What are the estimated costs of childhood overweight and obesity on the island of Ireland?

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To be cited as

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List of abbreviations

BMI	body mass index
CAMHS	Child and Adolescent Mental Health Services
CCEMG EPPI-Centre	Campbell and Cochrane Economics Methods Group Evidence for Policy and Practice Information and Coordinating Centre
CCLaS	Cork Children's Lifestyle Study
CEA	cost-effectiveness analyses
CHD	coronary heart disease
CHS	Child Health System
CI	confidence interval
COSI	Childhood Obesity Surveillance Initiative
CSO	Central Statistics Office
DALY	disability-adjusted life years
DVT	deep vein thrombosis
GB	Great Britain
GP	General Practice
GUI	"Growing Up in Ireland" study
HDL	high-density lipoprotein
HI	"Healthy Ireland" framework
HIPE	Hospital In-patient Enquiry system
HIQA	Health Information and Quality Authority
HPO	Healthcare Pricing Office
HSE	Health Service Executive
ICD	International Classification of Diseases

IOTF	International Obesity Task Force
IPH	Institute of Public Health
JANPA	Joint Action on Nutrition and Physical Activity
LDL	low-density lipoprotein
MS	multiple sclerosis
NAFLD	non-alcoholic fatty liver disease
NICE	National Institute for Health and Care Excellence
NICR	Northern Ireland Cancer Registry
NISRA	Northern Ireland Statistics and Research Agency
ONS	Office for National Statistics
OPD	Out-patients Department
OR	odds ratio
PAF	population-attributable fraction
PCRS	Primary Care Reimbursement Scheme
QALY	quality-adjusted life years
QOF	Quality and Outcomes Framework
RR	relative risk
SLAN	Survey on Lifestyle and Attitudes to Nutrition
TILDA	The Irish Longitudinal Study on Ageing
US	United States
WHO	World Health Organization
WP	work package
YLL	years of life lost

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Executive summary

Introduction

Over the past 3 decades the prevalence of overweight and obesity has increased markedly in Ireland and worldwide. In the Republic of Ireland it is currently estimated that 60% of adults and 25% of children are overweight or obese. Obesity is a chronic disorder described by the World Health Organization as a condition of abnormal or excessive fat accumulation to the extent that health may be impaired. Excess body weight is associated with a significant burden of chronic disease, with attendant negative effects on overall life expectancy, disability-free life expectancy, quality of life, healthcare costs and productivity.

While the personal and social cost of this global phenomenon are incalculable, researchers and policy makers in a number of countries have estimated the economic costs of overweight and obesity. Estimates of the economic burden of illness provide critical information for priority setting, policy development and investment in both prevention and health services. The lack of reliable data to estimate the cost of obesity in Ireland was noted in a report from the National Taskforce on Obesity (2005)[1].

safefood is a North–South body responsible for the promotion of food safety on the island of Ireland. It has coordinated several major initiatives to raise awareness of the problem of overweight and obesity among the general public and policy makers in both jurisdictions. ***safe***food commissioned the 2012 report *The cost of overweight and obesity on the island of Ireland* [2], which was based on a study [3] carried out by a research consortium with input from specialists in public health medicine, health economics and obesity epidemiology from the Health Service Executive (HSE), the Institute of Public Health (IPH) in Ireland and a number of Irish universities, led by the Department of Epidemiology and Public Health, University College Cork.

In the report, the direct healthcare costs and indirect costs to society of adult overweight and obesity in 2009 were estimated at €1.13 billion for the Republic of Ireland and €510 million for Northern Ireland. In the Republic of Ireland, 35% of these costs were direct healthcare costs and 65% were indirect costs. The direct costs represent 2.7% of the total healthcare costs for 2009. For Northern Ireland, 25% of the costs were direct healthcare costs and 75% were indirect costs; the direct costs represent 2.8% of the total healthcare expenditure for 2009.

Given the scale of the estimated costs associated with current levels of excess body weight in adults, and given the high current rates of overweight and obesity in childhood, there is a clear need to

address the projected lifetime costs of childhood overweight and obesity. ***safe*food** has therefore commissioned this report on current and projected lifetime costs of childhood overweight and obesity on the island of Ireland as part of its ongoing work to guide and inform our response to this public health crisis. The current study (led by Professor Ivan Perry, School of Public Health, University College Cork) is based on collaboration between University College Cork, the IPH in Ireland, the Department of Public Health, HSE Mid West, the National University of Ireland, Galway, Temple Street Children's University Hospital and the United Kingdom (UK) Health Forum (UKHF).

Aims and objectives

The overall aim of this research was to make as accurate an estimate as possible of the current annual costs, and projected lifetime costs, of childhood overweight and obesity for the Republic of Ireland and Northern Ireland. The specific objectives were:

- To conduct a series of systematic reviews addressing;
    1. The prevalence of overweight and obesity among children on the island of Ireland
    2. The effects of overweight and obesity on morbidity (disease or illness) and psychological well-being in childhood
    3. The effects of childhood overweight and obesity on the risk of obesity, chronic disease, reduced quality of life and mortality (death) in adult life
    4. The effects of overweight and obesity on educational outcomes and school attendance in childhood
    5. A review of the international literature on the direct and indirect lifetime costs of childhood overweight and obesity completed since the year 2000.
- To determine current annual direct healthcare costs amongst children attributable to childhood overweight and obesity in the Republic of Ireland and Northern Ireland from a public healthcare payer perspective.
- To estimate the lifetime costs, both direct healthcare costs and indirect societal costs (including productivity losses due to absenteeism, premature mortality and lifetime income losses), attributable to childhood overweight and obesity for the Republic of Ireland and Northern Ireland.
- To explore the effect on lifetime costs of a 1% and 5% fall in population mean childhood body mass index (BMI).

- To make recommendations based on the findings, including recommendations on measures that will facilitate ongoing work on the cost of overweight and obesity on the island of Ireland, drawing on both routine data collection in health and social care services, and specific population-based research programmes.

Link with EU Joint Action on Nutrition and Physical Activity (JANPA) project

This *safe*food-funded lifetime cost of childhood overweight and obesity project represents the Irish contribution to a larger pan-European Joint Action on Nutrition and Physical Activity (JANPA) project. The overall aim of the JANPA project is to contribute to halting the rise of overweight and obesity among children and adolescents by the year 2020.

In accordance with policy actions that address overweight and obesity at a European level, and as a contribution to the EU Action Plan on Childhood Obesity 2014–2020, JANPA is focussed on several aspects of childhood overweight and obesity. These include the economic burden of obesity on national health systems and a multilevel, multisectoral and "life-course approach" to the prevention of health problems linked to childhood obesity and sedentary or relatively immobile lifestyles.

The project is organised in 7 work packages (WP), each linked to specific objectives and activities. Ireland is leading on WP4 ("Evidence and economic rationale for action on childhood obesity") through the *safe*food-funded project and with some additional EU funding to support engagement with partner institutions in Croatia, Italy, Portugal, Greece, Romania and Slovenia. The JANPA project is led by Professor Kevin Balanda at the IPH in Ireland and involves collaboration with the UKHF, which has developed and refined the "Foresight Obesity Model" [4].

Literature review

Prevalence of overweight and obesity among Irish children

This report updates a previous systematic review of published and grey literature. ("Grey" literature is information produced by people and organisations that are not academic or traditional publishers.) The report aimed to synthesise, or combine, all available overweight and obesity prevalence data for school-aged children on the island of Ireland between 2002 and 2014. The updated literature review identified 18 national or regional studies specific to the Republic of Ireland and Northern Ireland.

For the Republic of Ireland, the prevalence of overweight and obesity ranged between 18% and 34%. Trend analysis suggests that there has been a slight decrease in the prevalence of obesity among 4- to

13-year-old boys and girls between 2002 and 2014. There was no significant trend for the prevalence of overweight for boys or girls.

For Northern Ireland, only 1 study, from 2002, was eligible for inclusion in the review [5]. Among children aged 4 to 13 years, the prevalence of overweight or obesity was 22.0% (95% confidence interval [CI[1]] level: 19.5% to 25.5%) for boys and 27.0% (95% CI: 23.9% to 30.3%) for girls. No significant trend was observed over time for the prevalence of overweight and obesity in Northern Ireland, and no significant trend was observed when overweight and obesity prevalence rates were combined across all included studies (Republic of Ireland and Northern Ireland).

Collectively, the findings of the updated review indicate that the prevalence of childhood overweight and obesity is levelling off in Ireland, and may be decreasing in primary school-aged children, with the greatest reduction in prevalence being observed among 5-year-olds. However, although these findings provide some grounds for cautious optimism, overweight and obesity prevalence among Irish children remains high, with 1 in 5 boys and over 1 in 4 girls being either overweight or obese. Also of note was that, in contrast to other European countries, the prevalence of overweight and obesity among children in Ireland appears to be consistently higher among girls than boys.

Morbidity in childhood associated with overweight and obesity

Major conditions (morbidities) associated with childhood overweight and obesity identified in the review include

- asthma
- hypertension (high blood pressure)
- type 2 diabetes
- sleep apnoea (a condition where breathing stops and starts during sleep)
- non-alcoholic fatty liver disease (NAFLD)
- depressive disorders.

The quality of the available evidence on obesity-related "comorbidity" – additional diseases or conditions related to the main health condition – in childhood is poor. This is due to inconsistencies across studies in the definitions and thresholds for overweight and obesity; and also to the larger number of cross-sectional studies, which take a "snapshot" of data at a certain point and so limit assessment of "temporal relations" – issues concerning the timing or sequence of events, for example whether obesity is a cause or consequence (effect) of asthma.

[1] The 95% confidence interval is the interval in which there is 95% probability that the true population value lies.

In many cases it appears that obesity occurs first, and that then the comorbidity arises. However, causality (linking a cause with an effect) cannot be determined until more prospective studies (which look for factors, development and outcomes relating to the condition) are conducted. Part of the challenge to the call for prospective studies is the length of time between a child being diagnosed as overweight or obese and the appearance of comorbidities, some conditions not being diagnosed until later adulthood.

Effects of childhood obesity on risk of overweight and obesity, chronic disease, reduced quality of life and mortality in adult life

The extent to which excess weight in childhood predicts adult overweight and obesity is a key determinant of the lifetime cost of excess weight. The findings from this review suggest that childhood obesity is a strong predictor of adult obesity. Pooled results from 15 high-quality cohort studies ("cohort", here, means a sample of individuals being studied or followed) demonstrated that children who were obese at the ages of 7 to 11 years were 5 times more likely (pooled relative risk [RR]: 4.86, 95% CI: 4.29 to 5.51) to be obese as adults, compared with non-obese children. Children who were obese at the ages of 12 to 18 years were also 5 times more likely (pooled RR: 5.45; 95% CI: 4.34 to 6.85) to be obese as adults as were children aged 7 to 18 years (pooled RR: 5.21; 95% CI: 4.50 to 6.02).

Prospective research suggests that approximately 55% of obese children will remain obese into adolescence and approximately 80% of obese adolescents will remain obese into adulthood. Seventy per cent of obese adolescents will remain obese over the age of 30 years [6,7]. It should be noted, however, that if children who are obese become normal weight by adulthood, the risks of many outcomes are similar to the risks for children who were never obese. It should also be noted that the majority of cases of obesity-related disease in adult life arise in individuals who were of healthy weight during childhood (the majority of children) and not in the smaller group of individuals who were overweight or obese during childhood.

This review also summarises the best available evidence (meta-analyses, or the combining of results from many studies, and systematic reviews of available literature) on the effect of childhood overweight and obesity on morbidity, quality of life and mortality in adulthood. There is consistent evidence that childhood overweight and obesity is positively associated with the development of type 2 diabetes and hypertension in adulthood; that is, there is a tendency for these conditions to develop or worsen as overweight increases. There is some evidence of associations between childhood BMI and dyslipidaemia (an excess of lipids, for example cholesterol, in the blood), coronary heart disease (CHD), gout (a type of arthritis) and NAFLD. Associations with a number of cancers such as, liver cancer and colon cancer are also reported.

There is a shortage of "longitudinal" studies (carried out on a particular group of individuals and over a long time period) that investigate the effect of childhood overweight and obesity on psychological (mental and emotional) health. The available evidence suggests that children and adolescents who are overweight or obese have lower self-esteem and social support, greater loneliness, sadness and nervousness, are more likely to drink and smoke and have lower health-related quality of life in adulthood.

There is consistent evidence of a positive association between childhood BMI and mortality in adult life. A review by Park et al. (2012) [8] reported that the risk of "all-cause mortality" – that is, death by any cause at all – in adulthood increased by between 40% and 60% in people who had a high BMI between the ages of 2 and 19 years, on the basis of 5 studies. However, the majority of studies examining the link between childhood BMI and adult mortality did not adjust for socioeconomic status (income, occupation and level of education), which may be an important confounding factor (a factor that somehow affects and so interferes with the validity of data).

Childhood obesity and educational outcomes and school attendance

A systematic review of the literature found 19 studies that examined the effect of childhood obesity on educational outcomes. Nine different measures of educational attainment were used in these studies. In 8 of the 19 studies there was evidence of a small but statistically significant inverse, or negative, association between obesity and educational attainment. However, in over half of the studies included in this review, the association between obesity and educational attainment lost statistical significance on adjustment in multivariable analyses for potential moderating variables such as physical and mental or emotional health.

By contrast, the findings on obesity and school attendance are less questionable. A total of 10 relevant studies were identified, and in 9 studies the results were consistent with a statistically significant inverse, or negative, association between overweight or obesity and school attendance among children and young people. For example, in one study it was found that the odds of missing 11 or more school days were 1.5 and 1.7 times higher, respectively, for overweight and obese youth compared with their non-overweight peers in multivariable analyses.

Across the 9 positive studies there were (as one would expect) some inconsistencies in the estimates of the strength of the association by gender and degree of obesity. There were also inconsistencies and concerns in relation to the extent and adequacy of adjustment for confounding or moderating variables, with particular reference to socioeconomic status; and health-related variables, reliance on self-reported measures of obesity and school attendance, and the use of cross-sectional data as opposed to longitudinal study designs.

All of the studies on obesity and school attendance in this review were from the United States (US), which raises additional concerns about the international generalisability of the findings.

Previous studies of lifetime costs of childhood overweight and obesity

This systematic review aimed to consolidate the evidence available in the global literature since 2000 on the average total lifetime costs, both direct healthcare and indirect productivity loss costs, per overweight or obese child or adolescent. Thirteen published articles were included in the review. The methodology used in the studies varied widely, and only 1 study estimated both direct and indirect costs.

Bearing in mind this level of diversity, the mean, or average, total lifetime cost of an obese child or adolescent from the studies reviewed was found to be €54,663 (range between €45,014 and €74,244) for males and €36,053 (range between €24,433 and €61,700) for females. This is divided into an average of €16,229 (range between €6,580 and €35,810) in direct costs and €38,434 in productivity losses for males; and €19,636 in direct costs (range between €8,016 and €45,283) and €16,417 in productivity losses for females. If income penalty (money not earned for reasons related to overweight or obesity) is added, the total mean lifetime costs amount to €151,779 (range between €131,985 and €181,508) per obese male adolescent and €162,161 (range between €150,541 and €187,808) per female adolescent.

There is evidence of consistent differences seen between the genders, with direct costs being greater for women and productivity costs greater in men. This is mainly due to higher wages among men.

The finding that lifetime indirect costs of childhood or adolescent overweight and obesity are greater than the direct costs highlights the need to include indirect costs in any lifetime cost study.

Importantly, this work has revealed that there are a large number of significant challenges in the review of evidence on lifetime costs of childhood obesity, making valid comparisons between studies problematic. These include the age at which it is assumed that excess costs start to accumulate – for example, whether costs during childhood and adolescence are incorporated into the models. Only 2 studies of the 13 identified modelled direct costs incurred during childhood. There is also variation in methods for calculating costs and cost components, and what type of direct or indirect costs are included.

Moreover, models vary as to whether changes in BMI status over time are incorporated or not, whether results are differentiated by childhood age of obesity, gender and race or ethnicity, and whether excess costs are given as lifetime per overweight or obese child or adolescent or as overall population costs. Finally, how “overweight” and “obesity” are defined for children, adolescents and adults varies between studies.

Another important consideration in attempting to deduce the total excess lifetime costs of childhood and adolescent overweight and obesity is that there are considerable costs that have not been incorporated to date. First, the costs of routine surgical procedures are often considerably greater than average costs for these conditions. (Surgery for obese patients carries a greater complication rate and therefore cost.) This has not been included in models. Second, no studies to date have modelled indirect costs due to overweight and obesity during childhood (for example, the time taken off work by parents due to a child's obesity-related illness). Other effects not considered in models include excess costs for normal weight adults who were obese as children or adolescents and the fact that morbidities due to obesity originating from childhood tend to be more severe than those from obesity acquired in adulthood.

Methods

Overview

In this study, the lifetime costs of childhood overweight and obesity are broken down into current annual costs and the future annual costs incurred in each year to 2105. For this report, 2 distinct approaches – a Closed Cohort Simulation Model and a Direct Cost-of-Illness Study – were used to estimate current annual direct healthcare costs amongst children. The Closed Cohort Simulation Model was also used to estimate lifetime costs, which included direct healthcare costs and indirect societal costs that are attributable to childhood overweight and obesity. Both the Closed Cohort Simulation Model and the Direct Cost-of-Illness Study approaches were used to estimate current annual costs, as the latter method is well established in the literature and was needed to validate the Closed Cohort Simulation Model, which represents a new modelling strategy. Brief descriptions of these approaches are described here, and in more detail in the main report.

Lifetime costs

To estimate lifetime costs of overweight and obesity, a variety of different impacts and costs (identified in the systematic reviews) that occur in childhood and adulthood must be recorded. These include:

- Disease incidence (the number of new cases occurring)
- Prevalence (how widespread or common a disease is)
- Deaths

- Disability weights[2]
- Quality-of-life weights
- Direct costs as a result of healthcare expenditure
- Indirect (non-health or "societal") costs due to work absenteeism, premature death and lifetime income losses.

A range of methods are then used to calculate the value of these impacts and costs: "top-down" methods, "bottom-up" methods and mixed methods.[3] The annual cost per case of each of these component costs are then used in a Closed Cohort Simulation Model to estimate lifetime excess impacts and costs experienced by overweight and obese children.

A Closed Cohort Simulation Model to estimate lifetime costs

The simulation modelling objectives were, for the Republic of Ireland and Northern Ireland,

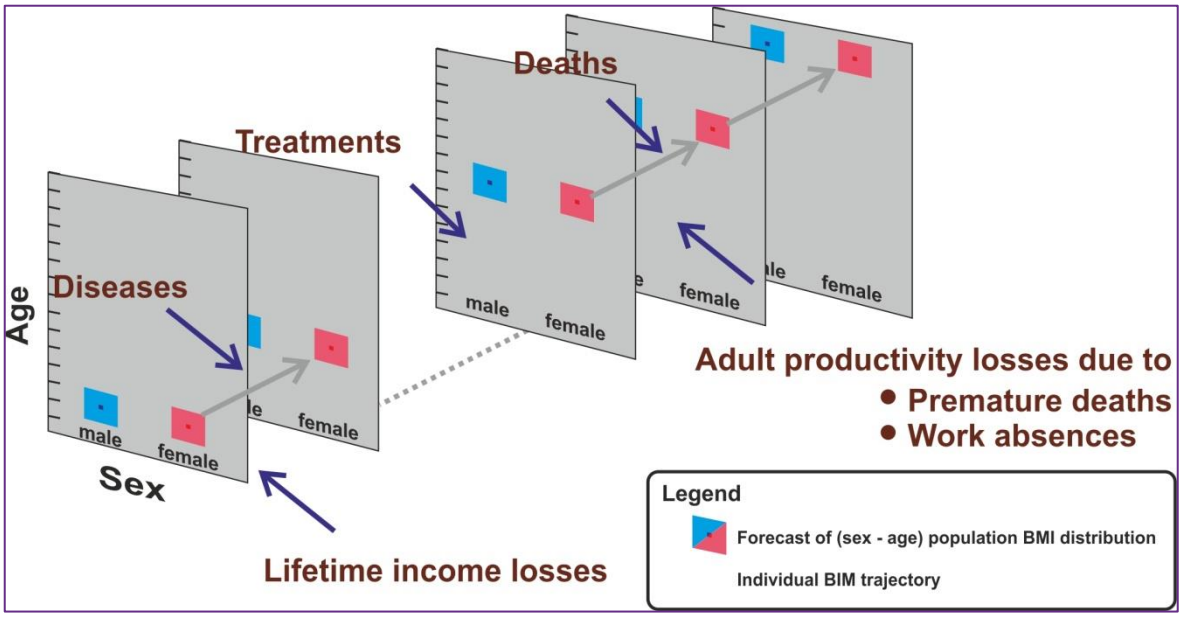
- To estimate the lifetime impacts and costs of current childhood overweight and obesity
- To assess the effect of reducing childhood obesity by 1% and 5% on these impacts and costs.

The modelling exercise is based on a Closed Cohort Simulation Model. This takes a cohort of "virtual" individuals representative of the child population of the Republic of Ireland and Northern Ireland in 2015, computer-models their lifetime BMI trajectories, or paths, and records the direct healthcare costs and indirect (non-health or societal) impacts and costs they are expected to experience over their lifetimes as a result of their modelled BMI trajectories (Figure 2). A range of impacts and costs are recorded over an individual's life-course. Each year, starting from 2015, these are summed over all individuals to produce annual impacts or costs. Ninety years of follow-up to the year 2105 are reported.

[2] A disability weight is a weight factor that reflects the severity of the disease on a scale from 0 (perfect health) to 1 (equivalent to death). Similarly, in the assessment of quality of life, weights are attached to different states of health.

[3] A description of these methods is provided in following sections.

