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Complete List of Authors:	Maruthappu, Mahiben Head, Michael; University College London, Infection & Population Health Zhou, Charlie; University of Oxford, Gilbert, Barnabas El-Harasis, Majd Raine, Rosalind Fitchett, Joseph; King's College London, School of Medicine Atun, Rifat; Harvard University, Harvard School of Public Health
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Investments in cancer research awarded to UK institutions and the global burden of cancer 2000-2013: a systematic analysis

Mahiben Maruthappu[a],* Michael G Head[b],* Charlie Da Zhou[c], Barnabas J Gilbert[d], Majd A El-Harasis[e], Rosalind Raine[f], Joseph R Fitchett[g], Rifat Atun[g]

a Senior Fellow to the CEO of NHS England, Epidemiology and Public Health, University College London, 1-19 Torrington Place, London, WC1E 6BT, UK

b Senior Research Fellow, Global Health Research Institute, Institute for Life Sciences, Faculty of Medicine, University of Southampton, Southampton, SO17 1BJ, UK

c Doctor, Medical Sciences Division, University of Oxford, Oxford OX1 2JD, UK

d Doctor, Harvard University, Cambridge, MA 02138, USA.

e Doctor, Faculty of Medicine, Imperial College London, London, SW7 2AZ, UK.

f Professor, Department of Applied Health Research, UCL, London, WC1E 7HB

g Professor, Harvard T. H. Chan School of Public Health, Harvard University, Boston, MA 02115, USA

* Authors Maruthappu and Head to be recognised as joint first-author

Corresponding author

Charlie Zhou

chazhou@gmail.com

New College, Holywell Street, Oxford, OX1 3BN, UK

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cancer; oncology; research investment; global burden of disease; global health; funding; research and development

What this study adds:

What is already known on this subject:

Prior to this study, we were unable to identify any studies investigating cancer research investment by the UK over time or any centralised database detailing public and philanthropic cancer research investment.

What this study adds:

We systematically compiled a comprehensive database for UK research funding for the period 2000-2013. We identify 4,299 awards with a total research investment of UK£2.4 billion. We generated a compound metric to capture cancer research investment relative to disease burden. We identify several potential investment “gaps”, for example, funding towards surgery and radiotherapy are comparatively neglected considering their utility in the cancer care pathway

ABSTRACT

Objectives

We sought to systematically categorise cancer research investment awarded to UK institutions in the period 2000-2013 and to estimate research investment relative to disease burden as measured by mortality, disability-adjusted life years (DALYs), and years lived with disability (YLDs).

Design

Systematic analysis of all open access data.

Setting and participants

Public and philanthropic funding to all UK cancer research institutions, 2000-2013

Main outcome measures

Number and financial value of cancer research investment reported in 2013 UK pounds. Mortality, DALYs and YLDs data was acquired from the Global Burden of Diseases Study. A compound metrics was adapted to estimate research investment relative to disease burden as measured by mortality, DALYs, and YLDs.

Results

We identified 4,299 funded studies with a total research investment of UK£2.4 billion. The highest funding by sites were haematological, breast, prostate, colorectal, and ovarian cancers. Relative to disease burden as determined by a compound metric combining mortality, DALYs and YLDs, gender-specific cancers were found to be highest funded - the five sites that received the most funding were prostate, ovarian, breast, mesothelioma, and testicular cancer; the least well-funded sites were liver, thyroid, lung, upper GI and bladder. Pre-clinical science accounted for 66.2% of award numbers and 62.2% of all funding. The top five areas of primary research focus by funding were pathogenesis, drug therapy, diagnostic, screening and monitoring, women's health, and immunology. The largest

individual funder was the Medical Research Council. In combination, the five lowest funded site specific cancers relative to disease burden account for 47.9%, 44.3% and 20.4% of worldwide cancer mortality, DALYs and YLDs.

Conclusions

Current and projected global cancer disease burden may be a consideration in the allocation of limited research funding. Funding agencies and industry need to openly document their research investment to enable the development of transparent and objective methods to allocate funding.

Strengths and limitations of this study:

- We systematically analyse UK investment in cancer research and identify areas of relative neglect.
- Our findings will inform funders and contribute towards policy discussions to prevent inequity in the allocation of limited resources
- However, it is not possible to equate gaps in funding with areas of neglect without consideration of other influences.
- Our study is dependent on the accuracy of original investment data from the funding bodies
- Assignment of disease categories and allocation of studies according to these categories is subjective.
- We could not openly access date of private sector research funding, nor were we able to obtain disaggregated award data from CRUK.
- Disease burden measures are typically an estimate and are subject to the potential introduction of bias.

Introduction

Cancers account for a high burden of morbidity and mortality worldwide. The Global Burden of Disease (GBD) Study estimates that cancer of all types resulted in 8,235,700 deaths in 2013[1]. Being predominantly a disease of older age, prevalence of cancers has historically fallen among high-income countries. However as low-income countries experience economic maturation, we are seeing an expanded distribution of this disease burden. Further deaths from cancer are projected due to global population growth and ageing[2,3]. Between 1990 and 2013, the proportion of all deaths that was attributable to cancer rose from 11.9% to 15.0%, largely among low- and middle-income countries and site-specific cancers accounted for 9 of the 50 leading causes of death, worldwide[1].

The socioeconomic impact of cancer, both in terms of direct costs involved in medical management as well as indirect costs resulting from productivity loss, on patients and caregivers are substantial. Direct health-related costs of cancer have been estimated to incur €51.0 billion within in the European Union[4] and $124.5 billion in the United States[5]. Indirect costs are estimated to account for additional losses of €75.2 billion and $115.8 billion, respectively. Economic evaluation of the impact of cancer outside of these two geographical regions has been lacking.

Investment in research and development (R&D) for cancers produces global public benefits that have a positive effect both locally and worldwide, irrespective of the site of the work or the location of the institution receiving an award, bringing substantial health, social, and economic benefit.

There are several national and international funding bodies that make cancer research investments along the R&D pipeline, from population health research, pre-clinical studies through to clinical trials and applied research. The UK remains one of the world's leading investors and producers of global biomedical and health research. Previous analyses by the Research Investments in Global Health study (ResIn, www.researchinvestments.org) has systematically analysed public and philanthropic awards totalling £3.7 billion to UK institutions for infectious disease from 1997 to 2013, and evaluated funding against global disease burden[6,7] and publications and citations as a marker of research output[8]. Tracking investments in R&D provides information and evidence to inform funding decisions and priority setting. Here, we present a systematic analysis of cancer-related research awarded by public and philanthropic funders to UK institutions from 2000 to 2013, categorise the data against a range of cancer-specific and cross-cutting disease areas, and assess the award data against global measures of mortality, disability-adjusted life years (DALYs), and years lived with disability (YLD) across three time points.

Methods

Our methods build on those developed for the infectious disease research investment analysis, which are described in detail elsewhere[6,7] and adapted in subsequent peer-reviewed publications (www.researchinvestments.org/publications).

