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**Title:** The Cost of Type 1 Diabetes Mellitus in the United Kingdom: A Review of Cost-of-Illness Studies

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## **ABSTRACT**

### **Aims**

To identify cost-of-illness studies of Type 1 diabetes mellitus (Type 1 DM) in the United Kingdom (UK) and review this literature to estimate the current cost of Type 1 DM to the UK National Health Service.

### **Methods**

Bibliographic databases and grey literature were systematically searched to identify all published and unpublished reporting of the costs of Type 1 DM in the UK. Studies were excluded if they did not present cost information from the UK or did not disaggregate information by diabetes type. Three grey literature sources and 11 published studies were identified for inclusion in the literature review.

### **Results**

The included studies and reports covered topics including the overall cost of Type 1 DM, costs of individual diabetic complications and costs of specific interventions for Type 1 DM. The most recent published estimate of the cost of Type 1 DM was over 15 years old, and although this estimate has been inflated to current prices the estimate is not adjusted for changes to treatment pathways over this period and is therefore not considered an accurate estimate of current costs of Type 1 DM.

### **Conclusions**

There is not a recently published estimate of the cost of Type 1 DM in the UK therefore it is recommended that an up-to-date national, comprehensive COI study should be conducted. Recommendations for the format of this study are made, including extending the scope to cover recent treatment developments and resource use where diabetes is a subsidiary diagnosis.

**Keywords:** diabetes, type 1 diabetes, cost, cost-of-illness, economic

**JEL codes:** I10 – General Health  
I19 Other Health

## 1. INTRODUCTION

Insulin treatment, regular screening for and treatment of long-term complications in Type 1 diabetes mellitus (Type 1 DM) result in costs to patients, carers, and the National Health Service (NHS) in the United Kingdom (UK). Scientific research priorities are set using a range of criteria and the burden of disease is often used to consider priority areas for research funding [1]. Type 1 DM has not been a specific research priority in the UK to date. There has instead been a focus on the costs associated with the increasing prevalence of Type 2 diabetes mellitus (Type 2 DM) and with the burden presented by diabetes as a whole [2, 3]. Ettaro et al [4] estimated that 3% of the UK population have diabetes (all types) but that it consumes more than 9% of the NHS budget, and Currie & Peters [5] estimated that all diabetes and its complications consume more than 5% of NHS annual expenditure.

The cost issues of Type 1 DM differ from those of Type 2 DM as all patients with Type 1 DM consume insulin-replacement resources throughout their lifetimes whereas Type 2 DM can often be prevented and/or treated with lifestyle modification alone. Type 1 DM also results in higher rates of hospitalisation for ophthalmic and renal complications compared with Type 2 DM [6]. This study focuses on the costs of Type 1 DM specifically as this area represents a gap in the national research agenda. Quantifying clear costs of Type 1 DM and disentangling the costs associated with the two main types of diabetes would contribute to several areas of healthcare provision and research in the UK. Overall cost burden estimates would support research funders to compare levels of funding for different disease areas to the distribution of costs to the NHS and to wider society of the same diseases. Disease-level cost estimates would also support commissioners at the strategic national level to consider whether the levels of expenditure for prevention and treatment of diseases are appropriate, for example by informing programme budgeting. The NHS reported that in 2009/10 £1.4 billion was spent on the diabetes care programme in England, compared to £2.5 billion on coronary heart disease care and £5.8 billion on cancer care [7]. The NHS Programme Budgeting data [7] do not include a breakdown of costs by type of diabetes therefore there is no guidance for commissioners regarding the allocation of diabetes resources between care programmes for the different types of diabetes.

Evidence which disentangles these top level costs would also be useful to the research and healthcare communities. For example, unit cost and unit resource use estimates would be valuable for use in cost-effectiveness models to support National Institute for health and Clinical Excellence (NICE) appraisals and in health technology assessment more widely. Healthcare trusts are also likely to benefit from clearer unit-level costs, which could be used

to assist in planning investments and in drawing up business cases for new healthcare technologies.

From a health economic perspective any chronic disease will incur several different types of costs. For Type 1 DM in the UK these include direct costs of treatment to the NHS (e.g. insulin), direct costs of complications to the NHS (e.g. Angiotensin-converting enzyme (ACE) inhibitors for nephropathy), indirect costs (including travel time and productivity losses) and intangible costs to the patients (e.g. pain and suffering associated with treatment).

Information on the cost of Type 1 DM can be identified from cost-of-illness (COI) studies or economic evaluations of particular interventions for the disease. COI is “...a *method of calculating the resources used to prevent, detect, and treat a disease, in absolute terms...*” [8] and is used to estimate the total cost of an illness in a specified healthcare setting. Economic evaluation involves the comparative analysis of alternative healthcare interventions in terms of both their costs and benefits [9].

The aims of the current study are to identify and critically appraise all previous COI studies of Type 1 DM in the UK and to provide a current estimate of the cost of Type 1 DM in the UK.

## 2. METHODS

### 2.1. Literature search

A search of published literature was conducted in March 2010 using the following bibliographic databases: Cochrane Database of Systematic Reviews via Cochrane library; DARE via Cochrane library; Health Technology Assessment via Cochrane library; NHS Economic Evaluation Database; EMBASE via Ovid; MEDLINE via Ovid 1948 to March 2010; PsychInfo via Ovid. The search used a combination of MeSH headings and free text key terms relating to Type 1 DM. The Scottish Intercollegiate Guidelines Network search filter for economic studies SIGN [10] was included to specify economic studies rather than other study designs of Type 1 DM. The full list of search terms is presented in Figure 1. The search covered a range of dates from the 1940s through to 2010.