Figure 1 Closed Cohort Simulation Model used to estimate lifetime burden of childhood overweight and obesity



For each impact and cost (Table 1) the comparison of individuals who were, as children, overweight or obese with individuals who were, as children, of healthy weight is used to estimate the burden associated with childhood obesity. Corresponding to each such excess metric – each element of impact or cost being studied – the effect of a 1% or 5% reduction in childhood obesity (mean childhood BMI) is estimated by comparing the excess in the current childhood obesity scenario to the excess in the reduced childhood obesity scenario.

Table 1 Impacts and costs included in the closed cohort simulation model

Impact and costs
Overweight and obesity
Prevalence
Cost of lifetime income loss
Mortality
Premature death
Years of life lost (YLL)
Cost of lost productivity due to premature mortality
Morbidity
Incidence
Prevalence
Disability-adjusted life years (DALY)*
Quality-adjusted life years (QALY)*
Direct healthcare costs
Cost of lost productivity due to absenteeism

*Not shown in the current analysis. Details on how these measures were calculated will be outlined in the Technical Appendix of the JANPA WP4 Report (due to be published in 2017).

Current direct costs

Closed Cohort Simulation Model-based current direct costs

Lifetime costs of childhood overweight and obesity are broken down into current annual costs and the annual costs incurred in each future year. The gender–age–BMI profile of the virtual childhood cohort in the starting year (2015) matches that of the child and adolescent population in the Republic of Ireland and Northern Ireland in 2015. The annual Closed Cohort Simulation Model-based costs for 2015 represent the current cost of providing treatment for obesity-related diseases to overweight and obese children in 2015.

Cost-of-Illness Study-based current direct costs for the Republic of Ireland

The current annual direct healthcare costs of providing treatment for obesity-related diseases can also be estimated using a direct cost-of-illness approach, which sums the current value of the component impacts and costs without using a Closed Cohort Simulation Model. A Cost-of-Illness Study of the current annual cost of providing treatment for obesity-related diseases to overweight and obese children was conducted. The purpose of this study was to investigate impacts and costs that could

not be incorporated into the Closed Cohort Simulation Model, and to assess the sensitivity of the Closed Cohort Simulation Model-based current estimates, as discussed earlier.

Details of the differences between the Cost-of-Illness Study- and Closed Cohort Simulation Model-based approaches are shown in Table 2. It was not possible to estimate current healthcare costs attributable to childhood overweight and obesity in Northern Ireland using the Cost-of-Illness Study approach. This was due to insufficient data on the prevalence of overweight and obesity among children in Northern Ireland, stratified (that is, separated into clear groups) by age and gender, and the lack of availability of hospital activity data, which could not be provided by the Health Information Branch of the Department of Health and Social Services.

Table 2 Comparison of the Cost-of-Illness Study- and Closed Cohort Simulation Model-based approaches for estimating current direct costs

Cost-of-Illness Study (Republic of Ireland)	Closed Cohort Simulation Model (Republic of Ireland and Northern Ireland)
Children only (0–18 years)	Children only (0–17 years)
Based on 3 separate surveys for 3 childhood age categories	Based on all available historical data relating to both children and adults (9 separate survey sources in the Republic of Ireland for the years 1998–2015; 6 separate survey sources in Northern Ireland for the years 2000–2015)
Uses International Obesity Task Force (IOTF) cut-off points (age- and gender-specific)	Uses BMI at age 18 years, except for cases of childhood death and disease in which case age- and gender-specific IOTF cut-offs are used
Combines overweight and obese categories	Combines overweight and obese categories
5 diseases	7 diseases
Childhood treatment costs only	Childhood treatment costs only
Shows age–gender breakdown of hospital costs	Does not present age–gender breakdown of hospital costs but these were used in analysis
Shows age–gender breakdown of drug costs	Does not present age–gender breakdown of drug costs but these were used in analysis
Bottom-up study of use of General Practice (GP) services	Bottom-up study of General Practice (GP) services for some diseases; expert opinion for other diseases
No accounting for multi-morbidities	No accounting for multi-morbidities
Includes details of specialised treatment for morbidly obese children	No details of “additional costs”

Estimating current value of component impacts and costs

The component costs associated with overweight and obesity are typically calculated using 1 of 2 main approaches: either a "top-down" or a "bottom-up" approach.

A top-down approach usually draws on country-specific data on the prevalence of overweight and obesity in the population and information on the risk of developing conditions known to be associated with a raised BMI. Specifically, RRs or odds ratios (ORs) for the relevant conditions are estimated by BMI category from observational studies. The RR/OR estimates are combined with the country-specific prevalence rates of overweight and obesity, using a standard formula, to estimate "population attributable fractions" (PAFs). The PAF estimates the proportion of cases with a particular condition that is due to overweight or obesity.

For example, the OR of type 2 diabetes in boys associated with overweight would be combined with the Irish prevalence rate of overweight in male children to give the Irish PAF for diabetes in overweight boys. This estimate is then applied to the healthcare expenditure on type 2 diabetes to estimate the cost of diabetes due to overweight in male subjects. This exercise is repeated for obese boys, and for overweight and obese girls. The process continues for each condition for which there is evidence of a causal link with overweight and obesity.

By contrast, the bottom-up approach typically uses individual-level data, usually collected in cross-sectional surveys, in which data are collected at the same time as data on BMI and healthcare utilisation patterns. The additional service utilisation associated with overweight and obesity is determined by multivariable regression analysis[4] and monetised, or expressed as currency, using cost data for the country concerned.

Data sources for estimating current and lifetime costs

The focus of the analyses of direct and indirect costs of childhood overweight and obesity is on 29 conditions (Table 3) for which there is strong evidence from systematic reviews and meta-analyses of a causal association with excess body fat. These include conditions specific to childhood, in addition to diseases that overweight and obese children are at risk of developing as adults by virtue of the link between childhood and adult BMI.

[4] Multivariable regression analysis is a statistical technique for estimating the relationship between a varying independent variable (such as BMI) and an outcome variable (such as costs associated with healthcare) when taking other independent variables (such as child's gender, birthweight, household income and other factors) into account.

It should be noted that a large cohort of healthy weight children will become overweight or obese in later life and thus will also be at risk of developing obesity-related diseases. This study does not include cost estimates for these individuals.

Table 3 Childhood and adult diseases included in the Cost-of-Illness Study and Closed Cohort Simulation Model

Childhood diseases	
Asthma*	Hypertension*
Chronic pain (musculoskeletal)	Non-alcoholic fatty liver disease (NAFLD)
Depression*	Sleep apnoea*
Diabetes (type 2)*	
Adult diseases	
Asthma	Knee osteoarthritis
Bladder cancer	Liver cancer
Breast cancer	Multiple sclerosis (MS)
Coronary heart disease (CHD)	Non-alcoholic fatty liver disease (NAFLD)
Chronic back pain	Oesophageal cancer
Colorectal cancer	Ovarian cancer
Deep vein thrombosis (DVT)	Pancreatic cancer
Depression	Prostate cancer
Diabetes (type 2)	Psoriasis
Endometrial cancer	Pulmonary embolism
Gallbladder cancer	Sleep apnoea
Gallbladder disease	Stroke
Gout	Thyroid cancer
Hypertension	
Kidney cancer	

*Cost-of-Illness Study included these diseases only.

The direct healthcare-related costs of overweight and obesity were estimated using a Closed Cohort Simulation Model and a combination of a top-down PAF method and a bottom-up approach for the Cost-of-Illness Study, with the latter based on cross-sectional analysis of the "Growing Up in Ireland" (GUI) dataset.[5]

Data on the prevalence of childhood overweight and obesity in the Republic of Ireland and Northern Ireland were obtained from a range of sources (details to be outlined in the Technical Appendix JANPA WP4 Report, 2017). Only objectively measured data were used. Self-reported data were excluded.

[5] Data are available at: http://www.ucd.ie/issda/data/growingupinirelandgui/.

Population data were used to construct a virtual cohort (a microsimulation)[6] of a population of children and adolescents representative of the Republic of Ireland and Northern Ireland child and adolescent population. The total population for each 1-year age group, by gender, was obtained for 2015 from the Republic of Ireland's Central Statistics Office (CSO) and the Northern Ireland Statistics and Research Agency (NISRA).

Incidence, prevalence, mortality and survival data for diseases were also collected from a range of sources (see Table 13 and Table 14, disease data summaries). When incidence data were not available for a disease, the estimate was computed using prevalence and mortality data if the disease was terminal, or prevalence only if the disease was not terminal. Information on age- and gender-specific RRs or ORs of acquiring disease by BMI category were provided by the UKHF, with additional information obtained through literature searches and reviews.

Data on direct healthcare costs were obtained using the Hospital In-patient Enquiry (HIPE) and the Primary Care Reimbursement Scheme (PCRS) databases in the Republic of Ireland. Additional healthcare costs linked to the tertiary (specialist) referral centre for severe obesity in childhood, based at Temple Street Children's University Hospital, Dublin, were also included in the Cost-of-Illness analysis. Direct healthcare costs for Northern Ireland were estimated from the previous ***safe***food report, *The cost of overweight and obesity on the island of Ireland* [2], and were scaled to 2015 costs.

The lifetime indirect costs estimated using the Closed Cohort Simulation Model were productivity losses associated with work absenteeism and premature mortality and lifetime income losses. The Closed Cohort Simulation Model requires an annual cost per case for absenteeism. These costs were also derived from the 2012 ***safe***food report. Information on average earnings by age and gender group was collected for use in calculations of the cost of premature mortality and lifetime income losses. The data sources were the Republic of Ireland's 2013 *National Employment Survey*, obtained from the CSO, and Northern Ireland's 2014 *Annual Survey of Hours and Earnings*, obtained from the NISRA. For each child aged 0 to 17 years in 2015, their life expectancy at birth (years 1998 to 2015) was extracted from national life tables provided by the CSO in the Republic of Ireland and the Office for National Statistics (ONS) in Northern Ireland.

For the Republic of Ireland, a 5% discount value for costs and health benefits was recommended in 2014 by the Health Information and Quality Authority (HIQA) [9]. For Northern Ireland, a 3.5% discount

[6] In health sciences, a microsimulation refers to a type of a simulation modelling that generates individual life histories.

value for both costs and benefits was recommended by the National Institute for Health and Care Excellence (NICE) [10].[7]

Results

Current direct costs

Cost-of-Illness Study estimates

Current (2015) annual healthcare costs amongst children attributable to childhood overweight and obesity in the Republic of Ireland

Table 4 summarises the findings on current annual healthcare costs amongst children attributable to childhood overweight and obesity in the Republic of Ireland, including in-patient, day-case, drug-prescribing, GP and additional costs, using a Direct Cost-of-Illness approach. The results suggest that 8% of total hospital in-patient and prescribing costs among children for the examined conditions (asthma, hypertension, type 2 diabetes, sleep apnoea and depressive disorders) are due to overweight and obesity; and that costs associated with these morbidities may account for over half (56%) of the total excess healthcare expenditure that is attributable to childhood overweight and obesity in Ireland. A further €754,750 in additional costs is spent on GP care, day-case care and the tertiary referral centre at Temple Street Children's University Hospital.

Total current annual direct healthcare costs amongst children attributable to childhood overweight and obesity in the Republic of Ireland were estimated at €1.7 million with a wide range (between €717,782 and €3,429,778), reflecting the imprecision and uncertainty in the estimates of disease burden.

Table 4 Total current (2015) annual healthcare costs amongst children attributable to childhood overweight and obesity in the Republic of Ireland – Cost-of-Illness Study estimates

Service	Costs €	Range €
In-patient costs	480,799	45,544 to 1,258,182
Prescribing costs	474,154	384,266 to 620,821
General Practice (GP), day-case and additional costs	754,750	287,972 to 1,550,775
Total costs	**1,709,703**	**717,782 to 3,429,778**

[7] Discounting in economic evaluation implies that costs occurring in the future are valued at less than costs occurring in the present. Countries tend to apply a standard discount rate in all costing exercises in the public sector.

Closed Cohort Simulation Model estimates

Current (2015) annual healthcare costs amongst children attributable to childhood overweight and obesity in the Republic of Ireland and Northern Ireland

Table 5 and Table 6 how current annual direct healthcare costs amongst children, estimated using a Closed Cohort Simulation Model-based approach. Gender differences were noted, with males accounting for 85% and 71% of total healthcare costs attributed to overweight and obesity for the Republic of Ireland and Northern Ireland, respectively.

Total current direct healthcare costs amongst children due to childhood overweight and obesity were estimated at €1.3 million for the Republic of Ireland and €0.7 million for Northern Ireland.

Lifetime direct and indirect costs – Closed Cohort Simulation Model estimates

Total lifetime costs attributable to childhood overweight and obesity in the Republic of Ireland and Northern Ireland

Table 7 and Table 8 display summaries of the lifetime impacts and costs attributable to childhood overweight and obesity for the Republic of Ireland and Northern Ireland. For the Republic of Ireland, the lifetime direct and indirect costs were estimated at €4.6 billion and for Northern Ireland the estimated cost was €2.6 billion. The total excess cost per person, discounted to 2015 values, was estimated to be €16,036 for the Republic of Ireland and €22,647 for Northern Ireland.

In the Republic of Ireland, 21% of these lifetime costs are direct healthcare costs, and 79% are indirect costs. For Northern Ireland, 26% of the costs estimated are direct healthcare costs, and 74% are indirect costs.

Table 5 Total current (2015) annual healthcare costs amongst children attributable to childhood overweight and obesity in the Republic of Ireland – Closed Cohort Simulation Model estimates

Sex	BMI at 18 years	Number of children in 2015	Cost per person (€, 2015 values)	Total cost (€ millions, 2015 values)
Males	Overweight or obese	137,459	57	7.8
	Healthy weight	475,335	49	23.2
	All BMIs	612,794	51	31.0
	Excess cost attributable to childhood overweight and obesity		8	1.1 (PAF = 3.5%)
Females	Overweight or obese	144,292	59	8.5
	Healthy weight	442,234	57	25.4
	All BMIs	586,526	58	33.9
	Excess cost attributable to childhood overweight and obesity		1	0.2 (PAF = 0.6%)
Total	Overweight or obese	281,751	58	16.3
	Healthy weight	917,569	53	48.6
	All BMIs	1,199,320	54	64.9
	Excess cost attributable to childhood overweight and obesity		5	1.3 (PAF = 2.1%)

Table 6 Total current (2015) annual healthcare costs amongst children attributable to childhood overweight and obesity in Northern Ireland – Closed Cohort Simulation Model estimates

Sex	BMI at 18 years	Number of children in 2015	Cost per person (€, 2015 values)	Total cost (€ millions, 2015 values)
Males	Overweight or obese	51,140	75	3.9
	Healthy weight	170,935	86	14.7
	All BMIs	222,075	84	18.6
	Excess cost attributable to childhood overweight and obesity		11	0.5 (PAF = 2.9%)
Females	Overweight or obese	60,735	88	5.4
	Healthy weight	149,981	92	13.8
	All BMIs	210,716	91	19.1
	Excess cost attributable to childhood overweight and obesity		3	0.2 (PAF = 1.1%)
Total	Overweight or obese	111,875	82	9.2
	Healthy weight	320,916	89	28.5
	All BMIs	432,791	87	37.7
	Excess cost attributable to childhood overweight and obesity		6	0.7 (PAF = 1.9%)

Table 7 Summary of total lifetime impacts and costs attributable to childhood overweight and obesity in the Republic of Ireland – Closed Cohort Simulation Model estimates

Sex	Direct healthcare (€ millions, 2015 values)	Productivity loss (absenteeism) (€ millions, 2015 values)	Productivity loss (premature mortality) (€ millions, 2015 values)	Lifetime income loss (€ millions, 2015 values)	Total cost (€ millions, 2015 values)	Per person cost (€, 2015 values)	Number of pre-mature deaths*
Males	422.0	223.5	2,105.3	151.7	2,902.5	21,115	26,202
Females	527.0	299.6	756.4	104.3	1,687.3	11,694	28,854
Total	949.0	523.1	2,861.7	256.0	4,589.8	16,036	55,056

*Lifetime risk of premature death was higher amongst males. However, the number of lifetime premature deaths is greater in females as the prevalence of overweight and obesity in the 2015 child population was higher amongst female children.

Table 8 Summary of total lifetime impacts and costs attributable to childhood overweight and obesity in Northern Ireland – Closed Cohort Simulation Model estimates

Sex	Direct healthcare (€ millions, 2015 values)	Productivity loss (absenteeism) (€ millions, 2015 values)	Productivity loss (premature mortality) (€ millions, 2015 values)	Lifetime income loss (€ millions, 2015 values)	Total cost (€ millions, 2015 values)	Per person cost (€, 2015 values)	Number of pre-mature deaths*
Males	334.8	59.2	1,248.7	69.8	1,712.5	33,487	15,279
Females	337.0	68.4	415.1	46.4	866.9	14,275	15,353
Total	671.8	127.6	1,663.8	116.2	2,579.4	22,647	30,632

*Lifetime risk of premature death was higher amongst males. However, the number of lifetime premature deaths is greater in females as the prevalence of overweight and obesity in the 2015 child population was higher amongst female children.

Reductions in lifetime costs associated with 1% and 5% reductions in population mean childhood body mass index (BMI) for the Republic of Ireland and Northern Ireland

Summaries of reduced impacts and costs that are associated with 1% and 5% reductions in population mean childhood BMI are shown in Table 9 and Table 10. For the Republic of Ireland, a 1% and 5% reduction was associated with a €270 million and €1.1 billion reduction in total lifetime costs, discounted to 2015 values. This equates to a reduction of €958 and €4,000 per person for a 1% and 5% reduction, respectively.

For Northern Ireland, a 1% and 5% reduction in population mean BMI was associated with a €95.8 million and €396.8 million reduction in total lifetime costs, which equates to an €856 and €3,546 cost per person reduction, respectively.

Table 9 Reductions in lifetime healthcare costs, productivity losses and income losses associated with 1% and 5% reductions in population mean childhood body mass index (BMI) in the Republic of Ireland – Closed Cohort Simulation Model estimates

Sex	Scenario – percentage reduction in mean BMI (%)	Direct health-care (€ millions, 2015 values)	Productivity loss (absenteeism)(€ millions, 2015 values)	Productivity loss (premature mortality) (€ millions, 2015 values)	Lifetime income loss (€ millions, 2015 values)	Total cost reduction (€ millions, 2015 values)	Total cost reduction per person (€, 2015 values)	Total reduction in number of pre-mature deaths
Males	1	26.4	16.1	125.5	8.6	176.5	1,284	1,272
	5	123.7	70.4	516.7	38.8	749.5	5,453	5,948
Females	1	27.5	17.4	43.5	5.0	93.5	648	683
	5	122.0	78.6	154.3	22.7	377.6	2,617	3,321
Total	1	53.9	33.5	169.0	13.5	270.0	958	1,955
	5	245.7	149.0	671.0	61.4	1,127.1	4,000	9,269

Table 10 Reductions in lifetime healthcare costs, productivity losses and income losses associated with 1% and 5% reductions in population mean childhood body mass index (BMI) in Northern Ireland – Closed Cohort Simulation Model estimates

Sex	Scenario – percentage reduction in mean BMI (%)	Direct health-care (€ millions, 2015 values)	Productivity loss (absentee-ism) (€ millions, 2015 values)	Productivity loss (premature mortality) (€ millions, 2015 values)	Lifetime income loss (€ millions, 2015 values)	Total cost reduction (€ millions, 2015 values)	Total cost reduction per person (€, 2015 values)	Total reduction in number of premature deaths
Males	1	11.2	2.1	52.7	2.6	68.6	1,341	269
	5	51.7	10.4	199.8	12.7	274.6	5,369	1,267
Females	1	11.0	2.2	12.6	1.5	27.2	448	289
	5	48.4	10.3	56.1	7.4	122.2	2,012	1,254
Total	1	22.2	4.4	65.2	4.0	95.8	856	558
	5	100.1	20.7	255.9	20.1	396.8	3,546	2,521

Discussion

This study provides the first estimates of the current and lifetime costs of childhood overweight and obesity on the island of Ireland. The current cost estimates incorporate direct healthcare costs. The lifetime costs take into account additional indirect costs such as productivity losses due to absenteeism and premature mortality, as well as income losses that are borne during adulthood.

The current annual direct healthcare costs amongst children attributable to childhood overweight and obesity for the Republic of Ireland (2015) are estimated at €1.7 million using a standard Cost-of-Illness analysis and €1.3 million using the Closed Cohort Simulation Model-based approach. For Northern Ireland, it was not possible to apply the direct Cost-of-Illness analysis. Based on the Closed Cohort Simulation Model analysis, the estimated current (2015) costs for Northern Ireland were €0.7 million.

The projected lifetime costs from the Closed Cohort Simulation Model analyses (including indirect costs) to the year 2105 that are attributable to overweight and obesity are €4.6 billion and €2.6 billion for the Republic of Ireland and Northern Ireland respectively. Thus, the total lifetime cost for the island of Ireland (discounted to 2015 rates) is estimated at €7.2 billion. The indirect societal costs account for 79% of total estimated lifetime costs in the Republic of Ireland and 74% of the costs for Northern Ireland.

The estimated excess lifetime cost attributable to childhood obesity and overweight for the Republic of Ireland (discounted to 2015 values) is €16,036 per person; the equivalent estimate for Northern Ireland is €22,647 per person.

The findings from the Closed Cohort Simulation Model suggest that a 1% and 5% reduction in population mean childhood BMI would be associated with a €270 million and €1.1 billion (Republic of Ireland) and €95.8 million and 396.8 million (Northern Ireland) reduction in projected lifetime costs, respectively.

Although the international literature on lifetime costs among children is limited and somewhat inconsistent, the findings on the distribution of costs between direct healthcare and indirect societal costs are in agreement with previous research. By contrast, the estimates of excess lifetime costs attributable to childhood overweight and obesity are lower than those reported in the literature to date. However, comparisons are difficult as a majority of the previous studies focussed exclusively on either direct or indirect costs; and the literature is dominated by studies from the US, where direct healthcare costs are considerably higher than in Europe.