We systematically examined funding awards from a number of public and philanthropic funding bodies (including the Medical Research Council, Department of Health, Biotechnology and Biological Sciences Research Council, Engineering and Physical Science Research Council, Wellcome Trust, European Commission, as well as 9 members of the Association of Medical Research Charities) between 2000 and 2013. Information was obtained by downloading openly-accessible information on the funder website, contacting the funder to request the information, or searching existing funding databases. For each award, the title and abstract, where available, were individually screened for relevance to cancer research. We excluded awards that were i) not obviously or immediately relevant to oncology; ii) led by a non-UK institution; iii) not considered to be for R&D activity. Unfunded studies were also excluded. Private sector data were not available to evaluate at the same level of detail as public and philanthropic research award data, and were therefore excluded from this analysis. Cancer Research UK (CRUK) would not provide their award data and so could not be included in the main analysis. There is some description of individual CRUK awards without grant amounts available at https://europepmc.org/. We report total number of studies in this analysis.

Where awards were described in currencies other than UK pounds, these were converted to UK pounds using the mean exchange rate in the year of the award. All included awards were adjusted for inflation and reported in 2013 UK pounds.

Each study in the dataset was reviewed by one author (either CDZ, GJG, MAE-H, MGH) and assigned to as many of 14 cross-cutting categories as appropriate. The 14 association categories were paediatric, geriatric, infection-associated, women's health, men's health, occupational health, pathogenesis, diagnostic/screening/monitoring, drug therapy, radiotherapy, surgery, immunology, psychosocial and global health. Awards were defined as global health if they were considered to pursue a clear non-UK focus (e.g. 'thyroid cancer in Kenya'). The other category was only used when none of the aforementioned categories were deemed to be appropriate. Studies were also allocated to one of five categories along the R&D pipeline: pre-clinical; phase I, II, or III clinical trials; product development (including phase IV activity); public health; and cross-disciplinary research. The cross-disciplinary category was defined as an award containing significant components across two distinct areas along the R&D pipeline (such as pre-clinical research leading directly into a phase I trial). Provisional datasets were circulated to all authors for review and comment with checks by second authors on sections of the data and any disagreements settled by consensus. Final datasets were then again circulated for further review by all authors. Microsoft Excel 2010 and 2013 and Stata (V13) software were used for data analysis.

Global data on mortality, disability-adjusted life years (DALYs) and years lived with disability (YLDs) were available at time points 2005, 2010 and 2013. All burden data were sourced from the findings of the Global Burden of Disease (GBD) study, for 2013[1,9,10] and for 2010[11,12]. Burden data from 2005 were obtained directly from colleagues at the Institute for Health Metrics and Evaluation, USA. As defined by the GBD study, YLDs for a disease or injury are the sum of the YLDs for each sequela associated with the disease or injury[10]. DALYS are the product of adding YLLs and YLDs for each age–sex–country group[9].

In order to allow direct comparison of relative investment with global health metrics across disease areas and between different time periods, metrics were adapted from the infectious disease analyses to estimate the 'investment per mortality/DALY/YLD observed [7]'. The metrics were created using the following equation –

Total research investment up to the year before the time point / number of deaths, DALYs or YLD at time point) / number of years of investment included

For example, for assessment of breast cancer mortality at the 2013 time point, we took the sum of breast cancer research investment 2000-2012 (£124,305,716) and divided that by number of deaths reported in 2013 (471000), and divided the result by the number of years of investment included (13) to get an 'investment per mortality observed' metric of £20.30.

These metrics were applied for research relating to 16 site-specific cancers, where there was comparable data in both the ResIn and GBD studies. We defined lung cancer by aggregating 'tracheal, bronchus and lung cancer' burden data from the GBD study. Similarly, we defined skin cancer by aggregating 'malignant skin melanoma' and 'non-malignant skin cancer', and we defined upper gastrointestinal (GI) cancer by aggregating 'oesophageal' and 'stomach cancer'. The use of total investment and the division by number of years included aimed to reduce the impact of the volatility of annual research funding and the relatively short periods between time points. Ranking scores of the investment metrics were developed for the 16 sites of cancer against 2013 burdens. Cancers were ranked in order of relative investment against burden from high to low and assigned a score (from 1 to 16). The mean ranking scores across mortality, DALYs and YLDs were used to illustrate an overall relative level of investment against 2013 global disease burden.

Patient involvement

There was no patient involvement in this study.

Results

We identified 4,299 funded studies that met our inclusion criteria (Table 1). The funding for these studies represented a total research investment of almost £2.4 billion. The mean award amount for each study was £555,513 (standard deviation (SD) £1,429,510) and median was £231,559 (inter-quartile range £114,619 – 487,063. 2,416 awards (56.2% of total) were designated towards a named site-specific cancer (Table 1), equating to £1.0 billion (40.3% of total). The top five cancer sites in terms of award number were haematological, breast, colorectal, prostate, and skin; the bottom five were testicular, bone, bladder, thyroid, and cholangiocarcinoma (Table 1). The top five cancer sites in terms of total funding were haematological, breast, prostate, colorectal and ovarian; the bottom five were testicular, mesothelioma, thyroid, bladder and chlangiocarinoma. Mean funding per award varied greatly between sites with prostate cancer receiving the most (£1.47 million) and bladder cancer the least (£117,385).

The top five areas of primary research focus, by number of awards, were drug therapy, diagnostic, screening and monitoring, women's health, immunology, and pathogenesis; the bottom five areas were men's health, surgery, occupational health, global health and geriatrics (Table 2). In terms of net funding, the top five areas of research were pathogenesis, drug therapy, diagnostic, screening and monitoring, women's health, and immunology; the bottom five were surgery, psychosocial, global health, occupational health, and geriatrics.

The majority of awards were focused on pre-clinical science, accounting for 66.2% of award numbers and 62.2% of all funding (Table 3). In terms of award number, this was followed by public health, cross-disciplinary, phase I-III, and product development. This order was reflected in terms of net investment, although cross-disciplinary studies ranked ahead of public health studies. Phase I-III clinical trials received the highest mean funding per award, at £736,172 (SD £3,361,312), whilst public health research received the least, at £496,744 (SD £1,000,757).

The largest individual funder of cancer research of the studies identified was the Medical Research Council, accounting for 35.1% of all funding (Table 4). The charitable sector was responsible for 39.5% of all awards (excluding CRUK) but 17.4% of funding. The European Commission was responsible for the largest mean grant per award (£1.58 million).

We generated a compound ranking score for the 16 sites of cancer against 2013 global disease burdens, across mortality, DALYs, and YLDs (table 5). We identified the five sites that received the most funding relative to disease burden as prostate, ovarian, breast, mesothelioma and testicular cancer. The least well-funded sites relative to disease burden were cancers of the liver, thyroid, lung, upper GI, and bladder.

We were able to obtain some disaggregated data for 3,284 CRUK research grants during the period of interest but this excluded individual award data. Compared to the aggregation of all other funders, CRUK placed more of a focus on funding towards cancers of the prostate, ovary and liver – by study number these sites accounted for 6.9%, 3.4% and 2.7% of CRUK funded studies compared to 2.1%, 1.1% and 0.9% of all studies in our quantitative database, respectively. CRUK preferentially funded research investigating pathogenesis, which accounted for 51.0% of all grants awarded. In comparison, only 5.3% of all awards in our quantitative database were identified as primarily focused on pathogenesis.