#### **Fig.1** Bibliographic database search strategy

A two-stage screening process was conducted using pre-specified inclusion and exclusion criteria. Firstly a reviewer screened the titles and abstracts of the search results for potentially relevant studies then the full manuscript of all potentially relevant studies was retrieved and assessed. A study was included if it reported UK-specific information on the costs of diabetes and reported Type 1-specific information separately from Type 2 information. Studies were excluded if they did not present cost information from the UK, did not disaggregate information by diabetes type, or were published in a language other than English. Economic evaluations were excluded unless they reported estimates of absolute annual or lifetime costs of interventions. The bibliographies of review studies that reported relevant results (i.e. UK setting and Type 1-specific results) were searched and pertinent primary studies were added to the review.

Grey literature was also searched to identify unpublished data on the costs of Type 1 DM. Online resources of relevant government, NHS and diabetes-related organisations [11-24] were accessed in July and August 2010 and searched for any information regarding the cost of Type 1 DM in the UK. Grey literature was only deemed relevant if it presented UK data split by diabetes type.

Epidemiological data on the incidence and prevalence of Type 1 DM was included if it was identified whilst searching for cost data in the grey literature. These burden-of-illness estimates were included in the review so that if an estimate of the cost per patient of Type 1

DM was identified this could be combined with epidemiological data to estimate population level costs.

## **2.2. Review methodology**

For each included study a single reviewer extracted data relating to the aims of the study, the study design, the setting, the data sources used and any reported characteristics of the population for which costs were estimated, the methods used to estimate costs, the types of cost included (e.g. direct or indirect; overall cost or cost of individual diabetic complications), and the results in terms of estimated unit costs, overall costs, and any epidemiological results.

Each included study was critically appraised based on the methodological framework outlined by Pagano et al [25]. This focused on definition of diabetes, the epidemiological approach, the perspective of the analysis, how resource use was estimated, how unit costs were valued, whether sensitivity analyses were conducted, and how results were presented.

Although the review was not a full systematic review it did fulfil items 3, 6-9, 17, and 24-26 of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2009 [26].

## **2.3. Data Analysis**

Data on annual costs of Type 1 DM was extracted from each included paper. Where multiple categories of costs were reported (e.g. drug costs and costs of contacts with healthcare practitioners) all the categories were extracted.

In order to estimate the current cost of Type 1 DM, each cost data item from the included papers was inflated to 2010-11 prices using Hospital & Community Health Services (HCHS) inflation indices from the Personal Social Services Research Unit (PSSRU) [27]. The cost in 2010-11 was calculated as the ratio of the HCHS Pay & Prices Index for 2010-11 to the HCHS Pay & Prices Index for the year of the published cost, multiplied by the published cost. No further adjustment was made in estimating current costs of Type 1DM.

### **3. RESULTS**

#### **3.1. Summary of evidence**

The search strategy returned a total of 2,107 records, of which nine fully met the inclusion criteria. The majority of the papers excluded as not being relevant to the UK were from non-European countries (n = 82, mostly US) and 35 were from non-UK European countries. Details of studies excluded at the full paper stage can be found in Appendix A. Five relevant reviews were also identified and two additional studies meeting the inclusion criteria were identified from their bibliographies, giving a total of 11 published studies that were included in the review (see Figure 2 and Table 1). Three grey literature sources also reported data relevant to the review [17, 28, 29]. All the studies used prevalence-based methods to report information about the cost of Type 1 DM for a specific annual period.

Three published studies provided estimates of the overall cost of Type 1 DM [8, 30, 31], three estimated the cost of a single diabetic complication only [32-34], two estimated the total costs of prescribing for Type 1 DM [5, 35], and one estimated the costs of insulin treatment [36]. Two published studies [37, 38] and one grey literature report [28] estimated the cost of insulin pumps and two further grey literature sources provided evidence on the epidemiology of Type 1 DM but not costs [17, 29].

**Fig.2** Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart of study selection process

#### **3.2. Epidemiology of Type 1 DM in the UK**

Of the 11 included published studies, six did not include any estimate of the incidence or prevalence of Type 1 DM in the UK [5, 30-32, 36, 37]. Of the remaining five studies, one reported an incidence rate of 19.3 per 10,000 patient years [38], and the others reported prevalence rates of 1.84 [8], 2.40 [35], and 2.67 per 1,000 people [33, 34]. The 2010 population of the UK has been estimated by the Office for National Statistics as 62,262,000 [39]. Combining this value with the prevalence rates reported in the four studies results in estimates of the number of people with Type 1 DM in the UK ranging from 114,562 and 166,240.



Two of the included grey literature sources [17, 29] provided information on the epidemiology of Type 1 DM. However, a nationally accepted estimate of the prevalence or incidence of Type 1 DM in the UK was not identified. The Association of Public Health Observatories (APHO) Diabetes Prevalence Model [29] was identified as the most up to date estimate of overall diabetes prevalence in the UK [Yorkshire and Humber Public Health Observatory personal communication 2010]; however this tool did not split results by diabetes type. de Lusignan et al [40] developed an algorithm to estimate the prevalence of Type 1 DM using data from the CONDUIT [41] and QICKD [42] studies which was recommended by the Yorkshire and Humber Public Health Observatory (YHPHO) [personal communication 2010] as the most robust current evidence regarding the proportion of people with diabetes that have Type 1. A weighted average of Type 1 DM prevalence rates was estimated as 6.08% of all people with diabetes. Applying this weighted average to overall prevalence estimates from the APHO Model resulted in an estimate of 219,337 adults aged over 16 years with Type 1 DM in the UK in 2010. This estimate falls within the estimated prevalence range reported by Diabetes UK of 5-15% of 2.8 million people diagnosed with diabetes, equating to 140,000 to 420,000 people with Type 1 DM in the UK in 2010 [17]. However, the estimate is higher than implied by the prevalence rates reported in published studies.

