Foodborne Diseases

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Abstract

The category of foodborne diseases (FBDs) includes all diseases whose causative agent, often of zoonotic origin, may be carried—although not exclusively—by food. This chapter will focus only on biological agents, responsible for approximately 600 million FBDs cases yearly. Globally, a disease burden of >33 million DALYs was calculated based on a selection of 11 agents causing diarrhoea, 8 agents responsible for invasive forms and 10 helminths. Over 80% of the burden is attributable to bacteria. The median DALYs rates are particularly high in three WHO regions, AFR, SEAR and EMR, where the occurrence of FBDs is strongly influenced by poverty and lack of essential sanitation facilities (drinking water supply and adequate sewage disposal). Several targets included in the SDGs 2015–2030 call for interventions to reduce the enormous global health impact of FBDs, for which the set goal is control and not elimination.

Keywords

Foodborne diseases (FBDs) · Biological agents · Diarrheal disease or diarrhoea · Invasive diseases · Helminths

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23.1 Definition

According to the WHO, a foodborne disease (FBD) is simply defined as 'a disease commonly transmitted through ingested food'. However, this is a very complex topic that also closely intersects with waterborne diseases and is of great interest for global health. The over 200 FBDs of various aetiologies have a significant impact on the morbidity and mortality worldwide and on the health systems and socio-economic development of different countries [1]. This chapter will only focus on biological agents, excluding other causative agents (e.g., chemical or physical agents).

23.2 Descriptive Epidemiology and Global Burden Assessment

The epidemiology of FBDs is influenced by the broad spectrum of agents involved, the great variety of clinical manifestations (from asymptomatic to life-threatening), their burden in the general population and in at-risk groups, and transmission pathways. For many foodborne pathogens, also transmission through water, soil, air, direct contacts between people, and between people and animals may be involved.

Data obtained from passive surveillance systems generally only represent the tip of the iceberg. For a FBD case to be diagnosed and reported to health authorities, after the consumption of

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contaminated food, a series of conditions must be met, and this causes an underestimation (underdiagnosis and/or underreporting) of the number of cases. Underestimations vary considerably in relation to the type of disease and the sensitivity of the surveillance systems of the various countries. The need for more reliable estimates of global FBDs burden was highlighted in 2007 by the WHO, which established the Foodborne Disease Burden Epidemiology Reference Group (FERG) [1]. The FERG has estimated the global, regional and sub-regional burden for 11 diarrhoeal disease agents (1 virus, 7 bacteria, 3 protozoa), 8 invasive infectious disease agents (1 virus, 6 bacteria and 1 protozoon), 10 helminths (3 cestodes, 2 nematodes and 5 trematodes) and 3 chemicals (Table 23.1 and Box 23.1). Of all biological agents, only 10 are exclusively transmitted via food vehicles. The proportion of cases attributable to transmission via food is approximately 29% for the group of diarrhoeal diseases, 34% for invasive diseases, and 45%, 72% and 100% for the helminthic FBDs caused by nematodes, cestodes and trematodes, respectively [2–4].

It was estimated that 600 million FBD cases occurred globally in 2010, with a high proportion (92%) being diarrhoeal diseases. The total global burden of FBD is estimated to 33 million DALYs (Disability Adjusted Life Years), but—given the high frequency of cases among children under 5 years of age—almost 83% of this number is given by the YLLs (*Years of Life Lost*), while DALYs (*Disability Adjusted Life Years*) represent only 17% of the total burden [2]. FBDs distribution is non-homogeneous among the six WHO regions, with a higher burden in AFR, SEAR and EMR (Fig. 23.1).

Box 23.1 Global Burden of Foodborne Illnesses Estimates: Key Points from Table 23.1

Above all, what emerges is the burden of bacterial agents, which account for 64% of cases and over 80% for both mortality and Disability Adjusted Life Years (especially EPEC among diarrhoeal forms and *S. Typhi* among invasive diseases).

Although invasive forms and helminthiasis account for only 6% and 2% of total FBD cases, respectively, their burden in terms of mortality (30% and 12%) and DALYs (26% and 18%) is considerably higher than that of viral diseases.

Among viral agents, while Noroviruses are relevant as the number of cases in the group of diarrhoeal diseases (almost 125,000 cases corresponding to more than 20% of illnesses), the hepatitis viruses are relevant among invasive diseases (about 13,700 cases, almost 40%).

