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Next steps to evidence-based food safety risk analysis: opportunities for health technology assessment methodology implementation

Food safety risk analysis and health technology assessment (HTA) are two different paradigms sharing multiple common features. Decision makers in both fields have the responsibility to promote the health of society deciding on intervention opportunities based on disease burden, intervention feasibility, effectiveness and cost, equity and ethical considerations. The evolution of HTA in the last two decades has resulted in the establishment and widespread use of quantitative tools to support and justify evidence-based decisions. In contrast, decision making in the food safety domain is still a qualitative process rendering ad hoc weights to all aspects considered. This review evaluates whether HTA methodology is suitable for quantitative decision support in food safety risk analysis. We conclude that cost-utility analysis (CUA) could better serve the priority settings in food safety risk management than the currently (rarely) applied cost-benefit analysis (CBA), considering either broad resource allocation or specific safety measure decisions. Development of multi-criteria decision analysis tools could help the introduction of consistent and explicit weighting among cost and health impacts, equity and all other relevant aspects. Cost-minimisation and cost-effectiveness analyses would be relevant for 'threshold' and 'as low as reasonably achievable' approaches to single food safety risk assessments, respectively. Assuming a future widespread use of HTA methodology in the food safety paradigm, a vision of integrated healthcare, food safety and nutritional policy emerges, with the re-evaluation of budgets and resources of these large systems in a rational and socially acceptable way.

Keywords: foodborne disease, cost-utility analysis, MCDA, health technology assessment, risk analysis, priority setting

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Introduction

In the field of food chain safety, decision makers have a responsibility to promote the health of plants, animals and humans, and to protect the national and international economy. For that purpose, decisions should be made on different intervention opportunities, based on the risk analysis framework defined first by FAO/WHO (2006). However, during this process, not only the risk (or burden) of the diseases, but intervention feasibility, effectiveness and cost, equity and ethical considerations also play increasingly important roles. In this respect, food safety risk analysis and health technology assessment (HTA) in healthcare system development are analogue paradigms. The aim of this paper is to identify those elements of HTA methodology suitable for quantitative decision support in food safety risk analysis.

The different methodologies for ranking the risks related to feed/food safety and nutritional hazards, on the basis of their anticipated human health impact, assessed by Van der Fels-Klerx *et al.* (2015) show a large variability in application, emphasising that each tool has its optimal purpose of use. The decision making process in the food chain safety domain uses many quantitative tools, especially during risk assessment, however the decision making as a whole is still mostly a qualitative process that applies ad hoc weights to all aspects considered. Interestingly, the practice of multi-aspect HTA decision making has changed a lot in the last two decades, resulting in the establishment and widespread use of sophisticated quantitative approaches to support and justify evidence-based decisions (Bodrogi and Kaló, 2010).

In this paper, we overview the current status of foodborne pathogen ranking, explain the role of full economic evaluation and multi-criteria decision making in HTA with implications for food safety risk management, and discuss the opportunities and barriers of risk-benefit evaluations in food safety decisions.

Pathogen burden ranking for food safety risk prioritisation: from DALY to QALY

The burden of domestic foodborne diseases in the United States (U.S.) due to various pathogens has been systematically re-assessed by Scallan *et al*. (2011a, 2011b), providing new point estimates with 90 per cent credible intervals on the number of illness episodes, hospitalisations and deaths caused by 31 main pathogens (including bacteria, viruses and parasites). They found that no specific pathogens were recognised in the majority of illnesses, hospitalisations and deaths due to U.S. domestic foodborne diseases. Considering the cases with known pathogens, most illnesses were caused by norovirus (58 per cent), while non-typhoidal *Salmonella* species were the leading cause of hospitalisation (35 per cent) and deaths (28 per cent). Ranking the pathogens according to their disease burden strongly depends on how the disease burden is measured. For example, *Listeria monocytogenes* is responsible only for a negligible number of annual illness episodes as compared with other pathogens, but is ranked among the top three causes of domestic foodborne disease-related deaths. The annual health burden of domestically acquired foodborne illnesses in the U.S. (incidence of illnesses, hospitalisations and deaths) was estimated by Mead *et al*. (1999) and Scallan *et al*. (2011a, 2011b). Note that the different methods do not allow trend analyses between the

Mead and the Scallan studies.