### **3.3. Overall cost of Type 1 DM in the UK**

Gray et al [8] reported a bottom-up COI study in England and Wales using a diabetic cohort generated from incidence data from Oxford, England. The study included direct costs of treatment of Type 1 DM and its complications, costs of informal care, and indirect costs in the form of productivity losses. Unit costs published by the Department of Health and the Office of Health Economics (at 1992 prices) were combined with incidence data from the Oxford-generated cohort and resource use data from a US study of hospitalisation rates. The estimated total population with Type 1 DM in England and Wales in 1992 was 93,581. It was estimated that this cohort incurred direct costs of £95.6 million (sensitivity analyses range £77 million to £113 million) and indirect costs of £113 million (see Table 2). Currie & Peters [30] published a letter in response to Gray et al suggesting that their reported annual cost was a significant underestimate. In particular, the estimate of the number of in-patient admissions and their costs were considered low, based on comparison with Welsh data collected by Currie & Peters. This data suggested that in-patient treatment for Type 1 DM in England and Wales cost approximately £180 million annually, and insulin and monitoring cost approximately £45 million annually. These figures would lead to a substantially higher estimate of the overall annual cost of Type 1 DM to the NHS.

Currie et al [31] used a self-report survey to estimate that Type 1 DM cost an average of £3,224 (2005 prices) per patient per year in Wales. A population level cost estimate was not provided. The per-patient cost reported by Currie et al of £3,224 is very high in comparison to the costs reported by Gray et al [8], which equate to approximately £1,022 per patient per year. The difference is likely to be due to Currie et al's cohort being older with a longer duration of diabetes. This cohort was therefore likely to have higher rates of diabetic complications than Gray et al's hypothetical cohort, leading to the higher per-patient cost estimate. Unfortunately this hypothesis cannot be tested as the assumptions about rates of diabetic complications were not reported by Gray et al. Due to the atypical nature of the Currie et al cohort we did not combine their per-patient estimate with reported prevalence rates to give a population level estimate.

Several estimates of the total cost of diabetes overall in the UK were identified from the grey literature. National governmental bodies such as the Department of Health, the NHS, and HM Treasury all provide estimates of the overall cost of diabetes [7, 21, 24]. Despite these abundant sources, no estimate of the cost of Type 1 DM specifically was identified. National governmental and charitable bodies have thus far neglected to report the cost of diabetes split by diabetes type.

### **3.4. Cost of complications of Type 1 DM in the UK**

Four studies were identified that estimated the cost of individual diabetic complications: two for severe hypoglycaemia [32, 33], one for diabetic neuropathy [31] and one for diabetic nephropathy [34]. No studies were identified that estimated the cost of other diabetic complications (see Table 3).

Two studies estimated the cost of severe hypoglycaemia in the UK. Leese et al [33] used prevalence data from the Diabetes Audit and Research in Tayside Scotland/Medicines Monitoring Unit (DARTS/MEMO) Collaboration and cost data from the Information Statistics Division cost book to estimate the annual cost of severe hypoglycaemia in the UK as  $\leq$  £13 million. The cost results were not reported by diabetes type, but if it is assumed that an episode of severe hypoglycaemia costs the same for both main types of diabetes then we can estimate that severe hypoglycaemia in Type 1 DM cost  $\leq$  £6 million in the UK in 1997-98. Hammer *et al.* [32] conducted a cost analysis based on a survey of 639 patients in Spain, Germany and the UK that asked diabetes patients about their consumption of healthcare resources. By combining this data with published unit costs the authors estimated the total cost per severe hypo event for Type 1 DM patients in the UK in 2007 as ranging

from £37 to £887 (including direct costs during and following the severe hypoglycaemic event and indirect productivity loss costs). Population level cost estimates were not provided.

Currie et al [31], described above, provides data to suggest that the annual per-patient cost of diabetes increases with increasing severity of diabetic peripheral neuropathy. However, these results were not split by diabetes type so an estimate of the cost of peripheral neuropathy in Type 1 DM was not possible.

Gordois et al [34] constructed a prevalence-based COI model to estimate the annual cost of diabetic nephropathy in the USA and UK in 2001. The number of people diagnosed with diabetes and the number of people experiencing different nephropathy health states (microalbuminuria, overt nephropathy, end-stage renal disease and kidney transplant) were estimated from published data on diabetes prevalence and complication rates. These prevalence estimates were combined with published resource use and unit cost data from the USA and UK to estimate the total annual cost of diabetic nephropathy in each country. The model considered direct costs only and focussed on costs incurred in excess of what a person with diabetes but no nephropathy would incur. The total annual cost to the NHS of nephropathy in Type 1 DM in 2001 was estimated at £152 million (sensitivity analysis range £115 to £239 million). The model estimated that 12% of people with diabetes have Type 1 DM, but that Type 1 DM patients account for 20% of the total costs of diabetic nephropathy.

### **3.5. Cost of interventions for Type 1 DM in the UK**

Two studies [5, 35] investigated the total costs of prescribing for Type 1 DM using healthcare provider prescribing data. Currie & Peters [5] analysed Welsh prescribing data to estimate the cost of drugs that directly affect glucose metabolism (not drugs to treat complications of diabetes). They estimated that drugs for Type 1 DM cost on average £468 per patient year (1993-94 prices). Population level cost estimates were not reported by diabetes type. Evans et al [35] used DARTS/MEMO Collaboration data to estimate the cost of all drugs prescribed to patients diagnosed with diabetes (including drugs to treat diabetic complications). Type 1 diabetic patients accounted for 0.8% of total prescribing costs in Tayside, equating to approximately £246 per patient. This estimate is lower than that of Currie & Peters, which is surprising given that Evans et al were considering a wider range of drugs. Differences may be partly explained by the different region-specific cost sources used in the studies. Based on the total prescribing costs of the NHS, the authors suggest

that the total cost of drugs for Type 1 diabetic patients in 1995 in the UK was £36 million (£22 million for anti-diabetic drugs and £14 million for other drugs).

One study specifically investigated the cost of insulin for treatment of Type 1 DM: Poole et al [36] conducted a cost comparison of insulin glargine and insulin detemir in the UK and estimated the annual cost of treatment with glargine in 2004 as £1,198 per person and with detemir as £1,330 per person. These costs differ from anti-diabetic costs estimated by Currie & Peters [5] as the latter study was conducted before insulin detemir or glargine had been launched. Currie & Peter's analysis also excluded pen injectors and needles, whereas Poole et al conducted a more comprehensive analysis including all insulin delivery devices, testing strips, and sharps. Absolute population-level costs were not reported.

