



National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

Public health burden of exposure to microbes and parasites originating from pigs

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22 June 2011



Key pathogens related to pigs and pork

- *Salmonella* spp. (non-typhoidal)
 - *Yersinia enterocolitica*
 - Meticillin-resistant *Staphylococcus aureus* (MRSA)
 - *Toxoplasma gondii*
 - *Trichinella* spp.
 - *Taenia solium*
 - Hepatitis- E virus
-
- Very different with respect to reservoirs, transmission routes!!
 - Very different with respect to health outcomes in humans!!
 - How to assess the public health burden in a transparent way?



Estimating the burden of zoonotic diseases

- Epidemiology
 - Incidence of primary disease
 - Sequelae
 - Mortality
- Valuation: Disability Adjusted Life Years
 - Disability weights
 - Duration / life tables
 - Discounting / age weighting
- Attribution

3

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Studies on the burden of foodborne pathogens (1)

- The Netherlands: priority setting of foodborne pathogens
- WHO: Foodborne Disease Burden Epidemiology Reference Group (FERG)
 - To provide epidemiological estimates on the global burden of all relevant foodborne diseases (according to age, sex and WHO regions)
 - To assist WHO to strengthen the capacity of countries to conduct burden of foodborne diseases and policy context studies
 - To assist WHO in bridging the gap between collection of scientific evidence and food safety policy making



4

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Studies on the burden of foodborne pathogens (2)

Foodborne Illness Acquired in the United States—Major Pathogens

Elaine Scallan, Robert M. Hoekstra, Frederick J. Angulo, Robert V. Tauxe, Marc-Alain Wittesowan, Sharon L. Roy, Jeffrey L. Jones, and Patricia M. Griffin

Estimates of foodborne illness can be used to direct food safety policy and interventions. We used data from active and passive surveillance and other sources to estimate that each year 51 major pathogens acquired in the United States caused 3.8 million episodes of foodborne illness (95% confidence interval [CI] 3.0–4.7 million), 90,000 hospitalizations (95% CI 70,500–109,500), and 1,500 deaths (95% CI 1,122–2,068). Most (60%) illnesses were caused by agents isolated by surveillance. Contaminated eggs (11%), undercooked poultry (10%), and undercooked beef (9%) leading causes of hospitalization were nearly identical. Contaminated eggs (25%), raw produce (20%), ready-to-eat meats (15%), and non-occlusive parasites (15%) leading causes of death were hospitalized patients (25%), 7 people (2%), cattle management (10%), and rodents (10%). These estimates cannot be compared with prior (1990) estimates of disease trends because different methods were used. Additional eggs and more robust methods can improve future estimates.

Estimates of the overall number of episodes of foodborne illness are helpful for allocating resources and guiding interventions. However, activity in these estimates is changing because food may become contaminated by many agents (e.g., a variety of bacteria, viruses, parasites, and fungi), transmission can occur by multiple mechanisms (e.g., contact with animal or consumption of contaminated meat), the proportion of disease transmitted by food differs by pathogen and by host factors (e.g., age and immunity), and only a small proportion of illnesses are confirmed by laboratory testing and reported to public health agencies.

Laboratory-based surveillance provides critical indications for monitoring foodborne disease trends. However, active surveillance systems for disease prevention, including surveillance of public health agencies.

Emerging Infectious Diseases • www.cdc.gov/eid • Vol. 17, No. 1, January 2011

because only a small proportion of illnesses are diagnosed and reported, periodic assessments of total episodes of illness are also needed. Alternative estimates of illness are referred to as "illnesses." Several countries have conducted population-based or cross-sectional studies to determine overall rates and estimate the overall burden of foodborne illnesses (3). In 2007, the World Health Organization launched an initiative to estimate the global burden of foodborne diseases (2).