Estimation of the overall disease burden of particular pathogens requires an integrated approach with appropriate weights for mild cases, hospitalisations and acute deaths. Moreover, disease burden calculations should also consider the potential long-term consequences, such as increased risk of Guillain-Barré syndrome after *Campylobacter* infections, haemolytic uremic syndrome with or without end-stage renal disease after *E. coli* O157 and Shiga toxin producing *E. coli* (STEC) non-O157 infections, or newborn complications after listeriosis and toxoplasmosis (Hoffmann *et al*., 2012; Scharff, 2012; Batz *et al*., 2014). The new incidence estimates published by Scallan *et al.* (2011b) elicited a series of updated estimations on overall domestic foodborne disease burden due to particular pathogens in the U.S. Scharff (2012) calculated the total cost of illness as the sum of costs of physician care, hospitalisation, pharmaceuticals, cost of productivity loss and the value of statistical life for fatal cases, also considering long-term consequences. Decreased quality of life as captured by *quality adjusted life years* (QALY) loss (health utility decrements of 0.492 during hospitalisation and 0.311 during illness episode) was also monetised and included in the enhanced cost of illness model. Hoffmann *et al.* (2012) integrated the new incidence estimates of Scallan *et al.* (2011b) with a thorough literature review and reconsidered the disease outcome trees (symptoms, severity, duration and likelihood of health outcomes) for 14 key pathogens in the U.S. Symptom definitions were scored along the five domains of EQ-5D and new, health state-specific utility decrement data were generated and reviewed by clinical experts of foodborne diseases. Updated disease outcome trees were then used to estimate the total cost of illness (sum of medical costs, productivity loss and value of premature mortality) and total QALY loss (including decreased life quality and disease related mortality). The cost of illness and QALY loss are not additive in this study because both capture the burden of premature mortality. In a recent paper, the same team published new estimates on QALY loss for the same 14 key pathogens, with slightly reduced QALY losses in *Cryptosporidium* and Shiga toxin producing non-O157 *E. coli* infections (Batz *et al.,* 2014).

Ranking of foodborne pathogens by their disease burden is part of a new risk-ranking model of the Food Safety Research Consortium, with the intention of attributing pathogen-specific disease burden and costs to categories of food vehicles, based on outbreak data and expert judgment (Batz *et al*., 2004; Hoffmann *et al.,* 2007). The ultimate goal of this work is to support priority setting and resource allocation for food safety, in two contexts (Batz *et al*., 2005). The first context ('Purpose 1' or 'High level/Strategic priority setting') is broad resource allocation, i.e. which of many possible pathogens or pathogen-food pairs pose the greatest concern to public health and therefore deserve priority attention for intervention or further analysis. This level of prioritisation intends to support programmes or agencies during strategic planning, developing annual work plans or annual budget requests. The second context ('Purpose 2' or 'Decision on risk management options') is to support the choice of specific risk management actions and strategies with respect to a particular hazard. This latter context may also utilise the results of foodborne pathogen attribution to key food sources, by focusing the attention to the critical elements and steps in the food supply chain.