Discussion

We identified 4,299 funded studies, with a total research investment of £2.4 billion. We performed qualitative analysis on a further 3,284 CRUK funded awards. The vast majority of all awards awarded were investigating at least one of pathogenesis, diagnosis, monitoring and screening and drug therapy. In the absence of CRUK data, the Medical Research Council and the Department of Health were the two leading funding sources. Preclinical research accounted for £1.5 billion (62.2%) of total R&D investment. Four of the five highest funded cancer sites relative to global disease burden were gender-specific – namely prostate, ovarian, breast, and testicular cancers. Cancer research with a clear focus on women's health accounted for 640 studies (14.9%) and £199.5 million (8.4%) of investment. In comparison, 111 studies (2.6%) and £143.3 million (6.0%) of investment had a clear link with men's health. This may reflect the successes of various institutions and charities that have sought to increase awareness of these sex-specific cancers. Breast cancer, the most commonly diagnosed cancer in the UK and the leading cause of cancer death in women, and prostate cancer, the second most frequently diagnosed cancer and the sixth leading cause of cancer death among men, were found to be relatively well funded[1,13].

We highlight several cancer sites where there might be underinvestment, namely that of liver, thyroid, lung, upper GI tract, and bladder. In our analysis cancer of the upper GI tract combines oesophageal and stomach cancer. These site-specific cancers identified to be relatively underfunded account for a substantial proportion of global cancer burden. Globally, these sites account for 47.9%, 44.3% and 20.4% of the global mortality[1], DALYs[9] and YLDs[10] of all cancers, respectively. The disparity between YLDs and DALYs demonstrates the poor prognosis and high mortality of these particular sites when compared against all neoplastic disease. Lung, liver, stomach and oesophagus are the first, second, third and fifth, leading sites of neoplastic mortality worldwide[1].

With regard to interventions research, there is heavy investment in drug-based modalities. £620.9 million (26.0%) was invested in novel drug therapies and £194.1 million (8.1%) was invested in the emergent role of immunomodulation. In comparison, funding towards radiotherapy and surgical interventions accounted for £88.2 million (3.7%) and £37.9 million (1.6%), respectively. In high-income settings, around half of new cancer diagnoses will undergo a course of radiotherapy treatment during their clinical management; roughly a quarter will receive two or more courses[14,15]. Globally, over 80% of cancer cases will warrant surgical intervention, where it has preventative, diagnostic, curative, supportive, palliative, and reconstructive roles[16].

Analysis by R&D pipeline showed that research investment in the UK places a heavy emphasis on pre-clinical research, but relatively little investment towards phase I-III clinical trials or product development, and this is line with previous research in infectious disease investment[6]. This may reflect the strengths of UK institutions in preclinical science, but also could suggest a need to strengthen research capacity further down the R&D chain. It would be useful to determine whether investment reflects the priorities of funding agencies and whether this is comparable to research investment in other countries. We noted a lack of readily available data from the pharmaceutical industry and this is likely to leave a data gap in particular for sum totals of investment in clinical trials of pharmaceutical products.

Our findings contribute to the development of transparent and objective methods to couple the allocation of limited research funds with disease burden. Previous studies have suggested that financial investment might appropriately be coupled with DALYs as a measure of burden[17–20]. Furthermore, previous UK research suggests that publicly funded cancer research offers substantial rates of return in terms of both health and monetary benefit [21]. We have further sought to incorporate mortality rates and YLDs into the consideration of cancer research investment. However, defining an appropriate amount of research investment for each site specific cancer is challenging since cancers of similar disease burdens may warrant different levels of investment to develop cost-effective interventions. Decisions may be influenced by any of a number of factors, for example due to exceptional need, as may be the case in mesothelioma, or due to public awareness and third-party lobbying, as may be the case with regards to the gender-specific cancers.

A variety of factors contribute towards the difficulty in tracking net cancer research investment within the UK. Fragmentation of data from a large number of diverse public and private sources of funding, poorly designed donor accounting structures, where available, and the paucity of information from the private sector limit the evidence base to inform policy in real-time. In our study, we were unable to obtain quantitative data from CRUK, the world's largest cancer research charity and a leader in cancer research. They do not routinely publish or make available disaggregated investment data which is, in our experience across the infection and cancer analyses, unique amongst the more high-profile UK funders who are universally more transparent in their award decisions. Transparency in the tracking and monitoring of cancer research financing is essential to enable accountability and equity in resource allocation and to facilitate further future research in this area.

In this study we systematically analyse UK investment in cancer research and identify areas of relative neglect. Although the competitive application process used by most funders to allocate research grants ensure a portfolio of high quality, the absence of explicit resource allocation criteria could contribute towards inequalities in R&D by disease burden. Funding agencies will have particular areas of focus, and UK funders may have considered the focus of international agencies in their own research strategies. As a result, international data is essential to complete the mapping of cancer research investment. Nevertheless, our findings will inform funders and contribute towards policy discussions to prevent inequity in the allocation of limited resources.

By demonstrating the relationship between disease burden and research funding, we enable the identification of potential investment gaps. However, it is not possible to equate gaps in funding with areas of neglect without consideration of other influences such as the feasibility of research, costs of technologies, infrastructure and skill requirements, political and social considerations, and the accuracy of disease burden estimates.

There are several potential limitations to our study. We are dependent on the accuracy of original investment data as sourced from the funding bodies. Although checks were made on any obvious discrepancies or errors, interpretation of these original data may contain errors. We made no attempt to investigate the contribution of any indirect or estate costs. Currency conversions were averaged across each financial year and any intra-year fluctuations may not have been captured. Unless clearly documented, we were unable to assess how funding was distributed from lead institutions to collaborative partners. We considered individual awards, rather than number of studies.

Furthermore, assignment of disease categories and allocation of studies according to these categories is subjective, and there might be disagreements regarding certain inclusion criteria.

We could not openly access data of private sector research funding, nor were we able to obtain disaggregated award data from CRUK. Whilst our analysis did demonstrate that CRUK funding (with some exceptions) broadly reflected the findings of our quantitative database, it is likely that substantial awards towards particular areas of research could skew results; for example, the CRUK accounts for 2014/15 suggest £394 million was invested into research or research-related activity, and we hypothesise that much of that would have met our inclusion criteria for this analysis[22]. Disease burden measures are typically an estimate and are subject to the potential introduction of bias from missing or unobtainable data as well as from differences in classification and diagnosis.

Our report presents the latest investment data on cancer research warded to UK institution between 2000 and 2013. Cancers of the liver, thyroid, lung, upper GI tract, and bladder as well as research towards radiotherapy and surgical techniques in particular may warrant increased rates of investment. We will make the entire database and associated figures available online (www.researchinvestment.org) to assist policy makers, funding organisations, and researchers in the identification of investment gaps. We further encourage funding organisations to make their investment portfolios openly accessible to facilitate future research.

We hope that open funding data in this area can contribute to redressing the misalignments in investments for cancer research. Cancer research can improve the clinical course of disease and offer tangible improvements in health outcomes[21]. Both policy makers and the scientific community need to ensure that limited resources are allocated appropriately to most effectively alleviate the morbidity and mortality associated with cancer.

Contributions

MM and MGH are the guarantors of this study. MM, MGH, JRF and RA conceived and designed the study. MGH, CDZ, BJG and MAE-H obtained the data. MM and MGH conducted data formatting and statistical analysis. All authors helped interpret the findings. MM, MGH and CDZ wrote the first draft of the manuscript with input from RR, JRF and RA; all authors provided input to subsequent drafts. All authors had full access to all of the data in the study and take responsibility for its integrity and the accuracy of data analysis.