In 1999, the Centers for Disease Control and Prevention provided comprehensive estimates of foodborne illnesses, hospitalizations, and deaths in the United States caused by bacteria and nonbacteria agents (4). This effort identified many data gaps and methodologic limitations. Since then, new data and methods have become available. This article is a first attempt to provide estimates of foodborne disease acquired in the United States. Estimates referred to as "diseases" are reported. This article provides estimates of major foodborne pathogens; the other provides estimates for agents of more gastrointestinal not specified in this article (4).

Methods

Multiple data for preparing national estimates were available for 31 pathogens. We estimated the number of foodborne illnesses, hospitalizations, and deaths caused by these 31 domestically acquired pathogens by using data shown in the online Appendix Table (www.cdc.gov/eid/content/17/01/table1.htm) and online Technical Appendix 1 (www.cdc.gov/eid/content/17/01/techapp1.pdf).

Data were mostly from 2000–2008, and all estimates were based on US population in 2006 (294 million persons). Estimates were derived from statistical models with many inputs, each with some measure of uncertainty (5). To reflect this uncertainty, we used probability distributions to describe a range of plausible values for all model

Quantile estimates. Centers for Disease Control and Prevention, Atlanta, Georgia, USA.



RANKING THE RISKS: THE 10 PATHOGEN-FOOD COMBINATIONS WITH THE GREATEST BURDEN ON PUBLIC HEALTH

MICHAEL B. BATZ, SANDRA HOFFMANN AND J. GLENN MORRIS, JR.

UF Emerging Pathogens Institute UNIVERSITY OF FLORIDA



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Primary disease outcomes

- *Salmonella* spp., *Yersinia enterocolitica*
 - Gastroenteritis
- MRSA
 - Colonisation – soft tissue infections
- *Toxoplasma gondii*
 - Congenital toxoplasmosis: classical triad (hydrocephalus, intracranial calcifications, chorioretinitis)
 - Acquired toxoplasmosis: chorioretinitis
- *Trichinella* spp.
 - Trichinellosis
- *Taenia solium*
 - Neurocysticercosis - epilepsy
- Hepatitis- E virus
 - Acute hepatitis

7

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Assessing incidence of pathogen-specific illness

- Cohort studies
 - Syndromic surveillance in the general population– etiological studies – attributable fractions
 - Direct etiological studies in risk groups
- Disease notification or laboratory surveillance
 - Underreporting and underascertainment - pyramid reconstruction
- Etiological studies may include (geno)typing to distinguish subtypes with different ecology

8

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Population cohort studies for acute gastroenteritis

- Sensor/Nivel (NL, 1996-1999)
- Incidence rate of acute GE in the Netherlands in 1999 was 290 cases per 1,000 person years
- 1.2% of cases attributable to Salmonella spp. and 1.6 % to Campylobacter spp.
- 4.8 million cases of GE per year in the Netherlands, of these 33,000 salmonellosis and 88,000 campylobacteriosis
- 4.2 million GP consultations for GE, of these 4,900 salmonellosis and 20,000 campylobacteriosis
- Decreasing trend in laboratory-confirmed human salmonellosis (-45% in 2009) compared to 1999 (4,200 cases)

Havelaar et al., in preparation

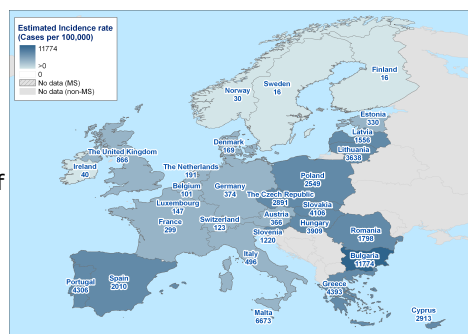
9

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Pyramid reconstruction for salmonellosis

- Swedish travellers as sentinels
- Average risk: 8.4 per 100,000 journeys
- Varies between 0.1 (Finland) to 94 (Bulgaria)
- Relative risk anchored to the Netherlands to estimate incidence of campylobacteriosis in all EU MS
- Total incidence: 6.2 million cases per year (1 per 50 inhabitants)
- Underreporting factor at EU level: 51 (0.4 to 1,800)