In parallel with the work in the U.S., the estimation of foodborne disease burden is the subject of intensive research worldwide with the intention of ranking foodborne pathogens and food pathogen-food pairs to guide foodborne disease-related policy decisions. The systematic estimation of the numbers of illnesses, hospitalisations and deaths for 30 foodborne pathogens in Canada have been recently published (Thomas *et al*., 2013), and the attribution of selected pathogens to food sources was also approached (Davidson *et al*., 2011). The World Health Organization continues its programme to quantify the global burden of foodborne diseases in *disability-adjusted life years* (DALY), recently initiating four pilot country studies in Albania, Japan, Uganda and Thailand (Kuchenmüller *et al.,* 2013). Country-specific research papers on disease burden of a single (Tariq *et al*., 2011; Fürst *et al*., 2012; Verhoef *et al*., 2013) or a couple of specific foodborne pathogens (Lindqvist *et al.*, 2001; Van den Brandhof *et al.*, 2004; Kemmeren *et al*., 2006; Haagsma *et al*., 2009; Lake *et al.*, 2010; Ruzante *et al.*, 2010; Havelaar *et al.*, 2012) also report on the health burden of foodborne diseases as captured in DALY metrics. An exception in this respect is the work of Shin *et al*. (2010), quantifying the Korean health burden of foodborne pathogens as QALY loss estimates. Unfortunately, this group failed to report pathogen-specific burden of disease data.

Although both DALY and QALY are population health metrics describing morbidity and mortality simultaneously in a single number, they were developed with different intentions and are not interchangeable. DALY was developed to describe health at population level, without the aim of responsiveness to slight health changes at individual level. In contrast, the primary aim of developing the QALY methodology was to support the evaluation of medical interventions (Gold *et al.,* 2002). Since QALY became the dominant, almost exclusively used, health denominator in health technology assessment, the authors argue that cost-utility analyses in food safety risk analysis shall also adopt QALY for the standard quantification of the health impacts of food safety policies. Applying QALY as a universal health currency could facilitate the comparison of effectiveness and cost-effectiveness of health and food safety policies, describing their health effects in a common language.

Full economic evaluation in HTA, with implications for food safety risk management

Once the expected health benefits of a planned new technology are quantified, the next step is to compare the health benefits with the economic impacts of the intervention. In HTA, the standard approach is a full economic evaluation which has two criteria: (a) the selection of a policy-relevant comparator (which can be an already-applied intervention or the lack of any intervention (watchful waiting), depending on the current state of the art); and (b) both the costs and

health gain must be examined. In other words, full economic evaluations compare at least two alternative technologies by examining both economic impacts and health consequences (Drummond *et al*., 1997). There is abundant literature on the full economic evaluations of health technologies. In contrast, published full economic analyses on food safety risk management (or risk analysis in the broader sense) measures are sparse. However, recent food safety publications tend to pay more and more attention to health quality beyond costs and mortality, providing important input and allowing for future full economic analyses. The Scharff (2012) study monetised the hospitalisation- and illness-related health losses in its enhanced cost of illness model. The extensive work described in Hoffmann *et al*. (2012) and Batz *et al*. (2014) opened the door for full economic analyses of risk management measures against 14 investigated foodborne pathogens, providing detailed disease outcome trees and QALY loss estimates. What is still missing is the identification of appropriate alternative intervention measures for comparison, with data on their expected effect on disease incidence, and information how the disease outcome trees would be changed by these interventions.

Health and cost data for a full economic evaluation can be generated in three parallel ways in HTA. *Randomised interventional studies* may collect data with high internal validity, although these studies are typically limited in size and duration, and their protocol may limit meaningful economic data collection (e.g. reduction in the number of outpatient visits cannot be evaluated in a study with protocol-specified regular investigator visits). *Naturalistic studies* provide information on a larger and less standardised population, with higher external validity. However, health outcomes may be subject to confounding in these studies due to the lack of randomisation, and conducting naturalistic studies for new health care technologies can hardly be implemented before approval on their market authorisation, pricing and reimbursement. A third line of evidence generation in HTA is *economic modelling*, with decision tree, Markov and discrete event simulation models as the most frequently applied techniques. In economic models, clinical data from randomised clinical trials and naturalistic studies or any other data sources are synthesised, enabling the model to project intermediate clinical and economic results to longer time horizons, and thus estimate the potential long-term value of the assessed technology. For comparison, multiple relevant data sources are available for food safety risk analysis. Short-term data of high scientific quality and internal consistency can be gathered, for example in statistically planned and evaluated experiments in the laboratory or in fieldwork (an analogue of randomised controlled clinical trials in HTA). Naturalistic, large-scale uncontrolled data are also available, for example from the analysis of the practices of different countries. There is also a need for risk management decisions on long-term and expensive programmes ex ante, without available data on their real-world effectiveness and cost-effectiveness – justifying the use of economic modelling in the evaluation of the planned measures as part of the food safety risk analysis process. The estimation of foodborne disease burden between 2020 and 2060 in the Netherlands (Bouwknegt *et al*., 2013), or the microsimulation of households behaviour to assess the impact of food safety policies on society (Stefani, 2008) are mentioned here as food safety modelling examples.