Transparency declaration

MM affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

Funding

No funding was received for this study

Competing interests

All authors declare no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval

Not required

Data sharing

All data used is publicly available. Entire database and associated figures are permanently available with open access online (www.researchinvestment.org) to assist policy makers, funding organisations, and researchers.

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Table Legends

Table 1: Cancer research investment awards and funding by site. All investment reported in 2013 UK pounds.

Table 2: Cancer research investment awards and funding by cross-cutting theme. All investment reported in 2013 UK pounds.

Table 3: Cancer research investment awards and funding by type of science. All investment reported in 2013 UK pounds.

Table 4: Cancer research investment awards and funding by funding agency (excluding CRUK). All investment reported in 2013 UK pounds.

Table 5: Compound ranking score for cancer research investment against 2013 global disease burdens, across mortality, DALYs, and YLDs, by cancer site.

	All funders where investment data was available						Cancer Research UK	
Site of cancer	**Number of awards**	**Percentage of total**	**Sum investment (£)**	**Percentage of total**	**Mean award, £ (SD)**	**Median award, £ (IQR)**	**Number of awards**	**Percentage of all oncology research awards**
Breast	571	13.3%	£137,960,107	5.8%	241611 (414584)	135752 (25000-216673)	273	8.3%
Haematological	1158	26.9%	£381,008,394	16.0%	329022 (476943)	186813 (120437-272324)	225	6.9%
Colorectal	147	3.4%	£77,279,857	3.2%	525713 (674881)	251800 (102078-819866)	205	6.2%
Prostate	92	2.1%	£135,290,779	5.7%	1470552 (6156372)	333757 (155227-721037)	123	3.7%
Ovarian	48	1.1%	£44,709,938	1.9%	931457 (3380145)	226764 (131990-627401)	112	3.4%
Lung	82	1.9%	£24,263,280	1.0%	295893 (556278)	146123 (66701-242934)	89	2.7%
Skin	87	2.0%	£22,179,011	0.9%	254931 (453726)	85406 (69629-248603)	84	2.6%
Brain	22	0.5%	£9,994,255	0.4%	454284 (498933)	401046 (196928-528008)	83	2.5%
Upper GI and	18	0.4%	£19,094,230	0.8%	1060791 (1448010)	788850 (80964-1296962)	80	2.4%
Head and neck	20	0.5%	£18,250,632	0.8%	912531 (1003091)	389751 (167358-1602465)	68	2.1%
Renal	19	0.4%	£13,885,496	0.6%	730815 (678732)	479197 (244075-1252574)	48	1.5%
Bladder	10	0.2%	£1,173,856	0.0%	117385 (106902)	94520 (29264- 173855)	48	1.5%
Cervical	26	0.6%	£14,328,402	0.6%	551092 (877250)	210179 (88934-368402)	43	1.3%
Pancreatic	16	0.4%	£9,453,577	0.4%	590848 (519850)	276237 (191804-1033948)	40	1.2%
Bone	13	0.3%	£17,242,183	0.7%	1326322 (1604685)	685853 (243559-1999907)	29	0.9%
Liver	37	0.9%	£25,037,541	1.0%	676690 (847151)	319082 (177974-776480)	20	0.6%
Mesothelioma	30	0.7%	£4,476,088	0.2%	149202 (101201)	137103 (95895-205500)	11	0.3%
Cholangiocarcinoma	2	0.0%	£582,405	0.0%	n/a	n/a	11	0.3%
Testicular	14	0.3%	£5,949,990	0.2%	424999 (507277)	242175 (102938-411010)	11	0.3%
Thyroid	4	0.1%	£1,375,881	0.1%	n/a	n/a	7	0.2%
Total	**4299**		**£2,388,152,318**		**555513 (1429510)**	**231559 (114619-487063)**	**3284**	

	All funders where investment data was available						Cancer Research UK	
Cross-cutting theme	**Number of awards**	**Percentage of total**	**Sum investment (£)**	**Percentage of total**	**Mean award, £ (SD)**	**Median award, £ (IQR)**	**Number of awards**	**Percentage of all oncology research awards**
Pathogenesis (mechanism)	227	5.3%	£1,374,387,838	57.6%	543881 (955710)	248573 (135752-506232)	1674	51.0%
Drug Therapy	1104	25.7%	£620,961,060	26.0%	562464 (1910050)	202342 (105622-436559)	935	28.5%
Diagnostic, Screening and Monitoring	681	15.8%	£359,618,823	15.1%	528074 (1155156)	205728 (102672-513836)	404	12.3%
Women's Health	640	14.9%	£199,534,693	8.4%	311773 (1041520)	153845 (56515-227202)	287	8.7%
Immunology (inc. biologics)	451	10.5%	£194,086,617	8.1%	430347 (760955)	240052 (125669-466250)	212	6.5%
Radiotherapy	112	2.6%	£88,262,353	3.7%	788056 (2413445)	243333 (106175-439419)	209	6.4%
Psychosocial	117	2.7%	£23,445,835	1.0%	200391 (352410)	87463 (27317-239059)	122	3.7%
Men's Health	111	2.6%	£143,392,908	6.0%	1291828 (5617919)	285203 (126037-700353)	120	3.7%
Paediatrics	175	4.1%	£62,641,938	2.6%	357953 (547484)	183099 (89522-322261)	118	3.6%
Surgery	72	1.7%	£37,900,334	1.6%	526393 (684908)	235413 (97890-761651)	95	2.9%
Infection-associated	129	3.0%	£56,819,379	2.4%	440460 (798013)	231836 (134693-439378)	48	1.5%
Global Health	12	0.3%	£6,434,960	0.3%	536246 (1089118)	129738 (77519-459274)	12	0.4%
Geriatrics	7	0.2%	£1,616,394	0.1%	230913 (254925)	121623 (76421-262167)	8	0.2%
Occupational Health	18	0.4%	£2,576,841	0.1%	143157 (116928)	137103 (33857-199998)	8	0.2%
Total	**4299**		**£2,388,152,318**		**555513 (1429510)**	**231559 (114619-487063)**	**3284**	

	All funders where investment data was available						Cancer Research UK	
Type of science	**Number of awards**	**Percentage of total**	**Sum investment (£)**	**Percentage of total**	**Mean award, £ (SD)**	**Median award, £ (IQR)**	**Number of awards**	**Percentage of all oncology research awards**
Pre-clinical	2845	66.2%	£1,485,997,379	62.2%	522318 (1006600)	240974 (132188-490872)	1809	55.1%
Phase I-III	303	7.0%	£223,060,276	9.3%	736172 (3361312)	178535 (70934-502399)	647	19.7%
Product development	172	4.0%	£104,214,364	4.4%	605897 (2213394)	193051 (75270-360813)	52	1.6%
Cross-disciplinary	441	10.3%	£315,145,351	13.2%	714615 (1586882)	238523 (126589-703764)	328	10.0%
Public health	512	11.9%	£254,333,282	10.6%	496744 (1000757)	209364 (82870-383623)	443	13.5%
Unable to specify	26	0.6%	£5,401,666	0.2%	n/a	n/a	5	0.2%
Total	**4299**		**£2,388,152,318**		**555513 (1429510)**	**231559 (114619-487063)**	**3284**	