Havelaar et al., in preparation

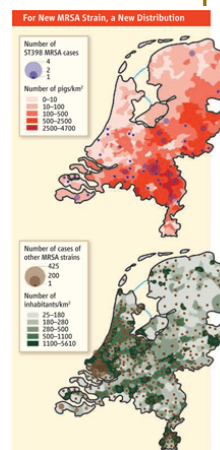
10

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MRSA is associated with contact with live pigs

- Specific subtypes (CC398)
- High frequency of carriage among farmers (pigs, veal calves, poultry), veterinarians, abattoir workers
- Strong reduction in periods of no animal contact
- Transient carriage after short-term exposure
- Does not spread readily among humans
- No colonisation in meat handlers
- No risk for consumers who handle contaminated meat
- Increased costs for search and destroy policy in hospitals



Ferber, *Science* 2010;329:1010-11

11

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Incidence of congenital toxoplasmosis, NL

- 10,008 dried blood spot (DBS) cards from children born in 2006
- Toxoplasma-specific IgM antibodies (screening and confirmation)
- True prevalence (corrected for sensitivity and specificity) of CT: 2 per 1,000 live-born children
- 194,000 live births in the Netherlands:
388 children (95% CI = 213-543) born with CT

Kortbeek et al., *Mem Inst Oswaldo Cruz*. 2009;104:370-3

12

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Trichinella spp.

- 1,073 reported cases in the EU in 2009
- 90% of reported cases from Romania and Bulgaria
- Associated with outbreaks and family clusters
- Traditional foods and habits

Figure 175. Mean trichinellosis notification rates in humans in EU per 100,000 population, 2007-2009



Figure 176. Findings of Trichinella in pigs, 2007-2009 (pork/d data)



EFSA Journal 2011;9(3):2090

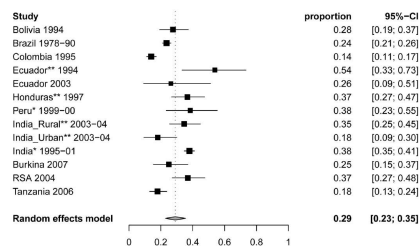
13

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Systematic review on global neurocysticercosis

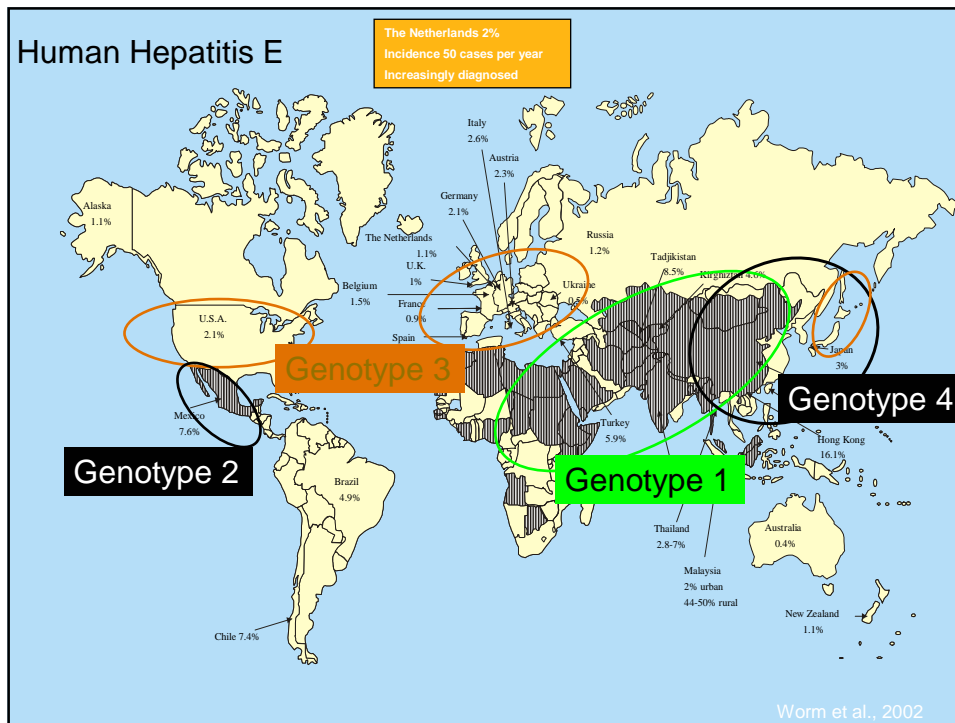
- Only studies using neuroimaging included
- Wide variation in the prevalence of NCC globally
 - 9% in Mexico, no symptoms
 - Hospitalisation 0.3-1.5 per 100,000 pyr in USA
- 30% of patients with epilepsy have NCC (Latin America, Sub-Saharan Africa, South-East Asia)