Full economic analyses in HTA are classified to cost-minimisation, cost-effectiveness, cost-utility and cost-benefit analyses, according to the measurement units of health gain. The relevance of these analyses in the food safety risk analysis process is summarised in Table 1.

Although cost-benefit analyses, which can aggregate and thus compare in monetary values any kind of food safety measures with each other or with non-health related investment options, have the widest scope, the validity, reliability and acceptance of converting health benefits into monetary values are low (Cowen, 1998; Bodrogi and Kaló, 2010). Therefore, cost-utility analyses should be preferred over cost-benefit analyses whenever appropriate. Such analyses can aggregate and thus compare any kind of food safety measures, including measures against different risks, or multiple risks in a comparative risk approach (for example (FAO/WHO, 2006), the possible loss of nutritional benefits if people eat less fish in order to avoid methylmercury; or the possible increase in cancer risks where chlorinated water is used to minimise pathogens in food during processing). Cost-utility analyses do not monetise health losses and benefits, but convert them into QALY changes – circumventing the uncertainties and ethical disputes about the monetary value of health. Another advantage of cost-utility analysis is that it emphasises the relevance of a thorough health impact assessment. Accordingly, cost-utility analysis would be the preferred method of economic assessment for broad

Table 1: Types of full economic analyses in health technology assessment, with their proposed applicability in food safety risk analysis.

Type of analysis	Unit of health gain	Applicability in HTA*	Applicability in food safety risk analysis
Cost-minimisation	Not specified (equal health gain)	Comparison of medical procedures with equal health gain.	Compare two measures both achieving the ALOP, or the respective FSO in a threshold approach.
Cost-effectiveness	Natural units	Comparison of medical procedures with non-equal health gain measurable in the same health dimension.	Compare two measures against the same risk in an ALARA approach.
Cost-utility	QALY	Comparison of any medical procedures.	Compare any kind of food safety measures and/or healthcare interventions (prioritisation among health-related investments).
Cost-benefit	Monetary value	Comparison of any medical and non-medical procedures and investment options.	Prioritisation of health-related versus not health-related investments.

* Source of information: Bodrogi and Kaló (2010)
Key: ALARA: as low as reasonably achievable; ALOP: appropriate level of protection; FSO: food safety objective; QALY: quality adjusted life years
Note: for all four types of analysis, the unit of costs is 'monetary value'
Source: own composition

resource allocation ('Purpose 1' prioritisation in Batz *et al*., 2005); whereas the selection of an optimal measure against a specific risk could rely on cost-utility, cost-effectiveness or cost-minimisation analyses, depending on the determination of the Appropriate Level of Protection and the occurrence of multiple risks or health consequences.

Systematic application of the above discussed full economic evaluations could contribute to the development of more rational and transparent food safety systems, with improved allocation effectiveness.