The estimates of both current and lifetime cost are based on comprehensive reviews of the relevant literature, including work on:

1. The current prevalence of overweight and obesity in childhood
2. The burden of childhood morbidity associated with excess weight
3. The effects of childhood adiposity (excess fat) on the risk of overweight and obesity, chronic disease, quality of life and mortality in adult life
4. The effects of childhood obesity on educational outcomes and school attendance
5. A detailed review of previous studies of the lifetime costs of childhood overweight and obesity.

Highlights from the series of literature reviews include evidence that the prevalence of childhood overweight and obesity has stabilised on the island of Ireland, and may be decreasing among primary school-aged children. Nevertheless, current prevalence estimates remain unacceptably high, with 20% of boys and 25% of girls being overweight or obese. The evidence for associations between increased adiposity in adulthood and a range of chronic conditions and premature mortality is clear and well established; but the quality of the evidence linking childhood overweight and obesity with current morbidity in childhood, and directly with morbidity and mortality in adult life, is relatively poor.

There is, however, clear and consistent evidence that childhood obesity is a strong predictor of adult obesity. The findings on this issue were integral to the development and application of the Closed Cohort Simulation Model. Pooled results from 15 high-quality cohort studies demonstrated that children who were obese at the ages of 7 to 18 years were 5 times more likely to be obese as adults compared with non-obese children. Approximately 55% of obese children will remain obese into adolescence and approximately 70% of obese adolescents will remain obese over the age of 30 years.

By contrast, evidence on the effects of excess weight on school attendance and educational outcomes in childhood remains uncertain due to inconsistencies and methodological limitations among studies, including over-reliance on cross-sectional study designs, which do not allow clear separation of causes from effects.

The review of previous studies of the lifetime costs of childhood overweight and obesity highlighted the extent to which the indirect societal costs of childhood overweight and obesity are consistently greater than the direct healthcare-related costs. This confirms the importance of including indirect costs in estimates of the economic burden of excess weight.

Additional important findings from the literature reviews included inconsistencies in how excess adiposity is defined (in particular among children and adolescents) and the fact that there are a number of potentially important impacts which have not been incorporated into cost-of-illness studies to date. These include presenteeism (working while sick) in adulthood, and indirect costs in childhood – such as school absenteeism with attendant family costs.

This work complements and extends the earlier work commissioned by ***safe*food** [2], which estimated the annual costs of overweight and obesity among adults on the island of Ireland. In that study, the current annual cost estimates for the Republic of Ireland and Northern Ireland were €1.13 billion and €510 million, respectively. In the Republic of Ireland, 35% of these costs were direct healthcare costs and 65% were indirect costs. For Northern Ireland, 25% of the costs were direct healthcare costs and 75% were indirect costs. While the annual costs to all adults are not directly comparable to the lifetime costs among all children, the distribution of costs between direct healthcare and indirect societal costs is broadly similar in the 2 studies.

The modelling of current and lifetime costs forms a continuum, or ongoing sequence. In this study the estimates of current excess healthcare costs attributable to childhood overweight and obesity are combined with estimates of direct and indirect costs over the life-course derived from the Closed Cohort Simulation Model. The Closed Cohort Simulation Model-based estimates of current excess healthcare costs amongst children in the Republic of Ireland (€1.3 million) and the Cost-of-Illness Study estimates (€1.7 million) are broadly similar. It should be noted that the level of agreement between these estimates would be even greater if the Closed Cohort Simulation Model had included the estimated annual costs of specialist tertiary care for children with severe obesity, provided by Temple Street Children's University Hospital, Dublin.

It was not possible to estimate the current cost of childhood overweight and obesity for Northern Ireland using the Direct Cost-of-Illness method due to a relative lack of granularity (detail) in the available data from Northern Ireland. However, the level of agreement between the Cost-of-Illness and Closed Cohort Simulation Model estimates for the Republic of Ireland provides a degree of confidence in the Closed Cohort Simulation Model-based estimates of current excess healthcare costs for Northern Ireland.

There will inevitably be some divergence between direct Cost-of-Illness and Closed Cohort Simulation Model-derived estimates of current costs, reflecting methodological differences between these approaches. The direct Cost-of Illness Study uses a top-down, largely deterministic approach (essentially looking for distinct causes and their cost effects); the Closed Cohort Simulation Model-based analysis introduces additional probabilistic variation linked to sampling error in the construction of the initial virtual cohort of children and in the model inputs on estimates of disease occurrence and survival from disease.[8] The Direct Cost-of-Illness Study defined a child as 0 to 18 years of age, while the Closed Cohort Simulation Model uses children aged 0 to 17 years.

[8] This reflects random sampling error and uncertainty to the extent in which the virtual cohort of children represents the underlying population.

Strengths and limitations

This work has a number of significant strengths:

- This is the first study to estimate both current and lifetime costs attributable to childhood overweight and obesity for the Republic of Ireland and Northern Ireland.
- The research examines both direct healthcare costs and a number of indirect societal costs, which are not often incorporated into studies of the costs of overweight and obesity.
- The use of the Closed Cohort Simulation Model, based on the well-established Foresight Obesity Model, also represents a significant strength. The UKHF, with whom we have collaborated on this work, have had extensive experience in modelling the obesity epidemic worldwide for almost 2 decades.

However, there are a number of important limitations that need to be considered in the interpretation of these findings:

- The adaptations required for the Closed Cohort Simulation Model deployed in the current study were substantial, and further development of this model can be anticipated. During this study it was noted that a number of significant improvements could have been made (both to the conceptual model and its software implementation) that would enhance the applicability of the model in the conduct of cost-of-obesity studies.
- It is accepted that overweight and obesity increase the risk of illness, absenteeism from the workplace and early death. However, the magnitude of these effects in the population is measured with poor accuracy and precision, which affect the overall accuracy and precision of the model outputs.
- For some impacts, such as the effects of childhood overweight and obesity on psychosocial wellbeing, human capital[9] and the economy (including school attendance, school performance, preparedness for work and position in the workforce), there was a lack of usable data for inclusion in either the direct Cost-of-Illness or Closed Cohort Simulation Model analyses.
- In the present study, it is noteworthy that the current direct healthcare cost estimates amongst children are modest. This chiefly reflects the fact that most of the obesity-related diseases occur later in life, and the non-inclusion of important indirect costs as discussed above.

[9] Human capital refers to the collective skills, knowledge and other intangible assets of individuals that can be used to create economic value for individuals, their employers and the community.

Conclusions

Given the limitations and caveats, or conditions, discussed above, we suggest that the value of cost-of-illness studies, including the current study, derives primarily from their ability to inform discussion of the relative economic burden associated with major health problems, as opposed to the precise quantification, or measurement, of absolute costs. There are additional conceptual and methodological challenges in the conduct of cost-of-illness studies. For instance, given the extent of fixed staffing and infrastructure cost in health systems, one might reasonably ask, how much of the estimated costs would be saved if the current burden of overweight and obesity were reduced? In the context of priority setting, it is arguable that estimation of the absolute burden, or costs of illness, provides a poor measure of relative need. The "need" is determined both by the burden of disease and the capacity to benefit from interventions. Thus, under ideal circumstances, the priority assigned to overweight and obesity in public policy should be driven primarily by estimates of the incremental costs and the incremental benefits of interventions to prevent and/or manage overweight and obesity[10].

To some extent, the issues of incremental costs and benefits are addressed in the Closed Cohort Simulation Model analysis, which estimates the reductions in impacts and costs that could be expected to follow from 1% and 5% reductions in population mean childhood BMI, with potential applications to cost-effectiveness analyses (CEA) focussed on specific interventions such as the proposed tax on sugar-sweetened beverages. However, as with all modelling exercises, and given the limitation addressed above, the findings from the Closed Cohort Simulation Model should be considered as indicative and interpreted with caution.

It may be argued that cost-of-illness studies (including the earlier current cost of obesity in adults study [2]) have influenced policy at an international (World Health Organziation [WHO]) level and in Ireland. The current epidemic of overweight and obesity in children and adults has evolved over a relatively short timescale (approximately 3 decades). Reliable, contemporary, or current, and locally relevant data on the human and economic burden of this epidemic provide powerful evidence on the consequences of our failure to manage this societal challenge. In particular, these data highlight the external (third-party) costs of current models of food production and marketing and our relative failure at a societal level to promote high levels of physical activity through walking, cycling and public transport throughout the life-course.

[10] This addresses the extent to which small or marginal changes in costs may lead to relatively large effects or benefits.

It is arguable, therefore, that these estimates of the current and future cost of childhood overweight and obesity, which err on the side of caution, are needed. They are necessary to initiate an appropriate level of urgency, among policy makers and wider society, regarding the need to implement effective system-level prevention strategies, with the potential to shift the entire population distribution of excess weight toward more optimal, or ideal, levels.

Policy context

The recommendations and implementation steps of the Republic of Ireland's current Obesity Policy and Action Plan 2016–2025 are noted. These are set out in *A Healthy Weight for Ireland* [11] and have been developed within the broader "Healthy Ireland" (HI) framework. The obesity policy and action plan has set short-term (5-year) targets for overweight and obesity. These are:

- A sustained downward trend (averaging 0.5% per annum as measured by the HI Survey) in the level of excess weight averaged across all adults
- A sustained downward trend (averaging 0.5% per annum) as measured by the Childhood Obesity Surveillance Initiative (COSI) in the level of excess weight in children
- A reduction in the gap in obesity levels between the highest and lowest socioeconomic groups by 10%, as measured by the HI and COSI surveys.

For Northern Ireland, policy is evolving within a broadly similar framework as set out in *Childhood Obesity – A Plan for Action* [12].

The estimates of the current and future costs of childhood overweight and obesity presented in this report, including the projected reductions in impacts and costs that could be expected to follow from 1% and 5% reductions in population mean childhood BMI, highlight the need for specific dedicated funding to ensure that, at minimum, we meet the targets set out in these policy documents.

As set out in *A Healthy Weight for Ireland*, access to a healthy diet can be addressed from a human rights perspective. In a report to the United Nations Human Rights Council, the then-Special Rapporteur (an independent expert reporting to the Council) identified 5 priority actions, based on evidence, to address the issues of obesity and unhealthy diets [13]. These were:

1. Taxing unhealthy products
2. Regulating foods high in saturated fats, salt and sugar
3. Restricting "junk food" advertising
4. Overhauling agricultural subsidies that make certain ingredients cheaper than others
5. Supporting local food production so that consumers have access to healthy, fresh and nutritious foods.

In the Republic of Ireland, the issue of childhood overweight and obesity may need to be considered in the context of the 2015 enactment of the Thirty-first Amendment of the Irish Constitution relating to children's rights. This may provide a legal basis for a more robust approach to the regulation of the food sector and the need to mitigate the effects of an obesogenic environment (that is, an environment that inclines people towards obesity).

It is increasingly clear that educational and other strategies focussed on the prevention of overweight and obesity in childhood that operate at the level of the individual, the family or the school, are not effective – even if applied with significant resources and at a high level of intensity. An epidemic rooted in societal-level structures and processes requires a societal-level response. The 2016 WHO *Report of the Commission on Ending Childhood Obesity* [14] highlights key societal-level measures required to promote the intake of healthy foods in order to reduce the intake of unhealthy foods and sugar-sweetened beverages by children and adolescents:

- Ensure that appropriate and context-specific nutrition information and guidelines, for both adults and children, are developed and disseminated, or communicated, in a simple, understandable and accessible way to all groups in society.
- Implement an effective tax on sugar-sweetened beverages.
- Develop and implement appropriate recommendations on the marketing of foods and non-alcoholic beverages to children in order to reduce the exposure of children and adolescents to, and the power of, the marketing of unhealthy foods and drinks.
- Develop nutrient profiles to identify unhealthy foods and beverages.
- Ensure international cooperation between Member States to reduce the impact of cross-border marketing of unhealthy foods and beverages.
- Implement a standardised global nutrient labelling system.
- Implement interpretive front-of-pack labelling, supported by public education of both adults and children, for nutrition literacy. (An example of this is the “traffic light” system where “red” indicates high levels of sugar, salt, saturated fats and so on.)
- Require settings such as schools, child-care settings, children’s sports facilities and events to create healthy food environments.
- Increase access to healthy foods in disadvantaged communities.

Progress on these issues will require strong central leadership in setting the policy direction, with sustained support at the highest levels of government to enable the intersectoral actions that are required.

Recommendations

1. The obesity strategies and action plans in the Republic of Ireland and Northern Ireland should be implemented and supported, with adequate resources to prevent and manage childhood overweight and obesity. The conservatively estimated lifetime costs estimated in this research identify an unsustainable situation, with costs falling to the taxpayer; these are creating a legacy of debt for future generations that require this public health epidemic be tackled.
2. A population and life-course approach to the obesity epidemic is necessary to ameliorate, or reduce the effects of, the current epidemic, with a strong emphasis on intervening in the obesogenic environment (by challenging unhealthy food choices and inadequate levels of physical activity), balanced with supports for parents and carers.
3. An annual evaluation of progress of the obesity action plans including, for example, the impact of measures such as the tax on sugar-sweetened drinks, is indicated, given the demonstrated potential benefit (financial and societal) of interventions to address overweight and obesity highlighted by this research.
4. There must be increased investment in data collection that will provide accurate and reliable population-based data for conducting cost-of-illness studies and related health economic analysis. Data collected must include information on utilisation of health services (both primary care and hospital services) and illness-related productivity loss and absenteeism from work and school.
5. Research into the psychosocial impacts of overweight and obesity on the island of Ireland is warranted given the information gap identified.

1 Introduction

Overview

Obesity is a chronic disorder described by the WHO as a condition of abnormal or excessive fat accumulation to the extent that health may be impaired [15]. Over the last 3 decades, the percentage of people who are overweight or obese has risen dramatically across many world populations, representing a major public health issue [16,17]. The WHO currently estimate that more than 1.3 billion adults worldwide are overweight and a further 600 million are obese [18].

In the Republic of Ireland, based on the findings from the 2015 *Healthy Ireland Survey*, the estimated prevalence of overweight in adults is 37%, with a further 23% meeting current BMI criteria for obesity [19]. National data from The Irish Longitudinal Study on Ageing (TILDA) suggest that in the Republic of Ireland 36% of adults aged 50 or over are obese, and a further 43% are overweight [20]. Recent published estimates determined using a model developed by the UKHF suggest that if current trends continue, 89% of Irish men and 85% of women are likely to be either overweight or obese by 2030 [4]. If these projections are correct, Ireland may soon be the most obese nation in Europe [21].

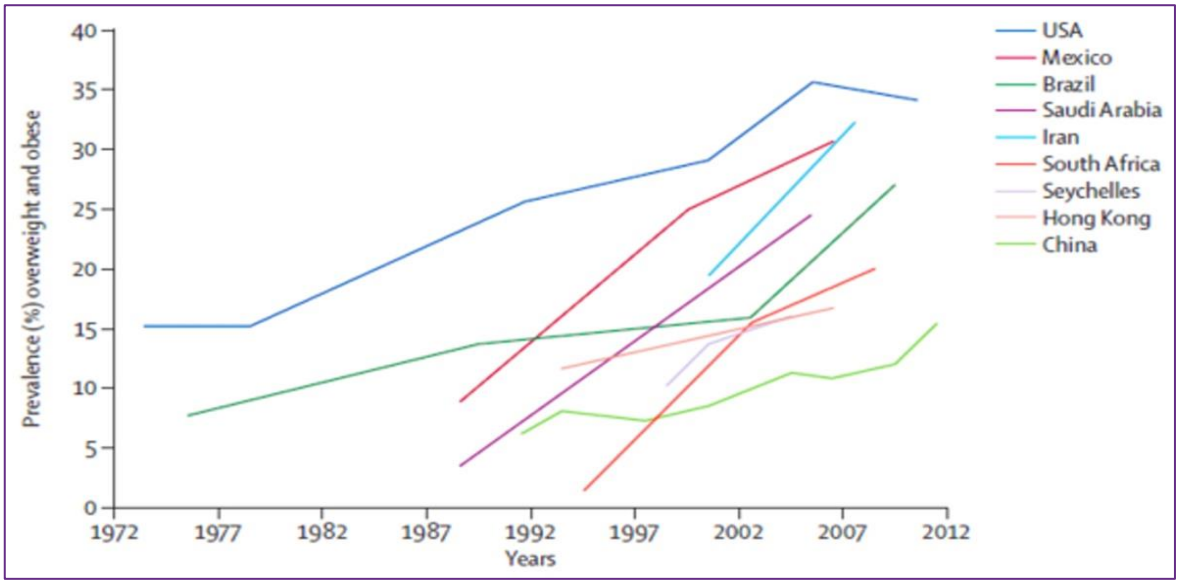
The increasing prevalence of overweight and obesity in recent decades poses significant threats to the health and wellbeing of populations, as abundant evidence supports an association between obesity and a wide range of chronic disorders including type 2 diabetes, cardiovascular disease, and other important conditions [22,23]. In addition to the major health consequences associated with obesity, there are also economic implications. Overweight and obesity in adults is estimated to cost at least €1.13 billion per year to the economy of the Republic of Ireland through increased health services utilisation, sickness absence and premature mortality [3].

Childhood obesity

Childhood obesity has also become a major challenge to public health. Overweight and obesity among children is associated with adverse outcomes in childhood such as the development of asthma and type 2 diabetes. It is also associated with a greater risk of morbidity and mortality in adulthood [24,25]. Increased adiposity in childhood is also inversely, or negatively, associated with psychological wellbeing [26].

Similar to trends observed in adults, the prevalence of overweight and obesity among children has increased significantly in most developed countries over the last 30 years [27].Figure 2 shows trends in childhood overweight and obesity prevalence from the early 1970s to 2012 in the United States (US) and selected low-income and middle-income countries.

Figure 2 Prevalence trends for childhood overweight and obesity in the United States (US) and 8 low-income and middle-income countries



Source: Lobstein et al., 2015 [27].

Recent research suggests that the prevalence of overweight and obesity among children on the island of Ireland has levelled off [28] in the last decade, with similar trends occurring across many other high-income countries [29] (see Section 3, literature review, opening paragraph). However, evidence indicates that childhood obesity prevalence remains high in Ireland, and thus remains a public health priority. In addition, the monitoring of childhood obesity on the island of Ireland has largely depended on prevalence estimates derived from cross-sectional research at national or local level, which often have disparate, or widely varying, methodologies, due to the absence of standardised operating procedures across studies. Programmes such as the Childhood Obesity Surveillance Initiative (COSI), the Cork Children's Lifestyle Study (CCLaS) and the Child Health System (CHS) are improving the quality of prevalence data collected in the Republic of Ireland and Northern Ireland [30-32].

Cost-of-obesity studies

Estimates of the economic burden of illness provide critical information for priority setting, policy development and investment in both prevention and health services. Health systems throughout the world are struggling to meet the challenge of increasing demand for healthcare and increasing costs, with diminishing resources from taxpayers and other payers.

Cost-of-illness studies for major health issues such as overweight and obesity have the potential to frame core policy issues, such as the relative priority of prevention and care, in language that is tangible and accessible to policy makers. For instance, in the US it has been estimated that if every US adult who was obese (that is, with a BMI of 30 kg/m^2 or more) in 2008 had a BMI of 25 kg/m^2, annual public medical expenditures (excluding private medical expenditure and productivity loss due to weight-related ill health and premature mortality) would have declined in that year by $173.7 billion. This represents 17.2% of annual public medical expenditures for that year. Assuming an optimal BMI distribution, it was estimated that the prevalence of obesity in 2008 resulted in a deadweight loss of $216.7 billion to the US economy [33]. "Deadweight loss" refers to the welfare loss that arises as a result of the additional tax burden created by the need to fund healthcare and other supports for those ill or unemployed as a result of overweight or obesity.

With regard to the Republic of Ireland, several estimates of the costs associated with overweight and obesity among adults have been conducted. One study looked at the direct costs in terms of hospital in-patient stays only. These were estimated at €4.4 million in 1997, rising to €13.3 million in 2004 [34]. This is likely to be a substantial underestimate of the total direct costs of overweight and obesity since it does not include other forms of healthcare usage – such as primary care, hospital out-patient consultations and, importantly, drug consumption – which are likely to be substantial. It also excludes indirect costs such as lost productivity or premature mortality.

The National Taskforce on Obesity estimated that the direct cost of obesity in Ireland in 2002 was €70 million, and the indirect cost was €0.37 billion, giving a total cost of €0.4 billion [35]. However, this estimate was based mainly on data from the UK, augmented with limited data from the Irish Hospital In-patient Enquiry (HIPE) database. Recent comprehensive research suggests that direct and indirect costs of adult overweight and obesity in the Republic of Ireland were €1.13 billion for 2009. For Northern Ireland, estimated costs attributable to overweight and obesity were €510 million [3]. However, to date, no study has examined the economic implications of childhood obesity on the island of Ireland.

The overall aim of this project was to produce a thorough estimate of the current annual costs and projected lifetime costs of childhood overweight and obesity for the Republic of Ireland and Northern Ireland. This study was based on collaboration between University College Cork, the Institute of Public

Health (IPH) in Ireland, the Department of Public Health, Health Service Executive (HSE) Mid West, the National University of Ireland, Galway, Temple Street Children's University Hospital, Dublin and the UK Health Forum (UKHF).

2 Aims and objectives

The overall aim of this research was to make as accurate an estimate as possible of the current annual costs, and projected lifetime costs, of childhood overweight and obesity on the island of Ireland. The specific objectives were:

- To conduct a series of systematic reviews addressing:
  1. The prevalence of overweight and obesity among children on the island of Ireland
  2. The effects of overweight and obesity on morbidity and psychological wellbeing in childhood
  3. The effects of childhood overweight and obesity on the risk of obesity, chronic disease, reduced quality of life and mortality in adult life
  4. The effects of overweight and obesity on educational outcomes and school attendance in childhood
  5. A review of the international literature on the direct and indirect lifetime costs of childhood overweight and obesity completed since the year 2000.
- To determine current annual direct healthcare costs amongst children attributable to childhood overweight and obesity in the Republic of Ireland and Northern Ireland from a public healthcare payer perspective.
- To estimate the lifetime costs, both direct healthcare costs and indirect societal costs (including productivity losses due to absenteeism, premature mortality and lifetime income losses), attributable to childhood overweight and obesity for the Republic of Ireland and Northern Ireland.
- To explore the effect on lifetime costs of a 1% and 5% fall in population mean childhood BMI.
- To make recommendations based on the findings, including recommendations on measures that will facilitate ongoing work on the cost of overweight and obesity on the island of Ireland, drawing on both routine data collection in health and social care services and specific population-based research programmes.

