Assessing the economic costs of unhealthy diets and low physical activity

47

Health Policy Series

An evidence review and proposed framework

Christine Joy Candari
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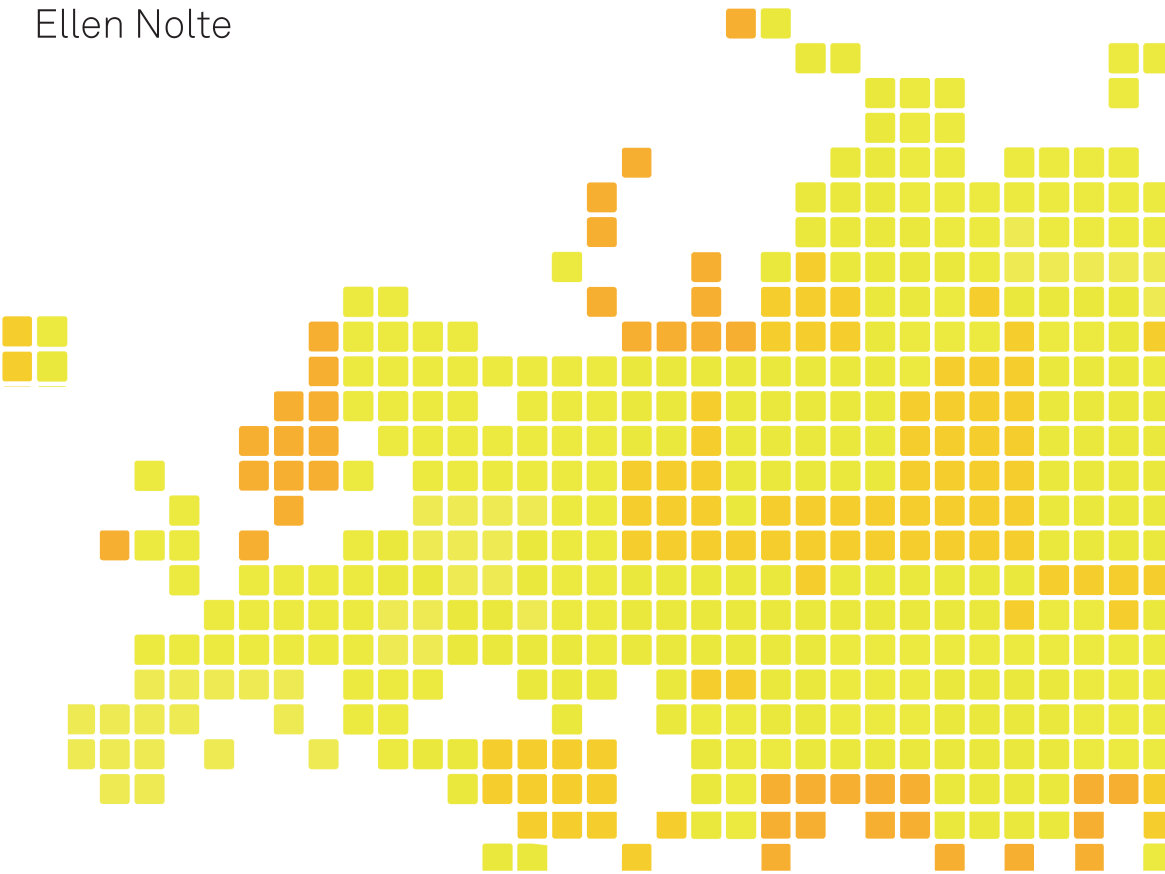
Ellen Nolte



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European Observatory on Health Systems and Policies
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Assessing the economic costs of unhealthy diets and low physical activity

An evidence review and proposed framework

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Acknowledgements

This study forms part of a wider programme of work that seeks to explore in further depth the available evidence on the economic costs that can be associated with unhealthy diet and lack of physical activity in Europe, or high-income countries more broadly, and their effects on health. A better understanding of the economic burden associated with these critical risk factors can provide important pointers to inform evidence-based decision-making within the European region as to the most appropriate policies to improve the health, well-being and quality of life of the population.

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Foreword

Lifestyle related health problems are now a challenge of global proportions. For example, levels of obesity have doubled since 1980, and it costs a staggering 2.8% of the world's GDP. Europe is not an exception: half of EU adults today are either overweight or obese, and rates for children are even more worrisome: one in three. Unless we act, we will condemn a whole generation to a lifetime of poor health.

With governments across Europe struggling to curb these ever-rising rates, it is more important than ever to make the economic case for investing in strategies that promote health and prevent diseases. Unhealthy diets and lack of physical activity are risk factors for developing a range of chronic diseases such as diabetes, cancer and cardiovascular disease. They not only reduce people's quality of life and life expectancy, but also place a burden on our health systems and our economies, and on society as a whole.

There is growing evidence that many prevention interventions are cost-effective. It is therefore surprising that OECD countries still spend an average of only 3% of their health care budgets on disease prevention programmes. In contrast, already some 7% of EU health budgets are spent on treating chronic diseases linked to obesity.

This clearly points to a need to change mindsets. If we wish to keep our population healthy, active and productive, and our health systems strong and resilient in the long term, and reduce the increasing pressure on national health care budgets, we need to reset our thinking. We need to focus more on disease prevention and health promotion to save future expenditure on treatment and cure. This sounds self-evident – yet it is a surprisingly difficult message to get across.

Underpinning policies with sound evidence is essential. I therefore welcome this report, which provides a useful contribution to the debate on the increasing importance of promotion and prevention, and I invite you to read the assessment of the evidence contained within these pages of the costs of unhealthy diets and low physical activity.

Xavier Prats Monné
Director General of the Directorate-General for Health and Food Safety

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Summary

Unhealthy diets and low levels of physical activity are among the main risk factors for major chronic diseases. While this is well documented, the economic burden associated with these two risk factors remains uncertain. A better understanding of the economic burden could help inform priority setting and motivate efforts to promote more effectively healthy diets and physical activity in Europe and worldwide. This volume seeks to help advance the debate through

- critically reviewing the literature that has sought to estimate the economic costs associated with unhealthy diets and low physical activity and presenting the range of estimates of economic burden;
- analysing the measurement, methodological and practical issues in assessing the economic burden from unhealthy diets and low physical activity; and
- developing a framework for assessing costs and testing the feasibility of this approach to provide better estimates of the economic burden.

The published evidence overwhelmingly shows that unhealthy diets and low physical activity are predictive of higher health care expenditure, but estimates vary greatly.

We used a rapid assessment of the evidence that has been published between January 2000 and February 2016, including a total of 30 studies for detailed review. Of these studies, six addressed diet, 21 looked at physical activity, and three considered both. Over half of the studies were set in North America, with only six set in Europe.

Most studies retrospectively assessed the economic burden of unhealthy diets and low physical activity. About half adopted a disease-based approach, often looking at cardiovascular disease, type 2 diabetes and selected cancers. In most cases this approach used the population-attributable fraction (PAF), which estimates the proportion of a disease that can be attributed to a particular risk factor.

We found that, overall, estimates presented in the reviewed studies varied widely. Not all included studies reported national or per capita costs that can be associated with the two risk factors. Of those that did, the estimated health care costs for unhealthy diets ranged from €3.5 per capita in China to €63 in Australia and

€156 in the United Kingdom. For low physical activity, the estimated annual per capita health care costs ranged from €3 in the Czech Republic to €48 in Canada. In the United States of America alone, these ranged from less than €1 in two studies up to €185. Only four studies also considered indirect costs in their estimates for low physical activity, and these varied from €3.7 per capita in China to between €127 and €224 in Canada.

It is plausible that differences in socioeconomic conditions and health care and labour costs might lead to some of the differences between cost estimates. But much of the observed variation results from differences in approaches to measurement, such as what is meant by 'unhealthy diets' or 'low physical activity'; large differences in the methodological approaches chosen (for example, the use of a retrospective, disease-based approach or of a prospective approach); differences in the populations studied and underlying data that are being used; and the range and types of costs considered.

Defining what constitutes an 'unhealthy diet' and 'low physical activity' remains challenging and different conceptualisations make a comparative assessment of available evidence difficult.

Definitions of unhealthy diets often refer to those high in specific nutrients such as saturated fats, salts or sugars. Yet, growing evidence finds that intakes of specific foods rather than the actual nutrients are most relevant for the development of chronic disease, and studies increasingly look at recommended intakes of selected food groups, such as fruit, vegetables, nuts and seeds, whole grains, seafood and unprocessed red meats. This is based on studies that found intake levels for these food groups to be associated with coronary heart disease, stroke, type 2 diabetes and certain cancers. But even with this approach there remains the problem of how to score different intake levels.

These conceptual challenges are reflected in the reviewed studies of unhealthy diets, which often focused on single food items, such as intakes of fruit and vegetables, while others considered a range of nutrients and foodstuffs including saturated- and trans-fat, fruit, vegetables and whole grains. Again others examined diets that scored low on a measure of dietary diversity, or they analysed dietary patterns according to national dietary recommendations. A small number of studies did not define what was meant by unhealthy diet.

There is more consensus about what constitutes low physical activity. For measurement purposes, physical activities are classified into categories of intensity, from light to moderate to vigorous, depending on the amount of effort required to perform the activity. Guidelines by the WHO combine intensity with duration, for example recommending that adults should engage in at least 150 minutes of moderate-intensity aerobic physical activity throughout the week, in bouts of at least 10 minutes' duration, to reduce the risk of chronic disease.

Yet, as with unhealthy diet, reviewed studies that have assessed the costs of low physical activity used different definitions, ranging from those focusing on different thresholds of intensity of activities to those looking just at the duration. Others only considered specific types of physical activity (or lack thereof), such as leisure-time physical activity, walking, participation in an exercise programme or sedentary behaviour. Two studies did not define low physical activity.

These differences in definitions and conceptualisations undermine the comparative assessment of available cost estimates that can be associated with either risk factor.

Costing studies differ in analytical approaches and in the nature and scope of data used, influencing estimates for the economic burden of unhealthy diets and low physical activity.

Just under half of reviewed studies used population-attributable fractions (PAFs) to assess the contribution of unhealthy diets or low physical activity to a range of diseases (or death) and this then formed the basis to estimate the economic burden.

Studies analysed different numbers and combinations of diseases, most commonly coronary heart disease, stroke, type 2 diabetes and colorectal and breast cancer. They also varied in the population-attributable fractions used. They commonly applied the PAFs to contemporary prevalence of unhealthy diets or low physical activity and then estimated the related disease costs incurred in the same year. Such an approach overlooks the time lag between exposure to the risk factor and the development of disease.

There was equally great variation in the range of costs being considered by individual studies. The majority only looked at the direct health care costs, and this is likely to greatly underestimate the true economic burden that can be associated with unhealthy diets or low physical activity. For example, three Canadian studies that had analysed the costs associated with low physical activity found indirect costs caused by lost productivity to be about twice as high as direct health care costs, together accounting for between 0.4% and 0.6% of gross domestic product (GDP).

We developed a framework for estimating the economic costs of unhealthy diets and low physical activity using a disease-based approach, and applied it to estimate the economic burden of type 2 diabetes associated with these two risk factors.

Building on the insights from the critical appraisal of the literature and the review of measurement and methodological challenges, we developed a framework for assessing the costs of unhealthy diets and low physical activity. We adopted a disease-based approach, which incorporates a time perspective to account for the natural progression of disease. We further estimated incidence rather than prevalence, included costs related to the disease and its complications, and considered indirect costs of productivity losses as a consequence of absenteeism, presenteeism, work disability, early retirement and premature mortality. The framework was tested by assessing the costs of type 2 diabetes. Diabetes has been associated with a high individual, social and economic burden and related expenditure was estimated to account for some 9% of total health care expenditure in the European region in 2015. There is the specific advantage of using diabetes as the disease for testing the framework in that there is a well-established causal pathway from these risk factors and disease.

We projected the total economic costs that can be associated with unhealthy diets and low physical activity in 2015 as manifested in incident type 2 diabetes cases in 2020 in five large European countries to be €883 million.

Using this approach, we projected the total economic cost of diabetes that can be associated with unhealthy diets and low physical activity. The approach takes the patterns of diet and activity levels in 2015 and projects incident diabetes cases for the year 2020. The estimated direct and indirect costs associated with these cases ranged from €82.4 million in Spain to €266.7 million in Germany. This equates to a per capita cost of €1.77 in Spain to €3.29 in Germany. Relating costs more specifically to the population projected to develop diabetes in 2020 as a consequence of unhealthy diets and low physical activity in 2015, the United Kingdom showed the highest amounts, at €18 953, closely followed by Germany and France, while Italy had the lowest cost, at just over €10 720.

The total cost in the five high-income countries studied (France, Germany, Italy, Spain and the United Kingdom) was projected to amount to about €883 million in 2020. The populations in the five countries studied account for almost two thirds of the total population in the European Union (EU-28). This would imply a total EU cost of around €1.3 billion, but care must be taken in any extrapolation given differences in population characteristics, costs of care and value of lost productivity. While these estimates of the economic costs are substantial, they represent only a small proportion of health care expenditure and a very small proportion of GDP. Even on the higher estimates in the sensitivity analysis it is likely that the burden of disease associated with unhealthy diets and low physical activity as measured by poor health and shortened life will be at least as important as the financial costs of additional health care and lost productivity.

It is difficult to compare the findings of the analyses presented here with estimates published elsewhere since only diabetes costs are estimated. The principal analytical steps used in our analysis are similar to those in the recent Lancet Physical Activity 2016 Series for low physical activity. Where our model differs is that we only considered the costs of new cases, which can be causally linked to the risk factor, and we take account of the expected time lag between exposure to the risk factor (unhealthy diets, low physical activity) and the development of the disease, and of complications that arise from diabetes. We also considered a wider range of indirect costs linked to lost productivity because of work absence, disability, early retirement and premature death among incident diabetes cases that can be attributed to unhealthy diets and low physical activity. While our estimates are restricted to diabetes, they provide a fuller picture of the likely future costs that can be attributed to contemporary dietary and physical activity patterns.

Where do we go from here?

This study has tested the feasibility of estimating the costs of unhealthy diets and low physical activity using a disease-based approach. While there are limitations, it has shown that it is broadly feasible to populate the model with data from a range of sources, and the results show a reasonable consistency across countries. While the disease burden from diabetes is not currently as large as that for, for example, ischaemic heart disease, it is a good exemplar because of the strong relationship between these lifestyle factors and the risk of diabetes. In other chronic diseases there will be additional challenges in identifying the contribution of these lifestyle factors and disease risk. Given the very wide range of estimates of costs from the studies reviewed, this may be a more promising approach.

Chapter 1

Introduction

Unhealthy diets and low physical activity are among the key risk factors for major chronic, non-communicable diseases such as cardiovascular diseases, cancers and diabetes. In 2015, diets that are low in fruit and vegetables or high in sugar, processed foods or sodium were estimated to directly account for 37% of all deaths and just over a quarter of the total disease burden (disability-adjusted life years, DALYs) (GBD 2015 Risk Factors Collaborators, 2016). Low levels of physical activity accounted for another 5% of all deaths and 3.4% of DALYs. Taken together, these two risk factors were thus responsible for some two in five deaths worldwide and about 30% of the global disease burden. It is against this background that several strategies have been launched at European and global levels since the early 2000s to promote healthy diets and physical activity and so reduce the related burden of ill-health (Commission of the European Communities, 2007; Council of the European Union, 2014; WHO Regional Office for Europe, 2001; WHO Regional Office for Europe, 2005; WHO Regional Office for Europe, 2015; WHO Regional Office for Europe, 2016; World Health Organization, 2004; World Health Assembly, 2013).

There is an expectation that effectively promoting healthy diets and physical activity can help reduce the economic burden associated with chronic diseases, which was estimated to account for 70–80% of health care budgets, or €700 billion annually across the European Union alone (European Commission, 2014). However, while there is good evidence about the positive impacts of, for example, a healthy diet on outcomes such as major cardiovascular events (Estruch et al., 2013; Stefler et al., 2015; Tong et al., 2016; Liyanage et al., 2016) or about the association between physical activity and mortality (Samitz et al., 2011; Woodcock et al., 2011), only a small number of studies have provided robust estimates for the economic impacts on health care and the wider society that are directly related to either factor. This is in part because the relationships between unhealthy diets or low physical activity and health care costs is complex, and it is the consequences of these behaviours, for example obesity or specific lifestyle-related diseases, that lead to health care costs. However, there may be more direct effects of unhealthy diets and low physical activity on lost productivity.

Available studies provide widely varying estimates, reflecting the range of assumptions and estimates that inform underlying models (Cecchini & Bull, 2015). For example, Scarborough et al. (2011) estimated the economic burden of ill health that could be attributed to unhealthy diet to the National Health Service in the United Kingdom in 2006–07 to be £5.8 billion (€8.5 billion) and £0.9 billion (€1.3 billion) for low physical activity. Maresova (2014) calculated the financial cost of low physical activity to public health insurance in the Czech Republic to be 0.4% of total health care cost in 2008. These figures do not take account of the wider societal costs that can be attributed to these risk factors. More recently, Ding et al. (2016) estimated that in 2013 health care costs associated with low physical activity accounted for an average of 0.6% of total health expenditure across EU Member States.

This volume seeks to help provide a clearer picture of the economic costs of unhealthy diets and low physical activity in Europe, to understand the methodological and practical difficulties in assessing costs, and to provide a test case to show how costs might better be assessed.

Chapter 2 provides a targeted review of the literature that has sought to estimate the economic costs associated with unhealthy diets and low physical activity. This provides estimates of the costs as reported in the different studies, and shows how the estimated costs vary with the different assumptions and methods used.

Chapter 3 reviews the methodological and practical challenges in estimating the economic costs of unhealthy diets and low physical activity. It looks in detail at issues of measurement of diet and physical activity, and at how there are strong interactions between diet and physical activity in terms of risks of disease (and indeed in different elements of diet), and shows how these challenges affect the estimates of costs.

Chapter 4 develops a bottom-up framework for assessing the costs of unhealthy diets and low physical activity using a disease-based approach. This is then tested out for a disease (type 2 diabetes) for which there is strong evidence that the disease is related to both diet and the level of physical activity. This provides a test of concept, and shows how evidence from a range of sources can potentially be combined to improve our understanding of the economic cost.

Chapter 5 briefly summarises the findings of the work and proposes avenues for further research.

Chapter 2

The economic costs of unhealthy diets and low physical activity: what does the published literature tell us?

This chapter reports the findings of a targeted review of the literature that has sought to estimate the economic costs associated with unhealthy diets and/or low physical activity. No previous review has covered costs associated with both of these, and existing reviews of costs of low physical activity (Kruk, 2014; Oldridge, 2008) did not provide information on the methodological approach or a critical evaluation of reviewed studies. The aim of this review is to present the current best estimates of the economic costs, and the strengths and weaknesses of the available studies.

Drawing on the principles of a rapid evidence assessment (Khangura et al., 2012), we carried out a targeted search of PubMed, the National Library of Medicine's Medline and pre-Medline database (NCBI, 2016). We identified studies using medical subject headings (MeSH) as follows ('/' indicating 'or'): 'sedentary lifestyle/leisure activities/motor activity' or 'diet/food' in combination with 'health care costs[statistics and numerical data]/costs and cost analysis/public health[economics]/cost of illness'. We limited our search to studies that were published between January 2000 and February 2016 and that were in the English language.

We included original studies estimating the costs that can be associated with unhealthy diets or low physical activity. We did not consider studies that focused on populations with established disease (e.g. people with osteoarthritis), intervention studies or those that compared different populations with different levels of physical activity or differing dietary behaviours, except where these were quantified further. Given the overall scarcity of studies, we adopted an inclusive approach and we did not formally assess the quality of included studies. We excluded editorials, commentaries or letters.

2.1 Characteristics of reviewed studies

This section briefly summarises the key characteristics of reviewed studies; a detailed overview is presented in Appendix 1.

The PubMed searches identified a total of 3661 records (diet: 2347; physical activity: 1314) and, following screening of abstracts and titles, we considered 38 studies for full-text review. Of these, 30 studies were considered eligible for inclusion in the review. Six addressed diet, 21 examined physical activity, and three considered both.

Eleven of the included studies were set in the United States of America (Ackermann et al., 2003; Anderson et al., 2005; Bachmann et al., 2015; Bland et al., 2009; Carlson et al., 2015; Chevan & Roberts, 2014; Daviglus et al., 2005; Garrett et al., 2004; Martinson et al., 2003; Wang et al., 2005; Wang et al., 2004), five in Canada (Alter et al., 2012; Janssen, 2012; Katzmarzyk, 2011; Katzmarzyk et al., 2000; Krueger et al., 2015), three each in the United Kingdom (Allender et al., 2007; Rayner & Scarborough, 2005; Scarborough et al., 2011) and in Australia (Collins et al., 2011; Doidge et al., 2012; Peeters et al., 2014), two in China (Popkin et al., 2006; Zhang & Chaaban, 2012) and one each in Brazil (Codogno et al., 2015), Germany (Idler et al., 2015), Czech Republic (Maresova, 2014), Japan (Kuriyama et al., 2004) and Taiwan, China (Lo et al., 2013). One study assessed the economic costs of disease-related malnutrition in health care settings in Ireland (Rice & Normand, 2012).

The majority of studies provided a retrospective assessment of the economic burden that can be associated with either unhealthy diets or low physical activity or both, while nine studies adopted a prospective approach by following a cohort of people over a defined period of time (Alter et al., 2012; Bachmann et al., 2015; Bland et al., 2009; Chevan & Roberts, 2014; Collins et al., 2011; Kuriyama et al., 2004; Lo et al., 2013; Martinson et al., 2003; Peeters et al., 2014).