One NICE technology appraisal [28], one Health Technology Assessment (HTA) report [37], and one published study [38] were identified that provided information on the cost of continuous subcutaneous insulin infusion (CSII) for Type 1 DM. The NICE technology appraisal [28] did not present population-level estimates of total annual costs. The associated costing report [43] estimated the annual per-patient cost of providing CSII in England in 2007-08 as £1,788. This equates to a total cost of nearly £25 million to provide pump therapy in all of England, taking into account savings from not providing multiple daily injections to pump patients. The HTA report [37] conducted a meta-analysis to estimate the per-patient annual cost of insulin pump therapy as £3,602 - £3,878. The cost to the NHS in England and Wales at 2001-02 prices was estimated as £3.5 million if 1% of Type 1 DM patients used insulin pumps, £10.5 million if 3% uptake and £17.5 million if 5% uptake. Feltbower et al [38] investigated the financial impact on Primary Care Trusts (PCTs) of providing insulin pumps to children aged under 15 years and estimated that the additional expense for a single PCT of providing insulin pumps at 2001-02 prices was £400-£1,300 if 1% of children received pumps, and £2,100 - £6,600 at a 5% take-up rate.

### **3.6. Current costs of Type 1 DM**

Using HCHS inflation indices from the PSSRU [27], cost values from the Type 1 DM COI literature were inflated to 2010-11 prices to give an estimate of current costs of Type 1 DM. Using this method we estimated the total direct annual cost of Type 1 DM in England & Wales in 2010-11 as approximately £175.4 million based on Gray et al [8]. This figure includes hospital, GP, and insulin costs directly attributable to Type 1 DM as well as to vascular, ophthalmic, neurological, and renal complications. Indirect costs as a result of productivity losses were estimated from Gray et al [8] to be just over £207 million, and

informal care costs were estimated at just over £20 million. These estimates derive from simple inflation of the costs reported in Gray et al [8]. Due to the age of this study the estimates may not adequately reflect current costs of Type 1 DM due to changes in treatment pathways for Type 1 DM, changes in prices of resource items (e.g. drugs coming off patent), and changes in costs of healthcare practitioner time and hospital admissions. This is a major limitation of the body of published Type 1 DM COI evidence and of the estimates presented in the current study.

Table 4 presents all reported costs and their inflated values.

## **4. DISCUSSION AND CONCLUSIONS**

Eleven published studies and three grey literature sources reporting information on the burden and costs of Type 1 DM in the UK were reviewed. Studies used COI methods to estimate the direct and indirect costs of all of Type 1 DM, the costs of individual diabetic complications, and the costs of specific interventions for Type 1 DM. The review estimated the direct costs to the NHS of treating Type 1 DM in England and Wales to be more than £175 million in 2010-11. However, this figure has been inflated from a study published more than 15 years ago without any adjustment for changing treatment paradigms or cost of individual treatments over this time period.

### **4.1. Limitations of published studies**

Very little information on the epidemiology and cost of Type 1 DM was identified from the grey literature. Governmental and non-government organisations alike failed to report cost estimates split by diabetes type. Type 1 and Type 2 DM are distinct illnesses with very different aetiology and treatment paradigms. Cost information should therefore be published split by diabetes type so that researchers and decision makers can support the efficient and equitable allocation of diabetes resources. The benefits of distinguishing costs by type of diabetes have been recognised in the literature for decades, for example Gerard et al [44] recognised that “it would be worthwhile to [distinguish between the various types of diabetes] as the types of costs and policies associated with each are likely to be different”. However, it seems this recognition has not been translated into routine research methodology.

The only formal COI study of Type 1 DM was published more than 15 years ago [8]. Nationally available costing resources such as NHS Reference Costs were not available when the analysis was conducted and treatment pathways for Type 1 DM have changed significantly over the last 15 years with the advent of insulin analogues, intensive insulin therapy, CSII, and national recommendations regarding diabetes education [45]. These issues combine to render the resource use estimates from Gray et al [8] inadequate as estimates of current day consumption.

There are two main approaches to COI studies: a prevalence-based approach that estimates the cost of illness of all prevalent cases over a defined period of time (often a year) and an incidence-based approach that follows an incident cohort of patients with the illness over their lifetimes. All the studies reported here used annual prevalence-based methods. Incidence-based methods provide information about lifetime costs and therefore would offer

more insight into what costs could be saved if an intervention could prevent Type 1 DM [4] or what each patient costs the NHS over their lifetime.

Resource use items were not generally included in analyses if Type 1 DM was a subsidiary diagnosis, therefore studies may underestimate the amount of healthcare resources consumed by Type 1 DM patients [46]. This is a particular problem as diabetes causes many severe complications which result in hospitalisations for which diabetes may not be recorded as the primary reason, despite it being the underlying cause [4]. Although ideally this resource use should be included in a COI study, the costs of diabetes as a subsidiary diagnosis have previously been extremely difficult to identify [44]. More recently the 'attributable risk' approach has been used to identify the relative contribution of Type 1 DM to the risk of comorbid conditions (e.g. renal failure) [4]. Only one of the studies included in the review [35] used the attributable risk approach, to identify the proportion of prescription costs for non-diabetic medication that can be attributed to a patient having Type 1 DM.