Multi-aspect decisions in food safety risk management and in HTA

Risk ranking tools, like the ranking of hazard-food combinations in a national context, are acknowledged scientific approaches in the framework of food safety risk analysis (FAO/WHO, 2006). However, the decision on a particular measure against a specific risk does not rely solely on the magnitude of the risk. It also needs to assess carefully the feasibility, effectiveness and cost of potential interventions, as well as their expected public health benefits (Batz *et al*., 2005; FAO/WHO, 2006). These considerations are also valid for broad resource allocation decisions and the planning of food safety programmes (Hoffmann, 2010; Hoffmann *et al*., 2012; Scharff, 2012). Assessment of health burden, intervention feasibility, effectiveness and costs allows the risk managers to select risk management measures which reach their targets, are cost-effective and are not over-restrictive. Risk managers shall also consider stakeholder equity, ethical considerations and potential consequences on other risks (for example, decreases in the availability or nutritional quality of foods, or increasing burden of currently well-controlled pathogens upon redistribution of food safety resources to key pathogens). Although cost-benefit analysis is a mandatory element of food safety policy decisions in some countries, it typically does not cover all relevant aspects, e.g. quality of life (Ragona and Mazzocchi, 2008) and is believed to have frustrating uncertainty in its parameter estimates (Irz, 2008). Hence, balancing between health burden, costs and expected benefits of intervention measures, considering different stakeholder perspectives, and dealing with the expected impact on food trade, trust of society in the food chain, and effects on economy is essentially a qualitative process. Accordingly, the selection of the implemented risk management options is fundamentally a political and social decision at present (FAO/WHO, 2006).

As a response to this challenge in health technology assessment, multi-criteria decision analysis (MCDA) tools have been developed to cover all important aspects of decision making with standardised weights. The quantitative result of a full economic analysis is typically an important component of the multi-criteria decision process, but equity, ethical and socio-cultural aspects are also covered with relevant weights, in an objective and transparent manner.

Developing appropriate MCDA tools to support evidence-based, objective risk management decisions, incorporating full economic analyses of the considered measures, is a future opportunity for international and national food safety policies. Previous steps in this direction include a multi-criteria decision support tool with integrated presentation of cost-benefit analysis and other criteria for food safety priority setting focusing on food-pathogen pairs (Caswell, 2008). Another example is the institution of Impact Assessment in the UK, which combines the findings of a full economic analysis with multiple other aspects of assessment (Irz, 2008) without the quantitative integration of all findings.

Opportunities and barriers to using HTA methodology in food safety risk management decisions

Frequently cited arguments against risk-benefit evaluations in food safety risk management decision processes include the issues of uncertainty in model parameters (Irz, 2008), unpredictable effects of risk management measures on stakeholders' behaviour (FAO/WHO, 2006; Ragona and Mazzocchi, 2008), and the technical and theoretical difficulties with calculation and monetisation of health benefits (Cowen, 1998; Irz, 2008).

Uncertainty is an inherent part of all ex ante impact analyses and is appropriately managed in the health technology assessment process by deterministic or probabilistic sensitivity analyses – which are quantitative tools also available for food safety risk management. It is claimed that the level of uncertainty is especially high in food safety risk analysis. For example, the lack of long-term human data on the biological effect of reduced levels of chemical contaminants does not allow reasonable assumptions on the expected health impact (Irz, 2008). Risk management measure concepts without reasonable assumptions on their effectiveness may be premature to implement (unless a precautionary approach is considered). Assumptions with a weak basis call for additional risk assessment exercises, sensitivity analyses in the full economic evaluation, representation of uncertainty in the decision process (preferably via an MCDA tool) and regular monitoring during practical implementation to adjust the assumptions and the full economic evaluation to the real-world experience.

Unpredictable effects of risk management measures on stakeholders behaviour is not considered to be a valid argument against risk-benefit analyses, because communication between all involved stakeholders is at the heart of risk analysis, with equally emphasised importance of risk management, risk assessment and good risk communication (FAO/WHO, 2006).