Table 23.1 Global burden of foodborne illnesses, deaths and disability adjusted life: % of the total of the group (diarrheal illness, invasive diseases, helminthiasis) with the exception of the % of the subtotals indicated with[a]. The highest percentage values are indicated in bold. (Adapted from references [2–4])

	foodborne hazard	proportion foodborne %	foodborne illnesses	foodborne deaths	foodborne DALYs
diarrheal diseases	**Viruses**		22,8%	15,2%	14,1%
	Norovirus	18	**22,7%**	15,2%	14,1%
	Bacteria		63,7%	81,4%	82,1%
	Campylobacter spp	58	17,4%	9,3%	12,1%
	Enteropathogenic E. coli– EPEC	30	4,3%	**16,1%**	**16,6%**
	Enterotoxigenic E. coli-ETEC	36	15,8%	11,4%	11,8%
	Shiga toxin-producing E. coli-STEC	48	0,2%	0,1%	0,1%
	Non-typhoidal S. enterica (NtS)^	52	14,3%	12,5%	12,4%
	Shigella spp	27	9,3%	6,6%	7,0%
	Vibrio cholera	24	0,1%	10,7%	9,8%
	Protozoa		12,2%	2,4%	2,8%
	Cryptosporidium spp	13	1,6%	1,6%	1,7%
	Entamoeba histolytica	28	5,1%	0,6%	0,8%
	Giardia spp	15	5,1%	0,0%	0,1%
invasive diseases	**Viruses**		38,3%	23,7%	16,8%
	Virus hepatitis A	30	**38,3%**	23,7%	16, 8%
	Bacteria		28,9%	72,7%	70,6%
	Brucella spp.	47	1,1%	1,7%	1,5%
	Listeria monocytogenes	100	0,0%	2,7%	1,5%
	Mycobacterium bovis	100	0,3%	9,0%	7,5%
	Salmonella Typhi	37	21,2%	**44,8%**	**46,1%**
	Salmonella Paratyphi A	37	4,9%	10,3%	10,6%
	Salmonella enterica iNtS^	48	0,8%	25,1%	22,2%
	Protozoa		28,7%	0,6%	10,3%
	Toxoplasma gondii	49	28,7%	0,6%	10,3%
Helminths	**Cestodes**		3,3%	80,7%	54,4%
	Echinicoccus granulosus	21	0,3%	1,1%	0,7%
	Echinicoccus multilocularis	48	0,1%	17,2%	5,4%
	Taenia solium	100	2,9%	**62,2%**	**48,0%**
	Nematodes		95,0%	2,2%	10,4%
	Ascaris lumbricoides	46	**95,0%**	2,2%	10,4%
	Trichinella spp.	100	<0,1%	<0,1%	<0,1%
	Trematodes		1,7%	16,7%	34,8%
	Clonorchis sinensis	100	0,2%	12,8%	9,0%
	Fasciola spp.	100	0,1%	0,0%	1,5%
	Intestinal flukes°	100	0,1%	0,0%	2,7%
	Opistorchis spp,	100	0,1%	3,3%	3,2%
	Paragonimus spp.	100	1,1%	0,6%	18,1%
Subtotal	**Diarrheal disease agents***		**91,8%**	**58,6%**	**56,0%**
	Invasive diseases or Invasive infections*		**6,0%**	**29,9%**	**25,6%**
	Helminths*		**2,2%**	**11,5%**	**18,4%**

^ non typhoidal Salmonella serotypes are agents of both diarrheal (NtS) and invasive diseases (iNtS)

°*intestinal flukes* included diseases caused by several species of Trematodes

*For the subtotal of the three diseases groups the % are calculated on the total of the 31 hazards (597.294.786 foodborne illnesses, 392.560 foodborne deaths, 31.535.396 foodborne DALYS)

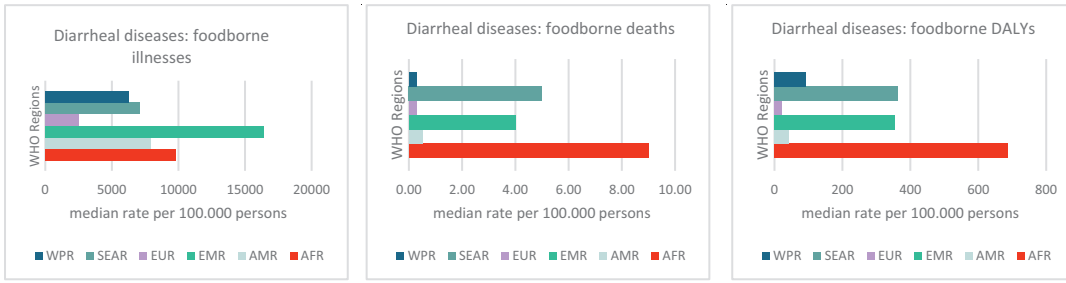

Fig. 23.1 Foodborne diarrheal illnesses: median rates Disability Adjusted Life Years (DALYs) per 100,000 population, by region. (Adapted from reference [3])

23.3 International Targets

The importance of the prevention and control of FBDs for global health was recognised by the WHO as early as 2000 (WHA53.15) [5]. Nowadays, among the 169 targets included in the 17 Sustainable Development Goals (SDGs, 2016–2030, available at https://www.globalgoals.org/goals/), many are interconnected with food- and waterborne diseases. In fact, FBDs are considered 'multifactorial', being widely influenced by (1) poverty and malnutrition, especially in children from low- and middle-income countries; (2) levels of food security and food safety; (3) accessibility to primary care and availability of health service resources; and (4) presence of sanitation infrastructure (drinking water supply, sewage disposal). Reducing FBDs burden involves different targets included in the SDGs and requires the commitment of different international players (WHO, United Nations, FAO).