#### **4.2. Heterogeneity between studies**

The published estimates of prevalence and cost of Type 1 DM vary greatly between sources. Comparison of cost estimates between studies was hindered due the disparate study designs, settings, populations, and data sources used in analyses. For example, Gordois et al [34] estimated the annual cost of diabetic nephropathy as £200 million which is incongruous with the cost estimate from Gray et al [8] of £172 million for the whole of Type 1 DM. As an 'official' estimate of the cost of Type 1 DM is not available it falls on healthcare researchers to critically appraise published estimates. The majority of studies [5, 32-38] focussed on a specific subset of diabetes care costs such as prescribing costs or the cost of a particular diabetic complication. Due to their narrow scope these studies are unable to offer information on the total costs of Type 1 DM. Gray et al [8] covered the whole of the Type 1 DM care programme but made many assumptions in calculating their estimates, including much generalisation from US data to the UK setting. Their published figures were publicly criticised by Currie and Peters [30] as being significant underestimates of the true cost of Type 1 DM. However, this criticism took the form of a letter and did not provide detailed information on how the authors' estimates were calculated, hindering the assessment of their accuracy. Currie et al [31] also provide disease-level cost estimates, however their costs come from an adult sample and as a proportion of the Type 1 DM population are under 18 [22] the cost estimates are unlikely to be representative of the whole population. Their figures are also based on self-reporting of resource use which may be less accurate than estimates based on routinely collected resource use data such as medical

records. The critical appraisal of the published cost estimates outlined above suggests that none of the available studies provide an accurate estimate of current costs of Type 1 DM in the UK. As highlighted by Rice [47], “The reliability of [COI] study results depends on a variety of factors: the scope and recency of the study, the methodology used, and the sources of the data.”

### **4.3. Limitations of our study**

The aim of the current study was to review existing evidence rather than to conduct a COI study therefore primary resource use and cost data sources were not searched. Although no studies were identified that estimated the cost of cardiovascular disease in Type 1 DM patients, resource use data from Hospital Episodes Statistics (with cardiovascular disease and Type 1 DM as co-morbid diagnoses) and cost data from NHS Healthcare Resource Groups [48] and Reference Costs [49] could be obtained and combined to provide such an estimate. However, this form of cost estimation was beyond the scope of the current study.

Although the costs reported in the literature have been inflated to recent prices, they are unlikely to be accurate estimates of the current costs of Type 1 DM to the NHS. Many factors other than inflation that are relevant to the cost of diabetes in the UK have changed over the last 15 years, some of which are outlined above. This study attempts to amalgamate evidence from across this period of time, from studies with differing designs, settings and scopes. However, no new data were sought or collected, meaning that the inflated cost estimates reported do not reflect current treatment pathways or levels of resource use. Provision of a more accurate estimate of the current cost of Type 1 DM in the UK would require a comprehensive COI study to collect up-to-date morbidity, resource use and unit cost data; this was outside the scope of the current study.

### **4.4. Recommendations**

A recently published estimate of the cost of Type 1 DM in the UK was not identified from bibliographic databases or the grey literature therefore further research in the area is necessary. It is recommended that an up-to-date national, comprehensive COI study should be conducted.



Future COI studies in the UK should:

1. Estimate the costs of Type 1 DM separately from other diabetes types, as treatments and policies are not the same across diabetes types.
2. Consider current treatment pathways to ensure that all treatment components, including newer developments in the care pathway such as insulin pumps and structured diabetes education, are included.
3. Use unit cost figures published by national bodies such as the NHS Reference Costs [49] wherever possible.
4. Use routinely collected resource use estimates wherever possible, for example the National Diabetes Audit (NDA) [22], as these will offer a more accurate representation of true resource use in the NHS than either self-report or resource use estimates from clinical trials.
5. Include resource use where Type 1 DM is a subsidiary diagnosis as well as where diabetes is the primary diagnosis (the attributable risk approach could be used to support this aim).
6. Use an incidence-based approach to provide information on the lifetime cost of Type 1 DM patients (Pagano et al [25] highlight the importance of an incidence-based approach for providing a baseline against which new interventions can be assessed).
7. Depending on the perspective of the COI study, attempt to quantify all types of costs related to Type 1 DM (including direct, indirect and intangible costs).

#### **4.5. Conclusion**

The current published studies and grey literature on the costs of Type 1 DM in the UK fall short of providing accurate up-to-date estimates. Many studies are outdated and diverse methodologies and populations have rendered comparisons between studies difficult. The total cost of Type 1 DM in the UK is currently unclear, as cost and epidemiological data are available from a variety of sources, none of which provide a complete and comprehensive estimate. There is a need for further research to update the published resource use and costing estimates of Type 1 DM in order to quantify the burden of Type 1 DM to the NHS.

Recommendations are made for a national, comprehensive COI study to address the shortcomings of the current evidence base.

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**Table 1** Published studies included in the review

Authors	Date	Title	Study design	Setting	Scope
Currie & Peters [5]	1995	Trends in the volume and cost of prescribing for diabetes	Population-based cost analysis	Wales	Direct cost of drugs for treating diabetes (not complications)
Gray et al [8]	1995	The cost of insulin-dependent diabetes mellitus (IDDM) in England and Wales	Cost-of-illness	England and Wales	All direct and indirect costs
Currie & Peters [30]	1996	Costs of insulin-dependent diabetes mellitus	Letter	England and Wales	All direct and indirect costs
Evans et al [35]	2000	Impact of type 1 and type 2 diabetes on patterns and costs of drug prescribing: a population-based study	Population-based cost analysis	Scotland	Direct cost of all drugs prescribed to people with diabetes
Leese et al [33]	2003	Frequency of Severe Hypoglycaemia Requiring Emergency Treatment in Type 1 and Type 2 Diabetes	Cost-of-illness	Scotland	Direct cost of hypoglycaemia
Colquitt et al [37]	2004	Clinical and cost-effectiveness of continuous subcutaneous insulin infusion for diabetes	Health Technology Assessment	UK	Direct cost of insulin pump therapy
Gordois et al [34]	2004	The health care costs of diabetic nephropathy in the United States and the United Kingdom	Cost-of-illness model	US and UK	Direct cost of nephropathy
Feltbower et al [38]	2005	Insulin pump therapy in childhood diabetes-cost implications for Primary Care Trusts	Population-based cost analysis	Yorkshire	Cost to PCTs of providing insulin pumps
Currie et al [31]	2007	The financial costs of healthcare treatment for people with Type 1 or Type 2 diabetes in the UK with particular reference to differing severity of peripheral	Cost-of-illness using postal survey	Wales	All direct costs

		neuropathy			
Poole [36]	2007	The prescription cost of managing people with type 1 and type 2 diabetes following initiation of treatment with either insulin glargine or insulin detemir in routine general practice in the UK: A retrospective database analysis	Cost comparison	UK	Direct cost of insulin glargine
Hammer et al [32]	2009	Costs of managing severe hypoglycaemia in three European countries	Cost-of-illness	Spain, Germany & UK	Direct and indirect cost of severe hypoglycaemia