	All funders where investment data was available					
Funder	**Number of awards**	**Percentage of total**	**Sum investment (£)**	**Percentage of total**	**Mean award, £ (SD)**	**Median award, £ (IQR)**
MRC	768	17.9%	£837,649,875	35.1%	1090690 (1770533)	504606 (305375-1153374)
Charity (excluding Wellcome and CRUK)	1,699	39.5%	£415,189,093	17.4%	244372 (391813)	151912 (81000-223244)
Department of Health	586	13.6%	£413,421,823	17.3%	705498 (2675223)	232173 (102391-471236)
BBSRC	511	11.9%	£223,651,002	9.4%	437673 (388793)	373356 (267848-501592)
EPSRC	356	8.3%	£201,861,623	8.5%	567027 (972696)	306906 (144056-604016)
Wellcome	193	4.5%	£140,425,805	5.9%	727594 (1679370)	226761 (164547-427455)
European Commission (inc ERC)	50	1.2%	£78,757,447	3.3%	1575149 (731858)	1409678 (1252574-1830017)
Other	136	3.2%	£77,195,650	3.2%	567615 (1901202)	129944 (69309-263613)
Total	**4299**		**£2,388,152,318**		**555513 (1429510)**	**231559 (114619-487063)**

	Research investment (UK pound) by burden observed, 2013			
Disease	**Mean ranking across all burden metrics**	**Mortality**	**Years lived with disability**	**Disability-adjusted life years**
Prostate	**2.7**	2	4	2
Ovarian	**3.0**	4	2	3
Mesothelioma	**4.0**	6	1	5
Breast	**4.0**	3	5	4
Testicular	**4.7**	1	3	10
Skin	**5.0**	5	9	1
Colorectal	**6.7**	7	7	6
Renal	**8.3**	8	10	7
Cervical	**9.7**	9	12	8
Pancreatic	**10.0**	12	6	12
Brain	**11.0**	11	11	11
Thyroid	**11.3**	10	15	9
Liver	**11.3**	13	8	13
Lung	**13.7**	14	13	14
Upper GI	**14.7**	15	14	15
Bladder	**16.0**	16	16	16

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Investments in cancer research awarded to UK institutions and the global burden of cancer 2000-2013: a systematic analysis

Mahiben Maruthappu[a],* Michael G Head[b],* Charlie Da Zhou[c], Barnabas J Gilbert[d], Majd A El-Harasis[e], Rosalind Raine[f], Joseph R Fitchett[g], Rifat Atun[g]

a Public Health Specialty Registrar, Epidemiology and Public Health, University College London, 1-19 Torrington Place, London, WC1E 6BT, UK

b Senior Research Fellow, Global Health Research Institute, Institute for Life Sciences, Faculty of Medicine, University of Southampton, Southampton, SO17 1BJ, UK

c Doctor, Medical Sciences Division, University of Oxford, Oxford OX1 2JD, UK

d Doctor, Harvard University, Cambridge, MA 02138, USA.

e Doctor, Faculty of Medicine, Imperial College London, London, SW7 2AZ, UK.

f Professor, Department of Applied Health Research, UCL, London, WC1E 7HB

g Professor, Harvard T. H. Chan School of Public Health, Harvard University, Boston, MA 02115, USA

* Authors Maruthappu and Head to be recognised as joint first-author

Corresponding author

Charlie Zhou

chazhou@gmail.com

New College, Holywell Street, Oxford, OX1 3BN, UK

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ABSTRACT

Objectives

We sought to systematically categorise cancer research investment awarded to UK institutions in the period 2000-2013 and to estimate research investment relative to disease burden as measured by mortality, disability-adjusted life years (DALYs), and years lived with disability (YLDs).

Design

Systematic analysis of all open access data.

Setting and participants

Public and philanthropic funding to all UK cancer research institutions, 2000-2013

Main outcome measures

Number and financial value of cancer research investment reported in 2013 UK pounds. Mortality, DALYs and YLDs data was acquired from the Global Burden of Diseases Study. A compound metric was adapted to estimate research investment relative to disease burden as measured by mortality, DALYs, and YLDs.

Results

We identified 4,299 funded studies with a total research investment of UK£2.4 billion. The highest funding by sites were haematological, breast, prostate, colorectal, and ovarian cancers. Relative to disease burden as determined by a compound metric combining mortality, DALYs and YLDs, gender-specific cancers were found to be highest funded - the five sites that received the most funding were prostate, ovarian, breast, mesothelioma, and testicular cancer; the least well-funded sites were liver, thyroid, lung, upper GI and bladder. Pre-clinical science accounted for 66.2% of award numbers and 62.2% of all funding. The top five areas of primary research focus by funding were pathogenesis, drug therapy, diagnostic, screening and monitoring, women's health, and immunology. The largest

individual funder was the Medical Research Council. In combination, the five lowest funded site specific cancers relative to disease burden account for 47.9%, 44.3% and 20.4% of worldwide cancer mortality, DALYs and YLDs.

Conclusions

Current and projected global cancer disease burden may be a consideration in the allocation of limited research funding. Funding agencies and industry need to openly document their research investment to enable the development of transparent and objective methods to allocate funding.

Strengths and limitations of this study:

- We systematically analyse UK investment in cancer research and describe trends by cancer site and type of science along the research pipeline.
- We consider cancer research investments alongside the global burden of disease to provide pragmatic commentary about areas of UK research strength and relative neglect to inform funder strategy and contribute towards policy discussions.
- Our study is dependent on the accuracy of original investment data from the funding bodies
- We could not openly access date of private sector research funding, nor were we able to obtain disaggregated award data from CRUK.
- Disease burden measures are typically an estimate and are subject to the potential introduction of bias; other variable influence funding decisions beyond the burden of disease.

Introduction

Cancers account for a high burden of morbidity and mortality worldwide. The Global Burden of Disease (GBD) Study estimates that cancer of all types resulted in 8,235,700 deaths in 2013[1]. Being predominantly a disease of older age, prevalence of cancers has historically fallen among high-income countries. However as low-income countries experience economic maturation, we are seeing an expanded distribution of this disease burden. Further deaths from cancer are projected due to global population growth and ageing[2,3]. Between 1990 and 2013, the proportion of all deaths that was attributable to cancer rose from 11.9% to 15.0%, largely among low- and middle-income countries and site-specific cancers accounted for 9 of the 50 leading causes of death, worldwide[1].

The socioeconomic impact of cancer, both in terms of direct costs involved in medical management as well as indirect costs resulting from productivity loss, on patients and caregivers are substantial. Direct health-related costs of cancer have been estimated to incur €51.0 billion within in the European Union[4] and $124.5 billion in the United States[5]. Indirect costs are estimated to account for additional losses of €75.2 billion and $115.8 billion, respectively. Economic evaluation of the impact of cancer outside of these two geographical regions has been lacking.

Investment in research and development (R&D) for cancers produces global public benefits that have a positive effect both locally and worldwide, irrespective of the site of the work or the location of the institution receiving an award, bringing substantial health, social, and economic benefit.