3 Literature review

Prevalence of overweight and obesity among children

A previous systematic review of published and grey literature aimed to synthesise, or combine, all available overweight and obesity prevalence data for school-aged children in the Republic of Ireland between 2002 and 2012 [28]. Fourteen studies (16 prevalence estimates) were included in the review. The combined prevalence of overweight and obesity within the studies ranged between 20% and 34%. No significant trend in overweight prevalence was observed. However, there was evidence of a slight decrease in obesity prevalence over the period, with a similar decline in the prevalence of morbid obesity.

The updated literature review identified 18 national or regional studies specific to the Republic of Ireland and Northern Ireland. For the Republic of Ireland, the prevalence of overweight and obesity ranged between 18% and 34%. Trend analysis suggests that there has been a slight decrease in the prevalence of obesity among 4- to 13-year-old boys and girls between 2002 and 2014. There was no significant trend for the prevalence of overweight for boys or girls.

The 12-year trends in overweight and obesity were also compared between 2 studies conducted by the Oral Health Services Research Centre [36], which applied the same methodology for their 2002 and 2014 data collection. Among those aged 4 to 13 years, there was a significant decrease in the prevalence of obesity among boys from 6.0% (95% CI: 5.3% to 6.4%) in 2002 to 4.0% (95% CI: 3.6% to 5.1%) in 2014, and a decrease in the prevalence of overweight and obesity for the total population of boys and girls from 26.0% (95% CI: 25.2% to 26.6%) in 2002 to 23.0% (95% CI: 22.3% to 24.6%) in 2014. Among 5-year-olds, there was a statistically significant decrease in the prevalence of overweight from 19.0% (95% CI: 18.0% to 20.3%) to 16.0% (95% CI: 14.8% to 17.9%) and a statistically significant decrease in the prevalence of overweight or obesity from 25.0% (95% CI: 23.6% to 26.1%) to 22.0% (95% CI: 19.8% to 23.3%). Among 12-year-olds, there were no significant changes in prevalence rates; the prevalence of overweight or obesity remained at 25% between 2002 and 2014.

For Northern Ireland, only 1 study from 2002 was eligible for inclusion in the review [5]. Among children aged 4 to 13 years, the prevalence of overweight or obesity was 22.0% (95% CI: 19.5% to 25.5%) for boys and 27.0% (95% CI: 23.9% to 30.3%) for girls. No significant trend was observed over time for the prevalence of overweight or obesity in Northern Ireland, and no significant trend was

observed when overweight and obesity prevalence rates were combined across all included studies (Republic of Ireland and Northern Ireland).

Collectively, the findings of the updated review indicate that the prevalence of overweight and obesity among children is levelling off in Ireland, and may be decreasing in primary school-aged children, with the greatest reduction in prevalence being observed among 5-year-olds. However, although these findings provide some grounds for cautious optimism, overweight and obesity prevalence among Irish children remains high, with 1 in 5 boys and over 1 in 4 girls being either overweight or obese.

Also of note was that, in contrast to other European countries, the prevalence of overweight and obesity in Ireland appears to be consistently higher among girls than boys. These unacceptably high figures highlight the need for a sustained policy response in order to tackle the issue of childhood obesity and begin a downward trend.

Childhood obesity, morbidity and body mass index (BMI) classification

Major conditions associated with childhood overweight and obesity identified in the review included asthma, hypertension, type 2 diabetes, sleep apnoea, NAFLD and depressive disorders [37-40]. However, although some studies are prospective or at least contain a prospective element within the study design, most of the studies identified were cross-sectional, or "snapshots" of data, which prevents examination of temporal relations – issues concerning the timing or sequence of events, for example whether obesity is a cause or consequence (effect) of asthma. In many cases it appears that obesity occurs first, and that then the subsequent comorbidity arises. However, causality cannot be determined until more prospective studies are conducted.

In addition, part of the challenge to the call for prospective studies is the length of time between a child being diagnosed as overweight or obese and the appearance of comorbidities, some conditions not being diagnosed until later adulthood. Another consideration with regard to prospective studies is the age at which a child becomes overweight or obese.

The definition of obesity in childhood, a basic yet fundamental concept to this area of research, is also a consistent challenge encountered by researchers in this domain [41]. Many studies conducted in the US in the past 10 years adhere to the same age and gender BMI percentiles recommended by the Center for Disease Control: eighty-fifth percentile for "overweight" and ninety-fifth percentile for "obese". In Ireland, the UK and Europe, the ninetieth percentile for "overweight" and ninety-seventh

percentile for "obese" are used in population studies. The WHO use 1 standard deviation[11] above the WHO growth standard median as a guideline for "overweight", and 2 standard deviations above the median to define "obese". Other researchers use the IOTF guidelines or thresholds specific to the country from where the research is being conducted [42]. In addition, it is evident from the literature review conducted for this report that some investigators use adult overweight (BMI of 25 kg/m^2 or more) and obesity (BMI of 30 kg/m^2 or more) cut-offs for children and adolescents.

Although the merits of each of these classification systems can be debated, the lack of consistency among BMI thresholds used by researchers makes consolidating evidence across studies problematic and presents a limitation of the literature as a whole. Body mass index also needs to be reported more rigorously. Though a majority of studies used trained staff to administer anthropometric (body size and type) assessments, some use self-reported weight and height, which is a limitation of a number of the large national database studies in Ireland, as research examining self-reported BMIs have reported discrepancies [43,44].

Finally, it should be noted that the BMI equation is itself an imperfect method for assessing adiposity. As a weight-for-height measure, BMI cannot distinguish between fat and lean mass, and research has suggested that body fat classification based on BMI may be inadequate [45-47].

Childhood obesity and risk of obesity, chronic disease, reduced quality of life and mortality in adult life

Results from the review suggest that, based on the best available evidence from meta-analysis, childhood obesity is a strong predictor of adult obesity. Pooled results from 15 high-quality cohort studies demonstrated that children who are obese at the ages of 7 to 11 years are 5 times more likely (pooled RR: 4.86, 95% CI: 4.29 to 5.51) to be obese as adults compared with non-obese children. Children who are obese at the ages of 12 to 18 years are also 5 times more likely (pooled RR: 5.45, 95% CI: 4.34-6.85) to be obese as adults as are children aged 7 to 18 years (pooled RR: 5.21, 95% CI: 4.50 to 6.02). Prospective research suggests that approximately 55% of obese children will remain obese into adolescence and approximately 80% of obese adolescents will remain obese into adulthood. Seventy per cent of obese adolescents will remain obese over the age of 30 [6,7]. These findings emphasise the importance of tackling the issue of childhood obesity, as it is very likely to persist into adulthood.

This review also presents a summary of the best available evidence (meta-analyses and systematic reviews) on the effect of childhood overweight and obesity on the risk outcomes such as morbidity,

[11] The WHO has defined a standard normal distribution of child BMI at different ages by gender. A standard deviation is a measure of spread. It is expected that 95% of measurements lie within 1.96 standard deviations above the median or midpoint.

quality of life and mortality in adulthood. Based on these findings, there is consistent evidence that childhood overweight or obesity is positively associated with the development of type 2 diabetes in adulthood.

Evidence was less consistent for adult metabolic syndrome and its components (a group of symptoms such as high blood pressure and high cholesterol that affect metabolism and are risk factors for heart disease and type 2 diabetes), although there was a strong positive association between childhood BMI and adult hypertension. There also appears to be some evidence of an association between childhood BMI and total low-density lipoprotein (LDL) cholesterol ("bad" cholesterol) and high-density lipoprotein (HDL) cholesterol ("good" cholesterol) and adverse triglyceride levels. ("Triglycerides" are a type of fat found in the blood; high levels could indicate metabolic syndrome.) There was moderate to strong evidence of an association between childhood BMI and conditions such as gout, atherosclerosis (harmful build-up of fat, cholesterol and calcium inside blood vessels) and NAFLD.

Results from meta-analysis reported that higher childhood BMI was associated with CHD and a number of cancers. Evidence of an association between childhood BMI and other adult outcomes, including some types of cancer and other cardiovascular outcomes and asthma, was less consistent and will require further high-quality longitudinal research.

A systematic review by Sikorski et al. (2015) [48], which examined the effects of childhood obesity on psychological wellbeing in adulthood, highlighted the lack of longitudinal studies that investigate the effect of childhood obesity on psychological health. Of the 4 articles included in this review, the longest follow-up period was 4 years. Key findings demonstrated that children or adolescents who were overweight or obese had lower self-esteem and social support, greater loneliness, sadness and nervousness, were more likely to drink and smoke and had lower health-related quality of life in adulthood.

There is consistent evidence of a positive association between childhood BMI and mortality, based on findings from studies including mixed-gender samples. A review by Park et al. (2012) [8] reported that the risk of all-cause mortality in adulthood increased between 40% and 60% in people who had a high BMI between the ages of 2 and 19 years on the basis of 5 studies. Engeland et al. (2003) reported that, after an average of 31.5 years of follow-up, obesity (BMI above the 95th percentile) at ages 14 to 19 years was associated with increased risk of all-cause mortality in adulthood for males (RR: 1.82, 95% CI: 1.48 to 2.43) and females (RR: 2.03, 95% CI: 1.51 to 2.72) compared with those in the twenty-fifth to seventy-fourth percentiles, after adjustment for age at measurement, year of birth and BMI [49]. However, a majority of studies examining the link between childhood BMI and adult mortality did not adjust for socioeconomic status (income, occupation and education), which may be a confounding factor.

It should also be noted that when researchers adjust for adult BMI, the association between childhood adiposity and a given outcome can be either attenuated (reduced) or inverted (as discussed below). Thus, as many studies do not adjust for adult BMI, it is difficult to establish whether childhood obesity is an independent risk factor (a single factor likely to cause an effect) for a particular outcome in adult life.

However, attenuation, or the reduction in magnitude, of effects following adjustment of adult BMI should be interpreted with caution, and it should not be assumed that childhood overweight or obesity has no effect on the risk of adult disease. As explained by Park et al. (2012) [8], adult obesity is likely to be on the causal pathway between childhood obesity and later onset of disease. Therefore, adjusting for adult BMI may result in over adjustment bias (over-compensation for the effects of certain variables), which draws associations towards the null – it tends to neutralise patterns in the data. It has been suggested that, in order to overcome these methodological limitations, studies which adjust for adult BMI should avoid standard methods of adjustment and instead use other more complex methods developed for life-course analyses.

One important finding by Juonala et al. (2011) [50] was that if children who are obese become normal weight by adulthood, the risks of many outcomes become similar to the risks for children who were never obese. Another key point observed by Llewellyn et al. (2016) [24] was that childhood obesity may be a poor predictor of adult morbidity. In this meta-analysis, only 31% of diabetes and 22% of CHD cases in adulthood occurred in children with a higher BMI. Hence, it may be that most morbidity in adulthood occurs in those who were of healthy weight in childhood.

However, as described in the review by Park et al. (2012), measuring BMI at a single point in time during a child's development does not capture the processes of growth over the life-course. For example, evidence suggests that children who are of small size at birth, and experience catch-up growth, are more susceptible to high levels of adiposity, reduced lean mass and increased risk of disease because of this pattern of growth. For this reason, it has been suggested that a healthy weight should be promoted for each childhood age group.

Childhood obesity and educational outcomes and school attendance

A systematic review of the literature found 19 studies that examined the effect of childhood obesity on educational outcomes. Nine different measures of educational attainment were used, with the calculation of average grades across a range of subject areas being the most commonly used measure, followed by Key Stage Scores and Peabody Individual Achievement Tests. Eight out of 19 studies in this review presented results suggesting that there was a statistically significant negative association between obesity and educational attainment.

However, in many cases the average differences in attainment between obese and normal weight children were small. For example, von Hinke et al. (2009) reported that a 1 standard deviation increase in adiposity led to a maximum 0.07 standard deviation decrease in educational outcomes [51]. A second study found no significant effect of obesity on educational attainment for girls, but did find an effect for boys. However, the authors acknowledged that this effect was also found to be small [52]. Over half of the studies included in this review found that the association between obesity and educational attainment lost statistical significance when other moderating variables were included.

A further systematic review of the literature identified 10 studies that examined childhood obesity and school attendance. Nine out of 10 studies in this review presented results suggesting that there was a statistically significant negative association between overweight or obesity and school attendance among children and young people. Six studies found that overweight and/or obese youth had higher rates of school absenteeism compared with their non-overweight counterparts. For example, Echeverria et al. (2014) [53] reported that the odds of missing 11 or more school days were 1.5 and 1.7 times higher, respectively, for overweight and obese youth compared with their non-overweight peers in fully adjusted models.

However, some studies found that increased body weight was independently associated with severe school absenteeism among children only, and not adolescents. Another found that only overweight boys exhibited a significant association with lower school attendance. Rappaport et al. (2011) [54] reported that the association between BMI and increased school absences was present only among extremely obese children and was non-significant for those who were overweight. One study concluded that there was no significant relationship between increased BMI and lower school attendance.

The incorporation of moderating variables throughout the literature was found to vary greatly. Two studies in particular failed to include important moderating variables such as physical and mental or emotional health. Also, the proxy or indirect measures used for estimating socioeconomic status in these studies were found to be particularly weak. For example, a proxy measure for socioeconomic status may be housing tenure, which may be poorly correlated with socioeconomic status in some circumstances.

When examining the relationship between overweight or obesity on school attendance among children and young people, it is important to consider that a number of underlying pathways may potentially explain an observed association. For example, socioeconomic and health factors are potentially important predictors of lower school attendance among overweight and obese children. Using a joint effects model, Echeverria et al. (2014) found that the probability of missing school was significantly greater for low-income obese groups compared with their normal weight, higher-income

peers [53]. Carey et al. (2015) observed that the addition of health and healthcare variables to statistical models decreased the odds of school absences, although the association still remained significant [55].

Other methodological drawbacks should be considered when examining the results from this review. Nine out of 10 studies used a cross-sectional study design and there is the possibility that observed relationships may be confounded (somehow affected) by unobserved differences between overweight and non-overweight children that are related to school attendance, such as parental social status and poverty.

Also of concern is that only 3 studies used direct exposure and outcome measures. Seven studies had exposure (child weight) or outcome measures (school attendance) that were either parent- or self-reported. The use of subjectively reported BMI or school attendance data increases the risk of both recall and reporting bias as parents may underestimate BMI and overestimate school attendance. In addition, all of the examined studies in this review were from the US. Therefore, sociodemographic confounders and the transferability of results to other scenarios are of potential concern.

Lifetime costs of childhood overweight and obesity

This systematic review aimed to consolidate the evidence available in the global literature since 2000 on the average total lifetime costs, both direct healthcare and indirect productivity loss costs, per overweight or obese child or adolescent.

Thirteen published articles were included in the review. The methodology used in the studies varied widely, and only 1 study estimated both direct and indirect costs. Bearing in mind this level of diversity, the mean total lifetime cost of an obese child or adolescent from the studies reviewed was found to be €54,663 (range between €45,014 and €74,244) for males and €36,053 (range between €24,433 and €61,700) for females. This is divided into an average of €16,229 (range between €6,580 and €35,810) in direct costs and €38,434 in productivity losses for males, and €19,636 (range between €8,016 and €45,283) and €16,417, respectively, for females. If income penalty is added, the total mean lifetime costs amount to €151,779 (range between €131,985 and €181,508) per obese male adolescent and €162,161 (range between €150,541 and €187,808) per female adolescent.

The consistent differences seen between the genders, with direct costs being greater for females and productivity costs greater in males, may be due to 2 key reasons: men may present earlier with an obesity-related condition, and sudden catastrophic events may be more common in men. According to Mozaffarian et al. (2015) [56], men have their first heart attack on average at age 65.0 years and women at 71.8 years of age. The incidence of CHD in females lags behind males by 10 years for total CHD and by 20 years for more serious clinical events such as heart attack and sudden death. Moreover, it may be that sudden catastrophic events occur not only earlier but also more often in

men, entailing minimal medical costs before the event and possibly a fatal outcome, resulting in both lower direct costs and higher productivity costs from early mortality.

According to Roger and colleagues (2012), between 70% and 89% of sudden cardiac events occur in men [57]. A study by Neovius et al.(2012) [58] demonstrated that approximately two-thirds of productivity losses in men who were obese in adolescence were caused by premature mortality. The higher direct costs and lower productivity costs incurred by women may also be due to a tendency amongst females to make greater use of medical services, as well as a tendency for women to earn less than men. The finding that income penalty might be greater in women may be related to "occupational sorting", where women, more so than men, are sorted into lower-paid occupations based on their BMI.

The finding that lifetime indirect costs of childhood and adolescent obesity are greater than direct costs highlights the need to include indirect costs in any lifetime cost study. Direct costs seem to be higher in the US than Europe, whereas productivity costs and income penalties are similar between the regions, reflecting higher healthcare costs in the US.

The need to include indirect costs is brought out particularly strongly in the paper by van Baal et al. [59], where it is suggested that obesity in adolescence leads to significant lifetime healthcare cost savings because early (and sudden) death due to obesity-related morbidity such as ischaemic heart disease (narrowing of the blood vessels to the heart due to the build-up of cholesterol) entails considerable health service savings on costs for other conditions – including non-obesity related ones – that would otherwise have been generated. However, early mortality entails proportionally greater indirect costs, with two-thirds of productivity costs arising from premature death, according to one study, suggesting that the greater the direct cost savings are, the greater the indirect costs will become. With indirect costs being up to 5 times greater than direct costs, it is likely that van Baal and colleagues would have arrived at very different conclusions had they included indirect costs.

Importantly, this work has revealed that there are a large number of significant challenges in the review of evidence on lifetime costs of childhood obesity, making valid comparisons between studies problematic. These include the age at which it is assumed that excess costs start to accumulate – for example, whether costs during childhood and adolescence are incorporated into the models. Only 2 studies of 13 identified modelled direct costs incurred during childhood.

There is also variation in methods for calculating costs and cost components, and what type of direct or indirect costs are included. Moreover, models vary as to whether changes in BMI status over time are incorporated or not, whether results are differentiated by childhood age of obesity, gender and race or ethnicity, and whether excess costs are given as lifetime per overweight or obese child or

adolescent or as overall population costs. Finally, how overweight and obesity are defined for children, adolescents and adults varies between studies.

Another important consideration in attempting to deduce the total excess lifetime costs of childhood and adolescent overweight and obesity is that there are considerable costs that have not been incorporated to date. First, the costs of routine surgical procedures are often considerably greater than average costs for these conditions. (Surgery for obese patients carries a greater complication rate and therefore cost.) This has not been included in models. Second, no studies to date have modelled indirect costs due to obesity during childhood (for example, time taken off work by parents due to a child's obesity-related illness). Other effects not considered in models include excess costs for normal weight adults who were obese as children or adolescents, and that morbidities due to obesity originating from childhood tend to be more severe than those from adult-acquired obesity [8].

Summary of literature review findings

- It is suggested that the prevalence of childhood overweight and obesity has stabilised on the island of Ireland, and may be decreasing among primary school-aged children.
- Current prevalence estimates remain unacceptably high, with 20% of boys and 25% of girls being overweight or obese.
- Despite well-established evidence demonstrating an association between increased adiposity in adulthood and a range of chronic conditions and premature mortality, the quality of the evidence linking childhood overweight and obesity with morbidity in childhood, and with morbidity and mortality in adult life, is relatively poor.
- Evidence on the effects of excess weight on school attendance and educational outcomes in childhood remains uncertain due to inconsistencies and methodological limitations among studies and the use of cross-sectional data.
- Indirect costs of childhood overweight and obesity are consistently greater than direct costs, indicating the necessity of including indirect costs in any cost-of-illness study.
- There are inconsistencies in how excess adiposity is defined, in particular among children and adolescents.
- There are a number of impacts and costs that have not been incorporated into cost-of-illness studies to date.
- The extent to which the costs rise with increasing BMI varies between countries depending on the prevalence of overweight and obesity in the population, patterns of healthcare utilisation and specific characteristics of the health and social welfare systems in different countries. Thus the review confirmed the need for country-specific estimations of the costs of overweight and obesity.

4 Methods

Section 4 describes the methods used to estimate the lifetime costs (current costs and future costs) of childhood overweight and obesity in the Republic of Ireland and Northern Ireland.

Overview

In this study, the lifetime costs of childhood overweight and obesity are broken down into current annual costs and the future annual costs incurred in each year to 2105. For this report, 2 distinct approaches (a Closed Cohort Simulation Model and a Direct Cost-of-Illness Study) were used to estimate current annual direct healthcare costs amongst children. The Closed Cohort Simulation Model was also used to estimate lifetime costs, which included direct healthcare costs and indirect societal costs that are attributable to childhood overweight and obesity.

Both the Closed Cohort Simulation Model and Direct Cost-of-Illness approaches described in this section were used to estimate current annual costs, as the latter method is well established in the literature and was needed to validate the Closed Cohort Simulation Model, which represents a new modelling strategy.

Lifetime costs

To estimate lifetime costs of overweight and obesity, a variety of different impacts and costs (identified in the systematic reviews) that occur in childhood and adulthood must be recorded. These include

- Disease incidence
- Disease prevalence
- Deaths
- Disability weights
- Quality-of-life weights
- Direct costs as a result of healthcare expenditure
- Indirect (non-health or societal) costs due to work absenteeism, premature mortality and lifetime income losses.

A range of methods are then used to calculate the value of these impacts and costs: top-down methods, bottom-up methods and mixed.[12] The annual cost per case of each of these component costs are then used in a Closed Cohort Simulation Model to estimate lifetime excess impacts and costs experienced by overweight and obese children.

