countries need to continue investing in food safety in order to maintain the current safety levels. Hazards that remain of importance in these countries, such as *Salmonella*, *Campylobacter*, and *Toxoplasma*, require novel control methods.

In addition to governments and food industries, consumers also play an important role in preventing FBD. The WHO calls on consumers and food handlers to handle and prepare food safely, following the "Five Keys to Safer Food," i.e., keep clean, separate raw and cooked, cook thoroughly, keep at safe temperatures, and use safe water and raw materials (Fig. 7.5).

Even though the current FERG estimates show that the global burden of FBD is considerable, the true FBD burden is expected to be even higher. Due to data limitations and limited resources, only 31 foodborne hazards could be included. The included microbiological hazards were the ones that were a priori deemed to contribute most to the global burden and for which sufficient global data were available. A systematic review of the incidence of diarrheal illness commissioned by FERG was only able to attribute half of the incidence to the diarrheal disease agents included (Pires et al. 2015). A significant proportion of the unattributed incidence is likely to be due to foodborne pathogens, and so it is evident that the total foodborne burden including these remaining and unknown etiologies will be considerably higher.

Estimation of the burden of foodborne disease from chemical hazards presents specific challenges, particularly due to the lack of well-established methods for attributing disease incidence to chemical exposures. Due to model uncertainties (such as observed discrepancies between multiplicative and additive models) and a lack of data, global estimates could be generated for only three chemical hazards (aflatoxin, cassava cyanide, and dioxins) and for only few associated health states (liver cancer, konzo, hypothyroidism, and infertility, respectively)—despite the vast spectrum of chemical food contaminants. Indeed, heavy metals such as cadmium, lead, and methyl mercury are known risk factors for various metabolic disorders, while arsenic is associated with several cancers. Various food allergens and fish toxins may cause potentially fatal acute intoxications. Estimates of the burden for these chemicals would provide a much more comprehensive understanding of the impact that chemicals in the food supply have on the burden of disease (Gibb et al. 2015).

Further underestimation of the global burden of FBD resulted from the fact that not all endpoints could be considered for the included hazards, e.g., malnutrition and stunting due to diarrheal agents, post-infectious irritable bowel syndrome due to non-typhoidal *S. enterica*, and psychiatric consequences of *Toxoplasma gondii* infection. Finally, for non-typhoidal *S. enterica*, infections among the HIV-associated cases were excluded, even though non-typhoidal *S. enterica* infections in HIV positives are preventable by food safety interventions.

Data availability and data quality issues were encountered for all hazards across all regions, but particularly in low-income countries. To address these issues, there was a need for imputation and expert judgment, often resulting in large uncertainty intervals. Documenting these gaps and uncertainties would hopefully serve as an impetus for countries to conduct new epidemiological studies and to undertake national FBD studies, thereby adding to the evidence base that is required to generate an even better picture of the global burden of FBD. To support this goal and help countries develop capacity for national FBD studies, a sixth Country Studies Task Force was established by FERG (Lake et al. 2015). This task force developed a suite of tools to assist with the development of DALY estimates and conducted four pilot studies in individual countries. The availability of the FERG regional estimates provides an opportunity to address many of the data gaps faced by individual countries in developing national estimates. Currently the tools are being updated to incorporate the FERG results, and it is hoped that this resource will stimulate additional studies by individual countries.

The FERG methodological framework is to date the most comprehensive effort for generating comparable estimates of the global burden of FBD, but has some key limitations. First, the results were only presented at a regional level, even though

FBD burden may vary significantly between countries and even within countries. Second, the available data did not allow for modeling time trends in FBD burden. Third, comorbidities were not systematically taken into account, except for the possible associations between HIV and invasive salmonellosis or tuberculosis. Finally, the framework does not explicitly address the financial burden of FBD, but merely focuses on the intangible costs of illness and premature mortality expressed as DALYs. Although disease burden data for populations could be translated into economic metrics, additional financial costs related to illness such as healthcare costs, patient costs, and costs to other sectors, and particularly the value of lost production due to illness, are not included (e.g., Mangen et al. 2015; Scharff 2015), nor are the potentially substantial outbreak investigation and control costs that occur in the case of a community-acquired (food-related) outbreak (Suijkerbuijk et al. 2016). Nonetheless, FERG acknowledges that estimates of the economic burden of foodborne disease could have greater impact with those responsible for setting policy. It should be noted, however that, by providing regional estimates of the incidence of the multitude of health outcomes from foodborne disease, FERG has addressed one of the fundamental inputs into developing cost-of-illness estimates.

7.5 Conclusion

The global burden of FBD is considerable and of the same order as the major infectious diseases such as HIV/AIDS, malaria, and tuberculosis. It is also comparable to certain other risk factors such as dietary risk factors, unimproved water and sanitation, and air pollution. FBD affect everyone, but particularly children under the age of 5 and persons living in low-income regions of the world. Although reported data underestimate the true FBD burden and not all foodborne hazards have been included, the FERG estimates may be used by national and international stakeholders to support evidence-based priorities and contribute to improvements in food safety and population health.

FERG generated the first global and regional estimates of the burden of FBD, demonstrating that the global burden of FBD is considerable and of the same order as the major infectious diseases such as HIV/AIDS, malaria, and tuberculosis. It is also comparable to certain other risk factors such as dietary risk factors, unimproved water and sanitation, and air pollution. FBD affect individuals of all ages, but show a disproportionately high burden in children under the age of 5. Furthermore, a disproportionately high burden was established for the low-income regions of the world and for the African and Southeast Asian regions in particular. Although some hazards, such as non-typhoidal *Salmonella enterica*, *Campylobacter* spp., and *Toxoplasma gondii*, were found to be important causes of FBD in all regions of the world, others, such as *Salmonella Typhi*, *Taenia solium*, and *Paragonimus* spp., were of highly focal nature, resulting in high local burden and calling for context-specific policies.

By using these estimates to support evidence-based priorities, all stakeholders, both at national and international levels, can contribute to improvements in food safety and population health.

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