There are several national and international funding bodies that make cancer research investments along the R&D pipeline, from population health research, pre-clinical studies through to clinical trials and applied research. The UK remains one of the world's leading investors and producers of global biomedical and health research. Previous analyses by the Research Investments in Global Health study (ResIn, www.researchinvestments.org) has systematically analysed public and philanthropic awards totalling £3.7 billion to UK institutions for infectious disease from 1997 to 2013, and evaluated funding against global disease burden[6,7] and publications and citations as a marker of research output[8]. Tracking investments in R&D provides information and evidence to inform funding decisions and priority setting. Here, we present a systematic analysis of cancer-related research awarded by public and philanthropic funders to UK institutions from 2000 to 2013, categorise the data against a range of cancer-specific and cross-cutting disease areas, and assess the award data against global measures of mortality, disability-adjusted life years (DALYs), and years lived with disability (YLD) across three time points.

Methods

Our methods build on those developed for the infectious disease research investment analysis, which are described in detail elsewhere[6,7] and adapted in subsequent peer-reviewed publications (www.researchinvestments.org/publications).

We systematically examined funding awards from a number of public and philanthropic funding bodies (including the Medical Research Council, Department of Health, Biotechnology and Biological Sciences Research Council, Engineering and Physical Science Research Council, Wellcome Trust, European Commission, as well as 9 members of the Association of Medical Research Charities) between 2000 and 2013. Information was obtained by downloading openly-accessible information on the funder website, contacting the funder to request the information, or searching existing funding databases. For each award, the title and abstract, where available, were individually screened for relevance to cancer research. We excluded awards that were i) not obviously or immediately relevant to oncology; ii) led by a non-UK institution; iii) not considered to be for R&D activity. Studies that were completed without funding were also excluded. Private sector data were not available to evaluate at the same level of detail as public and philanthropic research award data, and were therefore excluded from this analysis. Cancer Research UK (CRUK) would not provide their funding data at individual award level, as in accordance with their organisational policy, and so could not be included in the main analysis. There is some description of individual CRUK awards without grant amounts available at https://europepmc.org/. We report total number of studies in this analysis.

Where awards were described in currencies other than UK pounds, these were converted to UK pounds using the mean exchange rate in the year of the award. All included awards were adjusted for inflation and reported in 2013 UK pounds.

Each study in the dataset was reviewed by one author (either CDZ, GJG, MAE-H, MGH) and assigned to as many of 14 cross-cutting categories as appropriate. The 14 association categories were paediatric, geriatric, infection-associated, women's health, men's health, occupational health, pathogenesis, diagnostic/screening/monitoring, drug therapy, radiotherapy, surgery, immunology, psychosocial and global health. Awards were defined as global health if they were considered to pursue a clear non-UK focus (e.g. 'thyroid cancer in Kenya'). The other category was only used when none of the aforementioned categories were deemed to be appropriate. Studies were also allocated to one of five categories along the R&D pipeline: pre-clinical; phase I, II, or III clinical trials; product development (including phase IV activity); public health; and cross-disciplinary research. The cross-disciplinary category was defined as an award containing significant components across two distinct areas along the R&D pipeline (such as pre-clinical research leading directly into a phase I trial). Provisional datasets were circulated to all authors for review and comment with checks by second authors on sections of the data and any disagreements settled by consensus. Final datasets were then again circulated for further review by all authors. Microsoft Excel 2010 and 2013 and Stata (V13) software were used for data analysis.

Global data on mortality, disability-adjusted life years (DALYs) and years lived with disability (YLDs) were available at time points 2005, 2010 and 2013. All burden data were sourced from the findings of the Global Burden of Disease (GBD) study, for 2013[1,9,10] and for 2010[11,12]. Burden data from 2005 were obtained directly from colleagues at the Institute for Health Metrics and Evaluation, USA.

As defined by the GBD study, YLDs for a disease or injury are the sum of the YLDs for each sequela associated with the disease or injury[10]. DALYS are the sum of YLLs and YLDs for each age–sex–country group[9].

In order to allow direct comparison of relative investment with global health metrics across disease areas and between different time periods, metrics were adapted from the infectious disease analyses to estimate the 'investment per mortality/DALY/YLD observed [7]'. The metrics were created using the following equation –

(Total research investment up to the year before the time point / number of deaths, DALYs or YLD at time point) / number of years of investment included

For example, for assessment of breast cancer mortality at the 2013 time point, we took the sum of breast cancer research investment 2000-2012 (£124,305,716) and divided that by number of deaths reported in 2013 (471000), and divided the result by the number of years of investment included (13) to get an 'investment per mortality observed' metric of £20.30.

These metrics were applied for research relating to 16 site-specific cancers, where there was comparable data in both the ResIn and GBD studies. We defined lung cancer by aggregating 'tracheal, bronchus and lung cancer' burden data from the GBD study. Similarly, we defined skin cancer by aggregating 'malignant skin melanoma' and 'non-malignant skin cancer', and we defined upper gastrointestinal (GI) cancer by aggregating 'oesophageal' and 'stomach cancer'. The use of total investment and the division by number of years included aimed to reduce the impact of the volatility of annual research funding and the relatively short periods between time points. Ranking scores of the investment metrics were developed for the 16 sites of cancer against 2013 burdens. Cancers were ranked in order of relative investment against burden from high to low and assigned a score (from 1 to 16). The mean ranking scores across mortality, DALYs and YLDs were used to illustrate an overall relative level of investment against 2013 global disease burden.

Patient involvement

There was no patient involvement in this study.

Results

We identified 4,299 funded studies that met our inclusion criteria (Table 1). The funding for these studies represented a total research investment of almost £2.4 billion. The mean award amount for each study was £555,513 (standard deviation (SD) £1,429,510) and median was £231,559 (inter-quartile range £114,619 – 487,063. 2,416 awards (56.2% of total) were designated towards a named site-specific cancer (Table 1), equating to £1.0 billion (40.3% of total). The top five cancer sites in terms of award number were haematological, breast, colorectal, prostate, and skin; the bottom five were testicular, bone, bladder, thyroid, and cholangiocarcinoma (Table 1). The top five cancer sites in terms of total funding were haematological, breast, prostate, colorectal and ovarian; the bottom five were testicular, mesothelioma, thyroid, bladder and chlangiocarinoma. Mean funding per award varied greatly between sites with prostate cancer receiving the most (£1.47 million) and bladder cancer the least (£117,385).

The top five areas of primary research focus, by number of awards, were drug therapy, diagnostic, screening and monitoring, women's health, immunology, and pathogenesis; the bottom five areas were men's health, surgery, occupational health, global health and geriatrics (Table 2). In terms of net funding, the top five areas of research were pathogenesis, drug therapy, diagnostic, screening and monitoring, women's health, and immunology; the bottom five were surgery, psychosocial, global health, occupational health, and geriatrics.

The majority of awards were focused on pre-clinical science, accounting for 66.2% of award numbers and 62.2% of all funding (Table 3). In terms of award number, this was followed by public health, cross-disciplinary, phase I-III, and product development. This order was reflected in terms of net investment, although cross-disciplinary studies ranked ahead of public health studies. Phase I-III clinical trials received the highest mean funding per award, at £736,172 (SD £3,361,312), whilst public health research received the least, at £496,744 (SD £1,000,757).