A Closed Cohort Simulation Model to estimate lifetime costs

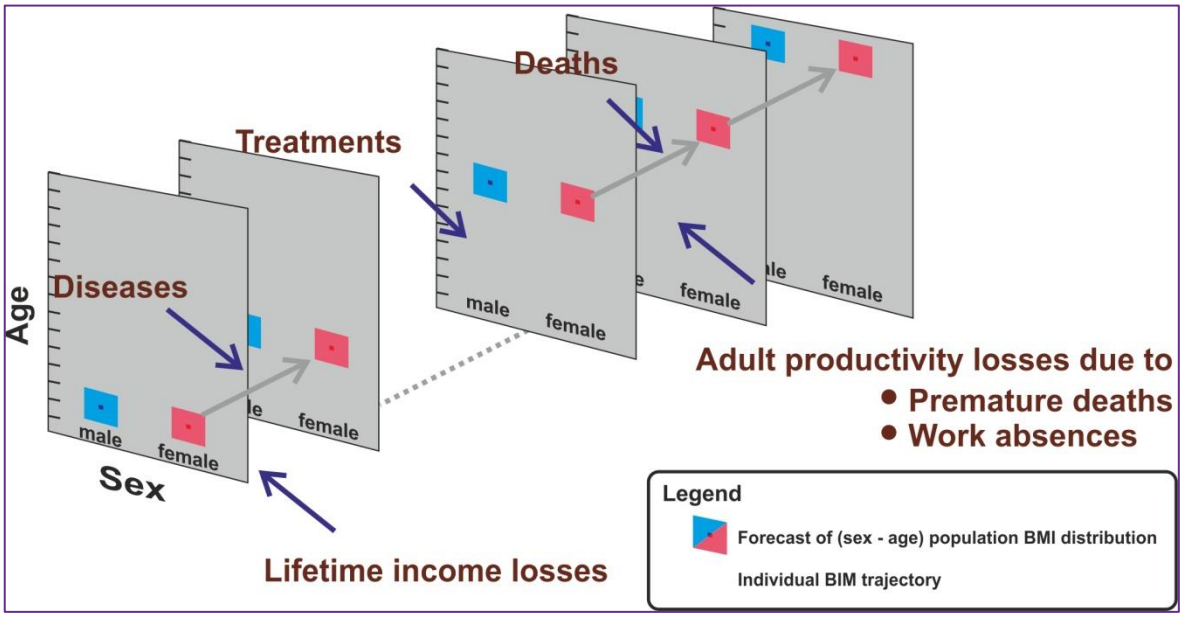
The simulation modelling objectives were, for the Republic of Ireland and Northern Ireland,

- To estimate the lifetime impacts and costs of current childhood overweight and obesity
- To assess the effect of reducing childhood obesity by 1% and 5% on these impacts and costs.

The modelling exercise is based on a "Closed Cohort Simulation Model", which takes a cohort of virtual individuals representative of the child population of the Republic of Ireland and Northern Ireland in 2015, models their lifetime BMI trajectories, and records the direct healthcare costs and indirect (non-health or societal) impacts and costs they are expected to experience over their lifetimes as a result of their modelled BMI trajectories (Figure 3). A range of impacts and costs are recorded over an individual's life-course. Each year starting in 2015, these are summed over all individuals to produce annual impacts or costs. Ninety years of follow-up to the year 2105 are reported.

[12] These methods are described in detail below.

Figure 3 Closed Cohort Simulation Model used to estimate lifetime burden of childhood overweight and obesity



For each impact and cost (Table 11), the comparison of individuals who were, as children, overweight or obese with individuals who were, as children, of healthy weight is used to estimate the burden associated with childhood obesity. Corresponding to each such excess metric, the effect of a 1% or 5% reduction in childhood obesity (mean childhood BMI) is estimated by comparing the excess in the current childhood obesity scenario to the excess in the reduced childhood obesity scenario.

Table 11 Impacts and costs included in the Closed Cohort Simulation Model

Impact and costs
Overweight and obesity
Prevalence
Cost of lifetime income loss
Mortality
Premature death
Years of life lost (YLL)
Cost of lost productivity due to premature mortality
Morbidity
Incidence
Prevalence
Disability-adjusted life years (DALY)*
Quality-adjusted life years (QALY)*
Direct healthcare costs
Cost of lost productivity due to absenteeism

*Not shown in the current analysis. Details on how these measures were calculated will be outlined in the Technical Appendix of the JANPA WP4 Report (due to be published 2017).

It should be noted that caution is needed when interpreting counts and rates (such as those for obesity-related diseases) in future years. This is because, although there may be a greater risk amongst surviving individuals who were overweight or obese as children, the number of surviving individuals who were of healthy weight as children may be larger. It should also be noted that a large cohort of these healthy weight children will become overweight or obese in later life. This study does not include cost estimates for these individuals.

Closed Cohort Simulation Model data sources and methodology for estimating lifetime costs

Population data

Population data were used to initialise the microsimulation of a population of children and adolescents representative of the Republic of Ireland and Northern Ireland population aged 0 to 17 years. The total population for each 1-year age group, by gender, was obtained for 2015 from the Republic of Ireland's Central Statistics Office (CSO) [60] and the Northern Ireland Statistics and Research Agency (NISRA) [61].

The modelled population was a cohort of children followed through time and not replenished, or restocked, by births or migration, so inputs for birth rates, fertility and migration were not used. An Open Cohort Simulation Model aims to have survivors in any future year representative of the

resident population in that year. Therefore, it allows new entries through birth and immigration into the country, as well as exits through emigration. A Closed Cohort Simulation Model does not include these factors.

Body mass index (BMI) data

The input for the projection software, which models trends in BMI over time, was current and historical prevalence data for 3 BMI categories (BMI up to 25 kg/m2; BMI from 25 to 30 kg/m2; and BMI of 30 kg/m2 or more) by gender and age (0 to 100 years). This was obtained from a range of sources (details to be outlined in the Technical Appendix JANPA WP4 Report, 2017). Only objectively measured data were used. Self-reported data were excluded.

The width of the age groups for which data were available ranged from 1 year (for example, 53-year-olds) to 36 years (for example, prevalence data for 65- to 100-year-olds). Data were sparse, often consisted of small sample sizes and did not cover all ages by gender for all years. Yearly age-group by gender data points with fewer than 10 individuals were dropped, as they create large uncertainty. There were too few Irish data and time points in the 0- to 4-year-old and 15- to 19-year old age groups to allow stable BMI projections to be made for these age groups. Therefore, proxy data from the UK Health Survey of England (2004–2014) [62] were used for these age groups.

Disease data

The analyses are focussed on the direct and indirect costs of childhood overweight and obesity on 29 conditions for which there is strong evidence from systematic reviews and meta-analyses of a causal association with excess body fat. These include conditions specific to childhood, in addition to diseases that overweight and obese children are at risk of developing as adults by virtue of the link between childhood and adult BMI.

Diseases were defined by several criteria, including whether they affected both genders, males only or females only, whether the disease was considered terminal and whether the disease was acute rather than chronic (long-term). Acute diseases were assumed to last only 1 year, and only occur once in an individual's life.

The childhood and adult diseases included in the Closed Cohort Simulation Model are listed below (Table 12). These reflect the childhood diseases that were associated with childhood obesity in the literature reviews, the adult diseases that are associated with adult obesity and the availability of data relating to these in the Republic of Ireland and Northern Ireland. It should be noted that, while diseases associated with childhood overweight and obesity contributed to the impact and costs in childhood, the impacts and costs in adults were mediated by the relationship between childhood overweight or obesity and adult overweight or obesity.

Table 12 Childhood and adult diseases included in the Closed Cohort Simulation Model

Childhood diseases	
Asthma*	Hypertension*
Chronic pain (musculoskeletal)	Non-alcoholic fatty liver disease (NAFLD)
Depression*	Sleep apnoea*
Diabetes (type 2)*	
Adult diseases	
Asthma	Knee osteoarthritis
Bladder cancer	Liver cancer
Breast cancer	Multiple sclerosis (MS)
Coronary heart disease (CHD)	Non-alcoholic fatty liver disease (NAFLD)
Chronic back pain	Oesophageal cancer
Colorectal cancer	Ovarian cancer
Deep vein thrombosis (DVT)	Pancreatic cancer
Depression	Prostate cancer
Diabetes (type 2)	Psoriasis
Endometrial cancer	Pulmonary embolism
Gallbladder cancer	Sleep apnoea
Gallbladder disease	Stroke
Gout	Thyroid cancer
Hypertension	
Kidney cancer	

*Cost-of-Illness Study included these diseases only.

Epidemiological data

The most recent national data on incidence and prevalence for all diseases, as well as mortality and survival for terminal diseases, were collected for all ages, and by gender, where available (see Table 13 and Table 14 for disease data summary). When proxy data were identified and found suitable for use, these were utilised.

Incidence and prevalence data

Incidence and prevalence data for diseases were collected from a range of sources. When incidence data were not available for a disease, the estimate was computed using prevalence and mortality data if the disease was terminal, or prevalence only if the disease was not terminal. When diseases spanned across several International Classification of Diseases (ICD) codes, the incidence (per 100,000 population) collected for each ICD code was summed to provide the total incidence for the disease.

When proxy data were identified and found suitable, these were used instead of converting prevalence to incidence.

Mortality and survival data

Mortality and survival data for diseases classified as terminal were also collected from a range of sources. Survival data were only available for specific age groups, depending on the source. In situations where incidence or prevalence data were available for an age group (for example, 15- to 20-year-olds) but survival data only started at age 35 (for example, the 35 to 45 age group), the lower age bound was changed to match the lowest age band with incidence data, such as survival changed to represent the 15 to 45 age group. When diseases spanned across several ICD codes, the survival data collected for each ICD code were pooled to provide the total survival probability for the disease.

Table 13 Republic of Ireland disease data summary

Disease	Terminal	Acute	Sex	Adult disease	Child disease	Incidence	Prevalence	Mortality	Survival	Adult RR	Child RR
Asthma	No	No	Both	Yes	Yes	NI Proxy – Northern Ireland Quality and Outcomes Framework (QOF)	CSO Quarterly National Household Survey Q3 2010	Non-terminal	Non-terminal	Guh et al. (2009) [23]	From reviews completed for this report
Bladder cancer	Yes	No	Males	Yes	No	http://www.ncri.ie/data/incidence-statistics	Not used	www.cso.ie	http://www.ncri.ie/data/survival-statistics	Used kidney RR World Obesity Federation Dynamic Modeling for Health Impact Assessment (DYNAMO-HIA) Project [63]	Not child disease
Breast cancer	Yes	No	Females	Yes	No	http://www.ncri.ie/data/incidence-statistics	Not used	www.cso.ie – aged 50+	http://www.ncri.ie/data/survival-statistics	World Obesity Federation DYNAMO-HIA Project [63]	Not child disease
Coronary heart disease (CHD)	Yes	No	Both	Yes	No	Computed from prevalence	TILDA 50+ years UK Proxy – Health Survey for England 16–54 years	www.cso.ie	Computed from prevalence and mortality	World Obesity Federation DYNAMO-HIA Project [63]	Not child disease
Chronic pain (back)	No	No	Both	Yes	No	Computed from prevalence	CSO Quarterly National Household Survey Q3 2010	Non-terminal	Non-terminal	Guh et al. (2009) [23]	Not child disease
Chronic pain (musculo-skeletal)	No	No	Both	No	Yes	PRIME-C study, not yet published –	PRIME-C study, not yet published – by personal	Non-terminal	Non-terminal	Not adult disease	From reviews completed

						by personal communi-cation	communicati on				for this report
Colorectal cancer	Yes	No	Both	Yes	No	http://www.ncri.ie/data/incidence-statistics	Not used	www.cso.ie	http://www.ncri.ie/data/survival-statistics	World Obesity Federation DYNAMO-HIA Project [63]	Not child disease
Depression	No	No	Both	Yes	Yes	Computed from prevalence	Child and Adolescent Mental Health Services (CAMHS)	Non-terminal	Non-terminal	From reviews completed for this report	From reviews completed for this report
Diabetes (type 2)	No	No	Both	Yes	Yes	Computed from prevalence	Tracey et al. (2016) [64]	Non-terminal	Non-terminal	Guh et al. (2009) [23]	From reviews completed for this report
Deep vein thrombosis (DVT)	No	Yes	Both	Yes	No	UK Proxy – https://th.schattauer.de/contents/archive/issue/1895/manuscript/21013.html	Not used	Non-terminal	Non-terminal	From reviews completed for this report	Not child disease
Endometrial cancer	Yes	No	Females	Yes	No	http://www.ncri.ie/data/incidence-statistics	Not used	www.cso.ie	http://www.ncri.ie/data/survival-statistics	World Obesity Federation DYNAMO-HIA Project [63]	Not child disease
Gallbladder cancer	Yes	No	Both	Yes	No	http://www.ncri.ie/data/incidence-statistics	Not used	www.cso.ie	http://www.ncri.ie/data/survival-statistics	Larsson & Wolk (2007) [65] updated using data by gender	Not child disease

Gallbladder disease	No	Yes	Both	Yes	No	HIPE 2014	Not used	Non-terminal	Non-terminal	Guh et al. (2009) [23]	Not child disease
Gout	No	No	Both	Yes	No	Computed from prevalence	UK Proxy – http://ard.bmj.com/content/74/4/661.full#F1	Non-terminal	Non-terminal	Bhole et al. (2010) [66]	Not child disease
Hypertension	No	No	Both	Yes	Yes	Computed from prevalence	TILDA 50+ years UK Proxy – Health Survey for England 16–54 years	Non-terminal	Non-terminal	World Obesity Federation DYNAMO-HIA Project [63]	From reviews completed for this report
Kidney cancer	Yes	No	Both	Yes	No	http://www.ncri.ie/data/incidence-statistics	Not used	www.cso.ie	http://www.ncri.ie/data/survival-statistics	World Obesity Federation DYNAMO-HIA Project [63]	Not child disease
Knee osteoarthritis	No	No	Both	Yes	No	Computed from prevalence	UK Proxy Arthritis Research UK – musculo-skeletal calculator	Non-terminal	Non-terminal	Zheng & Chen (2015) [67]	Not child disease
Liver cancer	Yes	No	Both	Yes	No	http://www.ncri.ie/data/incidence-statistics	Not used	www.cso.ie	http://www.ncri.ie/data/survival-statistics	Chen et al. (2012) [68]	Not child disease
Multiple sclerosis (MS)	No	No	Both	Yes	No	UK Proxy – http://jnnp.bmj.com/content/early/2013/09/19/jnnp-2013-	UK Proxy – http://jnnp.bmj.com/content/early/2013/09/19/jnnp-2013-	Non-terminal	Non-terminal	Hedstrom et al. (2012) [69] (converted from OR to RR using baseline risk)	Not child disease

						305450.full.pdf	305450.full.pdf				
Non-alcoholic fatty liver disease (NAFLD)	No	No	Both	Yes	Yes	PRIME-C study, not yet published – by personal communication	International-al Proxy – http://bmcpediatr.biomedcentral.com/articles/10.1186/1471-2431-13-40	Non-terminal	Non-terminal	From reviews completed for this report	From reviews completed for this report
Oesophageal cancer	Yes	No	Both	Yes	No	http://www.ncri.ie/data/incidence-statistics	Not used	www.cso.ie	http://www.ncri.ie/data/survival-statistics	World Obesity Federation DYNAMO-HIA Project [63]	Not child disease
Ovarian cancer	Yes	No	Females	Yes	No	http://www.ncri.ie/data/incidence-statistics	Not used	www.cso.ie	http://www.ncri.ie/data/survival-statistics	Aune et al. (2015) [70]	Not child disease
Pancreatic cancer	Yes	No	Both	Yes	No	http://www.ncri.ie/data/incidence-statistics	Not used	www.cso.ie	http://www.ncri.ie/data/survival-statistics	World Cancer Research Fund/ American Institute for Cancer Research (2008) [71]	Not child disease
Prostate cancer	Yes	No	Males	Yes	No	http://www.ncri.ie/data/incidence-statistics	Not used	www.cso.ie	http://www.ncri.ie/data/survival-statistics	Guh et al. (2009) [23]	Not child disease
Psoriasis	No	No	Both	Yes	No	UK Proxy – Global Epidemiology of Psoriasis – A Systematic Review of	Not used	Non-terminal	Non-terminal	Lønnberg et al. (2016) [72]	Not child disease

						Incidence and Prevalence; http://www.jidonline.org/article/S0022-202X(15)36098-X/pdf					
Pulmonary embolism	No	Yes	Both	Yes	No	UK Proxy – https://th.schattauer.de/contents/archive/issue/1895/manuscript/21013.html	Not used	Non-terminal	Non-terminal	Guh et al. (2009) [23]	Not child disease
Sleep apnoea	No	No	Both	Yes	Yes	Computed from prevalence	ROI proxy (source not provided)	Non-terminal	Non-terminal	From reviews completed for this report	From reviews completed for this report
Stroke	Yes	No	Both	Yes	No	HIPE 2014	IPH estimates using SLÁN self-report doctor diagnosed; also CSO QNHS Q3 2013	www.cso.ie	UK Proxy – HSE National Stroke Audit 2015	World Obesity Federation DYNAMO-HIA Project [63]	Not child disease
Thyroid cancer	Yes	No	Both	Yes	No	http://www.ncri.ie/data/incidence-statistics	Not used	www.cso.ie	http://www.ncri.ie/data/survival-statistics	Zhao et al. (2012) [73]	Not child disease

Table 14 Northern Ireland disease data summary

Disease	Terminal	Acute	Sex	Adult disease	Child disease	Incidence	Prevalence	Mortality	Survival	Adult RR	Child RR
Asthma	No	No	Both	Yes	Yes	Computed from prevalence	NI QOF data – by personal communication	Non-terminal	Non-terminal	Guh et al. (2009) [23]	From reviews completed for this report
Bladder cancer	Yes	No	Males	Yes	No	Northern Ireland Cancer Registry (NICR)	NICR	NISRA	NICR	Used kidney RR World Obesity Federation DYNAMO-HIA Project [63]	Not child disease
Breast cancer	Yes	No	Females	Yes	No	NICR	NICR	NISRA	NICR	World Obesity Federation DYNAMO-HIA Project [63]	Not child disease
Coronary heart disease (CHD)	Yes	No	Both	Yes	No	Computed from prevalence	NI QOF – CHD, heart failure, peripheral arterial disease, atrial fibrillation	NISRA	Computed from prevalence and mortality	World Obesity Federation DYNAMO-HIA Project [63]	Not child disease
Chronic pain (Back)	No	No	Both	Yes	No	Computed from prevalence	NI Health and Social Wellbeing Survey 2005/06 https://www.health-ni.gov.uk/news/health-survey-northern-ireland-first-results-201415	Non-terminal	Non-terminal	Guh et al. (2009) [23]	Not child disease

Chronic pain (musculo-skeletal)	No	No	Both	No	Yes	ROI Proxy – PRIME-C study, not yet published – by personal communi-cation	ROI Proxy – PRIME-C study, not yet published – by personal communication	Non-terminal	Non-terminal	Not adult disease	From reviews completed for this report
Colorectal cancer	Yes	No	Both	Yes	No	NICR	NICR	NISRA	NICR	World Obesity Federation DYNAMO-HIA Project [63]	Not child disease
Depression	No	No	Both	Yes	Yes	Computed from prevalence	Great Britain (GB) Proxy – Mental Health of Young People in Great Britain 2004 https://digital.nhs.uk/catalogue/PUB06116	Non-terminal	Non-terminal	From reviews completed for this report	From reviews completed for this report
Diabetes (Type 2)	No	No	Both	Yes	Yes	Computed from prevalence	England Proxy 0–17 years – Children and Young People Statistics 2013 (Royal College of Paediatrics & Child Health [RCPCH] Growing up with Diabetes: Children and Young People With Diabetes in England. (RCPCH, 2009)	Non-terminal	Non-terminal	Guh et al. (2009) [23]	From reviews completed for this report

							18+: ROI Proxy http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4748605/				
Deep vein thrombosis DVT	No	Yes	Both	Yes	No	UK Proxy – https://th.schattauer.de/contents/archive/issue/1895/manuscript/21013.html	Not used	Non-terminal	Non-terminal	From reviews completed for this report	Not child disease
Endometrial cancer	Yes	No	Females	Yes	No	NICR	NICR	NISRA	NICR	World Obesity Federation DYNAMO-HIA Project [63]	Not child disease
Gallbladder cancer	Yes	No	Both	Yes	No	ROI Proxy – http://www.ncri.ie/data/incidence-statistics	Not used	ROI Proxy – www.cso.ie	ROI Proxy – http://www.ncri.ie/data/survival-statistics	Larsson & Wolk (2007) [65] updated using data by gender	Not child disease
Gallbladder disease	No	Yes	Both	Yes	No	NI hospital data – https://www.health-ni.gov.uk/publications/acute-episode-based-activity-downloadable-data-201415	NI hospital data – https://www.health-ni.gov.uk/publications/acute-episode-based-activity-downloadable-data-201415	Non-terminal	Non-terminal	Guh et al. (2009) [23]	Not child disease
Gout	No	No	Both	Yes	No	Computed from prevalence	UK Proxy – http://ard.bmj.c	Non-terminal	Non-terminal	Bhole et al. (2010) [66]	Not child disease

							om/content/74/4/661.full#F1				
Hypertension	No	No	Both	Yes	Yes	Computed from prevalence	NI QOF	Non-terminal	Non-terminal	World Obesity Federation DYNAMO-HIA Project [63]	From reviews completed for this report
Kidney cancer	Yes	No	Both	Yes	No	ROI Proxy – applied proportion C64 from ROI data	Not used	NISRA	NICR	World Obesity Federation DYNAMO-HIA Project [63]	Not child disease
Knee osteo-arthritis	No	No	Both	Yes	No	Computed from prevalence	UK Proxy – Arthritis Research UK musculo-skeletal calculator	Non-terminal	Non-terminal	Zheng and Chen (2016) [67]	Not child disease
Liver cancer	Yes	No	Both	Yes	No	ROI Proxy – applied proportion C22.0 in ROI to NI data (because NI data is not available for C22.0)	Not used	NISRA	NICR	Chen et al. (2012) [68]	Not child disease
Multiple sclerosis (MS)	No	No	Both	Yes	No	UK Proxy – http://jnnp.bmj.com/content/early/2013/09/19/jnnp-2013-305450.full.pdf	UK Proxy – http://jnnp.bmj.com/content/early/2013/09/19/jnnp-2013-305450.full.pdf	Non-terminal	Non-terminal	Hedstrom et al. (2012) [69] (converted from OR to RR using baseline risk)	Not child disease
Non-alcoholic fatty liver	No	No	Both	Yes	Yes	ROI Proxy – PRIME-C study, not	International Proxy – http://bmcpedia	Non-terminal	Non-terminal	From reviews completed	From reviews completed

disease (NAFLD)						yet published – by personal communi-cation	tr.biomedcentral.com/articles/10.1186/1471-2431-13-40			for this report	for this report
Oesophageal cancer	Yes	No	Both	Yes	No	NICR	NICR	NISRA	NICR	World Obesity Federation DYNAMO-HIA Project [63]	Not child disease
Ovarian cancer	Yes	No	Females	Yes	No	NICR	NICR	NISRA	NICR	Aune et al. (2015) [70]	Not child disease
Pancreatic cancer	Yes	No	Both	Yes	No	NICR	NICR	NISRA	NICR	World Cancer Research Fund/ American Institute for Cancer Research (2008) [71]	Not child disease
Prostate cancer	Yes	No	Males	Yes	No	NICR	NICR	NISRA	NICR	Guh et al. (2009) [23]	Not child disease
Psoriasis	No	No	Both	Yes	No	UK Proxy – Global Epidemiology of Psoriasis – A Systematic Review of Incidence and Prevalence; http://www.jidonline.org/article/S0022-	Not used	Non-terminal	Non-terminal	Lønnberg et al. (2016) [72]	Not child disease