Cost-benefit analyses have their limitations, but are probably the most appropriate currently-used approach to the assessment of food safety interventions (Irz, 2008). A recent U.S. News Opinion Economic Intelligence comment also emphasises the distinguished thesis that more funding and more regulations do not automatically result in better health and food safety, and calls for well-done, peer-reviewed cost-benefit analyses of future regulations, as well as for retrospective review of similar regulations done in the past to show their effectiveness (Williams, 2014).

Although QALY are used routinely in health technology assessment, the integrated evaluation of environmental-related health risks traditionally uses alternative approaches (e.g. willingness to pay, or cost of disease (Hammitt, 2002; Scallan *et al*., 2011b; Hoffmann *et al*., 2012). The health burden of foodborne diseases is typically quantified in DALY, as summarised in the first section of this paper. Recently-published work in the U.S. (Hoffmann *et al*., 2012; Scharff, 2012; Batz *et al*., 2014) represent a breakthrough in this respect, providing updated, scientifically-sound disease outcome trees with disease state-specific estimates of QALY losses for 14 key foodborne pathogens. These pieces of information open the door for cost-utility analyses to enter the field of food safety risk management, avoiding the need to monetise the calculated health losses. The systematic use of cost-utility analyses is encouraged both for broad resource allocation and for evaluation of alternative measures in food safety risk management.

Full economic analyses followed by an MCDA tool provide an established, objective and transparent methodology for multi-aspect health technology and policy assessment. The application of the same methodology is an opportunity for the development of evidence-based, transparent food safety risk management. One could object to this approach in that it would further increase the information burden and unnecessary bureaucracy. However, even without the uptake of the proposed quantitative methodology, most probably the same pieces of information are considered by risk managers, but on an ad hoc basis (Caswell, 2008). The proposed integration of HTA methodology into the food safety risk analysis process is shown in Figure 1.

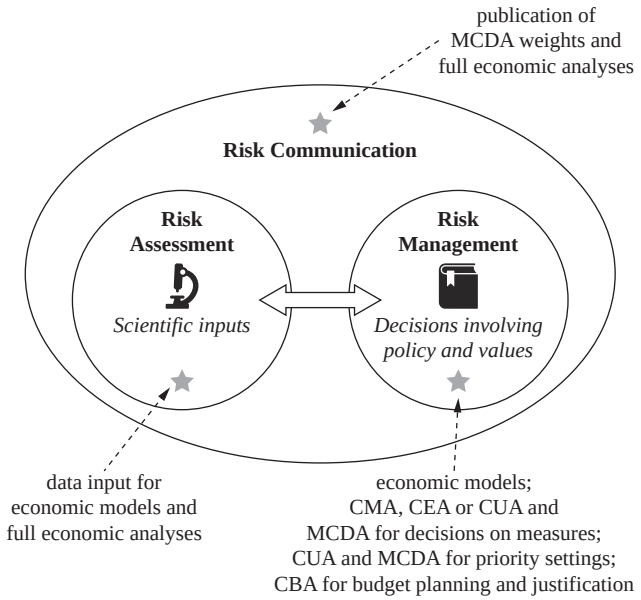

Figure 1: Place of health technology assessment tools in the food safety risk analysis process.

CBA: cost-benefit analysis; CEA: cost-effectiveness analysis; CMA: cost-minimisation analysis; CUA: cost-utility analysis; MCDA: multi-criteria decision analysis
Source: adapted from FAO/WHO (2006)

Conclusion: a vision of an integrated, evidence-based health and food policy

Sharing the established methodological tools of health technology assessment with food safety risk analysis would be a reasonable achievement. Moreover, the shared methodology would pave the way to the integration of health and food policies. According to this vision, cost-utility analyses of health and food policies would support the broad resource allocation between these policies, investing public expenditure in these fields proportionally to their expected health benefits. And within these policies, the selection of technologies, interventions and any policy measures would be supported by full economic analyses without health gain monetisation (i.e. cost-utility, cost-effectiveness and cost-minimisation analyses), together with the country-specific development of MCDA tools to deal explicitly and transparently with all relevant aspects of policy decisions. This would lead to systematic and evidence based food safety decision process along the whole risk analysis framework, with increased transparency, ensuring better and more justifiable decisions with higher societal values and gains.