About half of the reviewed studies adopted a disease-based approach to estimate the economic burden that can be associated with unhealthy diets or low physical activity, most frequently cardiovascular diseases (coronary heart disease, stroke, hypertension), type 2 diabetes, and colon and female breast cancer (Allender et al., 2007; Daviglus et al., 2005; Doidge et al., 2012; Garrett et al., 2004; Janssen, 2012; Katzmarzyk, 2011; Katzmarzyk et al., 2000; Krueger et al., 2015; Maresova, 2014; Popkin et al., 2006; Rayner & Scarborough, 2005; Scarborough et al., 2011; Wang et al., 2004; Zhang & Chaaban, 2012). The disease-based approach typically, although not always (Daviglus et al., 2005; Wang et al., 2004), uses the population-attributable fraction (PAF) to quantify the contribution of the individual risk factor (unhealthy diet, low physical activity) to the burden of a given disease or death (Box 1).

The remaining studies used a generic, non-disease-based approach, where unhealthy diets or low physical activity data of each individual were linked to health care cost data, regardless of the type of disease or diagnosis. Such an approach is typically followed by regression techniques to identify possible

Box 1 *Population-attributable fraction*

The population-attributable fraction (PAF) generally refers to the proportion of cases for a given outcome of interest that can be attributed to a given risk factor among the entire population. Specifically, the PAF is a function of the proportion of individuals in the population who are exposed to the factor of interest (P_{exp}), for example, unhealthy diet, and the relative risk (RR) of a particular outcome given that exposure, for example, the development of type 2 diabetes. If the exposure variable is dichotomous (i.e. the risk factor is present or absent), the mathematical formula reads:

$$PAF\,(\%) = \frac{P_{exp}\,(RR-1)}{[P_{exp}\,(RR-1)] + 1}$$

For example, if the relative risk for the effect of a given exposure on a disease outcome was approximately 5, and we can infer from a population survey that about 20% of the population was exposed to this risk factor, the proportion of all disease cases in the population that can be attributed to the risk factor is calculated as: PAF = 0.05 x (20-1) / (0.05 x (20-1) + 1) = 0.95 / 1.95 = 49%.

associations between the presence or absence of the risk factor and the magnitude of costs (Ackermann et al., 2003; Alter et al., 2012; Anderson et al., 2005; Bachmann et al., 2015; Bland et al., 2009; Carlson et al., 2015; Chevan & Roberts, 2014; Codogno et al., 2015; Collins et al., 2011; Idler et al., 2015; Kuriyama et al., 2004; Lo et al., 2013; Martinson et al., 2003; Peeters et al., 2014; Rice & Normand, 2012; Wang et al., 2005).

Studies using a disease-based approach based on population-attributable fractions reported costs that can be associated with unhealthy diets and/or low physical activity in aggregate terms, for example national costs. Conversely, studies that adopted a generic approach tended to report the costs as 'additional costs', that is, additional to the costs a non-exposed individual would otherwise incur, in per capita terms. Two studies reported risk estimates, in this case, odds ratio, illustrating the strength of the association between unhealthy diet or low physical activity and costs (Chevan & Roberts, 2014; Codogno et al., 2015).

2.2 What the evidence tells us: the economic costs of unhealthy diets

Drawing on those studies that have reported aggregate costs, the annual economic costs of unhealthy diets ranged from €1.4 billion in Australia (AU$ 2 billion) (Doidge et al., 2012) to €4.5 billion in China (US$ 4.2 billion) (Popkin et al., 2006) and €8.5–9.5 billion in the United Kingdom (£5.8–6 billion) (Rayner & Scarborough, 2005; Scarborough et al., 2011) (see Appendix 2 for conversion rates of currencies applied) (Table 1). Taking account of the population size, the per capita annual economic costs that can be associated with unhealthy diets is estimated to range from €143 to €156 for the United Kingdom, €63 for Australia and €3.5 for China. All of these costs were health care costs only.

Table 1 *Annual economic costs of unhealthy diets as reported in the published literature*

Country	Estimated annual economic costs of unhealthy diets (*per capita**)	Definition of unhealthy diets	Perspective of cost estimation	Population base	Source
Australia	€1.4 billion *(€63)*	Low levels of dairy consumption	Direct health care costs, not specified	General population	Doidge et al. (2012)
China	€4.5 billion *(€3.5)*	Diet high in saturated and trans-fat, low in fruit, vegetables and whole grains plus heavy alcohol drinking	Direct health care costs, not specified	General population	Popkin et al. (2006)
United Kingdom	€8.5 billion *(€143)*	Not defined	Direct health care costs, not specified	General population	Rayner & Scarborough (2005)
	€9.5 billion *(€156)*	Not defined	Direct health care costs, not specified	General population	Scarborough et al. (2011)

Note: * per capita costs calculated using United Nations population data (United Nations, 2015).

Reviewed studies varied widely in their definition of unhealthy diets, often focusing on single food items, such as dairy consumption (Doidge et al., 2012) or intakes of fruit or vegetables (Bland et al., 2009; Daviglus et al., 2005), while Popkin et al. (2006) considered a range of nutrients and foodstuffs including high consumption of saturated- and trans-fat, and low consumption of fruit, vegetables and whole grains, as well as heavy alcohol use. Lo et al. (2013) examined diets that scored low on a measure of dietary diversity, while Collins et al. (2011) analysed dietary patterns according to Australian national dietary recommendations. Two studies did not define unhealthy diets specifically (Rayner & Scarborough, 2005; Scarborough et al., 2011), and Rice & Normand (2012) analysed the cost of malnutrition in health care settings.

Similarly, studies also varied in relation to the data that were used to assess diet and costs. A small number of studies used national surveys of self-reported food intake (Doidge et al., 2012; Popkin et al., 2006), while others did not collect data on dietary patterns specifically but instead used readily calculated population-attributable fractions published elsewhere. For example, Rayner & Scarborough (2005) and Scarborough et al. (2011) drew on PAFs produced as part of the Global Burden of Disease studies (Ezzati et al., 2004; Murray & Lopez, 1997).

All reviewed studies estimated disease-based direct health care expenditures and only Rice & Normand (2012) also included social care costs. All estimated costs applied to the general population; the only exception was the study by Bland et al. (2009), which estimated the costs for a sample of members of one health insurance plan in the United States (n = 7983 individuals).

2.3 What the evidence tells us: the economic costs of low physical activity

Turning to the economic costs that can be associated with low physical activity, fourteen studies reported aggregate costs. These ranged from €29 million per annum in the Czech Republic (Kč 700 million) (Maresova, 2014) to €1.32–1.68 billion in the United Kingdom (£0.9–1.06 billion) (Scarborough et al., 2011; Allender et al., 2007), €1.3–7.9 billion in Canada (C$ 2.1–10.8 billion) (Katzmarzyk et al., 2000; Krueger et al., 2015; Janssen, 2012; Katzmarzyk, 2011), €1.8–4.9 billion in China (US$ 1.7–6.8 billion) (Popkin et al., 2006; Zhang & Chaaban, 2012) and €90.5 million–€57.7 billion in the United States (US$ 83.6 million–79 billion) (Garrett et al., 2004; Anderson et al., 2005; Carlson et al., 2015) (Table 2). Taking account of population, the estimated annual per capita health care costs ranged from €3 in the Czech Republic to €48 in Canada. In the United States alone, per capita health care cost estimates ranged from less than €1 in two studies up to €185. Only four studies also considered indirect costs in their estimates, and these varied from €3.7 per capita in China to between €127 and €224 in Canada.

As illustrated in Table 2, and similar to studies analysing unhealthy diets, low physical activity or physical inactivity was defined differently across studies, which makes it difficult to compare estimates. Four studies defined physical inactivity as not meeting recommendations for moderate- and vigorous-intensity types of physical activity (Idler et al., 2015; Janssen, 2012; Maresova, 2014; Zhang & Chaaban, 2012), while Carlson et al. (2015) considered only moderate-intensity activity and Garrett et al. (2004) only vigorous-intensity activity. Four studies defined physical inactivity as not meeting the recommended duration (which varied across studies), regardless of intensity (Alter et al., 2012; Anderson et al., 2005; Bland et al., 2009; Martinson et al., 2003). Katzmarzyk et al. (2000), Garrett et al. (2004), Katzmarzyk (2011) and Krueger et al. (2015) only considered leisure-time physical inactivity, Popkin et al. (2006) only considered sedentary behaviour, Kuriyama et al. (2004) focused on walking and Ackerman et al. (2003) defined physical activity as participation in an exercise programme. Bachmann et al. (2015) and Peeters et al. (2014) conceptualised activity in terms of metabolic equivalents achieved while performing a physical activity, and Wang et al. (2004; 2005) used small increases in heart rate or heavy breathing induced by physical activity as a measure of activity. Allender et al. (2007) and Scarborough et al. (2011) did not define physical inactivity specifically.

Table 2 *Annual economic costs of low physical activity reported in the published literature*

Country	Annual economic costs of low physical activity (per capita*)	Definition of low physical activity	Perspective of cost estimation	Population base	Source
Czech Republic	€29 million *(€2.8)*	Less than 150 minutes of moderate activity or less than 75 minutes of vigorous activity a week or less than 180 minutes of walking weekly or any combination resulting in less than 600-MET minutes a week on at least three days per week or no physical activity at all.	Direct health care costs, not specified	General population	Maresova (2014)
United Kingdom	€1.32 billion *(€22)*	Not defined	Direct health care costs, not specified	General population	Scarborough et al. (2011)
	€1.68 billion *(€28)*	Not defined	Direct health care costs: inpatient and outpatient, primary care, pharmaceutical and net community care service expenditures	General population	Allender et al. (2007)
Canada	€1.3 billion *(€43)*	Leisure-time energy expenditure of less than 12.6 kilojoules per kg bodyweight per day	Direct health care costs, not specified	General population	Katzmarzyk et al. (2000)
	€4.3 billion *(€127)*	Less than 150 minutes of moderate-vigorous physical activity per week	Direct health care costs: hospital, drugs, physician care, care in other institutions, 'additional' direct health care expenditures Indirect productivity costs: income lost due to sickness absence, injury-related work disability and premature deaths before retirement	General population	Janssen (2012)
	€5.4 billion *(€160)*	Leisure-time energy expenditure of <1.5 kcal per kg bodyweight per day	Direct health care costs: hospital, drugs, physician care, care in other institutions, other professional fees, public health, health research and pre-payment administration costs Indirect productivity costs: income lost due to premature death and short-term and long-term disability	General population	Katzmarzyk (2011)
	€7.9 billion *(€224)*	Average leisure-time energy expenditure of less than 1.5 kcal per kg per day over the past three months	Direct health care costs: hospital, physician services, other health care professional services (excluding dental services), drugs, health research and 'other' health care expenditures Indirect productivity costs: income lost due to short-term disability, long-term disability and premature mortality (before retirement)	General population	Krueger et al. (2015)

Country	Annual economic costs of low physical activity (per capita*)	Definition of low physical activity	Perspective of cost estimation	Population base	Source
China	€1.8 billion *(€1.4)*	Sedentary behaviour	Direct health care costs, not specified	General population	Popkin et al. (2006)
	€4.9 billion *(€3.7)*	Less than 30 minutes of moderate-intensity activity for five days per week or less than 20 minutes of vigorous-intensity activity for three days per week	Direct health care costs: hospital, drugs, physician care, other professional services, public health, health research, pre-payment administration costs Indirect productivity costs: income lost due to sickness absence, injury-related work disability and premature deaths before retirement	General population	Zhang & Chaaban (2012)
The United States	€90.5 million *(€0.3)*	Less than 20 minutes of vigorous leisure-time physical activity for at least three days a week or no leisure-time physical activity at all	Direct health care costs: inpatient and outpatient facility, professional, x-ray, laboratory and pharmaceuticals, including out-of-pocket payments	Sample population (n = 1.5 million)	Garrett et al. (2004)
	€212.4 million *(€0.8)*	Less than four days of physical activity lasting 30 minutes or more or no physical activity at all	Direct health care costs: hospital and professional fees, excluding pharmaceuticals	Sample population (n = 200 000)	Anderson et al. (2005)
	€26.5 billion *(€98)*	Less than 30 minutes of activity increasing the heart rate for ≥5 times per week or less than 20 minutes of activity substantially increasing the heart rate for ≥3 times per week	Direct health care costs: inpatient stays and outpatient visits, medications and home care, including out-of-pocket payments	General population	Wang et al. (2004)
	€57.7 billion *(€185)*	Less than 150 minutes per week of moderate physical activity or none at all	Direct health care costs: inpatient, and outpatient, emergency room, office-based, dental, vision and home health care, including prescription drugs	General population	Carlson et al. (2015)

Note: * per capita costs calculated using United Nations population data (United Nations, 2015).

Data on physical activity were typically self-reported (assessed through surveys). Janssen (2012) measured physical activity using accelerometers, and Bachmann et al. (2015) assessed cardiorespiratory fitness as a measure of habitual physical activity using a treadmill test. Four studies estimated indirect costs associated with low physical activity, in addition to health care costs (Janssen, 2012; Katzmarzyk, 2011; Krueger et al., 2015; Zheng et al., 2012). Analyses mostly applied to the general population, although six studies estimated costs for specific populations, such as members of a health plan in the United States (Ackermann et al., 2003; Anderson et al., 2005; Bachmann et al., 2015; Garrett et al., 2004; Idler et al., 2015; Wang et al., 2005). Idler et al. (2015) analysed the relationship between physical activity and health care and (parental) productivity costs among children aged 9 to 12 years.

Two studies reported the costs of low physical activity in combination with other risk factors. Alter et al. (2012) estimated the incremental health care costs that can be associated with obesity and additional risk factors, including low physical activity (described as sedentary) (data not shown in Table 2 as authors reported per capita costs only). They found that the cumulative additional costs attributable to overweight and obesity alone were small when compared with matched normal-weight adults. However, costs increased significantly with other risk factors. Thus, for obese individuals who were also physically inactive, health care costs exceeded those of normal-weight, healthy individuals over an 11.5-year period by around €3700 (C$ 4080; $p = 0.003$). Kuriyama et al. (2004) estimated that low physical activity increased monthly per capita health care costs among adults in Japan by 8%, from €172 for adults without lifestyle risk to €185, with further increases where low physical activity was combined with obesity (by 16.4%) (1995–2001). Idler et al. (2015) focused on children aged 9 to 12 years and found that low physical activity increased health care costs by €6 per child annually, but decreased the productivity costs (i.e. earnings lost due to parental absence from work) by €11 per physically inactive child. However, the relationship between physical activity and costs in this age group was not statistically significant. Similarly, Ackermann et al. (2003) found no significant difference in costs between physically active and inactive members of a health plan in the United States.

Three studies analysed the comparative impact of unhealthy diets and low physical activity on cost. Popkin et al. (2006) and Scarborough et al. (2011) estimated that the cost associated with unhealthy diets exceeded that associated with low physical activity by a factor of 1.5 to 5. Bland et al. (2009) found that low physical activity but not unhealthy diet (as measured by low fruit and vegetable consumption) was significantly associated with higher short-term medical costs. The latter study collected primary data on diet and physical activity among members of a health plan in the United States to estimate medical costs, whereas both Popkin et al. (2006) and Scarborough et al. (2011) based their analyses on published data on population-attributable fractions and studies are not easily comparable.

2.4 Review of the evidence: a summary

In summary, of the 30 studies reviewed, 27 found a significant association between diet and/or physical activity and costs, with unhealthy diets and low physical activity predictive of higher health care expenditure. The only exception was the study by Collins et al. (2011), which reported a healthy diet to be predictive of higher health care costs; the authors noted, however, that the findings of their study of women were likely confounded by charges incurred for routine screening services (e.g. cervical and breast cancer screening), with those with higher dietary index scores more likely to use these services than those with poorer scores. Three studies did not find a significant association between diet or physical activity and costs.

Studies that did report costs associated with the two risk factors found the annual cost of unhealthy diets to range from €3 to €148 per capita and for low physical activity from €3 to €181 per capita. The highest health care cost estimates are equivalent to between 2% and 6% of health spending in the countries. The review shows that there is a very wide range of estimates, and these are very sensitive to the measures of diet and activity and the ways in which the studies were carried out. The next section reviews these methodological and measurement challenges in assessing the costs of unhealthy diets and low physical activity.

Chapter 3

Estimating the economic costs of unhealthy diets and low physical activity is complex

We have shown in the review of published studies that the estimated economic burden associated with unhealthy diets or low physical activity varies widely. Reasons for this variation include differences in the definition of what constitutes unhealthy diets or low physical activity; the methodological approach chosen (such as the method to calculate population-attributable fractions); and the range and types of costs considered. We discuss each aspect in turn.

3.1 Defining the concepts: how can we understand 'unhealthy diet' and 'low physical activity'?

Our evidence review illustrates that 'unhealthy diets' and 'low physical activity' have been conceptualised and interpreted differently, making a comparative assessment of available studies difficult. For example, definitions of unhealthy diets often refer to those high in specific nutrients such as saturated fats, salts or sugars, but growing evidence suggests that intakes of specific foods rather than macro- or micro-nutrients are most relevant for the development of chronic disease (Morgan, 2012; Mozaffarian et al., 2011).

Table 3 *Intake of major food groups associated with the lowest risks for chronic disease*

Food group	Optimal intake levels (mean ± standard deviation)
Fruits	300 ± 30 grams/day
Vegetables	400 ± 40 grams/day
Nuts/seeds	113.4 ± 11.3 grams/week
Whole grains	100 ± 12.5 grams/day
Seafood	350 ± 35 grams/week
Unprocessed red meats	100 ± 10 grams/day
Processed meats	0

Source: Micha et al., 2015.

It is against this background that researchers have moved towards identifying and defining healthy diets based on recommended intakes of selected food groups. For example, Micha et al. (2015) described optimal consumption levels of selected food groups, based on probable or convincing evidence about the association of intake levels and the risk for coronary heart disease, stroke, type 2 diabetes and certain cancers. An unhealthy diet can be defined as one that does not meet the recommended intake levels of selected food groups shown in Table 3. Even with this approach there remains the problem of how to score different levels of deviation from optimal intake.

Intakes of beneficial dietary factors tend to be positively correlated with each other and inversely correlated with those considered unhealthy. This correlation could lead to overestimates of the relative risk of each dietary factor and the total effect of dietary risks at the population level (GBD 2015 Risk Factors Collaborators, 2016). Instead of individually assessing the risks associated with selected food groups, an alternative approach is to examine dietary patterns. Such an approach considers the balance among all food groups, including those that are recommended for frequent consumption and those that are not. It also accommodates different eating patterns, so allowing for variation depending on cultural, ethnic or personal preferences, or the costs and availability of certain foods. Examples include the Healthy Eating Index (HEI), which measures adherence to the 2005 dietary guidelines in place in the United States, and the Alternate Healthy Eating Index (AHEI), which is based on foods and nutrients predictive of chronic disease risk (Chiuve et al., 2012). Diets which score highly on either the HEI or the AHEI were shown to be associated with a significant reduction in the risk of all-cause mortality, cardiovascular disease, cancer and type 2 diabetes by around 20%, highlighting their relevance for population health (Schwingshackl & Hoffmann, 2015). The AHEI is discussed further in the context of our proposed costing framework below.

In contrast to diet, there is more consensus about what constitutes low physical activity. The World Health Organization (2010) has defined physical *inactivity* as the "absence of physical activity or exercise" (p. 53), and it recommends that adults meet the guidelines of at least 150 minutes of moderate-intensity or at least 75 minutes of vigorous-intensity aerobic physical activity throughout the week, in bouts of at least 10 minutes' duration, in order to improve cardiorespiratory and muscular fitness and bone health, and to reduce the risk of chronic disease and depression (World Health Organization, 2010). Physical activity includes activities undertaken while working, playing, carrying out household chores, travelling, and leisure-time activities but is distinct from exercise.

For measurement purposes, physical activities are classified into different categories, ranging from light to moderate to vigorous intensity, depending on the amount of effort (i.e. kilocalories of energy) required to perform the activity. This effort is measured in terms of the Metabolic Equivalents (METs), which is the ratio of a person's metabolic rate while doing the activity relative to their resting metabolic rate, and the intensity is then assessed by multiples of METs spent on a given activity (Box 2) (World Health Organization, 2004). However, as we have seen in the preceding section, studies that have assessed the costs of low physical activity vary in their use of intensity thresholds, or intensity is not taken account of altogether, which makes it difficult to interpret the evidence as highlighted.

Interpretation of the evidence is further complicated where low physical activity is conceptualised as sedentary behaviour, as for example in the study by Popkin et al. (2006). Individuals that are not meeting physical activity guidelines may be wrongly classified as 'sedentary'. Defined as "any waking behaviour with low energy expenditure (≤1.5 metabolic equivalents) while in a sitting or reclining posture" (p. 540) (Sedentary Behaviour Research Network, 2012), growing evidence suggests that prolonged sedentary time is independently associated with deleterious health outcomes independent of the level of physical activity (Biswas et al., 2015). Disentangling these relationships will be important, with for example Ekelund et al. (2016) showing that moderate levels of physical activity reduced the increased mortality risks associated with high sitting time.

Box 2 *Examples of moderate-intensity and vigorous-intensity physical activity*

One MET is equivalent to an energy consumption of 1 kilocalorie per kilogram of bodyweight per hour (i.e. energy cost of sitting quietly).