						202X(15)36098-X/pdf					
Pulmonary embolism	No	Yes	Both	Yes	No	UK Proxy – https://th.schattauer.de/contents/archive/issue/1895/manuscript/21013.html	Not used	Non-terminal	Non-terminal	Guh et al. (2009) [23]	Not child disease
Sleep apnoea	No	No	Both	Yes	Yes	Computed from prevalence	ROI Proxy (source not provided)	Non-terminal	Non-terminal	From reviews completed for this report	From reviews completed for this report
Stroke	Yes	No	Both	Yes	No	NI hospital data – https://www.health-ni.gov.uk/publications/acute-episode-based-activity-downloadable-data-201415	NI QOF	NISRA	Computed from prevalence and mortality	World Obesity Federation DYNAMO-HIA Project [63]	Not child disease
Thyroid cancer	Yes	No	Both	Yes	No	NICR	NICR	NISRA	NICR	Zhao et al. (2012) [73]	Not child disease

Survival data were processed to derive survival parameters (a set of factors to define "survival"). Different survival models were constructed, depending on the type of survival data available – for example, 1- and/or 5-year survival data, $p_{survival}(1)$ and $p_{survival}(5)$ respectively. The calculations were based partly on modelling the survival rate, "R", which was assumed to have an exponential death distribution (where the rate increases in a non-linear fashion over time), with higher death rates at older ages. In this formulation, the probability of surviving t years from some point in time t_0 is given as:

$$p_{\text{survival}}(t) = 1 - R^{-1}\int_0^t due^{-Ru} = e^{-Rt}$$

For a time period of 1 year:

$$p_{survival}(1) = e^{-R}$$
$$\Rightarrow$$
$$R = -\ln\left(p_{survival}(1)\right) = -\ln(1 - p_{\omega})$$

For a time period of, for example, 4 years:

$$p_{\text{survival}}(t=4) = 1 - R^{-1}\int_0^4 due^{-Ru} = e^{-4R} = (1 - p_{\omega})^4$$

In short, the rate is minus the natural logarithm of the 1-year survival probability.

Survival models

For any potentially terminal disease the UKHF model can use several survival models. The parameters describing these models are given here.

Survival model 0

The model uses 1 parameter {R}:

Given the 1-year survival probability $p_{survival}(1)$

$$R = -\ln\left(p_{survival}(1)\right)$$

Survival model 1

The model uses 2 parameters {p_1, R}:

Given the 1-year survival probability $p_{survival}(1)$ and the 5-year survival probability $p_{survival}(5)$

$$p_1 = 1 - p_{survival}(1)$$

$$R = -\frac{1}{4}\ln\left(\frac{p_{survival}(5)}{p_{survival}(1)}\right)$$

Relative risk (RR) and odds ratio (OR) data

Data on age- and gender-specific RRs or ORs of acquiring disease by BMI category were obtained from a range of sources (see Table 13 and Table 14). The UKHF provided the majority of RR/OR data, and the University College Cork/JANPA research team completed these with results from literature searches and reviews. For childhood-only diseases, RRs beyond the age of 17 were set to 1, while RRs for adult-only diseases were set to 1 before the age of 17.

Economic data

The start year of the simulation was 2015. If cost estimates varied in the year they were collected, then all cost estimates were converted to 2015 using the Campbell and Cochrane Economics Methods Group Evidence for Policy and Practice Information and Coordinating Centre (CCEMG–EPPI-Centre) Cost Converter [74], which is a free web-based tool for adjusting estimates of cost expressed in one currency and price year to a specific target currency and price year.

Direct healthcare costs

For the Republic of Ireland cost estimates for the Closed Cohort Simulation Model were calculated as the cost per case per year by condition.

Total in-patient and day-case costs were taken from the Healthcare Pricing Office's (HPO) HIPE online portal [75]. The published costs have not been updated since 2011, so it is likely that some underestimation or overestimation occurred, but they are the best available cost data.

Out-patient department (OPD) costs were calculated for all cancers using an estimate of 2 out-patient visits per year per patient. The cost of an out-patient visit was estimated as €130, based on advice from the HPO.

Out-patient department costs for type 2 diabetes were calculated based on data from the HPO OPD file for 2014, using all OPD clinics listed as diabetes-specific clinics. This is an underestimate, because many endocrinology clinics (which treat disorders of the endocrine system, which regulates the release of hormones, for example insulin) and general medicine clinics would also see diabetes

patients, but the proportion of patients attending these clinics with a diagnosis of diabetes is not possible to estimate.

Out-patient department costs for CHD were calculated using costs for cardiology clinics but, again, for the same reasons as for diabetes above, this inevitably leads to an underestimate.

Out-patient department costs for gonarthrosis (osteoarthritis of the knee) knee pain and chronic back pain were determined by estimating the proportion of OPD attendances at orthopaedic clinics (which treat disorders of the muscles and skeletal frame) – not fracture clinics – that were deemed to be for those conditions. Information on this was taken from communications with Galway University Hospital, which had information from an audit of OPD referrals by complaint. According to these data, 17% of referrals were for knee problems and 31% were for back or spinal problems (personal communication: Susan Hennessy, Waiting List Manager, Galway University Hospital).

It was not possible to estimate OPD clinic costs for other conditions, as disease-specific information was not available.

General Practice costs were estimated for cancers, type 2 diabetes, hypertension, knee pain and back pain. Cancers were attributed an average of 2 GP visits per year, based on expert opinion. The other conditions were estimated using average attendance data from 1 primary care centre (personal communication: Janice Sweeney, Livinghealth Clinic, Mitchelstown, Cork). Data on attendances for the other conditions were not available.

Prescription drug costs were calculated by condition using data from the Primary Care Reimbursement Service (PCRS), which includes all publicly funded drug expenditure in the community, but excludes those patients who pay “out of pocket” for drugs (private patients paying less than, or up to, €144 per month). Additional drug costs for cancer drugs were available for post-menopausal breast cancer and for prostate cancer only (personal communication: Patricia Heckmann, National Cancer Control Programme).

Total healthcare costs were calculated by adding all of the available cost data for each condition. The cost per case was calculated by dividing the total costs by the total number of people estimated to have the condition. The cost per case calculated was an annual cost and this was fed into the Closed Cohort Simulation Model as appropriate.

The total number of people with the various conditions was estimated in a number of ways. For cancers, the main data source was the National Cancer Registry Ireland. For CHD, asthma, hypertension, gout and pulmonary embolism, the number of hospital discharges, or the number of individuals on medication, was taken as a proxy prevalence measure.

Direct healthcare costs for Northern Ireland were estimated from the previous *safe*food report, *The cost of overweight and obesity on the island of Ireland* [2], and were scaled to 2015 costs.

Absenteeism costs

The Closed Cohort Simulation Model requires an annual cost per case for absenteeism. These costs were also derived from the 2012 *safe*food report. Costs were only available for type 2 diabetes, stroke, hypertension, CHD, DVT, asthma, gout, gonarthrosis knee pain, chronic back pain and gallbladder disease. For osteoarthritis, the proportions attributed to knee and back pain were taken from OPD referral data from Galway University Hospital.

Average earnings

Information on average earnings by age and gender group was collected for use in calculations of the cost of premature mortality and lifetime income losses. Data from the Republic of Ireland's 2013 *National Employment Survey* were obtained from the CSO. Data from Northern Ireland's 2014 *Annual Survey of Hours and Earnings* were obtained from the NISRA. These were converted to 2015 values using the same method as economic data.

Life expectancy

For each child aged 0 to 17 years in 2015, their life expectancy at birth (years 1998 to 2015) was extracted from national life tables provided by the CSO in the Republic of Ireland and the Office for National Statistics (ONS) in Northern Ireland [76]. Premature death is defined as when an individual dies before the year in which they would have reached their life expectancy at birth. Females therefore have greater person-years of exposure to premature death in this study because they live longer, and in these extra years female deaths are classified as premature, while male deaths are not..

Discounting

For the Republic of Ireland, a 5% discount value for costs and health benefits was recommended in 2014 [9]. For Northern Ireland, a 3.5% discount value for both costs and benefits was recommended by the National Institute for Health and Care Excellence [10].

Current direct costs

Closed Cohort Simulation Model-based current direct costs

Lifetime costs of childhood overweight and obesity are broken down into current annual costs and the annual costs incurred in each future year. The gender–age–BMI profile of the virtual childhood cohort in the starting year (2015) matches that of the child and adolescent population in the Republic of Ireland and Northern Ireland in 2015. The annual Closed Cohort Simulation Model-based costs for 2015 represent the current cost of providing treatment for obesity-related diseases to overweight and obese children in 2015.

Cost-of-Illness Study-based current direct costs for the Republic of Ireland

The current direct healthcare costs of providing treatment for obesity-related diseases can also be estimated using a direct cost-of-illness approach, which sums the current value of the component impacts and costs without using a Closed Cohort Simulation Model. Therefore, a cost-of-illness study of the current annual cost of providing treatment for obesity-related diseases to overweight and obese children was conducted. The purpose of this study was to investigate impacts and costs that could not be incorporated into the Closed Cohort Simulation Model, and to assess the sensitivity of the Closed Cohort Model-based current estimates, as discussed previously.

Details of the differences between the Cost-of-Illness Study and Closed Cohort Simulation Model-based approaches are shown in Table 15. It was not possible to estimate current healthcare costs attributable to childhood overweight and obesity in Northern Ireland using the Direct Cost-of-Illness Study approach. This was due to insufficient data on the prevalence of overweight and obesity among children in Northern Ireland, stratified by age and gender, and the lack of availability of hospital activity data, which could not be provided by the Health Information Branch of the Department of Health and Social Services.

Table 15 Comparison of the Cost-of-Illness Study and Closed Cohort Simulation Model-based approaches for estimating current direct costs

Cost-of-Illness Study (Republic of Ireland)	Closed Cohort Simulation Model-based approach (Republic of Ireland and Northern Ireland)
Children only (0 to 18 years)	Children only (0 to 17 years)
Based on 3 separate surveys for 3 childhood age categories	Based on all available historical data relating to both children and adults (9 separate survey sources in the Republic of Ireland for the years 1998 to 2015; 6 separate survey sources in Northern Ireland for the years 2000 to 2015)
Uses International Obesity Task Force (IOTF) cut-off points (age- and gender-specific)	Uses BMI at aged 18 years, except for cases of childhood death and disease in which case age- and gender-specific IOTF cut-offs are used
Combines overweight and obese categories	Combines overweight and obese categories
5 diseases	7 diseases
Childhood treatment costs only	Childhood treatment costs only
Shows age–gender breakdown of hospital costs	Does not present age–gender breakdown of hospital costs but these were used in analysis
Shows age–gender breakdown of drug costs	Does not present age–gender breakdown of drug costs but these were used in analysis
Bottom-up study of use of General Practice (GP) services	For some diseases, bottom-up study of General Practice (GP) services; expert opinion for other diseases
No accounting for multi-morbidities	No accounting for multi-morbidities
Includes details of specialised treatment for morbidly obese children	No details of "additional costs"

Estimating the current value of component impacts and costs

Odds ratios (ORs) and population-attributable fractions (PAFs)

The OR is a measure of the increased risk of a specific disease that is associated with a particular exposure, or factor. In this case, the increased risk is of various conditions (asthma, hypertension, type 2 diabetes, sleep apnoea and depression) associated with childhood overweight and obesity. Odds ratios are calculated from observational studies on populations.

The population attributable fraction (PAF) estimates the burden of disease attributable to a particular risk factor (for example, overweight or obesity). Viewed alternately, it is that fraction of disease that would not occur if the risk (in this case, excess weight) were not a health issue in the population. For overweight and obesity, the PAF is calculated by combining the prevalence of overweight and obesity with the ORs for associated conditions.

In this study, PAFs were determined using this formula, which accounts for multiple levels of exposure [77]

$$PAF = \frac{PF_1(RR_1 - 1) + PF_2(RR_2 - 1)}{1 + PF_1(RR_1 - 1) + PF_2(RR_2 - 1)}$$

where

PF_1 is the fraction of the population in exposure level 1 (for example, being overweight)

RR_1 is the risk of disease for exposure level 1

PF_2 is the fraction of the population in exposure level 2 (for example, being obese)

RR_2 is the risk of disease for exposure level 2.

The PAFs were stratified by age and gender to account for variations between groups, as the PAF is sensitive to the distribution of the exposure within a population.

This Cost-of-Illness Study used ORs determined from a review of the literature. The relevant ORs and data sources are summarised in Table 16.

Table 16 Odds ratios (95% confidence interval [CI]) for overweight and obesity in children regarding obesity-related conditions

Condition	Odds ratio (95% confidence interval [CI])		
	Overweight*	Obese*	Overweight and obese*
Asthma**	1.23 (range 1.17 to 1.29)	1.46 (range 1.36 to 1.57)	
Hypertension**			
Males	1.92 (range 1.77 to 2.08)	4.11 (range 3.89 to 4.34)	
Females	2.25 (range 1.96 to 2.59)	5.56 (range 5.09 to 6.07)	
Type 2 diabetes**			
Males	2.25 (range 1.96 to 2.59)	5.56 (range 5.09 to 6.07)	
Females	1.31 (range 0.15 to 11.19)	4.42 (range 3.90 to 5.00)	
Sleep apnoea**			6.60 (range 1.40 to 31.00)
Depression**	1.45 (range 0.73 to 2.89)	1.96 (range 1.07 to 3.57)	

*Compared with normal weight
**Odds ratios were derived from the followings studies: Asthma [37], Hypertension [38], Type 2 diabetes [38], Sleep apnoea [39], Depression [40].

Top-down and bottom-up approaches

The component costs associated with overweight and obesity are typically calculated using 1 of 2 main approaches: either top-down or bottom-up.

A top-down approach usually draws on country-specific data on the prevalence of overweight and obesity in the population and information on the risk of developing conditions known to be associated with a raised BMI. Specifically, RRs or ORs for the relevant conditions are estimated by BMI category from observational studies. As discussed earlier, the OR estimates are combined with the country-specific prevalence rates of overweight and obesity to estimate the PAF. The PAF estimates the proportion of cases with a particular condition that is due to overweight or obesity. For example, the OR of type 2 diabetes in boys associated with overweight would be combined with the Irish

prevalence rate of overweight in male children to give the Irish PAF for diabetes in overweight boys. This estimate is then applied to the healthcare expenditure on type 2 diabetes to estimate the cost of diabetes due to overweight in male subjects. This exercise is repeated for obese boys, and for overweight and obese girls. The process continues with each condition for which there is evidence of a causal link with overweight and obesity. As the ORs used in estimating PAFs have confidence intervals attached, these were employed to generate the upper and lower cost estimates (the ranges) referred to in text where PAF methodology was used.

By contrast, a bottom-up approach typically uses individual-level data, usually collected in cross-sectional surveys, in which data are collected at the same time as data on BMI and healthcare utilisation patterns. The additional service utilisation associated with overweight and obesity is determined by multivariable regression analysis and monetised, or expressed as currency, using cost data for the country concerned.

Cost-of-Illness Study data sources

Prevalence estimates of childhood of overweight and obesity

Estimates of childhood overweight and obesity prevalence for the Republic of Ireland were based on data from 3 sources:

- The Fluoride and Caring for Children's Health (FACCT) study [36], a cross-sectional sample of 5,232 primary school children conducted in 2013/14. This study was used to estimate overweight and obesity prevalence among children aged 0 to 6 years.
- A cross-sectional survey of third- and fourth-class children in primary schools (n = 1,075), the Cork Children's Lifestyle Study (CCLaS) [31], was undertaken in 2012/13. Data from this research were used to determine prevalence estimates for children aged 7 to 11 years.
- Data collected by the Economic and Social Research Institute's Survey Unit [78] were used to estimate overweight and obesity prevalence rates among adolescents aged 12 to 18 years. Conducted in 2005, this study was based on nationally representative survey data collected from students in second-level schools, and in fifth and sixth class in primary schools. The sample consists of 80 schools and 3,527 students at second level, and 137 schools and 3,833 pupils at primary level.

Although sample sizes and data collection periods for these studies vary, they were selected in order to provide estimates of childhood overweight and obesity prevalence over a range of ages. In addition, it was determined that only studies in which both weight and height were objectively assessed should be included in analysis. Prevalence rates of overweight and obesity among children in the Republic of Ireland derived from these data are shown in Table 17.

Table 17 Prevalence of overweight and obesity among children (0 to 18 years) in the Republic of Ireland, by gender and age group

	Males			Females		
Age group	Over-weight (%)	Obese (%)	Total over-weight and obese (%)	Over-weight (%)	Obese (%)	Total over-weight and obese (%)
0–6*	13.3	4.1	17.4	19.4	6.3	25.7
7–11**	19.5	4.2	23.7	20.8	6.9	27.7
12–18***	15.4	4.5	19.9	16.6	3.8	20.4

*Source: FACCT, 2014 [36]

**Source: CCLaS, 2013 [31]

***Source: Fahey et al., 2005 [78]

Healthcare costs

Hospital in-patient and day case costs

Information on hospital costs (in-patient and day cases) was accessed using the HIPE database through the HPO. The HIPE provides the Republic of Ireland dataset on hospital in-patient and day-case activity, and measures patient discharges by diagnosis. It is the primary source of national data on discharges from hospitals, and collects demographic (population statistics), clinical and administrative information.

"Diagnosis-related groups" are the cost groups for patient discharges, and for each condition they were summed for separate age groups and by gender. The International Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification (ICD-10-AM), included in these analyses are outlined in Table 18. The HIPE data utilised in this research refer to the period from January 1, 2014 to December 31, 2014, and are based on coding of discharges by hospital coding staff after each patient was discharged from hospital. The published costs have not been updated since 2011. The data was collated from the HIPE database in November 2016.

There were no reliable out-patient attendance data available for the paediatric conditions listed in Table 18, apart from depression. The costs for depression were calculated using different methodology because HIPE does not record mental health discharges. Depression in childhood is mainly dealt with on an out-patient basis through the Child and Adolescent Mental Health Services (CAMHS). In-patient care is generally provided in a specialist setting, and information with regard to activity at both in-patient and out-patient level is reported on in the Mental Health Division Annual Report [79]. From this report it is known that 37% of all in-patient admissions from CAMHS are for depressive illness.

These children have an average length of stay of 40 days, and an estimated cost per day of €550 (personal communication: Paul Braham, Senior Operations Manager, Operations and Service Improvement, Mental Health Division).

Table 18 Conditions and codes analysed for hospital in-patient and day-case analysis

Condition	ICD-10-AM Codes
Asthma	J45.1, J45.8, J45.9, J46
Hypertension	I10, I11, I12, I13
Type 2 diabetes	E11
Sleep apnoea	G47.32
Depression	Coding information not available
Obesity	E660, E662, E668, E669

Attendance as an out-patient was calculated using cost data provided by the CAMHS in the midwest region (personal communication: Helen Barry, Service Manager, Mid West CAMHS). The most recent CAMHS report [80] notes that 10.4% of CAMHS out-patient attendances are for depressive illness. Using that figure, and taking the total running costs of the Mid West CAMHS in 2015 of €4,307,296, using very crude methodology, 10.4% of this figure can be apportioned to the cost of treating depression. There were 2,350 open cases attending CAMHS in that year, therefore the cost per case was also calculated at €1,833 per case.

Prescribing costs

Data on the counts, type and cost of prescription drugs in the Republic of Ireland were provided by the PCRS. The PCRS is the unit within the HSE that reimburses community drug-prescribing and primary care costs. The drug costs relate to all schemes run by the unit. These include:

- The General Medical Scheme, which covers individuals who hold medical cards
- The Long-Term Illness Scheme, which covers some people with long-term chronic illnesses (for example, diabetes)
- The Payment Scheme, which covers the amount paid for drugs for private patients
- The High-Tech Drug Scheme, which covers certain expensive medications.

Data from all of these schemes were included in the current study. Thus information on drug cost has been captured on the entire population, apart from the excess paid by private patients – which is difficult to measure as the data are not formally captured, but is not insignificant in amount.

Prescribing costs for each condition were also summed for age groups and by gender. It should be noted that age groups for prescribing costs that were available do not entirely correspond to overweight and obesity prevalence and HIPE data. The PCRS information included in this research also refers to the period from January 1, 2014 to December 31, 2014, and was collated in November 2016.