**Table 2** Breakdown of costs of Type 1 DM in England & Wales in 1992, as reported by Gray et al [8] (£ millions)

Disease category	Routine insulin maintenance	Hospital costs	GP costs	Outpatient consultant costs	Informal care <sup>a</sup>	Renal replacement therapy	Total cost
Directly attributable to diabetes	23.1	11.0	0.7	12.5			47.3
Vascular complications		4.5	0.1	0.1			4.8
Ophthalmic complications		1.0	0.06	0.04			1.11
Neurological complications		1.2	0.03	0.03			1.2
Renal complications		3.5	0.1	0.09		26.5	30.2
Total cost	23.1	21.1	1.0	12.8	11.0	26.5	95.6
Percent	24.2%	22.1%	1.1%	13.3%	11.5%	27.7%	100%

<sup>a</sup> Social security non-transfer payments

**Table 3** Studies identified in the review, by diabetic complication

Complication	Studies
Nephropathy	Gordois et al [34]
Peripheral neuropathy	Currie et al [31]
Autonomic neuropathy	-
Retinopathy	-
Cardiovascular disease	-
Hypoglycaemia	Leese et al [33]; Hammer et al [32]
Ketoacidosis	-

**Table 4** Inflated costs from the COI literature (11 published studies and 1 NICE report)

Resource item category	Resource item detail	Paper	Year of published cost	Country	Cost from paper	Cost in 2010-11
Overall cost of type 1 diabetes	Total direct annual cost to health and social care system	Gray et al [8]	1992	England & Wales	£95,600,000	£175,436,170 <sup>a</sup>
	Total direct annual cost to health and social care system	Currie & Peters [30]	1994/95	England & Wales	£180,000,000	£311,278,195
	Total annual cost per patient	Currie et al [31]	2005	Wales	£3,224	£3,694
Insulin	Routine insulin maintenance	Gray et al [8]	1992	England & Wales	£23,100,000	£42,390,957
	Annual cost of glargine per person	Poole et al [36]	2004	UK	£1,198	£1,423
	Annual cost of detemir per person	Poole et al [36]	2004	UK	£1,330	£1,580
Insulin pumps	Annual cost of implementing CSII	NICE [28]	2007/08	England	£24,605,000	£26,424,047
	Annual cost of CSII if 1% of Type 1 patients use it	Colquitt et al [37]	2001/02	England & Wales	£3,500,000	£4,677,966
	Annual cost of CSII if 3% of Type 1 patients use it	Colquitt et al [37]	2001/02	England & Wales	£10,500,000	£14,033,898
	Annual cost of CSII if 5% of Type 1 patients use it	Colquitt et al [37]	2001/02	England & Wales	£17,500,000	£23,389,831
	Min. annual cost of CSII to a single PCT if 1% of children received CSII	Feltbower et al [38]	2001/02	England & Wales	£400	£535
	Max. annual cost of CSII to a single PCT if 1% of children received CSII	Feltbower et al [38]	2001/02	England & Wales	£1,300	£1,738
	Min. annual cost of CSII to a single PCT if 5% of children received CSII	Feltbower et al [38]	2001/02	England & Wales	£2,100	£2,807
	Max. annual cost of CSII to a single PCT if 5% of children received CSII	Feltbower et al [38]	2001/02	England & Wales	£6,600	£8,821
Prescription costs	Annual cost of prescribing (metabolic drugs only) per patient	Currie & Peters [5]	1993/94	Wales	£468	£831
	Total annual cost of prescribing	Evans et al [35]	1995	UK	£36,000,000	£59,855,422

Prescription costs continued	Annual cost of prescribing (exc. Anti-diabetic drugs)	Evans et al [35]	1995	UK	£14,000,000	£23,277,108
	Drug costs (per patient)	Currie et al [31]	2005	Wales	£1,008	£1,155
Hospital costs	Hospital costs	Gray et al [8]	1992	England & Wales	£21,100,000	£38,720,745
	Outpatient consultant costs	Gray et al [8]	1992	England & Wales	£12,800,000	£23,489,362
	In-patient costs (per patient)	Currie et al [31]	2005	Wales	£1,294	£1,483
	Out-patient costs (per patient)	Currie et al [31]	2005	Wales	£655	£750
	Nurse costs (per patient)	Currie et al [31]	2005	Wales	£53	£61
GP costs	GP costs	Gray et al [8]	1992	England & Wales	£1,000,000	£1,835,106
	GP costs (per patient)	Currie et al [31]	2005	Wales	£173	£198
Hypoglycaemia costs	Direct costs of severe hypoglycaemia	Leese et al [33]	1997/98	UK	£6,000,000	£9,544,669
	Cost of severe hypo (family/domestic setting)	Hammer et al [32]	2007	UK	£37	£40
	Cost of severe hypo (community HCP setting)	Hammer et al [32]	2007	UK	£256	£275
	Cost of severe hypo (hospital HCP setting)	Hammer et al [32]	2007	UK	£887	£953
Nephropathy costs	Renal replacement therapy	Gray et al [8]	1992	England & Wales	£26,500,000	£48,630,319
	Total cost of nephropathy in Type 1 DM	Gordois et al [34]	2001	UK	£152,000,000	£203,157,385
Other costs	Social security non-transfer payments (informal care)	Gray et al [8]	1992	England & Wales	£11,000,000	£20,186,170
	Other costs (per patient)	Currie et al [31]	2005	Wales	£41	£47

<sup>a</sup> The discrepancy between this value and the sum of the preceding rows is due to rounding in the Gray et al [8] published paper.