Since globalisation has made food safety a concern also for middle- and high-income countries, an International Food Safety Authority (INFOSAN) was established on the initiative of the WHO and the FAO, to deal with food-related epidemic emergencies.

23.4 Determinants and Risk Factors

The occurrence of FBDs is influenced by host and external factors. Host factors consist of (1) age (people aged <5 and >65 years are the most at-risk); (2) nutritional deficiencies and eating habits, (3) underlying diseases, (4) immunodepression (primary or secondary), and (5) concomitant therapies [6]. Environmental risk factors vary in relation to the natural habitat/reservoir of the agents involved (environmental, animal, or human source), transmission routes, and food chain characteristics. The spread of FBDs in lower income countries is mainly influenced by food and water quality, given the high risk of faecal contamination of food due to the difficulties to access potable water and the lack of hygiene services. In higher income countries, global trade (long food chain and large-scale distribution) and the frequency of travel are more important. Additionally, climatic (e.g., temperature, humidity, natural events such as floods) and sociodemographic (e.g., migration, inequalities, vulnerable population groups, precariousness of health services) factors play a key role in FBDs occurrence [5, 7, 8].

23.5 FBD Control Challenges

Elimination and/or eradication can be hypothesised only for diseases with an exclusive human reservoir or strictly referable to a faecal-oral circuit (e.g., typhoid fever, hepatitis A). Otherwise, zoonotic diseases (e.g., salmonellosis) are controllable, but not eliminable, by multiple approaches along the food chain (from farm to fork) and public health interventions. The former includes control activities on primary production (e.g., hygiene on farms, slaughtering, and plant

supply chain) and on the subsequent stages of food processing, to reduce the risk of contamination as well as the survival and multiplication of pathogens in food (e.g., self-control, Hazard Analysis Critical Control Point—HACCP). Today, the food safety approach is based on risk assessment, risk management and risk communication, which involve producers, stakeholders and consumers, and must consider the presence of vulnerable groups in the populations [6, 9]. Surveillance based on national and international networks is one of the fundamental public health activities and was already the focus of WHO's attention in the early 2000s (Resolution WHO Assembly, May 2000). The purposes of surveillance are to: (1) identify causative agents (also through metagenomics); (2) describe characteristics of cases ('who-where-when'); (3) recognise clusters of cases and conduct epidemiological investigation on outbreaks and epidemics; and (4) implement measures necessary to interrupt transmission chains (e.g., alerts, withdrawal of contaminated foods recognised) [9–11].

Given the characteristics of FBDs, it is preferable to base their control on a combination of 'non-specific' measures rather than on immunoprophylaxis, which can help to control only a small number of FBDs (e.g., typhoid fever, hepatitis A, cholera, rotavirus). Vaccines for other etiological agents (including parasites) are under development [12]. The sometimes-secondary role that immunoprophylaxis can have for FBDs control is exemplified by the case of cholera, whose elimination in many countries is primarily attributable to the interruption of the faecal-oral transmission chain thanks to environmental sanitation measures. Overall, the control (but not the elimination) of FBDs is based on a 'One Health' approach and involves multiple activities concerning animal reservoir, environment, food chains and employing public health measures.

23.5.1 Cost-Effectiveness

FBDs are also complex to assess in terms of associated costs. Besides direct costs (diagnosis, treatment and care of the individual case) and indirect costs (absence from work, loss of productivity), there are also costs for the society and businesses. Costs for surveillance activities, outbreak investigations, control over supply chains and for food withdrawals must be considered. Unfortunately, available data (mostly from high-income countries) are not easily comparable. In the United States, a recent analysis estimated yearly costs of USD10-83 billion [13, 14].

23.6 Responsibilities

In the 'One Health' perspective, many national and international institutions are involved. All processes that from primary production, through processing and distribution phases, reach the final consumer must be managed. Nowadays, the consumer may have access to food produced elsewhere, which may have been contaminated during any phase 'from farm to fork'. To improve safety, quality and equality of international food trade, the FAO and the WHO established in 1963 a Commission to draft a *Codex Alimentarius* that collects and updates internationally standardised good practice guidelines [15]. Of particular importance are the Codex Principles and Guidelines for National Food Control Systems (CAC/GL 82-2013). A Food Control System—defined as 'the integration of regulatory activities across all responsible competent authorities to achieve the key objectives of food control, including preventive and educational strategies that protect the whole food chain'—should be evaluated with respect to the objectives of the system, control programme effectiveness, and legislative and regulatory requirements, to allow further improvements and favour the interest of all players along the whole food production chain, including the final consumer [15].

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