Ndimubanzi et al., PLoS Negl Trop Dis 4(11): e870

14

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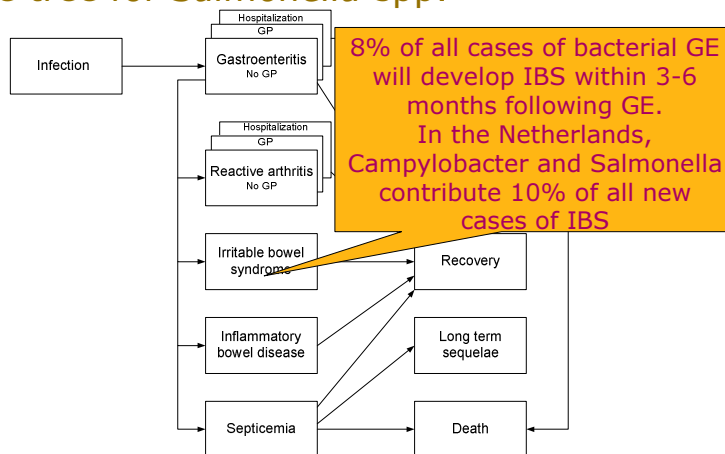
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16
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Outcome tree for *Salmonella* spp.



Haagsma et al., *Epidemiol Inf* 2010;138:1650-56

17

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Estimating the burden of zoonotic diseases

- Epidemiology
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18

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Mortality of key pathogens related to pork

- Data from different sources
 - Outbreaks
 - Registry based studies
 - Other cohorts
 - Surveillance

	The Netherlands			USA		
	Cases	Fatalities	CFR 1 in:	Cases	Fatalities	CFR 1 in:
<i>Salmonella</i> spp.	33000	40	825	1027561	378	2718
<i>Yersinia enterocolitica</i>	ND	ND	ND	97656	29	3367
Hepatitis E virus	53	1	53	ND	ND	ND
<i>Toxoplasma gondii</i>	797	13	61	86686	327	265
<i>Trichinella</i> spp.	ND	ND	ND	156	0	NA



Diarrhea morbidity and mortality in children ≥ 5 years and adults

- 5 billion episodes per year, of which 3.2 billion in SEARO
- Average incidence rate 0.5/yr, similar for all regions except EMRO (0.9/yr)
- 1.2 million deaths per year in SEARO and AFRO
- Approx. 6% of all deaths in these regions
- Estimate for SEARO 6-fold higher than previously published
- Compare with 1.1 million deaths in children < 5 years in these two regions (approx. 15% of all deaths)

Epidemiol. Infect. Page 1 of 17. © Cambridge University Press 2010
doi:10.1017/S095026881000095

REVIEW ARTICLE Diarrhoea morbidity and mortality in older children, adolescents, and adults

C. L. FISCHER WALKER* AND R. E. BLACK

Johns Hopkins Bloomberg School of Public Health, Department of International Health, Baltimore, MD, USA

(Accepted 17 February 2010)

SUMMARY

Diarrhoea is a leading cause of morbidity and mortality yet diarrhoea-specific incidence and mortality rates for older children, adolescents, and adults have not been systematically calculated for many countries. We conducted a systematic literature review to generate regional incidence rates by age and to summarize diarrhoea-specific mortality rates for regions of the world with inadequate vital registration data. Diarrhoea morbidity rates range from 29.9 episodes/100 person-years for adults in the South East Asian region to 88.4 episodes/100 person-years in older children in the Eastern Mediterranean region and have remained unchanged in the last 30 years.