Examples of moderate-intensity physical activity *Equivalent to approximately 3–6 METs; requires a moderate amount of effort and noticeably accelerates the heart rate*	**Examples of vigorous-intensity physical activity** *Equivalent to approximately >6 METs; requires a large amount of effort and causes rapid breathing and a substantial increase in heart rate*
• Brisk walking • Dancing • Gardening • Housework and domestic chores • Traditional hunting and gathering • Active involvement in games and sports with children/walking domestic animals • General building tasks (e.g. roofing, thatching, painting) • Carrying/moving moderate loads (<20kg)	• Running • Walking/climbing briskly up a hill • Fast cycling • Aerobics • Fast swimming • Competitive sports and games (e.g. traditional games, football, volleyball, hockey, basketball) • Heavy shovelling or digging ditches • Carrying/moving heavy loads (>20kg)

Source: World Health Organization, 2004.

3.2 Costing studies differ in key assumptions, influencing estimates for the economic burden of unhealthy diets and low physical activity

As noted earlier, reviewed studies considered different numbers of diseases to derive estimates of the economic burden that can be associated with unhealthy diets or low physical activity. The most common conditions considered include coronary heart disease, stroke, type 2 diabetes and colorectal and breast cancer, with Garrett et al. (2004) also adding mood and anxiety disorders as directly related to individual physical activity patterns in adults. The range and combination of disease groups varied among studies, as did the main approaches to estimating costs, including the use of population-attributable fractions; consideration of lag times between exposure to a given risk factor, the development of disease and ensuing cost; and the conceptualisation of economic cost itself, which we briefly discuss here.

3.2.1 Use of population-attributable fractions

Fourteen reviewed studies used population-attributable fractions (PAFs) to assess the contribution of unhealthy diets or low physical activity to a range of diseases (or death) as a basis to estimate the economic burden that can be attributed to either risk factor.

As noted earlier, the PAF generally refers to the proportion of cases for a given outcome of interest that can be attributed to a given risk factor among the entire population. Calculation of PAFs commonly uses a relative risk that has been adjusted for potential confounders of the association between risk factors and outcomes, such as age or sex, and the prevalence of exposure in the population under investigation (the partially-adjusted method). However, where confounding or effect modification affects the relative risk, the estimate of the attributable fraction is potentially biased even if the relative risk has been adjusted for confounding (Benichou, 2001). This is likely to be the case for the unhealthy diet and low physical activity–disease relationships, with multiple factors, in addition to age and sex, such as family history or physiological risk factors such as weight found to confound the association (Laaksonen et al., 2009; Li et al., 2015; Montonen et al., 2005).

Baliunas (2011) compared the partially-adjusted method for estimating population-attributable fractions with the fully-adjusted approach, which stratifies the relative risk according to confounder or effect modifier. The comparison was applied to mortality from lung cancer, ischaemic heart disease, chronic obstructive pulmonary disease and cerebrovascular disease related to smoking. It found that the partially-adjusted method overestimated the attributable fractions by

10%. The majority of studies reviewed in this volume have used the partially-adjusted method, and cost estimates are therefore likely to be biased, although the direction of the bias is not clear. The use of a fully-adjusted method would reduce the risk of over- or under-estimating the 'true' association between risk factors and costs.

In addition, population-attributable fractions used in the reviewed studies varied widely. This is illustrated further in Table 4 for PAFs used for costing studies of low physical activity.

Table 4 *Population-attributable fractions used in costing studies: low physical activity*

	Ischaemic heart disease (%)	Stroke (%)	Diabetes type 2 (%)	Breast cancer (%)	Colon cancer (%)
Katzmarzyk et al. (2000)	36	20	20	11	20
Garett et al. (2004)	31	31	18	19	31
Allender et al. (2007)	23	–	15	11	16
Katzmarzyk (2011)	18	23	20	13	17
Scarborough et al. (2011)	23	12	15	11	–
Janssen (2012)	26 (m)* 27 (f)	25 (m)* 26(f)	38 (m)* 29 (f)	15 (f)*	24 (m, f)*
Zhang & Chaaban (2012)	12	16	14	–	–
Maresova (2014)	7	3	4	3	4

Note: * m – males; f – females

This variation reflects, to great extent, the source of PAFs and whether they were adjusted for the population under investigation. For example, Allender et al. (2007) and Scarborough et al. (2011), in their analyses of the economic burden of ill health that can be attributed to low physical activity in the United Kingdom in the mid-2000s, used PAFs that were produced in the context of the first Global Burden of Disease study for the western European population (Murray & Lopez, 1997). There is uncertainty about the degree to which these PAFs are applicable to the country they were used for (in this case the United Kingdom) as PAFs should take account of the underlying prevalence of a risk factor in the population under study. Although a sensitivity analysis by Scarborough et al. (2011) revealed little impact of the choice of PAFs on the cost estimates for low physical activity, population-specific PAFs remain preferable to increase the accuracy of estimates.

3.2.2 Consideration of time lags between risk factor exposure, disease development and associated costs

Reviewed studies tended to apply population-attributable fractions using the prevalence of a given risk factor (unhealthy diets, low physical activity) in a given year and estimating the related disease costs incurred in the same year (Allender et al., 2007; Garrett et al., 2004; Janssen, 2012; Katzmarzyk, 2011; Katzmarzyk et al., 2000; Maresova, 2014; Popkin et al., 2006; Scarborough et al., 2011; Zhang & Chaaban, 2012). Such an approach ignores the time lag between exposure to the given risk factor and the development of disease. For example, Weyer et al. (1999) found that it takes approximately five years between the initial normal glucose-tolerant stages and the development of clinically verified type 2 diabetes. Where the development of diabetes can be linked to unhealthy diet or low physical activity at the outset, associated economic costs would thus be expected to emerge only after five years at the earliest. Therefore, accurately estimating the cost that can be attributed to unhealthy diets or low physical activity would need to take account of the time it takes for the natural progression of exposure to disease.

3.3 The nature and range of costs considered is likely to underestimate the 'true' economic burden of unhealthy diets and physical activity

Reviewed studies tended only to consider costs that can be associated with primary disease outcomes, such as type 2 diabetes or coronary heart disease. Yet, a full costing would also need to take account of complications associated with the primary disease outcome. Considering, for example, type 2 diabetes: data from the UK National Diabetes Audit found that within a one-year follow-up period between 2011–12 and 2012–13, people with type 2 diabetes were significantly more likely than those without diabetes to be admitted to hospital for complications such as angina, at 135.1%, heart failure (121.1%), heart attack (87.6%) or stroke (59.1%) (Health and Social Care Information Centre, 2015). Disregarding the costs associated with the development of complications will inevitably underestimate the true economic burden that can be associated with a given risk factor, but this also assumes that it is possible to quantify the contribution of the risk factor under consideration to the observed complication.

Furthermore, the majority of reviewed studies considered only the direct health care costs, further underestimating the true economic burden that can be associated with unhealthy diets or low physical activity (see also Box 3). For example, three Canadian studies that had analysed the costs associated with low physical activity found indirect costs caused by lost productivity to be about twice as high as direct health care costs, and together these accounted for between 0.4% and 0.6% of gross domestic product (GDP) (Janssen, 2012; Katzmarzyk, 2011; Krueger et al., 2015). It is difficult to generalise from these studies to other settings and it will be important to broaden existing costing estimates to also capture indirect costs in order to better understand the size of the burden that can be associated with the two risk factors.

3.4 Conceptual and methodological challenges of estimating the economic costs of unhealthy diets and low physical activity: a summary

This section reviewed the measurement and methodological issues in assessing the economic burden of unhealthy diet and low levels of activity. We note that the measurement of what constitutes an 'unhealthy' diet is made more difficult by there being positive effects of some foods, negative effects of others and interactions between the effects of different foods. Calibrating the extent of deviation from optimal consumption and the effects of this deviation is difficult. It is also clear that the context should be taken into account in terms of other population characteristics.

Box 3 *Conceptualizing economic costs*

Costing methodology generally distinguishes direct, indirect and intangible costs, although these have been conceptualized in different ways (Johnston et al., 1999). Direct costs typically refer to costs of health care services as they relate to the prevention, diagnosis and treatment of a given condition, such as inpatient or outpatient care, rehabilitation, community health services and pharmaceuticals; direct costs may also include social care costs where relevant (Suhrcke et al., 2008). Costs considered typically include those associated with service *utilization*, that is the use of a particular service over time (for example, physician visits, emergency room or accident and emergency department visits, hospital (re-)admissions, length of hospital stay, number of hospital days), and the actual *cost* of providing a particular service (health, nursing, social care), including the costs of procedures, therapies and medications, or *expenditure*, that is, the amount of money paid for the services, and from fees (the amount charged), regardless of cost. There are also direct costs borne directly by people using the services; these include transportation costs, out-of-pocket payments for medications and devices, special diets and home help.

Indirect costs typically refer to productivity losses to society because of ill health or its treatment (Koopmanschap et al., 1995). Commonly considered dimensions include presenteeism, absenteeism, early retirement and premature mortality. *Presenteeism* costs refer to the value of productivity losses accrued by employees who are present at work but are unable to work at full capacity because of illness (Johns, 2010), measured as the value of reduced work output, errors on the job and failure to meet the company's production standards (Schultz & Edington, 2007). *Absenteeism* costs refer to those costs incurred because of absence from work because of ill health. Costs related to *early retirement* refer to potential earnings forgone by not working to the formal age of retirement, while *premature mortality* refers to the loss of economic output calculated as the income that individuals who die before or at a given age will lose over the period of remaining labour market participation (under or to age 65).

Finally, intangible costs generally describe the psychological burden placed on patients and their carers, including pain, bereavement, anxiety and suffering (Suhrcke et al., 2008).

While there is more consensus about the measurement of physical activity, similar issues arise in terms of the independent effects of moderate and vigorous activity and sedentary behaviour, but also the interactions between these. Studies take broader and narrower perspectives in terms of what costs are included, with some limited to formal health care costs, and others aiming to take a more societal view. While current evidence makes it difficult to make accurate comparisons, it is likely that much of the economic burden comes from non-health care costs, especially from effects on productivity, absenteeism, presenteeism and other indirect costs.

Chapter 4

Taking available approaches to determining the economic costs of unhealthy diets and low physical activity further: a proof-of-concept approach applied to five European countries

This chapter develops a bottom-up framework for assessing the costs of unhealthy diets and low physical activity using a disease-based approach. Building on the insights from the evidence review and critical appraisal of measurement and methodological issues in the preceding sections, this section builds a framework for assessing costs of unhealthy diets and low physical activity. It then applies this framework as a proof-of-concept to demonstrate the feasibility of undertaking a comprehensive, bottom-up cost assessment that addresses some of the identified limitations of existing costing studies.

The evidence review demonstrated that there are essentially two approaches to estimating the economic burden associated with unhealthy diets and low physical activity. One involves the use of a disease-based approach, based on the observation that the two risk factors have been identified to be causally related to major chronic diseases such as coronary heart disease, stroke, type 2 diabetes and selected cancers (Lee et al., 2012; Micha et al., 2015), which have been associated with considerable costs to health care systems and wider society through productivity losses (European Commission, 2014). About half of the reviewed studies adopted the disease-based approach, typically using the population-attributable fraction to quantify the contribution of the individual risk factor (unhealthy diet, low physical activity) to the burden of a given disease or death and the associated economic costs. An alternative method involves a generic, non-disease-based approach that uses individual data on unhealthy diets or low physical activity data and links these to (health care) cost data, regardless of the type of disease or diagnosis. This second approach requires availability of and access to individual-level data on dietary and physical activity patterns along with data on health care use and productivity. Such data are difficult to access even within individual country settings, let alone in multiple countries.

We use a disease-based approach to estimate the costs that can be associated with unhealthy diets and low physical activity. Diseases associated with these lifestyle factors include coronary heart disease, stroke, type 2 diabetes and selected cancers (Box 4) (Lee et al., 2012; Micha et al., 2015). As a test of concept we apply the framework using type 2 diabetes. This was chosen because of the strong association of type 2 diabetes with either risk factor, as shown in the literature. Diabetes is already an important public health issue but perhaps more importantly, globally the number of people with diabetes has doubled during the past 20 years, making it a growing challenge for health systems (Zimmet et al., 2014). Estimates for the early 2000s place the costs for type 2 diabetes in the EU at some 7.4% of total health care expenditure, compared to 12% for cardiovascular diseases (Muka et al., 2015). More recently, expenditure on diabetes was estimated to account for some 9% of total health care expenditure in the European region in 2015 (International Diabetes Federation, 2015).

Taking a disease-based approach, we used population-attributable fractions to provide population-level quantitative estimates for the economic costs that

Box 4 *Health risks associated with unhealthy diets and low physical activity*

A wide range of studies have presented convincing or probable evidence for an association between the intake of selected foods and food groups and major chronic conditions (Micha et al., 2015). For example, coronary heart disease has been linked to intake of fruit and vegetables, nuts and legumes, whole grains, fish, and red and processed meat (Afshin et al., 2014; Aune et al., 2016; Boeing et al., 2012; Micha et al., 2010; Zheng et al., 2012); stroke to fruit and vegetables, nuts and legumes, fish, and red and processed meat (Afshin et al., 2014; Boeing et al., 2012; Chowdhury et al., 2012, Micha et al., 2010; Zheng et al., 2012), type 2 diabetes to nuts and legumes, whole grains, red and processed meats (Afshin et al., 2014; Aune et al., 2016; Micha et al., 2010; Zheng et al., 2012) and selected cancers to fruit and vegetables, nuts and legumes, whole grains, fish, and red and processed meats (Aune et al., 2016; Boeing et al., 2012; Bouvard et al., 2015; World Cancer Research Fund and American Institute for Cancer Research, 2007). Based on the available evidence, Micha et al. (2015) concluded that "even modest dietary changes are associated with meaningful reductions in [cardiovascular disease] morbidity and mortality, type 2 diabetes [and] specific cancer sites" (p. 2), along with major risk factors, such as hypercholesterolaemia, hypertension and obesity.

These conditions have also been linked to physical activity, with Warburton et al. (2010) demonstrating that low physical activity was associated with an increased risk for cardiovascular disease, stroke, hypertension, colon and breast cancer and type 2 diabetes. The authors further demonstrated that higher levels of physical activity reduced the risk for premature all-cause mortality.

can be associated with unhealthy diets and low physical activity. In the light of the reviewed evidence, we adapted the PAF methodology by (i) using a full-adjustment formula that takes account of confounding between unhealthy diets and low physical activity and associated diseases; (ii) incorporating a time perspective that takes account of the natural progression from risk factor exposure to the development of disease; (iii) applying the PAFs to costs based on data on incidence rather than prevalence; (iv) estimating the direct costs that can be associated with the primary outcome and those associated with complications using the annual incidence rates for complications; and (v) considering indirect costs of productivity losses as a consequence of absenteeism, presenteeism, work disability, early retirement and premature mortality.

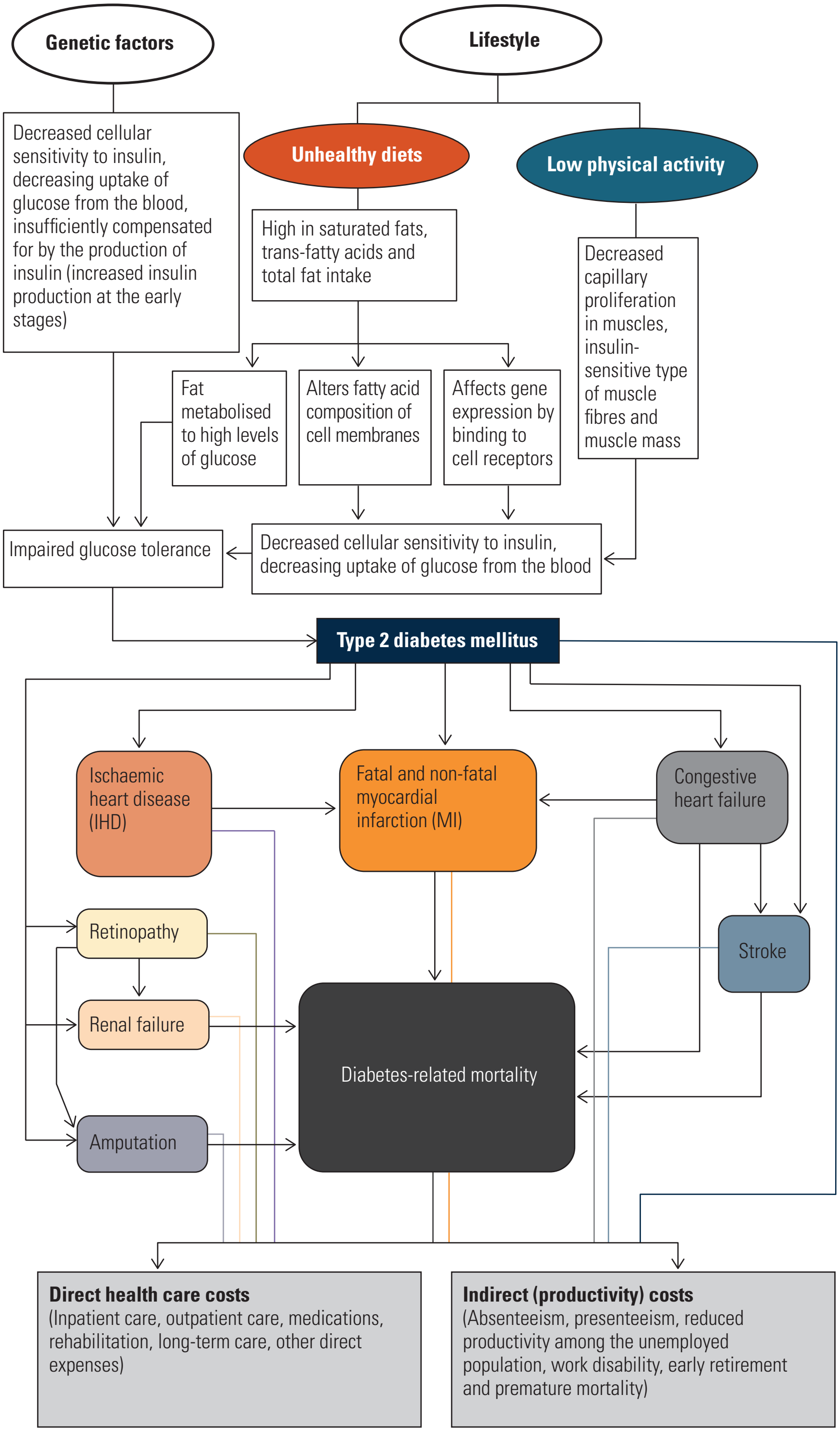
The following sections provide a sample computation of the economic costs of unhealthy diets and low physical activity in five European countries: France, Germany, Italy, Spain and the United Kingdom, using type 2 diabetes and its complications as the primary outcome.

4.1 Diabetes as an outcome of unhealthy diets and low physical activity

As noted above, we chose type 2 diabetes as the primary outcome because of the convincingly strong evidence of its association with unhealthy diets and low physical activity (Afshin et al., 2014; Micha et al., 2010; Warburton et al., 2010; Zheng et al., 2012). Diabetes mellitus, commonly referred to as diabetes, is a group of metabolic diseases characterized by high levels of sugar in the blood for a prolonged period of time.

The most common form of diabetes is type 2, which typically occurs in adults, although it is increasingly seen in young people, including children (Zimmet et al., 2014). It results primarily from insulin resistance, and at later stages the pancreas may also fail to produce sufficient levels of insulin. Insulin resistance in type 2 diabetes is associated mainly with high bodyweight and low physical activity. The role of genetic factors in the development of type 2 diabetes tends to be small compared to lifestyle and clinical factors such as increased bodyweight, elevated liver enzymes, current smoking status and reduced measures of insulin secretion and action (Lyssenko et al., 2008). Factors that increase the likelihood of developing diabetes include high consumption of sugar-sweetened drinks (Malik et al., 2010a; Malik et al., 2010b), of saturated and trans-fatty acids (Risérus et al., 2009) and of refined grains such as white rice (de Bakker et al., 2012), which, when metabolised to glucose, increase blood sugar levels. Low physical activity has also been linked to type 2 diabetes through causing insulin resistance (Warburton et al., 2010) (Figure 1).

Figure 1 *Relationship between unhealthy diets and low physical activity with type 2 diabetes and associated costs*



Source: authors.

4.2 The principal approach used in this study to estimate the economic costs that can be associated with unhealthy diets and low physical activity

The identification of the economic costs that can be associated with unhealthy diets and low physical activity as conceptualised in this study involves five principal steps:

1. determining the prevalence of unhealthy diets and low physical activity among the general population and estimating the prevalence in populations eventually developing the disease using adjustment factors;
2. determining the population-attributable fraction, or the proportion of cases attributable to unhealthy diets and low physical activity;
3. estimating the proportion of incident diabetes cases in future year X that can be attributed to present unhealthy diets and low physical activity patterns;
4. estimating the average annual per patient health care costs that can be associated with diabetes and with diabetic complications to yield diabetes-related direct costs; and
5. estimating the indirect costs that can be associated with diabetes attributable to unhealthy diets and low physical activity.

We discuss these steps in turn.