General Practice (GP) costs

Estimates of annual GP costs for the Republic of Ireland are based on a "negative binomial count model", which estimates the impact of overweight and obesity on GP service use. For this analysis, 2 waves of the "Growing Up in Ireland" (GUI) study for children were used when they were 9 and 13 years, respectively. In each wave, the models controlled for:

- Child's BMI category (non-overweight and overweight or obese, using the IOTF cut-offs for boys and girls at age 9 and 13 years, respectively)
- Child's gender
- Birth weight
- Gestation age
- Mother's age
- Mother's self-reported health
- Mother's education
- Mother's marital status
- Medical Card status
- Private health insurance
- Household income
- Location (urban or rural).

Based on this, the estimated impact of overweight and obesity on service use was determined (relative to non-overweight children). This was then combined with the cost of the service (€50 per visit) and number of children in these age categories (based on the 2011 census) in order to estimate the incremental cost associated with overweight and obesity.

We found that there was no statistical difference in the estimated number of GP visits between non-overweight and overweight/obese children at 9 years of age. Therefore we did not estimate additional costs associated with overweight or obesity for 9-year-old children. It was found that for children at 13 years, both overweight and obesity were associated with significantly higher GP healthcare utilisation, and therefore costs, compared with non-overweight 13-year-old children.

Additional costs

At the time of this research, the largest tertiary centre for treating clinical obesity among children and adolescents in the Republic of Ireland was provided by the Temple Street Children's University Hospital, Dublin. The "W82GO!" Obesity Service delivers obesity intervention in line with NICE Clinical Guidelines. The intervention provides families with education and practical skills to address health, nutrition, self-esteem, family communication and physical activity, along with support in a safe environment, so that families can achieve the healthiest lifestyle for their child. The service is multidisciplinary and involves healthcare professionals from general paediatrics (medical care for infants, children and adolescents), paediatric physiotherapy, paediatric dietetics (nutrition), paediatric nursing and paediatric psychology. The multidisciplinary team delivers either a group-based intervention or one–to–one intervention, depending on the needs of the child and family.

Before commencing suitable intervention, a child is screened for underlying medical causes of obesity and associated physical and psychological comorbidities. Then, families are invited to either a group programme run in the evening or to one–to–one daytime out-patient appointments. The intervention is delivered over 10 sessions during a 12-month period and aims to:

- Improve nutrition
- Improve fitness
- Increase physical activity levels
- Reduce sedentary or sitting time
- Improve emotional wellbeing and family functioning.

An observational study of treatment outcomes concluded that the intervention was a promising form of treatment and observed significant reductions in obesity over 12 months.

For the current research, the yearly staffing costs associated with the running of the W82GO! Service were provided by the Temple Street Children's University Hospital and included in analysis.

5 Results

Current direct costs – Cost-of-Illness Study estimates

Section 5 presents the findings from the Direct Cost-of-Illness Study conducted in the Republic of Ireland, which estimated current annual direct healthcare costs amongst children attributable to childhood overweight and obesity.

Current (2015) annual healthcare costs amongst children

In-patient costs

A breakdown of in-patient costs for the examined conditions is shown in Table 19. Depressive disorders are responsible for the highest hospital in-patient costs among these conditions, accounting for 88% of total in-patient costs and 80% of in-patient costs attributable to overweight and obesity. After depression, asthma and hypertension were the next highest costs, accounting for 8% and 2% of total in-patient expenditure, respectively.

Sleep apnoea, however, was responsible for a greater proportion of total costs attributable to overweight and obesity (10%). After sleep apnoea, the highest overweight and obese attributable fractions were for type 2 diabetes (in males) and hypertension (in males and females). Results from analysis indicate that childhood overweight and obesity may account for just over 10% of the total in-patient health service costs incurred for these conditions.

Prescribing costs

Medications for asthma were responsible for a greater percentage of total prescribing costs with regard to the examined illnesses, accounting for 94% of total costs and 78% of prescription charges that were attributable to overweight or obesity (Table 20). After asthma, medications for hypertension were the next highest costs, responsible for almost 20% of prescribing costs attributable to overweight and obesity. Approximately 7% of total medication costs spent on children for these obesity-related conditions may be explained by childhood overweight or obesity.

Table 19 Breakdown of current (2015) annual in-patient costs amongst children in the Republic of Ireland regarding obesity-related conditions, by gender and age group – Cost-of-Illness Study estimates

Sex, condition and age group	PAF (%)*	Costs (€)	Costs attributable to childhood overweight and obesity (€)	Range (€)
Males				
Asthma				
0–6	5	111,809	5,590	4,472 to 6,709
7–11	6	61,417	3,685	3,071 to 4,299
12–18	5	44,541	2,227	1,782 to 3,118
Hypertension				
7–11	24	7,241	1,738	1,521 to 1,883
12–18	22	34,633	7,619	6,927 to 8,312
Type 2 diabetes				
12–18	29	9,544	2,768	2,386 to 3,054
Sleep apnoea				
12–18	53	38,631	20,474	2,704 to 33,223
Total costs (males)		307,816	44,101	22,863 to 60,608
Females				
Asthma				
0–6	7	85,096	5,957	4,255 to 6,808
7–11	7	26,199	1,834	1,572 to 2,358
12–18	5	12,457	623	498 to 871
Hypertension				
7–11	37	12,338	4,565	4,072 to 5,059
12–18	28	35,017	9,805	8,404 to 10,855
Type 2 diabetes				
12–18	15	19,089	2,863	0 to 12,408
Sleep apnoea				
12–18	53	48,496	25,703	3,880 to 41,707
Total costs (females)		238,692	51,350	22,681 to 80,066
Depression**	10	3,853,476	385,348	0 to 1,117,508
Total costs (males and females)		4,399,984	480,799	45,544 to 1,258,182

*PAF total for overweight and obese

**In-patient costs for males and females combined, all ages

Table 20 Breakdown of current (2015) annual prescribing costs amongst children in the Republic of Ireland regarding obesity-related conditions, by gender and age group – Cost-of-Illness Study estimates

Sex, condition and age group	PAF (%)*	Costs (€)	Costs attributable to childhood overweight and obesity (€)	Range (€)
Males				
Asthma				
0–4	5	286,862	14,343	11,474 to 17,212
5–9	6	1,320,715	79,243	66,036 to 92,450
10–18	5	2,315,193	115,760	92,608 to 162,063
Hypertension				
5–9	24	51,036	12,249	10,718 to 13,269
10–18	22	124,552	27,401	24,910 to 29,892
Type 2 diabetes				
10–18	29	36,566	10,604	9,142 to 11,701
Depression				
10–18	10	30,711	3,071	0 to 8,906
Total costs (males)		4,165,635	262,671	214,888 to 335,493
Females				
Asthma				
0–4	7	195,390	13,677	9,770 to 15,631
5–9	7	941,846	65,929	56,511 to 84,766
10–18	5	1,590,340	79,517	63,614 to 111,324
Hypertension				
5–9	37	39,884	14,757	13,162 to 16,352
10–18	28	109,634	30,698	26,321 to 33,987
Type 2 diabetes				
10–18	15	15,090	2,264	0 to 9,809
Depression				
10–18	10	46,409	4,641	0 to 13,459
Total costs (females)		2,938,593	211,483	169,378 to 285,328
Total costs (males and females)		7,104,228	474,154	384,266 to 620,821

*PAF total for overweight and obese

General Practice (GP), day-case and additional healthcare costs

Excess GP costs due to overweight and obesity among children in the Republic of Ireland were estimated to be €139,049, while in-patient and day-case costs for children being treated for clinical obesity were €29,224 and €6,045, respectively (Table 21). Total annual costs for the Temple Street Children's University Hospital W82GO! Service were €215,041.

Table 21 Current (2015) annual General Practice (GP), day-case and additional healthcare costs amongst children attributable to childhood overweight and obesity in the Republic of Ireland – Cost-of-Illness Study estimates

Service	Costs (€)	Range (€)
General Practice (GP) costs*		
Overweight	74,064	7,290 to 140,952
Obese	64,985	30,372 to 99,740
In-patient costs for obesity*	29,224	-
Day-case costs for obesity*	6,045	-
Child and Adolescent Mental Health Service (CAMHS) attendances for depression*	365,391	0 to 1,059,773
Temple Street Children's Hospital costs*		
Senior dietician	30,223	-
Senior physiotherapist	32,786	-
Clinical physiotherapist	32,612	-
Clinical psychologist	32,464	-
Senior psychologist	17,879	-
Administrative assistant	35,859	-
Nurse	1,237	-
W82GO! group coordinator	11,588	-
Paediatric consultant	20,393	-
Total Temple Street Children's Hospital costs	215,041	-
Total costs	754,750	287,972 to 1,550,775

*For males and females combined, all ages

Total current (2015) annual healthcare costs amongst children

Results from the Direct Cost-of-Illness Study suggest that 8% of total hospital in-patient and prescribing costs amongst children for the examined conditions (asthma, hypertension, type 2 diabetes, sleep apnoea and depressive disorders) are due to overweight and obesity, and that costs associated with these morbidities may account for over half (56%) of the total excess healthcare

expenditure that is attributable to childhood overweight and obesity in the Republic of Ireland. A further €754,750 additional costs are spent on GP care, day-case care and other services (Table 22). Total current direct healthcare costs amongst children attributable to childhood overweight and obesity were estimated at €1.7 million (range between €717,782 and €3,429,778).

Table 22 Total current (2015) direct annual healthcare costs amongst children attributable to childhood overweight and obesity in the Republic of Ireland – Cost-of-Illness Study estimates

Service	Costs €	Range €
In-patient costs	480,799	45,544 to 1,258,182
Prescribing costs	474,154	384,266 to 620,821
General Practice (GP), day-case and additional costs	754,750	287,972 to 1,550,775
Total costs	1,709,703	717,782 to 3,429,778

Direct and indirect costs – Closed Cohort Simulation Model estimates

Section 5 also presents the findings from the Closed Cohort Simulation Model study conducted in the Republic of Ireland and Northern Ireland, which estimated current annual direct healthcare costs amongst children, and projected lifetime healthcare costs in addition to lifetime indirect costs. The indirect costs were productivity losses due to absenteeism, premature mortality and lifetime income losses attributable to childhood overweight and obesity.

Current (2015) direct annual healthcare costs amongst children

Table 23 and Table 24 show current annual direct healthcare costs amongst children, estimated using a Closed Cohort Simulation Model-based approach. Gender differences were noted, with males accounting for 85% and 71% of total healthcare costs attributed to overweight and obesity for the Republic of Ireland and Northern Ireland, respectively. Total current direct healthcare costs amongst children due to childhood overweight and obesity were estimated at €1.3 million for the Republic of Ireland and €0.7 million for Northern Ireland.

Table 23 Total current (2015) direct annual healthcare costs amongst children attributable to childhood overweight and obesity in the Republic of Ireland – Closed Cohort Simulation Model estimates

Sex	BMI at 18 years	Number of children in 2015	Cost per person (€, 2015 values)	Total cost (€ millions, 2015 values)
Males	Overweight or obese	137,459	57	7.8
	Healthy weight	475,335	49	23.2
	All BMIs	612,794	51	31.0
	Excess cost attributable to childhood overweight and obesity		8	1.1 (PAF = 3.5%)
Females	Overweight or obese	144,292	59	8.5
	Healthy weight	442,234	57	25.4
	All BMIs	586,526	58	33.9
	Excess cost attributable to childhood overweight and obesity		1	0.2 (PAF = 0.6%)
Total	Overweight or obese	281,751	58	16.3
	Healthy weight	917,569	53	48.6
	All BMIs	1,199,320	54	64.9
	Excess cost attributable to childhood overweight and obesity		5	1.3 (PAF = 2.1%)

Table 24 Total current (2015) direct annual healthcare costs amongst children attributable to childhood overweight and obesity in Northern Ireland – Closed Cohort Simulation Model estimates

Sex	BMI at 18 years	Number of children in 2015	Cost per person (€, 2015 values)	Total cost (€ millions, 2015 values)
Males	Overweight or obese	51,140	75	3.9
	Healthy weight	170,935	86	14.7
	All BMIs	222,075	84	18.6
	Excess cost attributable to childhood overweight and obesity		11	0.5 (PAF = 2.9%)
Females	Overweight or obese	60,735	88	5.4
	Healthy weight	149,981	92	13.8
	All BMIs	210,716	91	19.1
	Excess cost attributable to childhood overweight and obesity		3	0.2 (PAF = 1.1%)
Total	Overweight or obese	111,875	82	9.2
	Healthy weight	320,916	89	28.5
	All BMIs	432,791	87	37.7
	Excess cost attributable to childhood overweight and obesity		6	0.7 (PAF = 1.9%)

Lifetime direct healthcare costs

The estimated lifetime direct healthcare costs for the Republic of Ireland and Northern Ireland are displayed in Table 25 and Table 26. For the Republic of Ireland, total estimated excess costs due to overweight and obesity were higher for female children (€527 million) compared with males (€422 million). This may reflect higher overweight and obesity prevalence rates among female children in the Republic of Ireland, with costs occurring primarily in later life as opposed to current costs. The total estimated lifetime direct healthcare costs to the year 2105 for the Republic of Ireland were estimated at €949 million. This estimate is based on 2015 values, using a 5% annual discount rate.

For Northern Ireland, lifetime healthcare cost estimates were broadly similar for male and female children (€334.8 million and €337 million, respectively). The total estimated lifetime direct healthcare

costs to the year 2105 for Northern Ireland were estimated at €671.8 million. This estimate is based on 2015 values, using a 3.5% annual discount rate.

Table 25 Lifetime direct healthcare costs attributable to childhood overweight and obesity in the Republic of Ireland – Closed Cohort Simulation Model estimates

Sex	BMI at 18 years	Number of children in 2015	Cost per person (€, 2015 values)	Total cost (€ millions, 2015 values)
Males	Overweight or obese	137,459	8,335	1,145.8
	Healthy weight	475,335	5,265	2,502.9
	All BMIs	612,794	5,954	3,648.6
	Excess cost attributable to childhood overweight and obesity		3,070	422.0 (PAF = 11.6%)
Females	Overweight or obese	144,292	8,420	1,214.9
	Healthy weight	442,234	4,768	2,108.4
	All BMIs	586,526	5,666	3,323.3
	Excess cost attributable to childhood overweight and obesity		3,652	527.0 (PAF = 15.9%)
Total	Overweight or obese	281,751	8,379	2,360.7
	Healthy weight	917,569	5,025	4,611.2
	All BMIs	1,199,320	5,813	6,971.9
	Excess cost attributable to childhood overweight and obesity		3,353	949.0 (PAF = 13.6%)

Table 26 Lifetime direct healthcare costs attributable to childhood overweight and obesity in Northern Ireland – Closed Cohort Simulation Model estimates

Sex	BMI at 18 years	Number of children in 2015	Cost per person (€, 2015 values)	Total cost (€ millions, 2015 values)
Males	Overweight or obese	51,140	15,084	771.4
	Healthy weight	170,935	8,537	1,459.2
	All BMIs	222,075	10,044	2,230.6
	Excess cost attributable to childhood overweight and obesity		6,547	334.8 (PAF = 15.0%)
Females	Overweight or obese	60,735	15,001	911.1
	Healthy weight	149,981	9,452	1,417.6
	All BMIs	210,716	11,051	2,328.7
	Excess cost attributable to childhood overweight and obesity		5,549	337.0 (PAF = 14.5%)
Total	Overweight or obese	111,875	15,039	1,682.5
	Healthy weight	320,916	8,964	2,876.8
	All BMIs	432,791	10,535	4,559.3
	Excess cost attributable to childhood overweight and obesity		6,074	671.8 (PAF = 14.9%)

Lifetime indirect costs

Productivity losses due to absenteeism

Table 27 and Table 28 show projected productivity losses due to absenteeism attributable to childhood overweight and obesity. For both the Republic of Ireland and Northern Ireland projected costs were higher among females than males (€299.6 million and €223.5 million, respectively, for the Republic of Ireland; and €68.4 million and €59.2 million, respectively, for Northern Ireland). This reflects, in part, differences between males and females in duration of illness due to differences in life expectancy of the genders. Total projected excess costs due to absenteeism for the Republic of Ireland and Northern Ireland were estimated at €523.1 million and €127.6 million, respectively.

Table 27 Lifetime productivity losses due to absenteeism attributable to childhood overweight and obesity in the Republic of Ireland – Closed Cohort Simulation Model estimates

Sex	BMI at 18 years	Number of children in 2015	Cost per person (€, 2015 values)	Total cost (€ millions, 2015 values)
Males	Overweight or obese	137,459	3,011	413.9
	Healthy weight	475,335	1,386	658.6
	All BMIs	612,794	1,750	1,072.5
	Excess cost attributable to childhood overweight and obesity		1,626	223.5 (PAF = 20.8%)
Females	Overweight or obese	144,292	3,326	479.9
	Healthy weight	442,234	1,250	552.6
	All BMIs	586,526	1,760	1,032.5
	Excess cost attributable to childhood overweight and obesity		2,076	299.6 (PAF = 29.0%)
Total	Overweight or obese	281,751	3,172	893.8
	Healthy weight	917,569	1,320	1,211.2
	All BMIs	1,199,320	1,755	2,105.0
	Excess cost attributable to childhood overweight and obesity		1,852	523.1 (PAF = 24.8%)

Table 28 Lifetime productivity losses due to absenteeism attributable to childhood overweight and obesity in Northern Ireland – Closed Cohort Simulation Model estimates

Sex	BMI at 18 years	Number of children in 2015	Cost per person (€, 2015 values)	Total cost (€ millions, 2015 values)
Males	Overweight or obese	51,140	2,601	133.0
	Healthy weight	170,935	1,443	246.7
	All BMIs	222,075	1,710	379.7
	Excess cost attributable to childhood overweight and obesity		1,157	59.2 (PAF = 15.6%)
Females	Overweight or obese	60,735	2,920	177.4
	Healthy weight	149,981	1,794	269.1
	All BMIs	210,716	2,119	446.4
	Excess cost attributable to childhood overweight and obesity		1,126	68.4 (PAF = 15.3%)
Total	Overweight or obese	111,875	2,774	310.4
	Healthy weight	320,916	1,607	515.8
	All BMIs	432,791	1,909	826.2
	Excess cost attributable to childhood overweight and obesity		1,167	127.6 (PAF = 15.8%)

Productivity losses due to premature mortality

Table 29 and Table 30 show projected productivity losses due to premature mortality amongst the Republic of Ireland and Northern Ireland's 2015 child population. These are based on estimates of premature death attributable to childhood overweight or obesity. Excess productivity losses due to overweight and obesity are noticeably higher amongst males, accounting for 74% and 75% of total projected excess costs for the Republic of Ireland and Northern Ireland, respectively. Total lifetime productivity losses due to premature death were estimated at €2.9 billion for the Republic of Ireland and €1.7 billion for Northern Ireland.

Table 29 Lifetime productivity losses due to premature mortality attributable to childhood overweight and obesity in the Republic of Ireland – Closed Cohort Simulation Model estimates

Sex	BMI at 18 years	Number of children in 2015	Cost per person (€, 2015 values)	Total cost (€ millions, 2015 values)
Males	Overweight or obese	137,459	29,098	4,000
	Healthy weight	475,335	13,783	6,551
	All BMIs	612,794	17,218	10,551
	Excess cost attributable to childhood overweight and obesity		15,316	2,105.3 (PAF = 20.0%)
Females	Overweight or obese	144,292	11,225	1,620
	Healthy weight	442,234	5,984	2,646
	All BMIs	586,526	7,273	4,266
	Excess cost attributable to childhood overweight and obesity		5,242	756.4 (PAF = 17.7%)
Total	Overweight or obese	281,751	19,945	5,620
	Healthy weight	917,569	10,024	9,198
	All BMIs	1,199,320	12,355	14,817
	Excess cost attributable to childhood overweight and obesity		9,921	2,861.7 (PAF = 18.9%)

Table 30 Lifetime productivity losses due to premature mortality attributable to childhood overweight and obesity in Northern Ireland – Closed Cohort Simulation Model estimates

Sex	BMI at 18 years	Number of children in 2015	Cost per person (€, 2015 values)	Total cost (€ millions, 2015 values)
Males	Overweight or obese	51,140	36,736	1,879
	Healthy weight	170,935	12,319	2,106
	All BMIs	222,075	17,942	3,984
	Excess cost attributable to childhood overweight and obesity		24,417	1,248.7 (PAF = 31.3%)
Females	Overweight or obese	60,735	12,461	757
	Healthy weight	149,981	5,625	844
	All BMIs	210,716	7,595	1,600
	Excess cost attributable to childhood overweight and obesity		6,835	415.1 (PAF = 25.9%)
Total	Overweight or obese	111,875	23,557	2,636
	Healthy weight	320,916	9,191	2,949
	All BMIs	432,791	12,904	5,585
	Excess cost attributable to childhood overweight and obesity		14,367	1,663.8 (PAF = 28.8%)

Lifetime income losses

The lifetime income losses to the year 2105 for the 2015 child population in the Republic of Ireland and Northern Ireland are examined in Table 31 and Table 32. It should be noted that income losses are calculated relative to the total population and, unlike other impacts and costs, are not experienced by individuals that were of healthy weight at age 18 years. For the Republic of Ireland, total lifetime income losses were estimated at €256 million (€151.7 million for males and €104.3 million for females). For Northern Ireland, total projected income losses were estimated at €116.2 million (€69.8 million for males and €46.4 million for females).