## Appendix 1 Studies excluded at the full text stage

Paper	Full reference	Reason for exclusion
DICET (1994)	Integrated care for diabetes: clinical, psychosocial, and economic evaluation. Diabetes Integrated Care Evaluation Team. <i>British Medical Journal</i> 1994; 7 (308): 1208-12	Does not split costs by diabetes type
Gerard et al (1989)	Gerard K, Donaldson C, Maynard AK. The cost of diabetes. <i>Diabetic Medicine</i> 1989; 6:164-170.	Does not split costs by diabetes type
Boren (2009)	Boren SA, Fitzner KA, Panhalkar PS, Specker JE, Boren SA, Fitzner KA, et al. Costs and benefits associated with diabetes education: a review of the literature. <i>Diabetes Educator</i> 2009;35(1):72-96.	No UK-specific data and does not split by diabetes type
Bottomley (2007)	Bottomley JM, Raymond FD, Bottomley JM, Raymond FD. Pharmaco-economic issues for diabetes therapy. <i>Best Practice &amp; Research Clinical Endocrinology &amp; Metabolism</i> 2007;21(4):657-85.	Focus is on type 2 diabetes and does not report UK data
Boutayeb (2004)	Boutayeb AT. A mathematical model for the burden of diabetes and its complications. <i>BioMedical Engineering Online</i> 2004;3:28.	Does not split by diabetes type
Chukwuma (1993)	Chukwuma C, Sr., Chukwuma CS. Type I diabetic nephropathy: clinical characteristics and economic impact. <i>Journal of Diabetes &amp; its Complications</i> 1993;7(1):15-27.	No UK information on prevalence or costs
Icks (2007)	Icks A, Holl RW, Giani G, Icks A, Holl RW, Giani G. Economics in pediatric Type 1 DM - results from recently published studies. <i>Experimental &amp; Clinical Endocrinology &amp; Diabetes</i> 2007;115(7):448-54.	Literature review of paediatric Type 1 DM COI and economic evaluation studies

Jendle (2009)	Jendle JH. Resource utilisation and costs for the treatment of diabetes in the developed world: An economical burden that needs to be solved. <i>International Journal of Clinical Practice</i> 2009;63(7):997-1007	No data reported
Laing & Williams (1989)	Laing W, Williams R. Diabetes: A model for health care management. Office of Health Economics, London 1989.	No primary data and not split by diabetes type
Leese (1992)	Leese B, Leese B. The costs of diabetes and its complications. <i>Social Science &amp; Medicine</i> 1992;35(10):1303-10.	No primary data and not split by diabetes type
Mallick (1996)	Mallick NPD. The changing population on renal replacement therapy: Its clinical and economic impact in Europe. <i>Nephrology Dialysis Transplantation</i> 1996;11(SUPPL. 2):2-5	Not diabetes-specific, not split by type, no cost data
Milton (2006)	Milton B, Holland P, Whitehead M, Milton B, Holland P, Whitehead M. The social and economic consequences of childhood-onset Type 1 DM mellitus across the lifecourse: a systematic review. <i>Diabetic Medicine</i> 2006;23(8):821-9.	Does not report cost data
Morris (2002)	Morris AD. Considerations in assessing effectiveness and costs of diabetes care: Lessons from DARTS. <i>Diabetes/Metabolism Research and Reviews</i> 2002;18(SUPPL. 3): S32-5	No Type 1-specific results presented
Narins (1988)	Narins BE, Narins RG, Narins BE, Narins RG. Clinical features and health-care costs of diabetic nephropathy. <i>Diabetes Care</i> 1988;11(10):833-9.	US population not UK



Palmer (2004)	Palmer AJ, Roze S, Valentine WJ, Minshall ME, Foos V, Lurati FM, et al. The CORE Diabetes Model: Projecting long-term clinical outcomes, costs and cost-effectiveness of interventions in diabetes mellitus (types 1 and 2) to support clinical and reimbursement decision-making. <i>Current Medical Research &amp; Opinion</i> 2004;20 Suppl 1:S5-26.	Description of a cost-effectiveness model; no cost results reported
Rippin (2004)	Rippin JDB. Cost-Effective Strategies in the Prevention of Diabetic Nephropathy. <i>Pharmacoeconomics</i> 2004;22(1):2004.	No cost-of-illness data reported
Salas (2009)	Salas M, Hughes D, Zuluaga A, Vardeva K, Lebmeier ME-MA, Salas Mmue. Costs of medication nonadherence in patients with diabetes mellitus: A systematic review and critical analysis of the literature. <i>Value in Health</i> 2009;12(6):915-22	USA not UK
Sear (2008)	Sear JW. Glucose control: What benefit, what cost? <i>Southern African Journal of Anaesthesia and Analgesia</i> 2008 Jan;14(1):14-17	Includes good epidemiology information but no costs
Simell (1993)	Simell T, Simell O, Sintonen H, Simell T, Simell O, Sintonen H. The first two years of Type 1 DM in children: length of the initial hospital stay affects costs but not effectiveness of care. <i>Diabetic Medicine</i> 1993;10(9):855-62.	Costs in GBP£ but study took place in Finland
Simell (1996)	Simell TT, Sintonen H, Hahl J, Simell OG, Simell TT, Sintonen H, et al. Costs of insulin-dependent diabetes mellitus. <i>Pharmacoeconomics</i> 1996;9(1):24-38.	No UK-specific data reported
Skyler (2000)	Skyler JS, Skyler JS. The economic burden of diabetes and the benefits of improved glycemic control: the potential role of a continuous glucose monitoring system. <i>Diabetes Technology &amp; Therapeutics</i> 2000;2 Suppl 1:S7-12.	USA-focused. No cost information reported
Summers (2003)	Summers KS. Cost of diabetes-related complications: Current issues, future directions. <i>Expert Review of Pharmacoeconomics and Outcomes Research</i> 2003 Feb;3(1): 17-24	Literature search for studies on costs of diabetes in North America. No UK data