4.2.1 Determining the prevalence of unhealthy diets and low physical activity

Our proposed approach requires knowledge of the prevalence of the risk factor (here: unhealthy diets, low physical activity) among populations that eventually develop the outcome (here: type 2 diabetes), rather than among the general population, in order to enhance the accuracy of the estimation of costs that can be associated with the given risk factor. For low physical activity, we drew on work by Lee et al. (2012) who calculated adjustment factors for different outcomes (coronary heart disease, type 2 diabetes, breast and colon cancer, and those who died) to identify the *added extent* to which low physical activity occurred in people who eventually developed the outcome in question compared to the general population. Lee et al. (2012) illustrate this with an example from the Shanghai Women's Health Study, where the prevalence of low physical activity in all women at baseline was 45.4% compared to 51.6% among women who eventually died, yielding an adjustment factor of 1.14 (51.6/45.4 = 1.14). They then calculated such an adjustment factor for a large number of original studies, and, for type 2 diabetes, derived a factor of 1.23 after averaging estimates across studies (for comparison, adjustment factors for coronary heart disease or colon cancer were 1.20 and 1.22, respectively, and for breast cancer, it was 1.05). We used the adjustment factor of 1.23 to estimate the prevalence of low physical activity among people who will eventually develop diabetes in France, Germany, Italy, Spain and the United Kingdom.

Data on prevalence for low physical activity in the five countries were derived from the WHO Global Health Observatory database (World Health Organization, 2016). According to this source, the proportion of the general population who were not active, or who did not meet the recommendations of at least 150 minutes per week of moderate-intensity physical activity or at least 75 minutes per week of vigorous-intensity physical activity in 2010 were: 23.8% in France, 21.1% in Germany, 33.2% in Italy, 30.5% in Spain and 37.3% in the United Kingdom. Applying the adjustment factor of 1.23 to these rates yielded estimated prevalence rates of 29.3% in France, 26% in Germany, 40.8% in Italy, 37.5% in Spain and 45.9% in the United Kingdom among populations who will eventually develop diabetes.

In contrast to low physical activity, determining the prevalence rate for unhealthy diets is more complex given the limited availability of appropriate data. We drew on the alternate healthy eating index (AHEI) 2010 developed by Chiuve et al. (2012). The AHEI assesses components of the diet by assigning scores ranging from 0 (worst) to 10 (best) (Table 5); scores between 67 and 110 are rated as adherence to what has been described as a healthy diet that emphasises high intakes of whole grains, polyunsaturated fatty acids, nuts and fish, and reductions in red and processed meats, refined grains and sugar-sweetened beverages. As noted above, studies found that diets that scored highly on the AHEI were shown to be associated with a significant reduction in the risk of all-cause mortality, cardiovascular disease, cancer and type 2 diabetes by around 20% (Schwingshackl & Hoffmann, 2015).

We used the European Food Safety Authority (EFSA) Database to estimate the prevalence of unhealthy diets in the five countries under study. The EFSA contains information on the mean consumption of over 1500 food items in European countries, based on data from national dietary surveys (European Food and Safety Authority, 2015). Based on these data, we derived the mean intake of AHEI food groups for each country (Appendix 3) and allocated AHEI scores as shown in Table 6. Assuming that the figures shown in Appendix 3 and Table 6 are representative of the five countries as a whole, we estimate the proportions of those following an unhealthy diet to be 44% of the general population in France, 25% in Germany, 33.9% in Italy, 34.6% in Spain and 26.5% in the United Kingdom, as assessed by scores of 43% (France), 34% (Germany), 58% (Italy), 48% (Spain) and 37% (the United Kingdom) according to the 2010 alternate healthy eating index.

Table 5 *The quality of diets according to the alternate healthy eating index (AHEI) 2010*

Component	Criteria for minimum score (0)	Criteria for maximum score (10)	Serving size for food components
Vegetables[1] (servings per day)	0	≥5	0.5 cup or 1 cup of green leafy vegetables
Fruit[2] (servings per day)	0	≥4	1 medium piece or 0.5 cup of berries
Whole grains (grams per day)			
Women	0	75	
Men	0	90	
Sugar-sweetened beverages and fruit juice (servings per day)	≥1	0	8oz.
Nuts and legumes (servings per day)	0	≥1	1oz. of nuts or 1 tablespoon (15 ml) of peanut butter
Red and processed meat (servings per day)	≥1.5	0	4oz. of (red) unprocessed meat or 1.5oz. of processed meat
Trans-fats (% of energy)	≥4	≥0.5	
Omega-3 fatty acids (EPA + DHA) (mg per day)	0	250	Equivalent to two 4oz servings per week
Polyunsaturated fatty acids (% of energy)	≤2	≥10	
Sodium (mg per day)			
Women	≥3 337	≤1 112	
Men	≥5 271	≤1 612	
Alcohol (drinks per day)			
Women	≥2.5	0.5–1.5	One drink equivalent to 4oz. wine, 12oz. beer or 1.5oz. liquor
Men	≥3.5	0.5–2.0	
TOTAL	**0**	**110**	

Source: adapted from Chiuve et al., 2012.

Notes: [1] Excludes potatoes (including french fries) because they are not associated with lower risk of chronic disease in epidemiologic studies; [2] whole fruits only.

Unlike for low physical activity, we were unable to identify studies that provide adjustment factors that would allow assessment of the degree to which unhealthy diet is present in cases of the outcome compared to the overall population. Jacobs et al. (2015) estimated approximate adjustment factors based on a cohort of white Americans (which formed part of a larger multi-ethnic cohort in Hawaii) with poor dietary patterns assessed using the 2010 alternate healthy eating index (31 864 individuals), of whom 7.1% eventually developed diabetes (2274 subjects). The prevalence of unhealthy diets in the study population was 61.3%

Table 6 *Assignment of AHEI scores on mean dietary intakes of AHEI food groups in France, Germany, Italy, Spain and the United Kingdom*

Dietary component	AHEI recommended intake per day for maximum score (10 points)	MEAN INTAKE PER DAY					AHEI SCORE				
		France (2007)	Germany (2007)	Italy (2005–6)	Spain (2009)	United Kingdom (2008)	France (2007)	Germany (2007)	Italy (2005–6)	Spain (2009)	United Kingdom (2008)
Vegetables	≥5 cups green leafy vegetables	0.09 cups	0.12 cups	0.20 cups	0.18 cups	0.03 cups	0	0	0	0	0
Fruit	≥453.44g berries	10.97g	13.66g	2.89g	6.35g	10.81g	0	0	0	0	0
Whole grains	≥82.5g *	12.2g	0.49g	35.29g	6.84g	2.80g	1	0	4	0	0
Sugar-sweetened beverages and fruit juice	≤0.79oz.	4.19oz.	12.05oz.	1.98oz.	4.61oz.	7.91oz.	5	0	8	5	1
Nuts	≥1oz.	0.04oz.	0.10oz.	0.04oz.	0.07oz.	0.04oz.	0	1	0	0	0
Processed meat	≤0.224oz.	1.33oz.	1.76oz.	1.05oz.	1.73oz.	1.06oz.	5	3	6	3	6
Trans-fat	≤0.5% of energy intake (equivalent to ≤1.39g for a 2 500kcal diet per day)	63.5g	68.57g	30.23g	48.31g	33.48g	0	0	0	0	0
Long-chain (n-3) fats (EPA + DHA)	≥0.25g	21.39g	13.76g	31.05g	57.31g	21.1g	10	10	10	10	10
PUFA	≥10% of energy intake (equivalent to ≥27.78g for a 2 500kcal diet per day)	10.92g	2.93g	36.63g	32.6g	1.46g	3	0	10	10	0
Sodium	≤1.36g *	1.5g	0.01g	0.01g	0.17g	0.08g	9	10	10	10	10
Alcohol	≤7oz. wine, ≤21oz. beer, ≤2.6oz. liquor *	2.75oz.	6.33oz.	2.50oz.	3.12oz.	6.43oz.	10	10	10	10	10
TOTAL							**43**	**34**	**58**	**48**	**37**

Note: * Median of recommended intakes for men and women and among those eventually developing diabetes, the proportion of those with unhealthy diets was 67.1%; this equates to an adjustment factor of 1.09, which we used in our study.

4.2.2 Determining the population-attributable fraction, or the proportion of cases attributable to unhealthy diets and low physical activity

Determining the population-attributable fraction first requires assessment of the relative risks for developing diabetes that can be associated with unhealthy diets and low physical activity. We drew on work by Li et al. (2015) who prospectively assessed the joint association of birth weight and five behavioural risk factors (smoking status, daily alcohol consumption, body mass index, dietary patterns and physical activity) in adulthood with incident type 2 diabetes based on a cohort of almost 150 000 male and female health professionals (median age 45 years), who were followed up for a period of 20–30 years (median follow-up: 24 years) (see also Appendix 4 for a justification of using the study by Li et al.). During the follow-up period, 11 709 new cases of type 2 diabetes were reported, equating to an incidence rate of 7.8%. Table 7 shows the adjusted relative risks for different levels of exposure to unhealthy diets or low physical activity as estimated by Li et al. (2015).

Table 7 *Relative risks for diabetes related to unhealthy diets and low physical activity estimated by Li et al. (2015)*

Risk factor	Risk factor category			
AHEI score (≥67% classified as healthy diet)				
Level of exposure	0–22%	23–44%	45–66%	≥67%
Relative risk	1.15	1.06	1.02	1.00 (ref)
Low physical activity (moderate-to-vigorous intensity physical activity in hours/week)				
Level of exposure	0	0.01–1.0	1.0–3.5	≥3.5
Relative risk	1.28	1.19	1.03	1.00 (ref)

Source: Li et al., 2015.

Table 8 provides a summary overview of the various estimates for the prevalence of unhealthy diets and low physical activity in the populations eventually developing diabetes in France, Germany, Italy, Spain and the United Kingdom described above and the associated relative risks for incident diabetes that can be associated with these risk factors as derived from Li et al. (2015). As the data on low physical activity among the general population derived from the WHO Global Health Observatory Database described above do not quantify the average weekly hours of physical activity performed by individuals, we used data from the 2013 Eurobarometer survey (TNS Opinion & Social, 2014). It assessed the frequency and duration of sport and physical activity among populations in the EU and quantified the proportions of the survey population who performed moderate- and vigorous-intensity physical activity. This showed that the majority of inactive individuals in the five countries studied performed physical activity for 0.01 to 1 hour per week, which gives a relative risk for the development of diabetes that can be associated with low physical activity of 1.19 (Table 7).

Table 8 *Estimated prevalence rates of unhealthy diets and low physical activity in the populations eventually developing diabetes and relative risks for incident diabetes in France, Germany, Italy, Spain and the United Kingdom*

	Prevalence in the population eventually developing diabetes		Relative risks for incident diabetes associated with unhealthy diets and low physical activity	
	Unhealthy diets (%)	**Low physical activity (%)**	**Unhealthy diets**	**Low physical activity**
France	48.0	29.3	1.06	1.19
Germany	27.3	26.0	1.06	1.19
Italy	37.0	40.8	1.02	1.19
Spain	37.7	37.5	1.02	1.19
United Kingdom	28.9	45.9	1.06	1.19

Estimates shown in Table 8 allow for the computation of the fully-adjusted population-attributable fraction for each setting as illustrated in Box 5.

4.2.3 Estimating the proportion of incident diabetes cases in future year X that can be attributed to present unhealthy diet and low physical activity patterns

We have noted that there is typically a time lag between exposure to a risk factor and the development of subsequent disease that can be (part-)attributed to the risk factor. In the case of type 2 diabetes, Weyer et al. (1999) analysed the major metabolic abnormalities occurring in the development of diabetes, finding that insulin action and secretion significantly decrease early in the development of diabetes, during the transition from normal glucose tolerance to impaired glucose tolerance, and that these early changes are preceded by increases in bodyweight. As impaired glucose tolerance progresses to established diabetes, insulin action and secretion further deteriorate, accompanied by an increase in the endogenous glucose output, and these changes are associated with further increases in bodyweight. Weyer et al. observed an average interval of 1.8 (± 0.8) years between normal glucose tolerance and impaired glucose tolerance, while the interval between impaired glucose tolerance and established diabetes was 3.3 (± 1.4) years. On average, then, it would require some 5.1 (± 1.4) years for normal glucose tolerance to develop into type 2 diabetes.

Box 5 *Computing the fully-adjusted population-attributable fraction (PAF)*

The computation of the fully-adjusted population-attributable fraction (PAF) follows the following principal formula:

$$PAF\ (\%) = \frac{Pd\ (RRadj-1)}{RRadj}$$

in which:

Pd: prevalence of the risk factor in the population eventually developing the disease

RR: The relative risk for a certain disease associated with the risk factor compared to absence of risk factor, adjusted for confounding variables

Applying this formula to the prevalence and relative risk estimates for each factor in each country yields the country- and risk-factor-specific PAFs as follows:

	Unhealthy diet	Low physical activity
France	$PAF\ (\%) = \frac{0.48 \times (1.06-1)}{1.06}$ **= 3%**	$PAF\ (\%) = \frac{0.293 \times (1.19-1)}{1.19}$ **= 5%**
Germany	$PAF\ (\%) = \frac{0.273 \times (1.06-1)}{1.06}$ **= 2%**	$PAF\ (\%) = \frac{0.26 \times (1.19-1)}{1.19}$ **= 4%**
Italy	$PAF\ (\%) = \frac{0.37 \times (1.02-1)}{1.02}$ **= 1%**	$PAF\ (\%) = \frac{0.408 \times (1.19-1)}{1.19}$ **= 7%**
Spain	$PAF\ (\%) = \frac{0.377 \times (1.02-1)}{1.02}$ **= 1%**	$PAF\ (\%) = \frac{0.375 \times (1.19-1)}{1.19}$ **= 6%**
United Kingdom	$PAF\ (\%) = \frac{0.289 \times (1.06-1)}{1.06}$ **= 2%**	$PAF\ (\%) = \frac{0.459 \times (1.19-1)}{1.19}$ **= 7%**

Weyer et al. (1999) further noted that the early deteriorations in insulin secretion and action are distinct from and additive to abnormalities that overweight and obese individuals may experience while normal glucose-tolerant. With the progression from impaired glucose tolerance to diabetes, the defects worsen in parallel with an increase in endogenous glucose output, implying that being overweight or obese prior to the observed stages does not alter the interval between normal glucose tolerance to impaired glucose tolerance and diabetes and that an interval of about five years is therefore consistent.

Based on these observations, in this study we assume a time lag of five years between exposure to the risk factors (unhealthy diets, low physical activity) and the eventual development of type 2 diabetes, starting from a 2015 population that is normal glucose tolerant. We drew on estimates of cumulative incidence of diabetes in the 53 countries of the WHO European region from 2010 to 2020 by Webber et al. (2014) to estimate the annual incidence of diabetes in 2020 in the five countries under study. We then applied the country-specific PAFs for unhealthy diets and low physical activity (Box 5) to the estimated 2020 incidence of diabetes, which gives the total number of incident cases in 2020 that can be attributed to 2015 levels of unhealthy diet and low physical activity (Table 9).

Table 9 *Estimated incident diabetic cases in 2020 attributable to unhealthy diet and low physical activity patterns in 2015*

Country	Risk factor	Population-attributable fraction (%)	Projected incidence in 2020	Number of incident diabetes cases attributable to risk factor
France	Unhealthy diets	3	151 590	4 548
	Low physical activity	5		7 580
	TOTAL			**12 128**
Germany	Unhealthy diets	2	242 571	4 851
	Low physical activity	4		9 703
	TOTAL			**14 554**
Italy	Unhealthy diets	1	151 306	1 513
	Low physical activity	7		10 591
	TOTAL			**12 104**
Spain	Unhealthy diets	1	106 929	1 069
	Low physical activity	6		6 416
	TOTAL			**7 485**
United Kingdom	Unhealthy diets	2	118 393	2 368
	Low physical activity	7		8 288
	TOTAL			**10 656**

4.2.4 Estimating the average annual per patient health care costs that can be associated with diabetes and with diabetic complications to yield diabetes-related direct costs

To estimate the direct health care costs associated with the incident diabetes cases attributable to unhealthy diets and low physical activity, we used data from the 2015 Diabetes Atlas, which provides estimates for the average annual per patient diabetes cost in the studied countries in 2015 (International Diabetes Federation, 2015). We adjusted these figures by the average annual growth rate in per capita health spending during 2005 to 2013 in each of the five countries (OECD, 2015). This yielded estimated per patient costs in 2020 to range from €3314 in Spain to €6810 in France. Based on these figures, the direct diabetes-related health care costs that can be associated with unhealthy diets and low physical activity in the five countries in 2020 are estimated to range from €24 805 290 in Spain to €96 638 560 in Germany (Table 10).

Table 10 *Estimated diabetes-related health care costs in 2020 attributable to unhealthy diets and low physical activity patterns in 2015 in France, Germany, Italy, Spain and the United Kingdom*

Country	Risk factor	Number of incident cases in 2020 attributable to the risk factor in 2015	Estimated per patient diabetes cost in 2020 (€) *	Estimated total health care cost in 2020 (€)
France	Unhealthy diets	4 548	6 810	30 971 880
	Low physical activity	7 580	6 810	51 619 800
	TOTAL	**12 128**		**82 591 680**
Germany	Unhealthy diets	4 851	6 640	32 210 640
	Low physical activity	9 703	6 640	64 427 920
	TOTAL	**14 554**		**96 638 560**
Italy	Unhealthy diets	1 513	3 935	5 953 655
	Low physical activity	10 591	3 935	41 675 585
	TOTAL	**12 104**		**47 629 240**
Spain	Unhealthy diets	1 069	3 314	3 542 666
	Low physical activity	6 416	3 314	21 262 624
	TOTAL	**7 485**		**24 805 290**
United Kingdom	Unhealthy diets	2 368	5 292	12 531 456
	Low physical activity	8 288	5 292	43 860 096
	TOTAL	**10 656**		**56 391 552**

Source: International Diabetes Federation, 2015, adjusted for average annual growth rate in per capita health spending during 2005 to 2013 at 1.2% in France, 2.4% in Germany, 0.55% in Italy, 0.95% in Spain and 1.75% in the United Kingdom (OECD, 2015).

We further estimated the direct health care costs that can be attributed to diabetic complications arising from these attributable cases. We drew on Hayes et al. (2013) who reported annual diabetes complications incidence rates based on the UK Prevention Diabetes Study Outcomes Model 2 (UKPDS-OM2) to estimate the number of incident cases of complications in 2020. Specifically, Hayes et al. derived models to predict the annual risk and incidence of a range of outcomes of diabetes, including myocardial infarction, stroke, congestive heart failure, ischaemic heart disease, amputation, blindness, renal failure and ulcer (Appendix 5). We first applied these incidence rates to the cases attributable to unhealthy diets and low physical activity in each country to estimate the number of incident cases of complications arising in 2020. We then applied the average annual per patient cost for each complication as derived from the published evidence to estimate the direct health care costs that can be associated with these complications (Table 11). Appendix 6 provides a detailed breakdown by country of the estimated number of incident cases of diabetes-related complications and related costs in 2020.

Table 11 *Estimated diabetic complication-related costs in 2020 attributable to unhealthy diets and low physical activity patterns in 2015 in France, Germany, Italy, Spain and the United Kingdom*

	Estimated number of incident cases of diabetes-related complications in 2020 attributable to the risk factor		Estimated complication-related total health care cost in 2020 (€)		
	Unhealthy diets	Low physical activity	Unhealthy diets	Low physical activity	Total cost
France	181	302	2 646 685	4 411 142	7 057 827
Germany	193	386	3 910 441	7 821 688	11 732 129
Italy	60	422	492 429	3 447 004	3 939 433
Spain	43	255	516 414	3 099 453	3 615 867
United Kingdom	94	330	1 874 299	6 560 047	8 434 347

Accordingly, we estimate that the total number of incident cases of complications arising from diabetes cases that can be attributed to unhealthy diets and low physical activity in 2020 would be 483 in France, 579 in Germany, 482 in Italy, 298 in Spain and 424 in the United Kingdom. The associated direct health care costs ranged from some €3.6 million in Spain to €11.7 million in Germany. Taken together, the total direct health care costs linked to incident diabetes and its complications in 2020 that can be attributed to unhealthy diets and low physical activity in 2015 are estimated to be €89.6 million in France, €108.4 million in Germany, €51.6 million in Italy, €28.4 million in Spain and €64.8 million in the United Kingdom (see also below for a detailed breakdown of numbers).

4.2.5 Estimating the indirect costs that can be associated with diabetes attributable to unhealthy diets and low physical activity

We considered two principal categories of indirect costs that can be associated with diabetes attributable to unhealthy diets and low physical activity: first, productivity loss in the workplace due to absenteeism and presenteeism, including among the unemployed population; second, productivity forgone because of work disability, early retirement or premature death. We first identified the proportion of diabetes cases in 2020 attributable to unhealthy diets and low physical activity who are of working age, using the average sex-specific proportions of incident type 2 diabetes cases in the United Kingdom for the period 1991–2010 as provided by Holden et al. (2013) (Appendix 7). We then computed the percentage of annual incident type 2 diabetes cases by five-year age group and sex in the United Kingdom for the period 1991–2010 (Appendix 8) and applied these to the total number of diabetes cases attributable to unhealthy diets and low physical activity in each country, again by sex and five-year age group (Appendix 9). This allowed us to compute the total number of incident type 2 diabetes cases at working age (15–64 years) that can be attributed to unhealthy diets and low physical activity in each country by 2020 (Table 12).

Table 12 *Estimated number of incident type 2 diabetes cases at working age (15–64 years) that can be attributed to unhealthy diets and low physical activity in France, Germany, Italy, Spain and the United Kingdom, 2020*

	Unhealthy diets	Low physical activity	Total
France	1 517	2 528	4 045
Germany	1 618	3 236	4 854
Italy	505	3 532	4 037
Spain	357	2 140	2 497
United Kingdom	790	2 764	3 554

We then computed the proportion of those of working age who are expected to be participating in the labour force. In the United Kingdom, labour force data for 2013 and 2014 suggest that the proportion of working age people with diabetes was 71.3% compared with 72.3% (2013) and 73.5% (2014) in the general population (Department for Work and Pensions, 2015). Based on these observations and in the absence of labour force participation data specific to people living with diabetes in the other countries studied, we assumed labour participation rates in the diabetic population to be similar to the general population, using annual national labour force participation rates for each of the five countries for the period 2000 to 2015 by five-year age group (OECD, 2016). We acknowledge that this is a conservative estimate that likely overestimates the 'true' proportion of people with diabetes who are in gainful employment across the five countries. Using this assumption, we computed the number of incident cases in 2020 attributable to unhealthy diets and low physical activity at working age who are expected to be in or out of the labour force by five-year age group (Appendix 10).