The largest individual funder of cancer research of the studies identified was the Medical Research Council, accounting for 35.1% of all funding (Table 4). The charitable sector was responsible for 39.5% of all awards (excluding CRUK) but 17.4% of funding. The European Commission was responsible for the largest mean grant per award (£1.58 million).

We generated a compound ranking score for the 16 sites of cancer against 2013 global disease burdens, across mortality, DALYs, and YLDs (table 5). The amount of investment per unit disease burden (£ per death/DALY/YLD) were used to compile this compound ranking score. The data for all site-specific cancers measured here are presented in the supplementary information (Supplemental Tables 1-3, Supplemental Figures 1-3). We identified the five sites that received the most funding relative to disease burden as prostate, ovarian, breast, mesothelioma and testicular cancer. The least well-funded sites relative to disease burden were cancers of the liver, thyroid, lung, upper GI, and bladder.

We were able to obtain some disaggregated data for 3,284 CRUK research grants during the period of interest but this excluded individual award data. Compared to the aggregation of all other funders, CRUK placed more of a focus on funding towards cancers of the prostate, ovary and liver – by study number these sites accounted for 6.9%, 3.4% and 2.7% of CRUK funded studies compared to 2.1%, 1.1% and 0.9% of all studies in our quantitative database, respectively. CRUK preferentially funded research investigating pathogenesis, which accounted for 51.0% of all grants awarded. In comparison, only 5.3% of all awards in our quantitative database were identified as primarily focused on pathogenesis.

Discussion

We identified 4,299 funded studies, with a total research investment of £2.4 billion. We performed qualitative analysis on a further 3,284 CRUK funded awards. The vast majority of all awards awarded were investigating at least one of pathogenesis, diagnosis, monitoring and screening and drug therapy. In the absence of CRUK data, the Medical Research Council and the Department of Health were the two leading funding sources. Preclinical research accounted for £1.5 billion (62.2%) of total R&D investment. Four of the five highest funded cancer sites relative to global disease burden were gender-specific – namely prostate, ovarian, breast, and testicular cancers. Cancer research with a clear focus on women's health accounted for 640 studies (14.9%) and £199.5 million (8.4%) of investment. In comparison, 111 studies (2.6%) and £143.3 million (6.0%) of investment had a clear link with men's health. This may reflect the successes of various institutions and charities that have sought to increase awareness of these sex-specific cancers. Breast cancer, the most commonly diagnosed cancer in the UK and the leading cause of cancer death in women, and prostate cancer, the second most frequently diagnosed cancer and the sixth leading cause of cancer death among men, were found to be relatively well funded[1,13].

We highlight several cancer sites where there might be underinvestment, namely that of liver, thyroid, lung, upper GI tract, and bladder. In our analysis cancer of the upper GI tract combines oesophageal and stomach cancer. These site-specific cancers identified to be relatively underfunded account for a substantial proportion of global cancer burden. Globally, these sites account for 47.9%, 44.3% and 20.4% of the global mortality[1], DALYs[9] and YLDs[10] of all cancers, respectively. The disparity between YLDs and DALYs demonstrates the poor prognosis and high mortality of these particular sites when compared against all neoplastic disease. Lung, liver, stomach and oesophagus are the first, second, third and fifth, leading sites of neoplastic mortality worldwide[1].

Two previous studies have compared UK cancer funding with years of life lost (YLLs). Burnett et al [14] reported the relative over-funding of breast cancers and leukaemia. Carter et al [15] likewise reported higher levels of funding than their burden suggests of testicular, leukaemia, Hodgkin's lymphoma, breast, cervical, ovarian, prostate cancer with relative underfunding of gallbladder, lung, nasopharyngeal, intestine, stomach, pancreatic, thyroid, oesophageal, liver, kidney, bladder, and brain/central nervous system. Although our site-specific classifications differed slightly, our findings are consistent with these previous studies. The slight differences that we report are likely due to our metrics which seek to capture mortality (global mortality and DALYs) and life burden (DALYs and YLDs) rather than just mortality, and also different included components in the respective datasets.

With regard to interventions research, there is heavy investment in drug-based modalities. £620.9 million (26.0%) was invested in novel drug therapies and £194.1 million (8.1%) was invested in the emergent role of immunomodulation. In comparison, funding towards radiotherapy and surgical interventions accounted for £88.2 million (3.7%) and £37.9 million (1.6%), respectively. In high-income settings, around half of new cancer diagnoses will undergo a course of radiotherapy treatment during their clinical management; roughly a quarter will receive two or more courses[16,17]. Globally, over 80% of cancer cases will warrant surgical intervention, where it has preventative, diagnostic, curative, supportive, palliative, and reconstructive roles[18].

Analysis by R&D pipeline showed that research investment in the UK places a heavy emphasis on pre-clinical research, but relatively little investment towards phase I-III clinical trials or product development, and this is line with previous research in infectious disease investment[6]. This may reflect the strengths of UK institutions in preclinical science, but also could suggest a need to strengthen research capacity further down the R&D chain. It would be useful to determine whether investment reflects the priorities of funding agencies and whether this is comparable to research investment in other countries. We noted a lack of readily available data from the pharmaceutical industry and this is likely to leave a data gap in particular for sum totals of investment in clinical trials of pharmaceutical products.

Our findings contribute to the development of transparent and objective methods to couple the allocation of limited research funds with disease burden. Previous studies have suggested that financial investment might appropriately be coupled with DALYs as a measure of burden[19–22]. Furthermore, previous UK research suggests that publicly funded cancer research offers substantial rates of return in terms of both health and monetary benefit [23]. We have further sought to incorporate mortality rates and YLDs into the consideration of cancer research investment.

We have chosen to compare cancer research funding to global rather than domestic UK disease burden. Due to increasing globalization, the emergence of non-communicable disease burden in resource poor settings, the internationalization of healthcare, the flow of people across national borders and the role of the UK as an international centre of biomedical research, we believe this approach to be justified.

However, defining an appropriate amount of research investment for each site specific cancer is challenging since cancers of similar disease burdens may warrant different levels of investment to develop cost-effective interventions. Decisions may be influenced by any of a number of factors, for example due to exceptional need, as may be the case in mesothelioma, or due to public awareness and third-party lobbying, as may be the case with regards to the gender-specific cancers.

A variety of factors contribute towards the difficulty in tracking net cancer research investment within the UK. Fragmentation of data from a large number of diverse public and private sources of funding, poorly designed donor accounting structures, where available, and the paucity of information from the private sector limit the evidence base to inform policy in real-time. In our study, we were unable to obtain quantitative data from CRUK, the world's largest cancer research charity and a leader in cancer research. They do not routinely publish or make available disaggregated investment data which is, in our experience across the infection and cancer analyses, unique amongst the more high-profile UK funders who are universally more transparent in their award decisions[24]. Transparency in the tracking and monitoring of cancer research financing is essential to enable accountability and equity in resource allocation and to facilitate further future research in this area.

In this study we systematically analyse UK investment in cancer research and identify areas of relative neglect. Although the competitive application process used by most funders to allocate research grants ensure a portfolio of high quality, the absence of explicit resource allocation criteria could contribute towards inequalities in R&D by disease burden. Funding agencies will have particular areas of focus, and UK funders may have considered the focus of international agencies in their own research strategies. As a result, international data is essential to complete the mapping of cancer research investment. Nevertheless, our findings will inform funders and contribute towards policy discussions to prevent inequity in the allocation of limited resources.