Trueman (2008)	Trueman P, Taylor M, Twena N, Chubb B, Trueman P, Taylor M, et al. The cost of needlestick injuries associated with insulin administration. <i>British Journal of Community Nursing</i> 2008;13(9):413-7.	Does not split by diabetes type
Yao (2006)	Yao GA, Albon E, Adi Y, Milford D, Bayliss S, Ready A, Raftery J, Taylor RS. A systematic review and economic model of the clinical and cost-effectiveness of immunosuppressive therapy for renal transplantation in children. <i>Health Technology Assessment</i> 2006;10(49):1-157	Not diabetes-specific

1 exp diabetes mellitus, insulin dependent/  
 2 exp Diabetic Ketoacidosis/  
 3 IDDM.tw.  
 4 (insulin? depend\$ or insulin?depend\$).tw.  
 5 ((typ\$ 1 or typ\$ I) adj diabet\$).tw.  
 6 (earl\$ adj diabet\$).tw.  
 7 ((juvenil\$ or child\$ or keto\$ or Labil\$ or brittl\$) adj diabet\$).tw.  
 8 ((auto?immun\$ or sudden onset) adj diabet\$).tw.  
 9 (insulin? defic\$ adj absolut\$).tw.  
 10 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9  
 11 exp diabetes insipidus/  
 12 diabet\$ insipidus.tw.  
 13 11 or 12  
 14 10 not 13

Combined with:

1 Economics/  
 2 "costs and cost analysis"/  
 3 Cost allocation/  
 4 Cost-benefit analysis/  
 5 Cost control/  
 6 Cost savings/  
 7 Cost of illness/  
 8 Cost sharing/  
 9 "deductibles and coinsurance"/  
 10 Medical savings accounts/  
 11 Health care costs/  
 12 Direct service costs/  
 13 Drug costs/  
 14 Employer health costs/  
 15 Hospital costs/  
 16 Health expenditures/  
 17 Capital expenditures/  
 18 Value of life/  
 19 Exp economics, hospital/  
 20 Exp economics, medical/  
 21 Economics, nursing/  
 22 Economics, pharmaceutical/  
 23 Exp "fees and charges"/  
 24 Exp budgets/  
 25 (low adj cost).mp.  
 26 (high adj cost).mp.  
 27 (health?care adj cost\$).mp.  
 28 (fiscal or funding or financial or finance).tw.  
 29 (cost adj estimate\$).mp.  
 30 (cost adj variable).mp.  
 31 (unit adj cost\$).mp.  
 32 (economic\$ or pharmaco-economic\$ or price\$ or pricing).tw.  
 33 Or/1-32

**Figure 1**

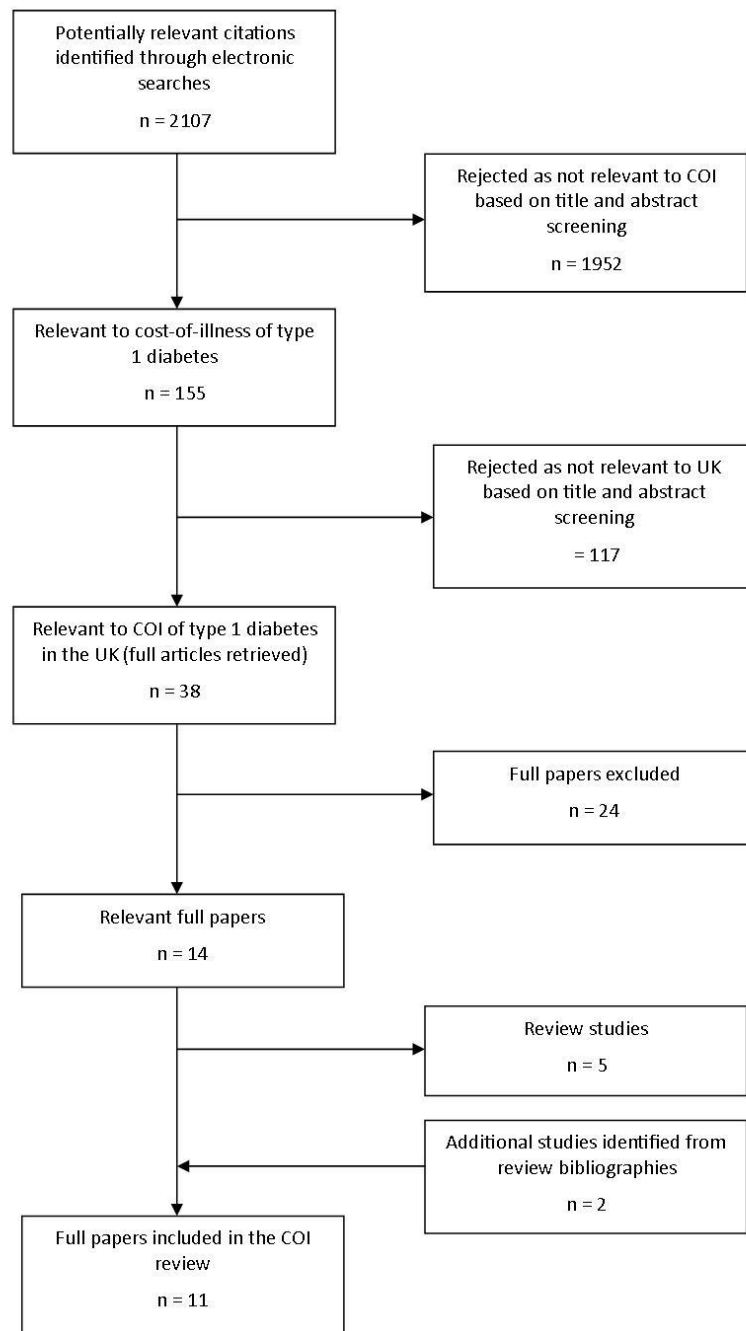


Figure 2