Setting up priorities between diseases caused by specific foodborne pathogens is clearly a necessary and straightforward approach. However, it must be remembered that most domestic foodborne pathogen related diseases, hospitalisations and deaths have consistently failed to be linked to a specific pathogen in the U.S. (Mead *et al*., 1999; Scallan *et al*., 2011a). Moreover, foodborne pathogens are by far not the only causes of foodborne diseases: food safety risk analysis activities must face also the risks due to food additives and contaminants (e.g. mercury and dioxins, natural toxins such as aflatoxins, residues of pesticides and veterinary drugs) as well as physical risks (Mead *et al*., 1999; FAO/WHO, 2006). Accordingly, the issue of broad resource allocation in food safety risk management shall not be restricted to the prioritisation among known foodborne pathogens.

In a wider context, let us consider the borders between food safety and nutritional policy. Beyond foodborne infections and toxicity, the qualitative and quantitative characteristics of food consumption also have tremendous impact on life quality and expectancy. Excess intake of calories, saturated and trans fats, free sugar and sodium, as well as low consumption of vegetables and fruits contribute significantly to rising rates of chronic diseases including hypertension, heart disease, stroke, diabetes and obesity (Nolte and McKee, 2008; DHHS, 2013). On the other hand, under-nutrition is an important burden in low income countries. Assuming an integrated food safety and nutritional policy, the overall ambition is not only to prevent foodborne infections and toxicity, but in a more global sense to promote health by any means targeting the proper consumption habits of safe food by society. In fact, food safety and nutrition policies are strongly interlinked at high-level decision making in the European Union at DG SANTE and in the European Food Safety Authority. In the U.S., the FDA Food Program has a dedicated sub-programme for better health through nutrition and labelling strategies (DHHS, 2013). Further steps to this integration might include the cost-utility analysis of food safety and nutritional policies to support optimal broad

resource allocation across these fields. Apparently, this is not the practice at present.

Healthcare, nutrition policy and food safety risk analysis are closely interlinked by their health promoting aspect. Patients with acute foodborne infections may later be faced with chronic consequences, such as renal failure after STEC infection, Guillain-Barré syndrome after *Campylobacter* infection, or hepatocellular cancer due to aflatoxin contamination in nuts. Patients with excess calorie intake have increased risk of type II diabetes, which is one of the largest burdens on current healthcare budgets in developed countries. Development of improved therapies should logically shape the prioritisation among nutritional risk factors. On the other hand, appropriate investments in food safety and nutritional policies may help to avoid significant health loss and healthcare expenditures. Accordingly, food safety and nutritional policies and interventions form two particular 'classes' of health technologies.

Consumption of specific nutrients or vitamins is part of medical therapy in some cases; examples include vitamin D and calcium in postmenopausal osteoporosis, or glucosamine and chondroitin in osteoarthritis. There are precedents for HTA analysis of the proposed nutritional practice in these cases, as reviewed for example in Black *et al*. (2009). These examples, together with the recently-published systematic data on QALY impact of key foodborne infections, are encouraging that the evolution of quantitative HTA methodology in recent decades may contribute to the improvement of evidence-based food safety and nutritional policies. Allocative effectiveness of budget planning would theoretically benefit from performing relative cost-utility analyses of these large systems, redistributing healthcare, nutritional policy and food safety investments in a rational and socially acceptable way. Quantitative health technology evaluation methodology could also support consistent and transparent decision making on specific intervention measures within food and nutritional policies. The proposed next steps in this direction include the development of country-specific cost-utility analyses of currently implemented and potential alternative/additional intervention measures against the most important foodborne pathogens, followed by the integration of the analysis results into the decision making in the specific risk management processes.

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