Based on these data, we first estimated the indirect costs that can be linked to incident cases of diabetes that can be attributed to unhealthy diets and low physical activity. We drew on a systematic review by Breton et al. (2015), which reported that people with diabetes lose an average of 11.9 days of productivity per year due to the disease. This included absenteeism (work time lost) and presenteeism (work time impaired). Using this figure, we estimated the total number of productivity days lost due to absenteeism and presenteeism in the five countries. We then applied this estimate to data on average daily salary in 2020, using hourly labour cost data collected by Eurostat (Eurostat, 2015), adjusted to 2020 figures (based on the average rate of hourly salary increase every five years in the five countries from 2000 to 2015). Assuming an eight-hour working day, we estimate the total cost of productivity lost due to absenteeism and presenteeism that can be attributed to diabetes because of unhealthy diets and low physical activity in 2020 to range from €2.7 million in Spain to €9.7 million in Germany (Table 13).

Table 13 *Estimated total number of productivity days lost and cost due to absenteeism and presenteeism among incident type 2 diabetes cases at working age that can be attributed to unhealthy diets and low physical activity and who are expected to be in the labour force in France, Germany, Italy, Spain and the United Kingdom, 2020*

Country	Risk factor	Estimated number of incident type 2 diabetes cases at working age attributable to the risk factor (in the labour force)	Estimated total number of days of productivity lost in 2020	Average daily wage in 2020 (€)	Estimated cost of productivity lost in 2020 (€)
France	Unhealthy diets	893	10 621	224.64	2 385 959
	Low physical activity	1 488	17 702	224.64	3 976 599
	TOTAL				**6 362 558**
Germany	Unhealthy diets	1 105	13 144	246.96	3 246 097
	Low physical activity	2 209	26 291	246.96	6 492 864
	TOTAL				**9 738 961**
Italy	Unhealthy diets	265	3 149	152.00	478 643
	Low physical activity	1 852	22 043	152.00	3 350 501
	TOTAL				**3 829 144**
Spain	Unhealthy diets	216	2 574	150.16	386 576
	Low physical activity	1 298	15 451	150.16	2 320 178
	TOTAL				**2 706 754**
United Kingdom	Unhealthy diets	545	6 488	220.16	1 428 341
	Low physical activity	1 907	22 699	220.16	4 997 459
	TOTAL				**6 425 800**

We further estimated the costs of productivity lost that can be linked to individuals with diabetes who are of working age but are outside the formal labour force. Productivity losses among this population relate to lost unpaid contributions to national productivity such as time spent providing child care, household activities and other activities such as volunteering in the community (American Diabetes Association, 2013). To determine the value of such losses, we again applied Breton et al.'s estimate of 11.9 productivity days lost per year per diabetic person to the number of cases attributable to unhealthy diets and low physical activity who are of working age but are outside the labour force. This gives the total number of productivity days lost per year among the diabetic population outside the formal labour force, to which we then applied the average minimum daily wage in 2020 as derived from Eurostat (2015) for the period 2000 to 2015, adjusted to 2020 figures. Again assuming an eight-hour working day, we estimate the total cost of productivity lost due to absenteeism and presenteeism that can be attributed to diabetes because of unhealthy diets and low physical activity among those outside the formal labour force in 2020 to range from €0.4 million in Spain to €1.8 million in Italy (Table 14).

Secondly, we computed the indirect costs that can be attributed to work disability, early retirement and premature deaths. We drew on work by Herquelot et al. (2011), which prospectively assessed the impact of diabetes on the risks of work disability, early retirement and premature death in a cohort of 20 625 employees of a national gas and electricity company in France, among whom 2.4% (506 individuals) had developed diabetes. They estimated the number of working years lost among diabetic persons aged 35–60 years to be 1.1 years per person. Of these, 0.09 years were attributed to work disability, 0.7 years to early retirement and 0.28 years to premature death. We applied these estimates to the number of diabetes cases attributable to unhealthy diets and low physical activity for those aged 35–60 who are expected to participate in the labour force. This yielded an estimate of the total number of working years lost due to work disability, early retirement and premature death because of unhealthy diet- and physical inactivity-related diabetes (Appendix 11). We then combined the total number of working years lost with the average annual salary in 2020, which we estimated using the average 2015 annual salary data collected by Eurostat (Eurostat, 2015), adjusted to 2020 values (based on the average rate of salary increase every five years from 2000 to 2015) (Table 15).

Table 14 *Estimated total number of productivity days lost and cost due to absenteeism and presenteeism among incident type 2 diabetes cases at working age that can be attributed to unhealthy diets and low physical activity and who are expected to be outside the formal labour force in France, Germany, Italy, Spain and the United Kingdom, 2020*

Country	Risk factor	Estimated number of incident type 2 diabetes cases at working age attributable to the risk factor (outside the formal labour force)	Estimated total number of days of productivity lost in 2020	Minimum daily wage in 2020 (€)	Estimated cost of productivity lost in 2020 (€)
France	Unhealthy diets	624	7 429	75.68	562 252
	Low physical activity	1 041	12 382	75.68	937 086
	TOTAL				**1 499 338**
Germany	Unhealthy diets	513	6 109	70.80	432 513
	Low physical activity	1 027	12 219	70.80	865 116
	TOTAL				**1 297 629**
Italy	Unhealthy diets	240	2 856	77.20	220 482
	Low physical activity	1 680	19 992	77.20	1 543 377
	TOTAL				**1 763 859**
Spain	Unhealthy diets	140	1 668	33.92	56 590
	Low physical activity	841	10 013	33.92	339 646
	TOTAL				**396 236**
United Kingdom	Unhealthy diets	245	2 911	92.88	270 339
	Low physical activity	856	10 182	92.88	945 746
	TOTAL				**1 216 085**

Table 15 *Estimated cost of working years lost due to work disability, early retirement and premature death among incident type 2 diabetes cases at working age that can be attributed to unhealthy diets and low physical activity and who are expected to be in the formal labour force in France, Germany, Italy, Spain and the United Kingdom, 2020*

Country	Risk factor to which cases are attributable	Average annual salary in 2020 (in €)*	Estimated costs of disability in 2020 (in €)	Estimated costs of early retirement in 2020 (€)	Estimated costs of premature death in 2020 (€)
France	Unhealthy diets	41 131.99	3 304 085	25 698 440	10 279 376
	Low physical activity	41 131.99	5 506 808	42 830 733	17 132 293
	TOTAL		**8 810 894**	**68 529 172**	**27 411 669**
Germany	Unhealthy diets	41 523.63	4 127 868	32 105 639	12 842 256
	Low physical activity	41 523.63	8 256 587	64 217 897	25 687 159
	TOTAL		**12 384 455**	**96 323 537**	**38 529 415**
Italy	Unhealthy diets	32 021.69	762 619	5 931 485	2 372 594
	Low physical activity	32 021.69	5 338 336	41 520 393	16 608 157
	TOTAL		**6 100 956**	**47 451 878**	**18 980 751**
Spain	Unhealthy diets	31 377.75	610 939	4 751 747	1 900 699
	Low physical activity	31 377.75	3 666 776	28 519 369	11 407 748
	TOTAL		**4 277 715**	**33 271 116**	**13 308 446**
United Kingdom	Unhealthy diets	49 359.15	2 421 903	18 837 024	7 534 810
	Low physical activity	49 359.15	8 473 719	65 906 700	26 362 680
	TOTAL		**10 895 622**	**84 743 725**	**33 897 490**

Note: * estimated from 2015 average annual salary adjusted using the average percentage of increase in salary every five years from 2000 to 2015 as derived from OECD (2016).

4.3 The estimated total economic costs of unhealthy diets and low physical activity related to diabetes and its complications

Table 16 summarises the total economic cost of diabetes in the five countries in 2020 that can be associated with unhealthy diets and low physical activity patterns in 2015. Costs associated with low physical activity tended to be higher than those associated with unhealthy diets in all countries, although differences varied, ranging from some 67% higher in France to a factor of six in Spain and seven in Italy. Indirect costs that can be associated with either risk factor were higher than direct health care costs in all countries, by between 25% in France and up to 100% in the United Kingdom.

The differences in total cost across countries reflect, to a great extent, differences in population sizes, health care costs and labour costs. When related to the population projected to develop diabetes in 2020 as a consequence of unhealthy diets and low physical activity in 2015, the United Kingdom showed the highest cost, at €18 953, closely followed by Germany and France, while Italy had the lowest cost, at just over €10 720 (Table 17).

4.3.1 Sensitivity analysis

We carried out a limited set of sensitivity analyses in order to better understand the likely range of cost estimates provided here. We repeated the above analyses using the lower and upper values (i.e. 95% confidence intervals) for those parameters where they were available. This was the case for the prevalence of low physical activity in the general population and the adjustment factor for low physical activity. Applying the lower value of these two parameters decreased the total estimated costs by between 27% and 63%. The highest impact was on estimates for Italy, reducing the total costs by 63% (from €146 million to €54.3 million), followed by Spain at 59% (€94.1 million to €39.0 million), Germany at 58% (€266.7 million to €112.0 million), France at 29% (€151.7 million to €107.4 million) and the United Kingdom at 27% (€202.0 million to €147.8 million).

Using the higher values of the same parameters increased the total costs by between 26% and 160%. The greatest effect was seen for Germany, where the total costs more than doubled (from €266.7 million to €694.1 million). A doubling of costs was also observed for Spain (€94.1 million to €212.3 million) and Italy (€146 million to €307.9 million). In France estimated costs rose by 29% (€151.7 million to €196.2 million) and in the United Kingdom by 26% (€202 million to €254.3 million).

Table 16 *Estimated economic cost that can be associated with unhealthy diets and low physical activity patterns in 2015 as manifested in incident diabetes and complication in France, Germany, Italy, Spain and the United Kingdom in 2020*

Country	Risk factor	Direct health care cost (€)	Indirect cost (€)	Total cost (€)
France	Unhealthy diets	33 618 565	42 230 112	75 848 677
	Low physical activity	56 030 942	70 385 985	126 416 927
	TOTAL			**202 265 604**
Germany	Unhealthy diets	36 121 081	52 774 976	88 896 057
	Low physical activity	72 249 608	105 530 564	177 780 172
	TOTAL			**266 676 229**
Italy	Unhealthy diets	6 446 084	9 765 824	16 211 908
	Low physical activity	45 122 589	68 415 902	113 538 491
	TOTAL			**129 750 398**
Spain	Unhealthy diets	4 059 080	7 706 874	11 765 955
	Low physical activity	24 362 077	46 253 942	70 616 019
	TOTAL			**82 381 974**
United Kingdom	Unhealthy diets	14 405 755	30 455 391	44 861 146
	Low physical activity	50 420 143	106 686 304	157 106 447
	TOTAL			**201 967 593**

Table 17 *Estimated total and per capita economic cost that can be associated with unhealthy diets and low physical activity patterns in 2015 as manifested in incident diabetes and complications in France, Germany, Italy, Spain and the United Kingdom in 2020*

Country	Total cost	Cost per head of total estimated population in 2020 (€)	Cost per incident case of type 2 diabetes in 2020 (€)	Cost per incident case of type 2 diabetes attributable to unhealthy diets and low physical activity in 2020 (€)
France	202 265 604	2.97	1 334	16 678
Germany	266 676 229	3.29	1 099	18 323
Italy	129 750 398	2.14	858	10 720
Spain	82 381 974	1.77	770	11 006
United Kingdom	201 967 593	3.01	1 706	18 953

Chapter 5

Discussion and conclusions

This study sought to contribute to a better understanding of the economic burden that can be associated with unhealthy diets and low levels of physical activity in order to help inform priority setting and motivate efforts to promote more effectively healthy diets and physical activity in Europe and worldwide. We did so through critically reviewing the available evidence on the economic costs associated with unhealthy diets and low physical activity; discussing the measurement, methodological and practical issues for estimating the economic burden from unhealthy diets and low physical activity; and developing a framework for assessing costs and testing the feasibility of this approach to provide better estimates of the economic burden.

We showed that the majority of reviewed studies found a significant association between diet and/or physical activity and costs, with unhealthy diets and low physical activity predictive of higher health care expenditure. Studies that did report costs that can be associated with the two risk factors estimated the annual cost of unhealthy diets to range from €3 to €148 per capita and for low physical activity from €3 to €181 per capita. The highest health care cost estimates were equivalent to between 2% and 6% of health spending in the countries. We noted that there is a very wide range of estimates, and these are very sensitive to the measures of diet and activity and the ways in which the studies were carried out.

Costing studies differ widely in their analytical approaches and in the nature and scope of data used, influencing estimates for the economic burden of unhealthy diets and low physical activity. Particular challenges arise from measuring unhealthy diets given the different effects of foods and the interactions between these effects. Calibrating the extent of deviation from optimal consumption and the effects of this deviation is difficult. It is also clear that the context should be taken into account in terms of other population characteristics. While there is more consensus about the measurement of physical activity, similar issues arise in terms of the independent effects of moderate and vigorous activity and sedentary behaviour, but also the interactions between these. Further, studies take broader and narrower perspectives in terms of what costs are included, with some limited to formal health care costs, and others aiming to take a more societal view. While current evidence makes it difficult to make accurate comparisons, much of the economic burden is likely to come from non-health care costs, especially from effects on productivity, absenteeism, presenteeism and other indirect costs.

Based on a critical appraisal of existing approaches, we developed a framework for estimating the economic costs of unhealthy diets and low physical activity using a disease-based approach, with type 2 diabetes mellitus chosen as a disease for which both are risk factors. The aim was to demonstrate the feasibility of undertaking a comprehensive, disease-based, bottom-up cost assessment drawing on the best available data as identified from a rapid review of the published evidence that addresses some of the limitations of existing costing studies. Our choice of type 2 diabetes as the exemplar outcome was motivated by its consistently strong association with either risk factor as shown in the literature.

Using this approach, we projected the total economic costs that can be associated with unhealthy diets and low physical activity patterns in 2015 as manifested in incident diabetes cases in 2020 to range from €82.4 million in Spain to €266.7 million in Germany. This equates to a per capita cost of €1.77 in Spain to €3.29 in Germany. Relating costs more specifically to the population projected to develop diabetes in 2020 as a consequence of unhealthy diets and low physical activity in 2015, the United Kingdom showed the highest cost, at €18 953, closely followed by Germany and France, while Italy had the lowest cost, at just over €10 720.

The total cost in the five high-income countries studied (France, Germany, Italy, Spain and the United Kingdom) was estimated to amount to about €883 million. The populations in the five countries studied account for almost two thirds of the total population in the European Union (EU-28), which would imply a total EU cost of around €1.3 billion, but care must be taken in any extrapolation given differences in population characteristics, costs of care and value of lost productivity. While these estimates of the economic costs are substantial, they represent only a small proportion of health care expenditure and a very small proportion of GDP. Even on the higher estimates in the sensitivity analysis it is likely that the burden of disease associated with unhealthy diets and low physical activity as measured by poor health and shortened life will be at least as important as the financial costs of additional health care and lost productivity.

It is difficult to compare the findings of the analyses presented here with estimates published elsewhere since only diabetes costs are estimated. Scarborough et al. (2011) calculated the cost of unhealthy diets and low physical activity in the United Kingdom in 2006–07 to be €9.8 billion (€8.5 billion and €1.3 billion for unhealthy diets and low physical activity, respectively). Ding et al. (2016), in their recent assessment of the global economic costs that can be associated with low physical activity, provided estimates of direct and indirect costs ranging from $(Int) 1.4 billion in Italy to $(Int) 2.6 billion in Germany. Again, data are difficult to compare as analyses by Ding et al. considered a wider range of disease outcomes (coronary heart disease, stroke, type 2 diabetes, breast cancer, colorectal cancer), and the cost estimates are not easily transferable.

The principal analytical steps employed in the present analysis are similar to those used by Ding et al. (2016) for low physical activity in that we calculated country-specific adjusted population-attributable fractions based on available prevalence data and relative disease risks causally linked to either risk factor in order to estimate the total number of cases for the outcome (here: diabetes) in each country. Ding et al. used the same definition of low physical activity that we used, and drew on the same data sources for prevalence of low physical activity and estimated the same relative risk-adjusted population-attributable fractions that we calculated for our analysis. We also estimated health care costs as well as indirect costs that can be associated with disease developed as a consequence of the risk factor and similar to Ding et al. we drew on the latest estimates of diabetes-related health care costs provided by the International Diabetes Federation (International Diabetes Federation, 2015). Where our model differs is that we only considered the costs of incident cases, that is, new cases, which can be causally linked to the risk factor, whereas Ding et al. calculated costs on the basis of prevalence data. Also, our approach takes account of the expected time lag between exposure to the risk factor (unhealthy diets, low physical activity) and development of the disease and complications. Further, we considered a wider range of indirect costs linked to lost productivity because of work absence, disability, early retirement and premature death among incident diabetes cases that can be attributed to unhealthy diets and low physical activity. Conversely, Ding et al. only considered lost productivity that can be associated with premature death. We therefore believe that our estimates provide a fuller picture of the likely future costs that can be attributed to contemporary dietary and physical activity patterns.

5.1 Limitations of the costing framework

As noted, the costing model as proposed here presents a 'proof of concept' approach, drawing on the best available data as identified from a rapid review of the published evidence and providing point estimates only (although we present data from a limited sensitivity analysis). Clearly, there is uncertainty associated with each input parameter, namely prevalence rates of unhealthy diets and low physical activity in the general population, adjustment factors, relative risks and average per patient disease and productivity costs, which will all impact on the estimated effect size of predicted incident diabetes cases and cost estimates. A fully costed model would consider ranges as input parameters as a reflection of variation at baseline, using for example probabilistic modelling such as Monte

Carlo simulation, and also employ sensitivity analyses in order to better understand the influence of the various input parameters on cost estimates.

A major challenge presents the availability of suitable data on the prevalence of unhealthy diets and low physical activity that are comparable across countries and over time. For example, the prevalence data for low physical activity used for the five countries were obtained from the WHO Global Health Observatory Database, with 2010 prevalence rates as the latest available data. The level of exposure among physically inactive individuals was not specified so data from a more recent Eurobarometer survey conducted in 2013 was used to assess the level of exposure. In order to arrive at comparable estimates there is therefore a need for more detailed national prevalence data on physical activity in each country, specifying the type, duration, frequency and intensity to identify the extent of low physical activity and levels of exposure to risk.

We defined a given dietary pattern as unhealthy, based on a score of <67% on the 2010 alternate healthy eating index (AHEI) and we used dietary data compiled by the European Food Safety Authority, which draws on national surveys that are not directly comparable in relation to assessment methods and data collection instruments. The EFSA database also only provides aggregate-level data of mean consumption of certain food groups (European Food and Safety Authority, 2015). In the absence of more detailed data sets, we assumed that mean intakes as presented in the EFSA database are nationally representative of a relatively homogenous dietary pattern in each of the five countries. But this is not necessarily the case and in order to arrive at more precise estimates more recent, individual-level data on mean intake of the different AHEI food-groups in different countries in Europe would be needed.

We considered a window period of five years from the occurrence of unhealthy diets and low physical activity to the development of diabetes and associated costs incurred. The five-year lag reflects the average latency period and it will vary according to individual risk profile, with those with other high-risk characteristics, such as genetic predisposition, likely to develop the condition more quickly. If the costing model was applied more widely this would require a systematic assessment of the evidence of the range of the latency period, and its incorporation in the form of a sensitivity analysis.

Likewise, we used average annual per patient costs for diabetes and its complications in previous years, which we adjusted to reflect more closely 2020 prices. However, average costs are not sensitive to variations in individual patterns of health care utilisation and a fully costed model would ideally derive a unique set of average per patient costs for each country that take account of patient characteristics such as age, sex, ethnicity, socioeconomic status and disease severity, which may influence patterns of use. A particular challenge relates to estimating the indirect costs that can be associated with diabetes as a manifestation of unhealthy diets and low physical activity, and within the scope of this study we applied very crude assumptions, which would need to be revisited for a fully costed model. Any future modelling exercise would also need to take account of the long-term care costs associated with diabetes which are estimated to be substantial, but which we have been unable to address in this work.

Finally, the costing framework as presented here uses only one outcome, namely type 2 diabetes, as a manifestation of exposure to unhealthy diets and low physical activity. Yet, unhealthy diets and low physical activity are associated with a range of other conditions of ill health as highlighted in earlier parts of this volume and a fully costed model would incorporate these also, along with their sequelae, guided by the strength of evidence of the association. Ding et al. (2016), in their analysis of the global economic cost of low physical activity, disaggregated cost figures by disease category, and diabetes cases that can be attributed to low physical activity accounted for a large majority of the estimated total health care costs. Specifically, according to Ding et al., for the five countries considered in the present study, diabetes cases accounted for approximately half (Italy) up to 85% (Spain) of the estimated total health care costs. This would mean that estimates for health care costs provided in the present study are likely to underestimate the 'true' health care costs that can be associated with low physical activity-related diabetes cases by at least one third. However, since Ding et al. (2016) calculated costs for prevalent cases it is very difficult to generalise from their estimates.