Fischer Walker CL, Black RE. *Epidemiol Inf* 2010;138:1215-1226



Etiology of diarrhea in children ≥ 5 years and adults

- *V. cholerae* (O1 and O139) and ETEC most frequently isolated in hospitalized patients
- *Salmonella* spp., *Shigella* spp. and *E. histolytica* most frequently isolated in outpatients
- Isolation frequencies lower in studies that looked for 5 or more pathogens
- Data very limited, prospective cohort studies needed

Etiology of Diarrhea in Older Children, Adolescents and Adults: A Systematic Review

Christa L. Fischer Walker*, David Sack, Robert E. Black

Department of International Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, United States of America

Abstract

Background: Diarrhea is an important cause of morbidity and mortality in all regions of the world and among all ages, yet little is known about the fraction of diarrhea episodes and deaths due to each pathogen.

Methodology/Principal Findings: We conducted a systematic literature review to identify all papers reporting the proportion of diarrhea episodes with positive laboratory tests for at least one pathogen in hospital, outpatient, and community settings that met our inclusion and exclusion criteria. We identified a total of 25,761 papers with possible etiologic data and after final screening included 22 papers that met all inclusion and exclusion criteria. Enterovirus, *Escherichia coli* and *V. cholerae* O1/O139 were the leading causes of hospitalizations in outpatient settings. *Salmonella* spp., *Shigella* spp. and *E. histolytica* were the most frequently isolated pathogens.

Conclusions/Significance: This is the first systematic review which has considered the relative importance of multiple diarrhea pathogens. The few studies identified suggest that there is a great need for additional prospective studies around the world in these age groups to better understand the burden of disease and the variation by region.

Fischer-Walker et al. *PLoS Negl Trop Dis* 2010;4(8):e768

21

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Estimating the burden of zoonotic diseases

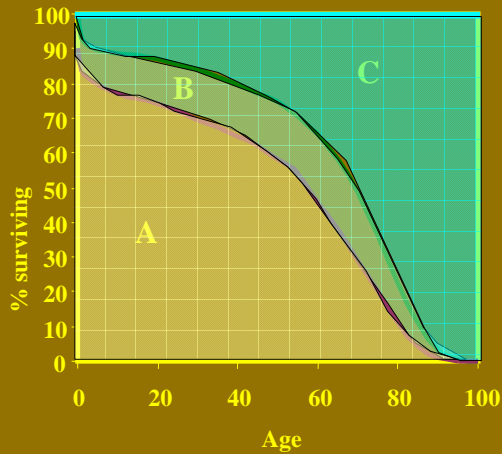
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22

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A typology of Summary Measures



C = Time lost due to mortality

B = Time spent in less than perfect health

A = Time spent in perfect health

23

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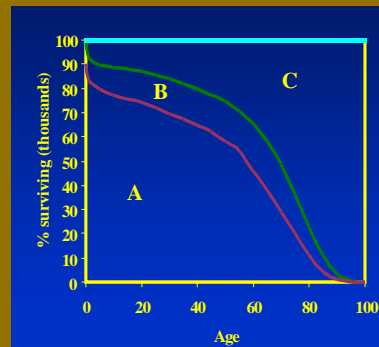
Disability Adjusted Life Years

YLL Years of life lost due to mortality → C

YLD Equivalent years of healthy life lost due to disability → f(B)

DALY = YLL + YLD

Gap compared to ideal healthy life expectancy



Time as the common metric for mortality and imperfect health

24

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Interpretation of DALYs

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

High number of deaths

High incidence

Young adult deaths
(age weighting!)