Table 31 Lifetime income losses attributable to childhood overweight and obesity in the Republic of Ireland – Closed Cohort Simulation Model estimates

Sex	Number of overweight or obese children in 2015	Lifetime income loss per person (€, 2015 values)	Total lifetime income loss (€ millions, 2015 values)
Males	137,459	1,104	151.7
Females	144,292	723	104.3
Total	281,751	909	256.0

Table 32 Lifetime income losses attributable to childhood overweight and obesity in Northern Ireland – Closed Cohort Simulation Model estimates

Sex	Number of overweight or obese children in 2015	Lifetime income loss per person (€, 2015 values)	Total lifetime income loss (€ millions, 2015 values)
Males	51,140	1,365	69.8
Females	60,735	764	46.4
Total	111,875	1,039	116.2

Total lifetime direct and indirect impacts and costs attributable to childhood overweight and obesity

Table 33 and Table 34 display a summary of the lifetime impacts and costs attributable to childhood overweight and obesity for the Republic of Ireland and Northern Ireland. For the Republic of Ireland, the lifetime direct and indirect costs were estimated at €4.6 billion and for Northern Ireland the estimated cost was €2.6 billion. The total excess cost per person, discounted to 2015 values, was estimated to be €16,036 for the Republic of Ireland and €22,647 for Northern Ireland.

In the Republic of Ireland, 21% of these lifetime costs are direct healthcare costs, and 79% are indirect costs. For Northern Ireland, 26% of the costs estimated are direct healthcare costs, and 74% are indirect costs.

Reductions in lifetime costs associated with 1% and 5% reductions in population mean childhood body mass index (BMI)

A summary of reduced impacts and costs that are associated with 1% and 5% reductions in population mean childhood BMI is shown in Table 35 and Tabl3 36.

For the Republic of Ireland, a 1% and 5% reduction was associated with a €270 million and €1.1 billion reduction in total lifetime costs, discounted to 2015 values. This equates to a reduction of €958 and €4,000 per person, respectively.

For Northern Ireland, a 1% and 5% reduction in population mean BMI was associated with a €95.8 million and €396.8 million reduction in total lifetime costs, which equates to an €856 and €3,546 cost per person reduction, respectively.

Table 33 Summary of total lifetime direct and indirect impacts and costs attributable to childhood overweight and obesity in the Republic of Ireland – Closed Cohort Simulation Model estimates

Sex	Direct healthcare (€ millions, 2015 values)	Productivity loss (absenteeism) (€ millions, 2015 values)	Productivity loss (premature mortality) (€ millions, 2015 values)	Lifetime income loss (€ millions, 2015 values)	Total cost (€ millions, 2015 values)	Cost per person (€, 2015 values)	Number of pre-mature deaths*
Males	422.0	223.5	2,105.3	151.7	2,902.5	21,115	26,202
Females	527.0	299.6	756.4	104.3	1,687.3	11,694	28,854
Total	949.0	523.1	2,861.7	256.0	4,589.8	16,036	55,056

*Lifetime risk of premature death was higher amongst males. However, the number of lifetime premature deaths is greater in females as the prevalence of overweight and obesity in the 2015 child population was higher amongst female children.

Table 34 Summary of total lifetime direct and indirect impacts and costs attributable to childhood overweight and obesity in Northern Ireland – Closed Cohort Simulation Model estimates

Sex	Direct healthcare (€ millions, 2015 values)	Productivity loss (absenteeism) (€ millions, 2015 values)	Productivity loss (premature mortality) (€ millions, 2015 values)	Lifetime income loss (€ millions, 2015 values)	Total cost (€ millions, 2015 values)	Cost per person (€, 2015 values)	Number of pre-mature deaths*
Males	334.8	59.2	1,248.7	69.8	1,712.5	33,487	15,279
Females	337.0	68.4	415.1	46.4	866.9	14,275	15,353
Total	671.8	127.6	1,663.8	116.2	2,579.4	22,647	30,632

*Lifetime risk of premature death was higher amongst males. However, the number of lifetime premature deaths is greater in females as the prevalence of overweight and obesity in the 2015 child population was higher amongst female children.

Table 35 Reductions in lifetime healthcare costs, productivity losses and income losses associated with 1% and 5% reductions in population mean childhood body mass index (BMI) in the Republic of Ireland – Closed Cohort Simulation Model estimates

Sex	Scenario: reduction in mean BMI (%)	Direct health-care (€ millions, 2015 values)	Productivity loss (absenteeism) (€ millions, 2015 values)	Productivity loss (premature mortality) (€ millions, 2015 values)	Lifetime income loss (€ millions, 2015 values)	Total cost reduction (€ millions, 2015 values)	Total cost reduction per person (€, 2015 values)	Total reduction in number of pre-mature deaths
Males	1	26.4	16.1	125.5	8.6	176.5	1,284	1,272
	5	123.7	70.4	516.7	38.8	749.5	5,453	5,948
Females	1	27.5	17.4	43.5	5.0	93.5	648	683
	5	122.0	78.6	154.3	22.7	377.6	2,617	3,321
Total	1	53.9	33.5	169.0	13.5	270.0	958	1,955
	5	245.7	149.0	671.0	61.4	1,127.1	4,000	9,269

Table 36 Reductions in lifetime healthcare costs, productivity losses and income losses associated with 1% and 5% reductions in population mean childhood body mass index (BMI) in Northern Ireland – Closed Cohort Simulation Model estimates

Sex	Scenario: reduction in mean BMI (%)	Direct health-care (€ millions, 2015 values)	Productivity loss (absenteeism) (€ millions, 2015 values)	Productivity loss (premature mortality) (€ millions, 2015 values)	Lifetime income loss (€ millions, 2015 values)	Total cost reduction (€ millions, 2015 values)	Total cost reduction per person (€, 2015 values)	Total reduction in number of pre-mature deaths
Males	1	11.2	2.1	52.7	2.6	68.6	1,341	269
	5	51.7	10.4	199.8	12.7	274.6	5,369	1,267
Females	1	11.0	2.2	12.6	1.5	27.2	448	289
	5	48.4	10.3	56.1	7.4	122.2	2,012	1,254
Total	1	22.2	4.4	65.2	4.0	95.8	856	558
	5	100.1	20.7	255.9	20.1	396.8	3,546	2,521

6 Discussion

This study provides the first estimates of the current and lifetime costs of childhood overweight and obesity on the island of Ireland. The current cost estimates incorporate direct healthcare costs. The lifetime costs take into account additional indirect costs, such as productivity losses due to absenteeism and premature mortality, as well as income losses that are borne during adulthood.

The current annual direct healthcare costs amongst children attributable to childhood overweight and obesity for the Republic of Ireland (2015) are estimated at €1.7 million using a standard cost-of-illness analysis and €1.3 million using the Closed Cohort Simulation Model-based approach. For Northern Ireland, it was not possible to apply the direct cost-of-illness analysis. Based on the Closed Cohort Simulation Model analysis, the estimated current costs for Northern Ireland were €0.7 million. The projected lifetime costs from the Closed Cohort Simulation Model analyses (including indirect costs) to the year 2105 that are attributable to overweight and obesity are €4.6 billion and €2.6 billion for the Republic of Ireland and Northern Ireland, respectively. Thus, the total lifetime cost for the island of Ireland (discounted to 2015 rates) is estimated at €7.2 billion.

The indirect societal costs account for 79% of total estimated lifetime costs in the Republic of Ireland and 74% of the costs for Northern Ireland. For the Republic of Ireland, the estimated excess lifetime cost attributable to childhood obesity and overweight (discounted to 2015 values) is €16,036 per person; the equivalent estimate for Northern Ireland is €22,647 per person. The findings from the Closed Cohort Simulation Model suggest that a 1% and 5% reduction in population mean childhood BMI would be associated with a €270 million and €1.1 billion reduction in projected lifetime costs, respectively, in the Republic of Ireland; and €95.8 million and €396.8 million reductions in projected lifetime costs, respectively, in Northern Ireland.

Although the international literature on lifetime costs among children is limited and somewhat inconsistent, the findings on the distribution of costs between direct healthcare and indirect societal costs are in agreement with previous research. By contrast, the estimates of excess lifetime costs attributable to childhood overweight and obesity are lower than those reported in the literature to date. However, comparisons are difficult as a majority of the previous studies focussed exclusively on either direct or indirect costs, and the literature is dominated by studies from the US, where direct healthcare costs are considerably higher than in Europe.

The estimates of both current and lifetime cost are based on comprehensive reviews of the relevant literature, including work on

1. The current prevalence of overweight and obesity in childhood
2. The burden of childhood morbidity associated with excess weight
3. The effects of childhood adiposity on the risk of overweight and obesity, chronic disease, quality of life and mortality in adult life
4. The effects of childhood obesity on educational outcomes and school attendance
5. A detailed review of previous studies of the lifetime costs of childhood overweight and obesity.

Highlights from the series of literature reviews include evidence that the prevalence of childhood overweight and obesity has stabilised on the island of Ireland, and may be decreasing among primary school-aged children. Nevertheless, current prevalence estimates remain unacceptably high, with 20% of boys and 25% of girls being overweight or obese. Although the evidence for associations between increased adiposity in adulthood and a range of chronic conditions and premature mortality is clear and well established, the quality of the evidence linking childhood overweight and obesity with current morbidity in childhood, and directly with morbidity and mortality in adult life, is relatively poor.

There is, however, clear and consistent evidence that childhood obesity is a strong predictor of adult obesity. The findings on this issue were integral to the development and application of the Closed Cohort Simulation Model. Pooled results from 15 high-quality cohort studies demonstrated that children who were obese at the ages of 7 to 18 years were 5 times more likely to be obese as adults compared with non-obese children. Approximately 55% of obese children will remain obese into adolescence and approximately 70% of obese adolescents will remain obese over the age of 30 years.

By contrast, evidence on the effects of excess weight on school attendance and educational outcomes in childhood remains uncertain due to inconsistencies and methodological limitations among studies, including over-reliance on cross-sectional study designs, which do not permit clear separation of causes from effects.

The review of previous studies of the lifetime costs of childhood overweight and obesity highlighted the extent to which the indirect societal costs of childhood overweight and obesity are consistently greater than the direct healthcare-related costs, confirming the importance of including indirect costs in estimates of the economic burden of excess weight. Additional important findings from the literature review included inconsistencies in how excess adiposity is defined (in particular among children and adolescents) and the fact that there are a number of potentially important impacts that

have not been incorporated into cost-of-illness studies to date. These include presenteeism (working while sick) in adulthood, and indirect costs in childhood such as school absenteeism with attendant family costs.

This work complements and extends the earlier work commissioned by *safe*food [2], which estimated the annual costs of overweight and obesity among adults on the island of Ireland. In that study, the current annual cost estimates for the Republic of Ireland and Northern Ireland were €1.13 billion and €510 million, respectively. In the Republic of Ireland, 35% of these costs were direct healthcare costs and 65% were indirect costs. For Northern Ireland, 25% of the costs were direct healthcare costs and 75% were indirect costs. While the annual costs to all adults are not directly comparable to the lifetime costs among all children, the distribution of costs between direct healthcare and indirect societal costs is broadly similar in the 2 studies.

The modelling of current and lifetime costs forms a continuum. In this study we combine estimates of current excess healthcare costs attributable to childhood overweight and obesity with estimates of direct and indirect costs over the life-course derived from the Closed Cohort Simulation Model. The Closed Cohort Simulation Model-based estimates of current excess healthcare costs amongst children in the Republic of Ireland (€1.3 million) and the Cost-of-Illness Study estimates (€1.7 million) are broadly similar. It should be noted that the level of agreement between these estimates would be even greater if the Closed Cohort Simulation Model had included the estimated annual costs of specialist tertiary care for children with severe obesity, provided by Temple Street Children's University Hospital, Dublin.

It was not possible to estimate the current cost of childhood overweight and obesity for Northern Ireland using the Direct Cost-of-Illness method due to a relative lack of granularity (detail) in the available data from Northern Ireland. However, the level of agreement between the Cost-of-Illness Study and Closed Cohort Simulation Model estimates for the Republic of Ireland provides a degree of confidence in the Closed Cohort Simulation Model-based estimates of current excess healthcare costs for Northern Ireland.

There will inevitably be some divergence between Cost-of-Illness Study- and Closed Cohort Simulation Model-derived estimates of current costs, reflecting methodological differences between these approaches. The Direct Cost-of-Illness Study uses a top-down, largely deterministic approach; the Closed Cohort Simulation Model-based analysis introduces additional probabilistic (likely) variation linked to sampling error in the construction of the initial "virtual" cohort of children and in the model inputs on estimates of disease occurrence and survival from disease. The Direct Cost-of-Illness Study defined a child as 0 to 18 years of age, while the Closed Cohort Simulation Model uses children aged 0 to 17 years.

As discussed in the earlier work on current costs of obesity in adults [2], research on the costs of chronic conditions such as overweight and obesity has important limitations that must be noted in our interpretation of the findings presented in this report. While it is accepted that overweight and obesity increase the risk of illness, absenteeism from the workplace and early death, the magnitude of these effects in the population is measured with poor precision. There is even greater imprecision or uncertainty in the estimation of associated direct healthcare costs and indirect societal costs in both children and adults. Indeed, for some impacts, such as the effects of childhood overweight and obesity on psychosocial wellbeing, human capital and the economy (including school attendance, school performance, preparedness for work and position in the workforce), we lacked usable data for inclusion in either the Cost-of-Illness or Closed Cohort Simulation Model studies.

In the present study, it is noteworthy that the current direct healthcare cost estimates among children are modest. This chiefly reflects the fact that most of the obesity-related diseases occur later in life. The relatively small total current costs also reflect the fact that key health impacts such as behavioural and emotional difficulties, linked to overweight and obesity, could not be included in the analyses because adequate data are not available.

It should also be noted that additional factors such as stigmatisation, poor socialisation and reduced educational attainment have consequences and costs, both in childhood and adult life that are not adequately captured in this study. While the lifetime cost estimates derived from the Closed Cohort Simulation Model are substantial, similar issues of imprecision in key model inputs and lack of data on important potential impacts arise in relation to this model.

Thus, it may be argued that we have taken a conservative approach in estimating the burden of suffering, premature mortality and costs associated with childhood overweight and obesity over the life-course. For instance, although the impact of overweight and obesity on psychosocial wellbeing is well recognised in adults as in childhood, it is only incorporated in the Closed Cohort Simulation Model study through relatively imprecise measures of quality-adjusted life years (QALYs). It should also be noted that in the assessment of productivity losses, the economic and social contributions of retired people (those between 65 and 75 years) has been assumed to be one-third of those aged under 65 years, and no monetary value has been assigned to productivity losses experienced by persons over 75 years.

Further evidence of the conservative approach taken in these analyses is provided by the omission of “deadweight” costs from the overall estimates of the cost of overweight and obesity. Deadweight loss refers to the reductions in state funds available for other purposes that arise from the need to fund care and support for individuals who are ill or unemployed as a result of, in this case, overweight or obesity. Underlying the calculation of deadweight costs is the notion that governments must raise

taxes to fund these activities – taxes that draw on resources that could be deployed more productively in other settings.

It should be noted that the Closed Cohort Simulation Model developed for this study represents novel (new) modelling technology, and its application to the lifetime impacts and costs of childhood overweight and obesity is likely to require further refinement. While the Closed Cohort Simulation Model was based on the Foresight Obesity Model, which was developed by the UKHF and is now well established [4], the adaptations required for the model deployed in the current study were substantial and further development of this model can be anticipated. During this study we noted a number of significant improvements that could have been made (both to the conceptual model and its software implementation) that would enhance the applicability of the model in the conduct of cost-of-obesity studies.

7 Conclusions

Given the limitations and caveats, or conditions, discussed above, we suggest that the value of cost-of-illness studies, including the current study, derives primarily from their ability to inform discussion of the relative economic burden associated with major health problems, as opposed to the precise quantification of absolute costs.

There are additional conceptual and methodological challenges in the conduct of cost-of-illness studies. For instance, given the extent of fixed staffing and infrastructure cost in health systems, one might reasonably ask, how much of the estimated costs would be saved if the current burden of overweight and obesity were reduced? In the context of priority setting, it is arguable that estimation of the absolute burden, or costs of illness, provides a poor measure of relative need. The "need" is determined both by the burden of disease and the capacity to benefit from interventions. Thus, under ideal circumstances, the priority assigned to overweight and obesity in public policy should be driven primarily by estimates of the incremental costs and the incremental benefits of interventions to prevent and/or manage overweight and obesity.

To some extent, the issues of incremental costs and benefits are addressed in the Closed Cohort Simulation Model study, which estimates the reductions in impacts and costs that could be expected to follow from 1% and 5% reductions in population mean childhood BMI, with potential applications to cost-effectiveness analyses focussed on specific interventions such as the proposed tax on sugar-sweetened beverages. However, as with all modelling exercises, and given the limitation addressed above, the findings from the Closed Cohort Simulation Model should be considered as indicative and interpreted with caution.

It may be argued that cost-of-illness studies (including the earlier current cost of obesity in adults study [2]) have influenced policy at an international (WHO) level and in Ireland. The current epidemic of overweight and obesity in children and adults has evolved over a relatively short timescale (approximately 3 decades). Reliable, contemporary and locally relevant data on the human and economic burden of this epidemic provide powerful evidence on the consequences of our failure to manage this societal challenge. In particular, these data highlight the external (third party) costs of current models of food production and marketing and our relative failure at a societal level to promote high levels of physical activity through walking, cycling and public transport throughout the life-course.

It is arguable, therefore, that these estimates of the current and future cost of childhood overweight and obesity, which err on the side of caution, are needed to initiate an appropriate level of urgency, among policy makers and wider society, on the need to implement effective system-level prevention strategies, with the potential to shift the entire population distribution of excess weight toward more optimal levels.

Policy context

The recommendations and implementation steps of the Republic of Ireland's current "Obesity Policy and Action Plan 2016–2025" are noted. These are set out in *A Healthy Weight for Ireland* [11] and have been developed within the broader "Healthy Ireland" (HI) framework. The Obesity Policy and Action Plan has set short-term (5-year) targets for overweight and obesity. These are:

- A sustained downward trend (averaging 0.5% per annum as measured by the HI Survey) in the level of excess weight averaged across all adults
- A sustained downward trend (averaging 0.5% per annum) as measured by the Childhood Obesity Surveillance Initiative (COSI) in the level of excess weight in children
- A reduction in the gap in obesity levels between the highest and lowest socioeconomic groups by 10%, as measured by the HI and COSI Surveys.

For Northern Ireland, policy is evolving within a broadly similar framework as set out in *Childhood Obesity – A Plan for Action* [12].

The estimates of the current and future costs of childhood overweight and obesity presented in this report, including the projected reductions in impacts and costs that could be expected to follow from 1% and 5% reductions in population mean childhood BMI, highlight the need for specific dedicated funding to ensure that, at minimum, we meet the targets set out in these policy documents.

As set out in *A Healthy Weight for Ireland*, access to a healthy diet can be addressed from a human rights perspective. In a report to the United Nations Human Rights Council, the then-Special Rapporteur identified 5 priority actions, based on evidence, to address the issues of obesity and unhealthy diets [13]. These were:

- Taxing unhealthy products
- Regulating foods high in saturated fats, salt and sugar
- Restricting "junk food" advertising
- Overhauling agricultural subsidies that make certain ingredients cheaper than others
- Supporting local food production so that consumers have access to healthy, fresh and nutritious foods.

In the Republic of Ireland, the issue of childhood overweight and obesity may need to be considered in the context of the 2015 enactment of the Thirty-first Amendment of the Irish Constitution relating to children's rights. This may provide a legal basis for a more robust approach to the regulation of the food sector and the need to mitigate, or offset, the effects of an obesogenic environment.

It is increasingly clear that educational and other strategies focussed on the prevention of overweight and obesity in childhood that operate at the level of the individual, the family or the school, are not effective – even if applied with significant resources and at a high level of intensity. An epidemic rooted in societal-level structures and processes requires a societal-level response. The 2016 WHO Report of the Commission on Ending Childhood Obesity [14] highlights key societal-level measures required to promote the intake of healthy foods in order to reduce the intake of unhealthy foods and sugar-sweetened beverages by children and adolescents:

- Ensure that appropriate and context-specific nutrition information and guidelines, for both adults and children, are developed and disseminated (communicated) in a simple, understandable and accessible way to all groups in society.
- Implement an effective tax on sugar-sweetened beverages.
- Develop and implement appropriate recommendations on the marketing of foods and non-alcoholic beverages to children in order to reduce the exposure of children and adolescents to, and the power of, the marketing of unhealthy foods and drinks.
- Develop nutrient profiles to identify unhealthy foods and beverages.
- Ensure international cooperation between Member States to reduce the impact of cross-border marketing of unhealthy foods and beverages.
- Implement a standardised global nutrient labelling system.
- Implement interpretive front-of-pack labelling, supported by public education of both adults and children, for nutrition literacy. (An example of this is the “traffic light” labelling system where “red” indicates high levels of, say, sugar or saturated fats.)
- Require settings such as schools, child-care settings, children’s sports facilities and events to create healthy food environments.
- Increase access to healthy foods in disadvantaged communities.

Progress on these issues will require strong central leadership in setting the policy direction, with sustained support at the highest levels of government to enable the intersectoral actions that are required.

8 Recommendations

1. The obesity strategies and action plans in the Republic of Ireland and Northern Ireland should be implemented and supported, with adequate resources to prevent and manage childhood overweight and obesity. The conservatively estimated lifetime costs estimated in this research identify an unsustainable situation, with costs defaulting to the taxpayer, and are creating a legacy of debt for future generations that require this public health epidemic be tackled.
2. A whole population and life-course approach to the obesity epidemic is necessary to ameliorate, or lessen the effects of, the current epidemic, with a strong emphasis on intervening in the obesogenic environment (challenging unhealthy food choices and inadequate physical activity), balanced with supports for parents and carers.
3. An annual evaluation of progress of the obesity action plans including, for example, the impact of measures such as the tax on sugar-sweetened drinks, is indicated, given the demonstrated potential benefit (financial and societal) of interventions to address overweight and obesity highlighted by this research.
4. There must be increased investment in data collection that will provide accurate and reliable population-based data for conducting cost-of-illness studies and related health economic analysis. Data collected must include information on utilisation of health services (both primary care and hospital services) and illness-related productivity loss and absenteeism from work and school.
5. Research into the psychosocial impacts of overweight and obesity on the island of Ireland is warranted, given the information gap identified.

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