5.2 Implications for future studies

This study has tested the feasibility of estimating the costs of unhealthy diets and low physical activity using a disease-based approach. While there are limitations, it has shown that it is broadly feasible to populate the model with data from a range of sources, and the results show a reasonable consistency across countries. While the disease burden from diabetes is not currently as large as that for, for example, ischaemic heart disease, it is a good exemplar because of the strong relationship between these lifestyle factors and the risk of diabetes. In other chronic diseases there will be additional challenges in identifying the contribution of these lifestyle factors and disease risk. Given the very wide range of estimates of costs from the studies reviewed, this may be a more promising approach.

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Appendices

Appendix 1

Summary overview of key characteristics of included studies

DIET

Author/s	Study objective	Country	Principal approach	Methodology	Data	Type of costs	Base-year	Principal findings
Daviglus et al. (2005)	To examine whether fruit and vegetable intake in middle age is related to health care costs (total and disease-specific) in old age.	The United States	Based on disease-specific costs (cardiovascular disease and cancer) and overall national health insurance costs.	Intake of fruit and vegetables were determined from previous dietary histories and classified into one of three groups: <14 cups per month, 14–42 cups per month and >42 cups per month. Combined fruit and vegetable intake was classified as either low, medium or high. Using Medicare claims data, individual mean annual health care costs in old age and ten-year cumulative costs prior to death were estimated. The costs were linked to previous fruit and vegetable intake and examined across three intake groups to determine possible associations.	Fruit and vegetable intake: Dietary interview (using Burke's comprehensive dietary history method) Health care costs: estimated from national health insurance claims	Direct health care costs (USD)	1984–2000	Although most relationships were not statistically significant, higher fruit and vegetable intakes were generally associated with lower mean annual health care costs. Mean annual costs for cardiovascular disease for high vs low intake were US$ 3 128 vs US$ 4 223; for cancer: US$ 1 352 vs US$ 1 640 and for total costs: US$ 10 024 vs US$ 12 211. Trends were generally similar for fruit or vegetable intake alone. This trend also applied to fruit and vegetable intake and ten-year cumulative costs before death (US$ 92 757 total cumulative costs for high intake vs US$ 132 713 for low intake).
Rayner & Scarborough (2005)	To quantify the disease and financial burden of ill health related to food.	United Kingdom	Disease-based: cardiovascular disease, type 2 diabetes, other hormonal and immune system diseases, cancer, dental caries and digestive system diseases.	PAFs for diseases due to risk factors published by the WHO (2004) were applied to disease DALYs to estimate the proportion of disease burdens attributable to unhealthy diets. The same PAFs were applied to NHS disease costs.	PAFs: Global Burden of Disease (GBD) study (1997), WHO Comparative Quantification of Health Risks (2004) Disease DALYS: WHO Report on Diet, Nutrition and the Prevention of Chronic Diseases (2003) NHS cost data: extrapolated from estimates from an earlier study for 1992/93	Direct health care costs (GBP)	2002	Food-related disease accounted for about 10% of morbidity and mortality in the United Kingdom (as measured by DALYs). Food-related disease was associated with an annual health care cost of £6 billion, or about one third of the total NHS costs.

	Author/s	Study objective	Country	Principal approach	Methodology	Data	Type of costs	Base-year	Principal findings
DIET	Rice & Normand (2012)	To establish the annual public expenditures for patients with disease-related malnutrition (DRM).	Republic of Ireland	Based on overall public health and social care costs.	Prevalence of DRM in multiple health care settings were estimated from age-standardised comparisons between available Irish data and large-scale United Kingdom surveys. Frequency of health care utilisation among adults with DRM was estimated, to which relevant unit costs were applied to obtain DRM-related costs.	Prevalence of DRM: earlier studies which used the Malnutrition Universal Screening Tool, British Association for Parenteral and Enteral Nutrition Screening Week Surveys (2007, 2008, 2010) Patient activity levels and costs: Department of Health and Children, Health Service Executive, Economic and Social Research Institute	Direct health care costs (EUR)	2007	The annual public health and social care costs associated with disease-related malnutrition among adults was over €1.4 billion or 10% of the health care budget. The majority of the costs were from acute hospital or residential care settings (70%). The additional cost of DRM per adult patient was €5357.
DIET	Collins et al. (2011)	To examine whether higher diet quality was associated with lower health care claims and costs among middle-aged adults.	Australia	Based on national health insurance costs.	Individual dietary patterns were assessed using a survey consistent with national dietary recommendations. Based on survey results, the Australian Recommended Food Score (ARFS) was calculated and grouped into quintiles (1 = highest score; 5 = lowest score). Median five-year cumulative Medicare costs and six-year cumulative number of Medicare claims were linked to ARFS and examined across quintiles to determine possible associations between diet quality, number of health care claims and costs.	Dietary intake: Survey (using the Dietary Questionnaire for Epidemiological Studies) Number of health care claims and costs: Medicare Australia	Direct health care costs (AUD)	Costs: 2002–2006 Number of claims: 2002–2007	There was a statistically significant association between five-year cumulative health care costs and the ARFS, with individuals with dietary scores in the highest quintile having higher health care costs compared to those in the lowest quintile (cost difference of AU$ 110). The trend was not consistent across quintiles. Individuals in the highest quintile had a lower number of claims compared to those in the lowest quintile (significant difference of 10 claims). This trend was not consistent in the medium term.

	Author/s	Study objective	Country	Principal approach	Methodology	Data	Type of costs	Base-year	Principal findings
DIET	Doidge et al. (2012)	To quantify the potential effects of increasing dairy product consumption to recommended levels in terms of population health impact and direct health care costs.	Australia	Disease-based: type 2 diabetes, ischaemic heart disease, stroke, osteoporosis, obesity, hypertension.	PAFs for diseases related to low dairy consumption were identified based on fine levels of dairy consumption (i.e. increments of 0.1 standard serving per day), and distribution among the population and corresponding RRs. Two variant-formulas were used to calculate the PAFs, depending on data availability. Resulting PAFs were applied to disease DALYs and health care costs to determine proportions potentially avoided by increasing dairy consumption.	Dairy consumption levels and population distribution: Australian National Nutrition Survey (1995) RRs: Earlier studies representing the "highest level of evidence" (as per criteria by Phillips et al. (2009)) Disease DALYs and costs: Australian Institute of Health and Welfare, earlier studies, government reports, primary analysis of publicly available databases and government reports	Direct health care costs (AUD)	2010–2011	Increasing dairy consumption to recommended levels can potentially prevent 18.4% of the incident cases of obesity, 10.2% of type 2 diabetes, 5% of ischaemic heart disease, 16.2% of stroke and 8.3% of hypertension. Increasing dairy consumption can potentially save AU$ 2.0 billion in direct health care costs, while also saving an additional 75 012 DALYs. The amount comprises 1.7% of total direct health care expenditures and is comparable with total spending on public health (AU$ 2.0 billion in 2009–2010).
	Lo et al. (2013)	To assess the relationship between dietary quality and medical care utilisation and expenditures among populations aged ≥65 years.	China (Taiwan)	Based on national health insurance costs.	Individual dietary intakes were assessed through a 24-hour dietary recall. Dietary quality was scored from 0 points (lowest) to 6 points (highest) through the Dietary Diversity Score (DDS) method. National health insurance claims in the succeeding eight years were linked to DDS scores and examined across quartiles (DDS scores of ≤3, 4, 5, 6) to identify possible associations between diet quality and level of medical utilisation and costs.	Dietary intake: National Elderly Nutrition and Health Survey (1999–2000) Medical care utilisation and costs: National health insurance (covering >99% of the population)	Direct health care costs (TWD)	1999–2006	Participants with better diet quality (as indicated by higher DDS) had lower utilisation of and costs for emergency and hospitalisation services. Average annual emergency costs were NT$ 2 330 vs NT$ 1 560 for DDS of ≤3 vs DDS of 6. Hospitalisation costs were NT$ 47 600 vs NT$ 35 100. For preventive and dental services, however, higher DDS predicted greater utilisation (0.25 and 0.5 times) and costs (+NT$ 270 and +NT$ 420) compared to the lowest DDS. Overall expenditures were still lower for those with higher DDS at NT$ 64 200 (DDS of 6) vs NT$ 68 300 (DDS ≤3).

	Author/s	Study objective	Country	Principal approach	Methodology	Data	Type of costs	Base-year	Principal findings
PHYSICAL ACTIVITY	Katzmarzyk et al. (2000)	To estimate the mortality and economic costs of physical inactivity and the effect of a 10% reduction in inactivity levels on costs.	Canada	Disease-based: coronary artery disease, stroke, hypertension, colon cancer, breast cancer, type 2 diabetes mellitus, osteoporosis.	PAFs were calculated based on RRs from earlier meta-analyses and large prospective, epidemiological studies. The PAFs were applied to total numbers of premature deaths per disease and disease costs. A hypothetical scenario was assumed where inactivity prevalence was reduced by 10%, under which new PAFs were calculated and applied to disease costs.	Physical activity prevalence: Physical Activity Monitor Survey, Canadian Fitness and Lifestyle Research Institute (1999) RRs: Earlier meta-analyses and prospective studies Premature mortality: Statistics Canada (1995) Cost data: Canadian Health Expenditures Database, Economic Burden of Illness Canada (1993), American Heart Association (1999), earlier studies	Direct health care costs (CAD)	1999	Physical inactivity was responsible for 10.3% (21 000) of deaths from all causes in 1995, through the seven diseases. Physical inactivity accounted for C$ 2.1 billion or 2.5% of total direct health care costs. The amount represented 25.5% of the total costs of treating the seven diseases. Reducing the prevalence of physical inactivity by 10% would reduce direct health care expenditures by C$ 150 million per year.
	Ackermann et al. (2003)	To determine if changes in health care utilisation and costs for Medicare-eligible enrolees of a large health maintenance organization (HMO) are related to their choice to participate in a community exercise programme offered as a health benefit.	The United States	Based on private health insurance costs.	A retrospective, matched cohort study was conducted to determine if changes in health care costs for Medicare-eligible enrolees (aged ≥65 years) choosing to participate in the exercise programme were different from those of similar individuals who did not participate. Three enrolees who never attended the exercise programme were randomly selected as controls for each participant matching on age and gender. Changes in health care utilisation and costs were compared between the intervention and control groups.	Exercise programme participation and cost data: Group Health Cooperative of Puget Sound, Decision Support System (integrates clinical information, units of service and actual costs)	Direct health care costs (USD)	1997–2000	Overall, no significant differences were found in the total health care costs between exercise programme participants and non-participants. However, compared to those who did not participate, programme participants had 4.9% lower hospitalisations and displayed a stronger trend towards lower inpatient costs (i.e. US$ 708 lower). Among those who had high programme usage (i.e. ≥1 visit per week), annual total health care costs were US$ 1 057 lower and the hospitalisation risk was 7.9% lower compared to controls. These significant effects among higher users were observed at a relatively low attendance rate (average of 1.74 visits per week) and under normal daily operating conditions of the programme.

PHYSICAL ACTIVITY

Author/s	Study objective	Country	Principal approach	Methodology	Data	Type of costs	Base-year	Principal findings
Martinson et al. (2003)	To examine the impact of changes in physical activity over the course of a single year on short-term changes in health care charges among members of a health plan aged 50 and above.	The United States	Based on commercial health insurance costs.	Health plan members were surveyed twice for physical activity levels (in August 1995 and September 1996). Individuals were classified as active or inactive at each of the two time points. To account for alternative definitions of physical activity, five definitions of inactivity and activity were used: A: Inactive = 0 days, active = 1+ days B: Inactive = 0 days, active = 2+ days C: Inactive = 0–1 days, active = 2+ days D: Inactive = 0–1 days, active = 3+ days E: Inactive = 0–1 days, active = 4+ days A specific definition was used in categorising an individual's physical activity changes between August 1995 and September 1996 into one of five mutually exclusive groups: (1) inactive to inactive, (2) active to active, (3) active to inactive, (4) inactive to active and (5) unclassified (falling within the "gap"" between the inactive and active categories under B, D and E). Changes in health care charges between September 1994 to August 1995 and September 1996 to August 1997 were examined across 25 physical activity change groups to determine possible associations.	Physical activity levels: HealthPartners Minnesota health plan members' survey Health care charges: commercial health insurance	Direct health care costs (USD)	1994–1995 and 1996–1997	For physical inactivity/activity definitions A and B, physically active groups had larger decreases in health care charges relative to individuals who were physically inactive in both surveys. These declines ranged from US$ 1 200 to US$ 1 900. For definitions C, D and E, declines in total charges were observed primarily among individuals who moved from inactivity to activity. In particular for definition D, the decline in charges was significantly larger (in the inactive to active group) at US$ 2 200. Similar trends are seen in models using definitions C and E but the results are not significant.
Garrett et al. (2004)	To estimate the costs of physical inactivity among members of the Blue Cross Blue Shield health plan in Minnesota.	The United States	Disease-based: heart disease, stroke, hypertension, type 2 diabetes, colon cancer, breast cancer, osteoporosis, depression, anxiety.	PAFs were calculated based on RRs from earlier meta-analyses of published studies, stratified by level of exposure: inactive and irregularly active. The PAFs were applied to disease costs.	Physical activity prevalence: Behavioural Risk Factors Surveillance System (2000) RRs: Earlier meta-analyses of published studies Cost data: Blue Cross and Blue Shield health plan	Direct health care costs (USD)	2000	Physical inactivity was estimated to account for US$ 83.6 million of total medical expenditures among a health plan population of 1.5 million members. The cost per member was US$ 56.

PHYSICAL ACTIVITY

Author/s	Study objective	Country	Principal approach	Methodology	Data	Type of costs	Base-year	Principal findings
Kuriyama et al. (2004)	To examine the joint impact of physical inactivity, including smoking and obesity, on direct health care charges.	Japan	Based on national health insurance costs.	Risk factor status of participants in terms of BMI, physical activity and smoking status were assessed. Participants' health insurance claims and costs were then followed-up prospectively for seven years. They were classified into eight risk groups (i.e. different combinations of the three risk factors) and examined in terms of monthly per capita health care charges to determine the cost impact of different risk factor combinations.	Physical activity, BMI, smoking data: study interview Cost data: national health insurance (covers 35% of the Japanese population)	Direct health care costs (USD)	1995–2001	Participants without risk (i.e. never smoking, with normal BMI and physically active) had mean monthly per capita health care charges of US$ 171.6. Compared to this group, the presence of physical inactivity alone increased per capita costs by 8% (US$ 185.3), smoking and physical inactivity by 31.4% (US$ 225.4) and obesity and physical inactivity by 16.4% (US$ 199.8). Presence of all three risk factors increased per capita costs by 42.6% (US$ 244.7).
Wang et al. (2004)	To estimate the costs of cardiovascular disease (CVD) associated with physical inactivity.	The United States	Disease-based: CVD (including coronary heart disease, hypertension, stroke and rheumatic heart disease).	Individual medical expenditure data were linked to physical activity status in the previous year. Physical activity was categorised as active and inactive. Medical expenditures on CVD associated with inactivity were derived by comparing mean medical costs between population groups stratified by CVD status and physical activity status and obtaining the difference.	CVD status and physical activity: National Health Interview Survey (1995) Cost data: Medical Expenditure Panel Survey (1996)	Direct health care costs (USD)	1996	Among 7.3 million cases of CVD, 1.1 million or 15.3% were associated with physical inactivity. The total medical expenditure of persons with CVD was US$ 41.3 billion, of which US$ 5.4 billion (13.1%) was associated with physical inactivity. Applying the percentages to the national health and economic burden, 9.2 million CVD cases in the United States were associated with physical inactivity in 2001, costing US$ 23.7 billion in direct medical expenditures.

PHYSICAL ACTIVITY

Author/s	Study objective	Country	Principal approach	Methodology	Data	Type of costs	Base-year	Principal findings
Anderson et al. (2005)	To estimate the proportion of total health care charges associated with physical inactivity, overweight and obesity among populations aged 40 and older.	The United States	Based on commercial health insurance costs.	A predictive model of health care charges was developed through preliminary analysis of data from 8 000 health plan members. Five variables were assessed in association with health care charges: physical activity, BMI, chronic disease status (i.e. with diabetes and/ or hypertension or none) and smoking status. Counterfactual health care charges were also estimated by reclassifying all individuals as normal weight and physically active, leaving other characteristics unchanged. Model cells for hypothetical 200 000 health plan members were then developed and defined by status of BMI, physical activity and other co-variates. Total health care charges were estimated by multiplying the percentage of the health plan population in each cell with the predicted charges per cell and summing all cells. Counterfactual estimates were computed by using counterfactual charges. The difference between current risk profile total charges and counterfactual total charges were computed as charges associated with physical inactivity, overweight and obesity. The same calculation was performed but using national population percentages to identify national cost estimates.	BMI, physical activity and other variable data: HealthPartners Minnesota health plan survey (1995) Health care charges: commercial health insurance National population percentages: National Health Interview Survey (2001)	Direct health care costs (USD)	1996–1999	For a health plan with 200 000 white members aged 40 and above, total annualised health care charges of US$ 1.12 billion was estimated, 23% of which (US$ 236 million) was associated with physical inactivity and overweight or obesity. The three sub-populations with the largest charges associated with physical inactivity, overweight and obesity were: 1) men aged 50–64 without chronic disease (US$ 44.7 million) 2) men aged 65 and older with chronic disease (US$ 43.7 million) 3) men aged 40–49 with no chronic disease (US$ 41.7 million). At the national level, the percentage of national health care charges associated with physical inactivity, overweight and obesity was estimated to be 27%.

	Author/s	Study objective	Country	Principal approach	Methodology	Data	Type of costs	Base-year	Principal findings
PHYSICAL ACTIVITY	Wang et al. (2005)	To explore the relationship of physical activity with short-term health care costs across BMI groups among individuals aged 65 and above.	The United States	Based on national health insurance and indemnity/ PPO insurance costs.	Physical activity of participants was assessed by the number of times per week they engage in physical activity "hard enough to induce heavy breathing and fast heart beat" for at least 20 minutes. Participants were classified into three groups: sedentary, moderately active and very active. They were also divided by BMI group (normal weight, overweight, obese). In all three BMI groups, health care costs were linked to physical activity levels to determine possible associations. Analysis was also done in specific age groups (65–69, 70–74 and 75+ years).	Physical activity prevalence: study interview (using the modified Health Risk Appraisal questionnaire) Cost data: national health insurance (Medicare), indemnity/PPO plans	Direct health care costs (USD)	2001–2002	Higher levels of physical activity predicted lower short-term health care costs for older individuals across the three BMI groups. Moderately active retirees had US$ 1 456, US$ 1 731 and US$ 1 177 lower total health care costs than their sedentary counterparts in the normal weight, overweight and obese groups, respectively. The very active retirees had US$ 1 823, US$ 581 and US$ 1 379 lower costs than moderately active retirees in the same BMI groupings, respectively. The same association between physical activity and short-term health care costs applies when analysis is done in specific age groups (65–69, 70–74, 75+ years).
	Allender et al. (2007)	To estimate the health and economic burden of physical inactivity.	United Kingdom	Disease-based: ischaemic heart disease, ischaemic stroke, breast cancer, colon/ rectum cancer, type 2 diabetes.	PAFs published by the WHO (2004) stratified by sex were applied to disease DALYs in the WHO EUR-A region to determine health burdens attributable to physical inactivity. The same PAFs were applied to NHS disease costs.	Disease DALYs: WHO (2003) Cost data: extrapolated from estimates from earlier studies for 1992/93	Direct health care costs (GBP)	2002	Physical inactivity was estimated to be associated with 3% of DALYs lost. Physical inactivity was estimated to be associated with £1.06 billion in direct health care costs.

PHYSICAL ACTIVITY

Author/s	Study objective	Country	Principal approach	Methodology	Data	Type of costs	Base-year	Principal findings
Katzmarzyk (2011)	To estimate the economic burden of physical inactivity.	Canada	Disease-based: coronary heart disease, stroke, hypertension, colon cancer, breast cancer, type 2 diabetes, osteoporosis.	PAFs were calculated based on summary RRs derived in a previous meta-analysis of prospective longitudinal studies. The PAFs were applied to disease health care and productivity costs.	Physical activity prevalence: Canadian Community Health Survey (2009) RRs: earlier meta-analysis of studies Cost data: Economic Burden of Illness in Canada (1993, 1998), Health Canada (2002), National Cancer Institute of Canada (2002), Canadian Institute for Health Information (2010), American Heart Association (2002), US Centers for Disease Prevention and Control, earlier studies	Direct health care and indirect productivity costs (CAD)	2009	Physical inactivity in Ontario was associated with a cost of C$ 3.4 billion (C$ 1.02 billion in direct costs and C$ 2.34 billion in indirect costs). After extrapolation to the national situation, estimated costs reach C$ 8.6 billion (C$ 2.6 billion direct, C$ 5.95 billion indirect).