Sequela +++

High life expectancy
standard assumed

High disability
weight

Long duration of
disease/sequelae

25

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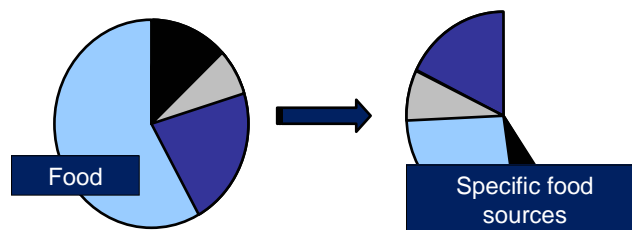
26

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Source Attribution

- Determine for each hazard (or specific groups of hazards) the proportion of the disease burden that is attributable to food and other pathways
- Identify – and if possible quantify - the responsible reservoirs and/or food commodities leading to illness



27

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Approaches to source attribution

- Microbiological approaches
 - Microbial subtyping
 - Comparative risk assessment
- Epidemiological approaches
 - Sporadic infections (incident or prevalent)
 - Outbreaks
- Field studies
 - Intervention studies
 - Natural experiments
- Expert elicitation
 - Unstructured, qualitative
 - Structured, quantitative

Pires et al., Foodb Path Dis 2009;6:417-24

28

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Attribution of salmonellosis to pork in the EU

- EFSA BIOHAZ Panel

“a cautious assessment would be that around 10-20% of human infections in EU may be attributable to pigs and pork. However, this “guesstimate” is believed to vary considerably between MSs depending on, for instance, Salmonella prevalence in pigs and pork, consumption patterns and preferences, pig production systems and the relative importance of other sources, such as eggs and chicken”

Data for more detailed source attribution were not available at that time

An updated attribution, based on recent data, will be published in July 2011

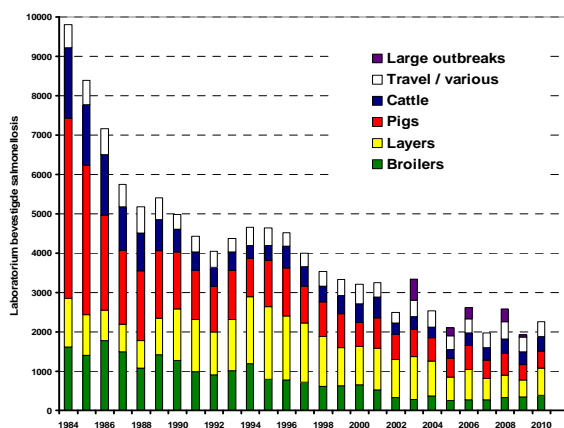
EFSA Journal 2010; 8(4):1547

29

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Attribution of salmonellosis by subtyping, NL

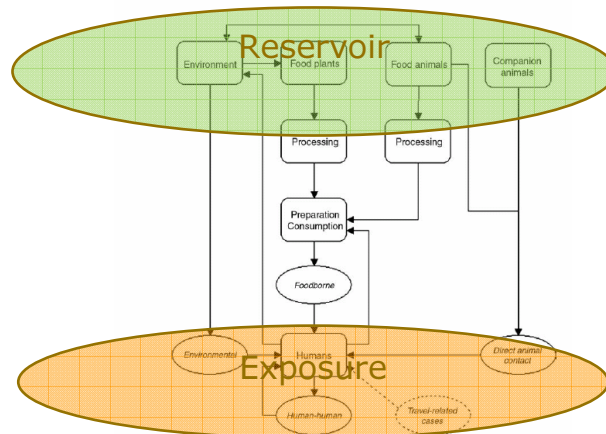


30

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Transmission routes for hazards potentially transmitted through food