	Author/s	Study objective	Country	Principal approach	Methodology	Data	Type of costs	Base-year	Principal findings
PHYSICAL ACTIVITY	Alter et al. (2012)	To estimate cumulative outcomes and costs associated with obesity alone and in combination with physical inactivity, including smoking and psychosocial distress among middle-aged adults.	Canada	Based on public health insurance costs.	Risk factor status in terms of BMI, physical activity, psychosocial status and smoking status were assessed through a telephone survey. Individual risk factor data were linked with health care utilisation and costs and followed longitudinally for 11.5 years. Propensity-matching was done where each exposed individual was matched in 1:1 fashion to a healthy, normal weight person, based on age, gender, socioeconomic status, co-morbidity and non-BMI risk factors. Differences in costs between the exposed and unexposed matched pairs were tallied and averaged throughout the follow-period and attributed to the corresponding risk factor.	Risk factor data: National Population Health Survey (1994–96) Cost data: public health insurance, Canadian Institutes of Health Information, Ontario Case Costing Initiative, Ontario Drug Benefits formulary Incidence of diabetes and hypertension: Ontario diabetes and hypertension databases Mortality: registered persons database	Direct health care costs (CAD)	1994/95/96 – 2005/06/07	Cumulative costs associated with obesity alone were C$ 8 294.67 per person, not significantly higher compared to costs among propensity-matched normal weight controls (C$ 7 323.59 per person). Obesity in combination with other lifestyle factors was associated with significantly higher cumulative expenditures as compared with normal-weight healthy matched controls. Excess costs were estimated to be: Overweight + physically inactive: C$ 1 095.30 Obese + physically inactive: C$ 4 079.47 Overweight + physically inactive + smoking: C$ 2 026.10 Obese + physically inactive + smoking: C$ 2 632.91 Overweight + physically inactive + distressed: C$ 1 868.57 Obese + physically inactive + distressed: C$ 7 156.94

PHYSICAL ACTIVITY

Author/s	Study objective	Country	Principal approach	Methodology	Data	Type of costs	Base-year	Principal findings
Janssen (2012)	To estimate the economic burden of physical inactivity.	Canada	Disease-based: coronary artery disease, stroke, hypertension, colon cancer, female breast cancer, type 2 diabetes, osteoporosis.	PAFs were calculated based on summary RRs derived in earlier meta-analyses of RRs in prospective cohort studies, stratified by sex. PAFs were applied to disease direct and indirect costs.	Physical activity prevalence: Canadian Health Measures Survey (2007–2009) RRs: earlier meta-analyses of studies Cost data: Economic Burden of Illness in Canada (2000) extrapolated to 2009 values	Direct health care and indirect productivity costs (CAD)	2009	Physical inactivity costs C$ 6.8 billion (C$ 2.4 billion in direct costs and C$ 4.3 billion in indirect costs). Direct costs represent 3.8% of the overall health care costs.
Zhang and Chaaban (2012)	To estimate the economic burden of physical inactivity.	China	Disease-based: coronary heart disease, stroke, hypertension, cancer, type 2 diabetes.	Impacts of physical inactivity were assessed through direct mechanisms (inactivity to NCDs) and indirect mechanisms (inactivity to overweight/obesity to NCDs). PAFs were calculated for each disease related to physical inactivity, overweight and obesity, based on RRs from earlier meta-analyses of prospective studies and single cohort studies. PAFs related to overweight and obesity were multiplied by 12% (i.e. the proportion of overweight and obesity attributable to physical inactivity). All three sets of PAFs were summed and the totals applied to disease direct and indirect costs.	Physical activity, overweight, obesity prevalence: Chinese Behavioural Risk Factors Surveillance Survey (2007) RRs: Earlier meta-analyses and single cohort studies Cost data: National Health Service Survey (2003) extrapolated to 2007	Direct health care and indirect productivity costs (USD)	2007	Economic costs associated with physical inactivity were US$ 6.7 billion (US$ 3.5 billion for direct costs and US$ 3.3 billion for indirect costs). This was equivalent to 15.2% of the total costs of the five diseases, 5.3% of total NCD costs and 3.8% of total costs for all diseases.

PHYSICAL ACTIVITY

Author/s	Study objective	Country	Principal approach	Methodology	Data	Type of costs	Base-year	Principal findings
Chevan & Roberts (2014)	To examine the association between leisure-time physical activity levels and short-term health care expenditures.	The United States	Based on short-term public and/or private health care costs.	Physical activity was assessed by the number of minutes of vigorous- and moderate-intensity activity completed per week. By equating 2 minutes of moderate activity to 1 minute of vigorous activity, physical activity was categorised in two ways. The first categorised participants as to: (1) whether they met the physical activity guidelines for strength and aerobic activity, (2) met guidelines only for strength, (3) met guidelines only for aerobic activity and (4) not meeting guidelines for both. The second focused on aerobic activity and split up participants as completing 0, <75, 75–149, 150–299 or >300 minutes per week. The two categorisations characterised weekly leisure-time physical activity levels which were linked to individual health care expenditures to determine possible associations.	Physical activity prevalence: National Health Interview Survey (2006, 2007) Cost data: Medical Expenditures Panel Survey (2007–2008 and 2008–2009)	Direct health care costs (USD)	2007–2009	Whether in terms of meeting the physical activity guidelines (i.e. for strength and aerobic activity) or the number of minutes spent on aerobic activity per week, not a single level of leisure-time physical activity had a significant association with all types of short-term health care expenditures.
Maresova (2014)	To estimate the economic burden of physical inactivity.	Czech Republic	Disease-based: coronary heart disease, ischaemic stroke, diabetes type 2, female breast cancer, colon cancer.	PAFs calculated from disease-specific RRs derived from WHO (2004) stratified by age group (15–69, 70–79, 80+) and physical activity level (level 1: inactive; level 2: insufficiently active). The PAFs were applied to disease costs.	Mortality data: Czech Statistical Office (CZSO) Morbidity (DALYs): WHO GBD study (2004) Physical activity prevalence: Czech Republic European Health Interview Survey (EHIS) Cost data: health insurance (covering approx. 75% of health care expenditure in the Czech Republic); earlier studies	Direct health care costs (CZK)	2008	Physical inactivity accounted for 2 442 of all deaths (2.3%) and 18 065 DALYs (1.24%). Physical inactivity accounted for almost CZK 700 million (~€29 million) of public health insurance expenditure (0.4% of total expenditure).

PHYSICAL ACTIVITY

Author/s	Study objective	Country	Principal approach	Methodology	Data	Type of costs	Base-year	Principal findings
Peeters et al. (2014)	To estimate the costs associated with prolonged sitting and physical inactivity among middle-aged women.	Australia	Based on national health insurance costs.	Participants were surveyed in terms of time spent sitting, walking and in moderate and vigorous leisure-time activities. Sitting time was categorised as low, moderate and high. Physical activity was categorised as inactive, low, moderate and high. Combined sitting time and physical activity or "activity patterns" were categorised into active + low sitting time, active + high sitting time, inactive + low sitting time and inactive + high sitting time. Medicare costs averaged over the survey year ±1 year were used to calculate the annual costs. Annual median costs were linked to sitting time, physical activity and activity patterns and examined across groups to determine possible associations. Analysis was also done by BMI strata to examine for potential effect modifications of BMI.	Sitting time and physical activity: Australian Longitudinal Study on Women's Health (2001, 2005, 2007, 2010) Cost data: National health insurance	Direct health care costs (AUD)	2010	The annual median costs for highly active vs inactive individuals were AU$ 689 vs AU$ 741, with a significant difference of AU$ 94. In terms of sitting time, annual median costs for people with low sitting time vs high sitting time were AU$ 671 vs AU$ 709, with a difference of AU$ 16. No statistically significant associations were found between sitting time and costs. A high sitting time did not add to inactivity-associated costs (AU$ 110 higher for inactive people with high sitting time vs active people with low sitting time). Although costs are higher for overweight and obese groups compared to normal weight, the effects of physical activity on costs were similar across BMI ranges, suggesting no BMI interaction effects.

PHYSICAL ACTIVITY

Author/s	Study objective	Country	Principal approach	Methodology	Data	Type of costs	Base-year	Principal findings
Bachmann et al. (2015)	To evaluate the association of health care costs in later life with cardio-respiratory fitness (an objective measure of habitual physical activity) in mid-life after adjustment for cardiovascular risk factors.	The United States	Based on public and/or private health care costs.	Participants' cardiorespiratory fitness at mid-life (mean age: 49 years) was assessed from a treadmill test and measured in terms of maximal metabolic equivalents (METs) achieved, categorised into age- and sex-specific quintiles of fitness. The quintiles were combined into three fitness groupings, into which participants were assigned: low fit (quintile 1), moderate fit (quintiles 2 and 3) and high fit (quintiles 4 and 5). Health care costs were followed up later in old age for an average period of 6.5 years, from the date of initiating Medicare coverage until death or at the end of follow-up. Average annual health care costs were examined across fitness groupings to determine possible associations.	Treadmill test data: Cooper Center Longitudinal Study Cost data: national health insurance (Medicare), Carrier, Durable Medical Equipment, Home Health Agency, Hospice, Center for Medicare and Medicaid Services	Direct health care costs (USD)	1999–2009	Health care costs among those aged 65 years and above were significantly associated with cardiorespiratory fitness in mid-life. Compared to men with low cardiorespiratory fitness, men with high cardiorespiratory fitness had significantly lower health care costs (i.e. US$ 12 811 vs US$ 7 569). The same trend applied to women (US$ 10 029 vs US$ 6 056). Average annual health care costs were incrementally lower per MET achieved (i.e. 6.8% and 6.7% decrease in costs per MET achieved in mid-life in men and women, respectively). The associations persisted when analysis was done between cohorts who died during the follow-up and those who survived.

PHYSICAL ACTIVITY

Author/s	Study objective	Country	Principal approach	Methodology	Data	Type of costs	Base-year	Principal findings
Carlson et al. (2015)	To examine the association between leisure-time aerobic physical activity and health care expenditures with and without adjusting for obesity status.	The United States	Based on public and/or private health care costs.	Physical activity was assessed through the frequency and, if applicable, the duration of leisure-time activity participated in for at least 10 minutes at a time in vigorous- and light- or moderate-intensity activities. Minutes of moderate-intensity equivalent activity were calculated by counting 1 minute of vigorous-intensity activity as 2 minutes of light- or moderate-intensity activity. Participants were classified into three activity levels: 1) active, 2) insufficiently active and 3) inactive. Physical activity levels were linked to individual health care costs to determine mean and per cent differences in expenditures. The sum of the differences in costs was divided by the total predicted expenditures for all groups to determine the percentage of aggregate costs associated with inadequate levels of physical activity. Two models were used: with and without adjustment for BMI.	Physical activity prevalence: National Health Interview Survey (2004–2010) Cost data: Medical Expenditure Panel Survey (2006–2011)	Direct health care costs (USD)	2006–2011	Higher levels of leisure-time aerobic physical activity were significantly associated with lower health care costs. There was a mean difference of 29.9% in annual per capita costs between active and inactive groups, as inactive individuals paid an additional cost of US$ 1 437. Insufficiently active individuals paid an additional cost of US$ 713 compared to active individuals (mean difference: 15.4%). After adjusting for BMI, the means of annual expenditure and per cent differences decreased but remained significant (26.6% or US$ 1 313 between active and inactive groups and 12.1% or US$ 576 between insufficiently active and inactive groups). Before adjustment for BMI, the percentage of aggregate health care expenditures associated with inadequate levels of physical activity was 12.5% (US$ 131 billion) and remained significant at 11.1% (US$ 117 billion) after adjusting for BMI. When adults with any reported difficulty walking due to a health problem were excluded from the analysis, the percentage was 8.7% (US$ 79 billion).

	Author/s	Study objective	Country	Principal approach	Methodology	Data	Type of costs	Base-year	Principal findings
PHYSICAL ACTIVITY	Codogno et al. (2015)	To analyse the association between physical inactivity in different domains and public health expenditures and identify whether clustering of physical inactivity in these domains contributes to increased health care costs.	Brazil	Based on public primary health care costs.	Participants' primary health care costs were estimated in the last 12 months prior to interview on physical activity. Individual habitual physical activity was assessed in three domains (i.e work, sports and leisure-time) using the Baecke Questionnaire and scored. Scores were categorised into quartiles: the bottom quartile with scores ≤25, middle quartiles with scores ≥25 but ≤75 and the high quartile with scores ≥75. Participants were analysed according to in how many domains of physical activity they were categorised in the bottom quartile (i.e. from 0 to 3 times). This frequency of being in the bottom quartile was correlated with annual expenditure data.	Cost data: Basic Healthcare Unit, Sao Paolo, Brazil Physical activity: study interview	Direct health care costs (USD)	2009	Lower physical activity (i.e. scores in the bottom quartile) in two or all of the domains was associated with higher expenditures (odds ratio for two domains: 1.75 and for three domains: 2.12). Those in the bottom quartile for all three domains had the highest overall expenditures (OR: 2.28). For specific domains, lower physical activity at work and in sports is associated with higher health care expenditures related to medicine discharge (OR for work: 1.58, OR for sport: 1.57). Lower physical activity in leisure-time was still associated with higher overall expenditures (OR: 1.53).

PHYSICAL ACTIVITY

Author/s	Study objective	Country	Principal approach	Methodology	Data	Type of costs	Base-year	Principal findings
Idler et al. (2015)	To analyse the relationship between physical activity and health care and (parental) productivity costs among children aged 9 to 12 years.	Germany	Based on public and/or private health care and parental work absence costs.	Information on children's physical activity and frequency of health care utilisation and costs were provided by parents in an interview (using a self-administered questionnaire). Children were grouped into two categories based on weekly hours spent on moderate and vigorous physical activity: <7 hours per week and ≥7 hours per week. Direct health care and indirect productivity costs (i.e. from parental absence at work) were examined across the two physical activity groups to determine possible associations.	Physical activity, frequency of health care utilisation: The German Infant Study on the Influence of Nutrition Intervention plus Air Pollution and Genetics on Allergy Development (GINIplus) study and the Influence of Lifestyle Factors on Development of the Immune System and Allergies in East and West Germany plus Air Pollution and Genetics on Allergy Development (LISAplus) study Direct medical unit costs, number of days of parental absence from work and costs per day: Working Group Methods in Health Economic Evaluation (AG MEG) national costing guide, earlier studies	Direct health care and indirect productivity costs (EUR)	2007	The mean annual cost for a child with a higher level of physical activity (i.e. ≥7 hours per week) vs a child with lower activity level (i.e. <7 hours per week) were €392 vs €398 for direct costs and €138 vs €127 for indirect costs. However, there were no statistically significant associations noted between physical activity and health care utilisation and costs among children aged 9 to 12 years. Different directions of estimates were noticeable throughout the cost components.

	Author/s	Study objective	Country	Principal approach	Methodology	Data	Type of costs	Base-year	Principal findings
PHYSICAL ACTIVITY	Krueger et al. (2015)	To identify the economic burden of physical inactivity and the potential reduction in economic costs if all provinces in Canada achieved a prevalence rate of physical inactivity equivalent to that of the province with the lowest rate.	Canada	Disease-based: malignant and other neoplasms, endocrine, nutritional and metabolic diseases, cardiovascular, respiratory infections, digestive and musculoskeletal diseases.	PAFs were derived based on sex-specific RRs from an earlier study and applied to disease costs. For indirect costs of physical inactivity, the ratio of direct and indirect costs for each diagnostic category from an earlier study were applied to PAF-based direct costs to generate equivalent indirect cost data. A second set of PAFs was derived using the prevalence rate of physical inactivity in British Columbia (the province with the lowest prevalence rate) and applied to populations living in other provinces to determine potential reductions in the economic burden.	Physical activity prevalence: Canadian Community Health Survey (2012) RRs: earlier study for 2001 Cost data: National Health Expenditure Database, Economic Burden of Illness in Canada (EBIC) online tool (2008) Ratio of direct to indirect costs: EBIC (1998)	Direct health care and indirect productivity costs (CAD)	2013	Economic costs associated with physical inactivity in 2013 (using actual provincial prevalence rates) were C$ 10.8 billion (males: C$ 5.2 billion, females: C$ 5.6 billion; direct costs: C$ 3.3 billion, indirect costs: C$ 7.5 billion). If all provinces were to achieve the low prevalence rate of physical inactivity in British Columbia, 14% (C$ 1.5 billion) of the costs could potentially be avoided, reducing the attributable costs to C$ 9.3 billion.
DIET AND PHYSICAL ACTIVITY	Popkin et al. (2006)	To determine the economic costs of unhealthy diets and physical inactivity through its direct effects on disease risks as well as indirect effects, through overweight and obesity.	China	Disease-based: coronary heart disease, type 2 diabetes, hypertension, stroke, cancers of the breast, colon, oesophagus, endometrium, lungs, stomach and bladder.	PAFs related directly to unhealthy diets and physical inactivity were calculated based on RRs from earlier meta-analyses of studies and applied to disease costs. PAFs related to overweight and obesity were also calculated, of which the proportion attributable to unhealthy diets and physical inactivity was also obtained and applied to disease costs.	Physical activity, overweight and obesity prevalence: China Health and Nutrition Survey RR: earlier meta-analyses of studies Cost data: National Survey of Health Services for China (1998)	Direct health care costs (USD)	2000 and 2025	In the year 2000 unhealthy diets accounted for US$ 4.2 billion of direct health care costs (US$ 3.4 billion for direct effects on disease risks and US$ 0.83 billion for indirect effects through overweight and obesity). Physical inactivity accounted for US$ 1.7 billion (US$ 1.3 billion for direct effects and US$ 0.35 billion for indirect effects through overweight and obesity). Costs predicted for 2025 did not increase considerably at US$ 6.1 billion (US$ 3.9 billion for unhealthy diets and US$ 2.2 billion for physical inactivity).

Appendix 2

Average annual currency exchange rates used to identify the EUR equivalent of costs in studies

Cost values in non-European currencies were converted into Euros, using the average of yearly currency exchange rates from the OANDA website (https://www.oanda.com/currency/average) during the base year/s for cost estimation in each study. The following table shows the average exchange rate used in each of the studies, according to the base year/s for cost estimation.

Study	Base year/s for cost estimation	Original currency used	Equivalent to EUR per one unit of original currency
Rayner & Scarborough (2005); Allender et al. (2007)	2002	GBP	1.59
Scarborough et al. (2011)	2006–2007	GBP	1.47
Lo et al. (2013)	1999–2006	TWD	0.03
Collins et al. (2011)	2002–2006	AUD	0.59
Peeters et al. (2014)	2010	AUD	0.69
Doidge et al. (2012)	2010–2011	AUD	0.72
Daviglus et al. (2005)	1984–2000	USD	0.96
Kuriyama et al. (2004)	1995–2001	USD	1.00
Anderson et al. (2005)	1996–1999	USD	0.90
Bland et al. (2009)	1999–2000/2001	USD	1.03
Bachmann et al. (2015)	1999–2009	USD	0.87
Garrett et al. (2004); Popkin et al. (2006)	2000	USD	1.08
Wang et al. (2005)	2001–2002	USD	1.09
Carlson et al. (2015)	2006–2011	USD	0.73
Zhang & Chaaban (2012)	2007	USD	0.73
Maresova (2014); Kruk (2014)	2008	CZK	0.04
Alter et al. (2012)	1994–2007	CAD	0.91
Katzmarzyk et al. (2000)	1999	CAD	0.63
Katzmarzyk (2011); Janssen (2012)	2009	CAD	0.63
Krueger et al. (2015)	2013	CAD	0.73

Note: Average annual exchange rates from USD to EUR in 1984 to 2000 only reflect the average of rates from 1990 to 2000 as earlier figures were not available. Costs in USD reported by Martinson et al. (2003) and Wang et al. (2004) were not converted into EUR as average exchange rates during the base year/s for cost estimation were not available from the sources used.

Appendix 3

Mean intake of AHEI food groups in France, Germany, Italy, Spain and the United Kingdom

Country	Dietary component	Mean intake (grams/day)	Mean intake (cups or ounces/day)[d]
France *(n = 23 048 consumers; 44% of surveyed population)* **2007 Individual and National Study on Food Consumption**	Vegetables[a]	20.99	0.09
	Fruit[b]	10.97	0.05
	Whole grains	12.2	
	Sugar-sweetened beverages and fruit juice	118.84	4.19
	Nuts	1.13	0.04
	Processed meat	37.59	1.33
	Trans-Fat	63.5	
	Long-chain (n-3) fats (EPA + DHA)	21.39	
	Polyunsaturated fatty acid	10.92	
	Sodium	1.5	
	Alcohol[c]	78.08	2.75
Germany *(n = 54 710 consumers; 25% of surveyed population)* **2007 National Nutrition Survey**	Vegetables[a]	27.31	0.12
	Fruit[b]	13.66	0.06
	Whole grains	0.49	
	Sugar-sweetened beverages and fruit juice	341.65	12.05
	Nuts	2.95	0.10
	Processed meat	49.82	1.76
	Trans-Fat	68.57	
	Long-chain (n-3) fats (EPA + DHA)	13.67	
	Polyunsaturated fatty acid	2.93	
	Sodium	0.01	
	Alcohol[c]	52.02	1.83

Country	Dietary component	Mean intake (grams/day)	Mean intake (cups or ounces/day)[d]
Italy *(n = 18 035 consumers; 33.9% of surveyed population)* **2005–2006 National Food Consumption Survey**	Vegetables[a]	45.62	0.20
	Fruit[b]	2.89	0.01
	Whole grains	35.29	
	Sugar-sweetened beverages and fruit juice	56.03	1.98
	Nuts	1.06	0.04
	Processed meat	29.87	1.05
	Trans-Fat	30.23	
	Long-chain (n-3) fats (EPA + DHA)	31.05	
	Polyunsaturated fatty acid	36.63	
	Sodium	0.01	
	Alcohol[c]	70.88	2.50
Spain *(n = 6 940 consumers; 34.6% of surveyed population)* **2009 Spanish Agency for Food Safety Survey**	Vegetables[a]	40.17	0.18
	Fruit[b]	6.35	0.03
	Whole grains	6.84	
	Sugar-sweetened beverages and fruit juice	130.65	4.61
	Nuts	1.99	0.07
	Processed meat	48.97	1.73
	Trans-Fat	48.31	
	Long-chain (n-3) fats (EPA + DHA)	57.31	
	Polyunsaturated fatty acid		
	Sodium		
	Alcohol[c]		1.01
United Kingdom *(n = 7 046 consumers; 26.5% of surveyed population)* **2008 National Diet and Nutrition Survey**	Vegetables[a]	6.96	0.03
	Fruit[b]	10.81	0.05
	Whole grains	2.80	
	Sugar-sweetened beverages and fruit juice	224.12	7.91
	Nuts	1.07	0.04
	Processed meat	30.1	1.06
	Trans-Fat	33.48	
	Long-chain (n-3) fats (EPA + DHA)	21.1	
	Polyunsaturated fatty acid	1.46	
	Sodium	0.08	
	Alcohol[c]	86.7	3.06

Source: European Food and Safety Authority, 2015.