Havelaar et al., *Foodb Path Dis* 2008;5:649-659

31

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Source attribution of toxoplasmosis

- Risk factor studies of incident cases (Cook et al., *BMJ* 2000;321:142-147)
 - 30-60% of cases in EU is related to consumption of meat
 - Meat types differ between countries, pork not significantly associated
 - Large proportion (14-49%) of cases unexplained
- Comparative risk assessment (M. Opsteegh 2011; PhD thesis Utrecht University)
 - Prevalence and concentration of *T. gondii* in different sources
 - Preparation and consumption, dose-response relation
 - Beef 68% of meat-borne infections, pork and sheep 11 and 14%
 - Overestimation of incidence of infections
- Expert elicitation (Havelaar et al., *Foodb Path Dis* 2008;5:649-656)
 - NL: 56% of infections by food, of these 50% pork, 23% beef&lamb
 - USA: 41% of all infections pork, 23% beef, 20% game

32

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Ranking the risks in the USA

TABLE ES-2: THE TOP 10 PATHOGEN-FOOD COMBINATIONS IN TERMS OF ANNUAL DISEASE BURDEN, BY COMBINED RANK

PATHOGEN-FOOD COMBINATIONS	COMBINED RANK	QALY LOSS	COST OF ILLNESS (\$ MIL)	ILLNESSES	HOSPITALIZATIONS	DEATHS
<i>Campylobacter</i> – Poultry	1	9,541	1,257	608,231	6,061	55
<i>Toxoplasma</i> – Pork	2	4,495	1,219	35,537	1,815	134
<i>Listeria</i> – Deli meats	3	3,948	1,086	651	595	104
<i>Salmonella</i> – Poultry	4	3,610	712	221,045	4,159	81
<i>Listeria</i> – Dairy products	5	2,632	724	434	397	70
<i>Salmonella</i> – Complex foods	6	3,195	630	195,655	3,662	72
Norovirus – Complex foods	6	2,294	914	2,494,222	6,696	68
<i>Salmonella</i> – Produce	8	2,781	548	170,264	3,204	63
<i>Toxoplasma</i> – Beef	8	2,541	689	20,086	1,026	76
<i>Salmonella</i> – Eggs	10	1,878	370	115,003	2,164	42
TOTAL		36,915	8,151	3,061,128	29,830	765

TABLE ES-3: DISEASE BURDEN BY FOOD CATEGORY, SUMMED ACROSS PATHOGENS, BY COMBINED RANK

FOOD CATEGORY	QALY LOSS	COST OF ILLNESS (\$ MIL)	ILLNESSES	HOSPITALIZATIONS	DEATHS
1 Poultry	14,744	2,462	1,538,468	11,952	180
2 Complex foods	7,518	2,078	3,001,858	11,674	189
3 Pork	7,830	1,894	449,322	4,334	201
4 Produce	6,171	1,484	1,193,978	7,125	134
5 Beef	5,766	1,338	760,789	4,818	191
6 Deli/Other Meats	5,065	1,338	204,283	1,889	129
7 Dairy products	5,410	1,292	292,410	2,933	114
8 Seafood	2,762	921	642,860	2,937	97
9 Game	2,551	651	46,636	1,106	69
10 Eggs	2,252	428	170,123	2,472	45
11 Baked goods	998	270	462,399	1,833	25
12 Beverages	403	94	146,577	666	8
TOTAL	61,061	14,114	8,914,713	53,879	1,322

Batz et al., 2011

33

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Conclusions

- Estimating the public health burden of pathogens related to pork and pigs is complex and demands high quality data
- Advances are being made to estimate the true incidence of diseases that may also be transmitted by pork and pigs
- Attribution of multifactorial diseases to foods and specific commodities is a major source of uncertainty
- Approaches exist to integrate diverse information in summary measures of population health, allowing meaningful comparisons
- Pork and pigs continue to contribute to the burden of food-related disease

34

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Contribute by supporting WHO FERG



35

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