Notes: [a] Vegetables refers to green leafy vegetables; [b] fruit refers to berries and small fruits; [c] alcohol refers to either beer and beer-like beverages, wines or liquors, whichever has the highest mean intake; [d] converted into units used in the AHEI: 240 g = 1 cup for liquids, 226.72 g = 1 cup for solids and 28.35 g = 1 oz for both solids and liquids.

Appendix 4

Quality of studies that have quantified the association between unhealthy diets and low physical activity and diabetes

Quality criterion as defined by Al Tunaji et al. (2014)	Quality assessment		
	Montonen et al. (2005)	**Laaksonen et al. (2009)**	**Li et al. (2015)**
The exposure (risk factor) is clearly defined	An unhealthy diet was defined as a 'conservative' dietary pattern characterised by consumption of butter, potatoes and whole milk	Physical inactivity was defined as less than 30 minutes of occasional or regular leisure-time exercise per day	Poor diet was defined as a dietary score in the 2010 alternate healthy eating index belonging to the third to fifth quintiles (i.e. score of <67%). Physical inactivity was defined as those not meeting 150 minutes per week of moderate-intensity exercise or 75 minutes per week of vigorous-intensity exercise
The exposure was measured objectively	No; the exposure was measured using a one-year dietary history interview	No; the exposure was self-reported in a health interview or a self-administered questionnaire	No; the exposure was measured using a food frequency questionnaire and interviews on lifestyle habits and medical history
The outcome (disease) was clearly defined	The outcome was defined as type 2 diabetes; no diagnostic criteria were presented	The outcome was defined as type 2 diabetes according to the WHO diagnostic criteria	The outcome was defined as type 2 diabetes, according to national diagnostic criteria
The outcome was ascertained by objective measures or, if self-reported, confirmed by other measures	The outcomes were identified from a nationwide registry of patients receiving drug reimbursement (including for diabetes). Study participants were linked to this register by unique social security codes	The outcomes were identified from a central register of all patients receiving drug reimbursement (including for diabetes). Study participants were linked to this register by unique social security codes	The outcomes were self-reported and confirmed by a validated supplementary questionnaire (validated through hospital records)

Quality criterion as defined by Al Tunaji et al. (2014)	Quality assessment		
	Montonen et al. (2005)	Laaksonen et al. (2009)	Li et al. (2015)
The analysis was based on raw data from a prospective or cohort study	Yes	Yes	Yes
The follow-up time was provided	23 years	10 years	20–30 years
Full adjustments were made	Adjustments were made for age, sex, body mass index, energy intake, smoking status, family history of diabetes, geographic area, serum cholesterol and hypertension	Adjustments were made for age, sex, other lifestyle risk factors (e.g. BMI, smoking, alcohol consumption and serum vitamin D) or components of metabolic syndrome (BMI, blood pressure, serum triglyceride levels, serum HDL cholesterol, fasting glucose)	Adjustments were made for sex, ethnicity (Caucasian yes/no), marriage status, living status (alone yes/no), family history of diabetes, menopausal status (pre- or post-menopausal; never, past or current menopausal hormone use), and for other lifestyle risk factors assessed in the study (i.e. BMI, smoking status, daily alcohol consumption)

Appendix 5

Annual incidence rate of diabetic complications from the UKPDS Outcomes Model 2

Complication	Annual incidence rate (%)
First myocardial infarction	1.13
Second myocardial infarction	0.19
First stroke	0.56
Second stroke	0.09
Congestive heart failure	0.39
Ischaemic heart disease	0.83
First amputation	0.19
Second amputation	0.06
Retinopathy/Blindness	0.3
Renal failure	0.13
Ulcer	0.11

Source: Hayes et al., 2013.

Appendix 6

Estimated diabetes complication-related costs in 2020 attributable to unhealthy diets and low physical activity in 2015

Country	Complication	Estimated number of incident cases of diabetes-related complications in 2020 attributable to the risk factor		Estimated per patient costs in 2020 (€)	Estimated diabetes complication-related costs in 2020 (€)	
		Unhealthy diets	Low physical activity		Unhealthy diets	Low physical activity
France	First myocardial infarction	51	86	19 097	981 441	1 635 734
	Second myocardial infarction	9	14	19 097	165 021	275 035
	First stroke	25	42	14 396	366 649	611 081
	Second stroke	4	7	14 396	58 926	98 210
	Congestive heart failure	18	30	4 838	85 813	143 021
	Ischaemic heart disease	38	63	3 200	120 795	201 325
	First amputation	9	14	39 191	338 657	564 429
	Second amputation	3	5	39 191	106 944	178 241
	Retinopathy/Blindness	14	23	468	6 385	10 642
	Renal failure	6	10	69 186	409 055	681 759
	Ulcer	5	8	1 399	6 999	11 665
	Total	**181**	**302**		**2 646 685**	**4 411 142**

Country	Complication	Estimated number of incident cases of diabetes-related complications in 2020 attributable to the risk factor		Estimated per patient costs in 2020 (€)	Estimated diabetes complication-related costs in 2020 (€)	
		Unhealthy diets	Low physical activity		Unhealthy diets	Low physical activity
Germany	First myocardial infarction	55	110	22 465	1 231 448	2 463 150
	Second myocardial infarction	9	18	22 465	207 058	414 158
	First stroke	27	54	29 032	788 672	1 577 506
	Second stroke	4	9	29 032	126 751	253 528
	Congestive heart failure	19	38	9 030	170 838	341 711
	Ischaemic heart disease	40	81	5 002	201 397	402 836
	First amputation	9	18	33 068	304 784	609 632
	Second amputation	3	6	33 068	96 248	192 515
	Retinopathy/Blindness	15	29	15 650	227 754	455 556
	Renal failure	6	13	86 975	548 490	1 097 094
	Ulcer	5	11	1 312	7 001	14 003
	Total	**193**	**386**		**3 910 441**	**7 821 688**
Italy	First myocardial infarction	17	120	12 580	215 079	1 505 553
	Second myocardial infarction	3	20	12 580	36 164	253 146
	First stroke	8	59	5 994	50 786	355 502
	Second stroke	1	10	5 994	8 162	57 134
	Congestive heart failure	6	41	3 363	19 844	138 908
	Ischaemic heart disease	13	88	2 091	26 259	183 810
	First amputation	3	20	9 266	26 637	186 459
	Second amputation	1	6	9 266	8 412	58 882
	Retinopathy/Blindness	5	32	5 021	22 790	159 532
	Renal failure	2	14	39 220	77 142	539 993
	Ulcer	2	12	694	1 155	8 085
	Total	**60**	**422**		**492 429**	**3 447 004**

Country	Complication	Estimated number of incident cases of diabetes-related complications in 2020 attributable to the risk factor		Estimated per patient costs in 2020 (€)	Estimated diabetes complication-related costs in 2020 (€)	
		Unhealthy diets	Low physical activity		Unhealthy diets	Low physical activity
Spain	First myocardial infarction	12	73	22 638	273 460	1 641 273
	Second myocardial infarction	2	12	22 638	45 980	275 966
	First stroke	6	36	5 447	32 608	195 709
	Second stroke	1	6	5 447	5 241	31 453
	Congestive heart failure	4	25	5 834	24 323	145 981
	Ischaemic heart disease	9	53	2 592	22 998	138 031
	First amputation	2	12	17 366	35 272	211 698
	Second amputation	1	4	17 366	11 139	66 852
	Retinopathy/Blindness	3	19	3 669	11 766	70 621
	Renal failure	1	8	36 679	50 973	305 932
	Ulcer	1	7	2 258	2 655	15 936
	Total	**43**	**255**		**516 414**	**3 099 453**
United Kingdom	First myocardial infarction	27	94	8 823	236 089	826 313
	Second myocardial infarction	4	16	8 823	39 696	138 938
	First stroke	13	46	5 131	68 041	238 144
	Second stroke	2	7	5 131	10 935	38 273
	Congestive heart failure	9	32	48 330	446 337	1 562 180
	Ischaemic heart disease	20	69	39 119	768 860	2 691 012
	First amputation	4	16	14 114	63 502	222 256
	Second amputation	1	5	14 114	20 053	70 186
	Retinopathy/Blindness	7	25	1 890	13 427	46 993
	Renal failure	3	11	63 949	196 861	689 012
	Ulcer	3	9	4 030	10 497	36 741
	Total	**94**	**330**		**1 874 299**	**6 560 047**

Appendix 7

Number of incident type 2 diabetes cases attributable to unhealthy diets and low physical activity in each country by sex

Country	Number of type 2 diabetes cases attributable to the risk factor					
	Unhealthy diets			Low physical activity		
	Males	Females	Total	Males	Females	Total
France	2 507	2 041	4 548	4 178	3 402	7 580
Germany	2 674	2 177	4 851	5 348	4 355	9 703
Italy	834	679	1 513	5 838	4 753	10 591
Spain	589	480	1 069	3 536	2 880	6 416
United Kingdom	1 305	1 063	2 368	4 568	3 720	8 288

Appendix 8

Average percentage of annual incident type 2 diabetes cases in the United Kingdom by sex and five-year age group, 1991–2010

Age range	Average percentage of annual total incident type 2 diabetes cases	
	Males (%)	Females (%)
0–4	0.16	0.14
5–9	0.13	0.14
10–14	0.13	0.16
15–19	0.25	0.46
20–24	0.32	0.79
25–29	0.46	0.97
30–34	0.77	1.19
35–39	1.30	1.61
40–44	2.39	2.33
45–49	3.94	3.40
50–54	5.90	5.00
55–59	8.04	7.05
60–64	10.79	9.56
65–69	12.57	11.61
70–74	13.31	12.95
75–79	13.28	13.61
80–84	11.64	12.42
85–89	9.25	10.56
90+	5.38	6.03

Appendix 9

Estimated number of diabetes cases attributable to unhealthy diets and low physical activity by sex and five-year age group in France, Germany, Italy, Spain and the United Kingdom

Country	Age-group	Number of diabetes cases attributable to the risk factor					
		Unhealthy diets			Low physical activity		
		Males	Females	Total	Males	Females	Total
France	0–4	4	3	7	7	5	12
	5–9	3	3	6	5	5	10
	10–14	3	3	7	5	5	10
	15–19	6	9	16	10	16	26
	20–24	8	16	24	13	27	40
	25–29	12	20	31	19	33	52
	30–34	19	24	44	32	40	73
	35–39	33	33	65	54	55	109
	40–44	60	48	107	100	79	179
	45–49	99	69	168	165	116	280
	50–54	148	102	250	247	170	417
	55–59	202	144	345	336	240	576
	60–64	270	195	466	451	325	776
	65–69	315	237	552	525	395	920
	70–74	334	264	598	556	441	997
	75–79	333	278	611	555	463	1 018
	80–84	292	254	545	486	423	909
	85–89	232	216	447	386	359	746
	90+	135	123	258	225	205	430
	TOTAL	**2 507**	**2 041**	**4 548**	**4 179**	**3 401**	**7 580**

Country	Age-group	Number of diabetes cases attributable to the risk factor					
		Unhealthy diets			Low physical activity		
		Males	Females	Total	Males	Females	Total
Germany	0–4	4	3	7	9	6	15
	5–9	3	3	7	7	6	13
	10–14	3	3	7	7	7	14
	15–19	7	10	17	13	20	33
	20–24	9	17	26	17	34	52
	25–29	12	21	33	25	42	67
	30–34	21	26	46	41	52	93
	35–39	35	35	70	70	70	140
	40–44	64	51	115	128	101	229
	45–49	105	74	179	211	148	359
	50–54	158	109	267	316	218	533
	55–59	215	153	368	430	307	737
	60–64	289	208	497	577	416	993
	65–69	336	253	589	672	506	1 178
	70–74	356	282	638	712	564	1 276
	75–79	355	296	651	710	593	1 303
	80–84	311	270	582	623	541	1 163
	85–89	247	230	477	495	460	955
	90+	144	131	275	288	263	550
	TOTAL	**2 674**	**2 177**	**4 851**	**5 349**	**4 354**	**9 703**
Italy	0–4	1	1	2	9	7	16
	5–9	1	1	2	8	7	14
	10–14	1	1	2	8	8	15
	15–19	2	3	5	15	22	36
	20–24	3	5	8	19	38	56
	25–29	4	7	10	27	46	73
	30–34	6	8	15	45	57	102
	35–39	11	11	22	76	77	152
	40–44	20	16	36	140	111	250
	45–49	33	23	56	230	162	392
	50–54	49	34	83	344	238	582
	55–59	67	48	115	469	335	804
	60–64	90	65	155	630	454	1 084
	65–69	105	79	184	734	552	1 286
	70–74	111	88	199	777	616	1 393
	75–79	111	92	203	775	647	1 422
	80–84	97	84	181	680	590	1 270
	85–89	77	72	149	540	502	1 042
	90+	45	41	86	314	287	601
	TOTAL	**834**	**679**	**1 513**	**5 838**	**4 752**	**10 591**

Country	Age-group	Number of diabetes cases attributable to the risk factor					
		Unhealthy diets			Low physical activity		
		Males	Females	Total	Males	Females	Total
Spain	0–4	1	1	2	6	4	10
	5–9	1	1	1	5	4	9
	10–14	1	1	2	5	5	9
	15–19	1	2	4	9	13	22
	20–24	2	4	6	11	23	34
	25–29	3	5	7	16	28	44
	30–34	5	6	10	27	34	61
	35–39	8	8	15	46	46	92
	40–44	14	11	25	85	67	152
	45–49	23	16	40	139	98	237
	50–54	35	24	59	209	144	353
	55–59	47	34	81	284	203	487
	60–64	64	46	109	382	275	657
	65–69	74	56	130	445	334	779
	70–74	78	62	141	471	373	844
	75–79	78	65	144	470	392	862
	80–84	69	60	128	412	358	769
	85–89	55	51	105	327	304	631
	90+	32	29	61	190	174	364
	TOTAL	**589**	**480**	**1 069**	**3 537**	**2 879**	**6 416**
United Kingdom	0–4	2	1	3	7	5	13
	5–9	2	1	3	6	5	11
	10–14	2	2	4	6	6	12
	15–19	3	5	8	11	17	29
	20–24	4	8	13	15	29	44
	25–29	6	10	16	21	36	57
	30–34	10	13	23	35	44	79
	35–39	17	17	34	59	60	119
	40–44	31	25	56	109	87	196
	45–49	51	36	88	180	126	306
	50–54	77	53	130	270	186	456
	55–59	105	75	180	367	262	630
	60–64	141	102	242	493	356	849
	65–69	164	123	287	574	432	1 006
	70–74	174	138	311	608	482	1 090
	75–79	173	145	318	607	506	1 113
	80–84	152	132	284	532	462	994
	85–89	121	112	233	423	393	815
	90+	70	64	134	246	224	470
	TOTAL	**1 305**	**1 063**	**2 368**	**4 569**	**3 719**	**8 288**

Appendix 10

Estimated number of diabetes cases attributable to unhealthy diets and low physical activity who are expected to be in and out of the formal labour force by five-year age group

Country	Working age range	Average annual labour force participation rate (%)	Number of diabetes cases attributable to the risk factor					
			Unhealthy diets			Low physical activity		
			Total	In the labour force	Out of the labour force	Total	In the labour force	Out of the labour force
France	15–19	14.94	16	2	14	26	4	22
	20–24	60.90	24	15	9	40	25	16
	25–29	86.52	31	27	4	52	45	7
	30–34	87.68	44	38	6	73	64	9
	35–39	88.98	65	58	7	109	97	12
	40–44	89.58	107	96	11	179	160	19
	45–49	88.59	168	149	19	280	248	32
	50–54	83.87	250	210	40	417	349	67
	55–59	62.14	345	215	131	576	358	218
	60–64	17.69	466	82	383	776	137	639
	TOTAL		**1 517**	**893**	**624**	**2 528**	**1 488**	**1 041**
Germany	15–19	30.16	17	5	12	33	10	23
	20–24	70.17	26	18	8	52	36	15
	25–29	81.62	33	27	6	67	55	12
	30–34	86.16	46	40	6	93	80	13
	35–39	87.88	70	61	8	140	123	17
	40–44	89.64	115	103	12	229	206	24
	45–49	88.99	179	160	20	359	319	40
	50–54	85.01	267	227	40	533	453	80
	55–59	74.50	368	275	94	737	549	188
	60–64	38.10	497	189	307	993	378	615
	TOTAL		**1 618**	**1 105**	**513**	**3 236**	**2 209**	**1 027**

Country	Working age range	Average annual labour force participation rate (%)	Number of diabetes cases attributable to the risk factor					
			Unhealthy diets			Low physical activity		
			Total	In the labour force	Out of the labour force	Total	In the labour force	Out of the labour force
Italy	15–19	12.48	5	1	5	36	5	32
	20–24	49.95	8	4	4	56	28	28
	25–29	70.99	10	7	3	73	52	21
	30–34	79.36	15	12	3	102	81	21
	35–39	80.59	22	18	4	152	123	30
	40–44	79.73	36	29	7	250	200	51
	45–49	77.45	56	43	13	392	303	88
	50–54	70.71	83	59	24	582	412	170
	55–59	50.48	115	58	57	804	406	398
	60–64	22.50	155	35	120	1 084	244	840
	TOTAL		**505**	**265**	**240**	**3 532**	**1 852**	**1 680**
Spain	15–19	23.57	4	1	3	22	5	17
	20–24	63.32	6	4	2	34	22	12
	25–29	85.63	7	6	1	44	38	6
	30–34	87.39	10	9	1	61	54	8
	35–39	85.69	15	13	2	92	79	13
	40–44	83.66	25	21	4	152	127	25
	45–49	80.22	40	32	8	237	190	47
	50–54	73.15	59	43	16	353	258	95
	55–59	60.20	81	49	32	487	293	194
	60–64	35.39	109	39	71	657	232	424
	TOTAL		**357**	**216**	**140**	**2 140**	**1 298**	**841**
United Kingdom	15–19	52.83	8	4	4	28	15	13
	20–24	74.60	13	9	3	44	33	11
	25–29	84.25	16	14	3	57	48	9
	30–34	84.52	23	19	4	79	67	12
	35–39	84.87	34	29	5	119	101	18
	40–44	86.02	56	48	8	196	168	27
	45–49	85.97	88	75	12	306	263	43
	50–54	83.29	130	108	22	456	379	76
	55–59	71.93	180	129	50	629	452	177
	60–64	44.74	242	108	134	849	380	469
	TOTAL		**790**	**545**	**245**	**2 763**	**1 907**	**856**

Appendix 11

Estimated total number of working years lost due to work disability, early retirement and premature death among incident type 2 diabetes cases at working age that can be attributed to unhealthy diets and low physical activity and who are expected to be in the formal labour force in France, Germany, Italy, Spain and the United Kingdom, 2020

Country	Risk factor	Estimated number of incident type 2 diabetes cases aged 35–60 attributable to the risk factor (in the labour force)	Total number of working years lost due to		
			work disability	early retirement	premature death
France	Unhealthy diets	893	80	625	250
	Low physical activity	1 488	134	1 041	417
Germany	Unhealthy diets	1 105	99	773	309
	Low physical activity	2 209	199	1 547	619
Italy	Unhealthy diets	265	24	185	74
	Low physical activity	1 852	167	1 297	519
Spain	Unhealthy diets	216	19	151	61
	Low physical activity	1 298	117	909	364
United Kingdom	Unhealthy diets	545	49	382	153
	Low physical activity	1 907	172	1 335	534

Unhealthy diets and low physical activity contribute to many chronic diseases and disability; they are responsible for some 2 in 5 deaths worldwide and for about 30% of the global disease burden. Yet surprisingly little is known about the economic costs that these risk factors cause, both for health care and society more widely.

This study pulls together the evidence about the economic burden that can be linked to unhealthy diets and low physical activity and explores

- How definitions vary and why this matters
- The complexity of estimating the economic burden and
- How we can arrive at a better way to estimate the costs of an unhealthy diet and low physical activity, using diabetes as an example

The review finds that unhealthy diets and low physical activity predict higher health care expenditure, but estimates vary greatly. Existing studies underestimate the true economic burden because most only look at the costs to the health system. Indirect costs caused by lost productivity may be about twice as high as direct health care costs, together accounting for about 0.5% of national income.

The study also tests the feasibility of using a disease-based approach to estimate the costs of unhealthy diets and low physical activity in Europe, projecting the total economic burden associated with these two risk factors as manifested in new type 2 diabetes cases at €883 million in 2020 for France, Germany, Italy, Spain and the United Kingdom alone. The 'true' costs will be higher, as unhealthy diets and low physical activity are linked to many more diseases.

The study's findings are a step towards a better understanding of the economic burden that can be associated with two key risk factors for ill health and they will help policy-makers in setting priorities and to more effectively promoting healthy diets and physical activity.

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