By demonstrating the relationship between disease burden and research funding, we enable the identification of potential investment gaps. However, it is not possible to equate gaps in funding with areas of neglect without consideration of other influences such as the feasibility of research, costs of technologies, infrastructure and skill requirements, political and social considerations, and the accuracy of disease burden estimates.

There are several potential limitations to our study. We are dependent on the accuracy of original investment data as sourced from the funding bodies. Although checks were made on any obvious discrepancies or errors, interpretation of these original data may contain errors. We made no attempt to investigate the contribution of any indirect or estate costs. Currency conversions were averaged across each financial year and any intra-year fluctuations may not have been captured. Unless clearly documented, we were unable to assess how funding was distributed from lead institutions to collaborative partners. We considered individual awards, rather than number of studies.

Furthermore, assignment of disease categories and allocation of studies according to these categories is subjective, and there might be disagreements regarding certain inclusion criteria. As YLLs were not included in our analysis, we may underrepresent the disease burden of cancers that occur disproportionately in the young and which are associated with poor survival, notably cancers of the ovary, cervix and CNS [14]. However, we would expect any additional information offered by YLL analysis to be predominantly captured by use of DALYs.

We could not openly access data of private sector research funding, nor were we able to obtain disaggregated award data from CRUK. Whilst our analysis did demonstrate that CRUK funding (with some exceptions) broadly reflected the findings of our quantitative database, it is likely that substantial awards towards particular areas of research could skew results; for example, the CRUK accounts for 2014/15 suggest £394 million was invested into research or research-related activity, and we hypothesise that much of that would have met our inclusion criteria for this analysis[25]. Disease burden measures are typically an estimate and are subject to the potential introduction of bias from missing or unobtainable data as well as from differences in classification and diagnosis.

Our report presents the latest investment data on cancer research awarded to UK institution between 2000 and 2013. Cancers of the liver, thyroid, lung, upper GI tract, and bladder as well as research towards radiotherapy and surgical techniques in particular may warrant increased rates of investment. We will make the entire database and associated figures available online (www.researchinvestment.org) to assist policy makers, funding organisations, and researchers in the identification of investment gaps. We further encourage funding organisations to make their investment portfolios openly accessible to facilitate future research.

We hope that open funding data in this area can contribute to redressing the misalignments in investments for cancer research. Cancer research can improve the clinical course of disease and offer tangible improvements in health outcomes[23]. Both policy makers and the scientific community need to ensure that limited resources are allocated appropriately to most effectively alleviate the morbidity and mortality associated with cancer.

Contributions

MM and MGH are the guarantors of this study. MM, MGH, JRF and RA conceived and designed the study. MGH, CDZ, BJG and MAE-H obtained the data. MM and MGH conducted data formatting and statistical analysis. All authors helped interpret the findings. MM, MGH and CDZ wrote the first draft of the manuscript with input from RR, JRF and RA; all authors provided input to subsequent drafts. All authors had full access to all of the data in the study and take responsibility for its integrity and the accuracy of data analysis.

Transparency declaration

MM affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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Competing interests

All authors declare no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval

Not required

Data sharing

All data used is publicly available. Entire database and associated figures are permanently available with open access online (www.researchinvestment.org) to assist policy makers, funding organisations, and researchers.

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Table Legends

Table 1: Cancer research investment awards and funding by site. All investment reported in 2013 UK pounds.

	All funders where investment data was available						Cancer Research UK	
Site of cancer	**Number of awards**	**Percentage of total**	**Sum investment (£)**	**Percentage of total**	**Mean award, £ (SD)**	**Median award, £ (IQR)**	**Number of awards**	**Percentage of all oncology research awards**
Breast	571	13.3%	£137,960,107	5.8%	241611 (414584)	135752 (25000-216673)	273	8.3%
Haematological	1158	26.9%	£381,008,394	16.0%	329022 (476943)	186813 (120437-272324)	225	6.9%
Colorectal	147	3.4%	£77,279,857	3.2%	525713 (674881)	251800 (102078-819866)	205	6.2%
Prostate	92	2.1%	£135,290,779	5.7%	1470552 (6156372)	333757 (155227-721037)	123	3.7%
Ovarian	48	1.1%	£44,709,938	1.9%	931457 (3380145)	226764 (131990-627401)	112	3.4%
Lung	82	1.9%	£24,263,280	1.0%	295893 (556278)	146123 (66701-242934)	89	2.7%
Skin	87	2.0%	£22,179,011	0.9%	254931 (453726)	85406 (69629-248603)	84	2.6%
Brain	22	0.5%	£9,994,255	0.4%	454284 (498933)	401046 (196928-528008)	83	2.5%
Upper GI and	18	0.4%	£19,094,230	0.8%	1060791 (1448010)	788850 (80964-1296962)	80	2.4%
Head and neck	20	0.5%	£18,250,632	0.8%	912531 (1003091)	389751 (167358-1602465)	68	2.1%
Renal	19	0.4%	£13,885,496	0.6%	730815 (678732)	479197 (244075-1252574)	48	1.5%
Bladder	10	0.2%	£1,173,856	0.0%	117385 (106902)	94520 (29264- 173855)	48	1.5%
Cervical	26	0.6%	£14,328,402	0.6%	551092 (877250)	210179 (88934-368402)	43	1.3%
Pancreatic	16	0.4%	£9,453,577	0.4%	590848 (519850)	276237 (191804-1033948)	40	1.2%
Bone	13	0.3%	£17,242,183	0.7%	1326322 (1604685)	685853 (243559-1999907)	29	0.9%
Liver	37	0.9%	£25,037,541	1.0%	676690 (847151)	319082 (177974-776480)	20	0.6%
Mesothelioma	30	0.7%	£4,476,088	0.2%	149202 (101201)	137103 (95895-205500)	11	0.3%
Cholangiocarcinoma	2	0.0%	£582,405	0.0%	n/a	n/a	11	0.3%
Testicular	14	0.3%	£5,949,990	0.2%	424999 (507277)	242175 (102938-411010)	11	0.3%
Thyroid	4	0.1%	£1,375,881	0.1%	n/a	n/a	7	0.2%
Total	**4299**		**£2,388,152,318**		**555513 (1429510)**	**231559 (114619-487063)**	**3284**	

Table 2: Cancer research investment awards and funding by cross-cutting theme. All investment reported in 2013 UK pounds.

	All funders where investment data was available						Cancer Research UK	
Cross-cutting theme	**Number of awards**	**Percentage of total**	**Sum investment (£)**	**Percentage of total**	**Mean award, £ (SD)**	**Median award, £ (IQR)**	**Number of awards**	**Percentage of all oncology research awards**
Pathogenesis (mechanism)	227	5.3%	£1,374,387,838	57.6%	543881 (955710)	248573 (135752-506232)	1674	51.0%
Drug Therapy	1104	25.7%	£620,961,060	26.0%	562464 (1910050)	202342 (105622-436559)	935	28.5%
Diagnostic, Screening and Monitoring	681	15.8%	£359,618,823	15.1%	528074 (1155156)	205728 (102672-513836)	404	12.3%
Women's Health	640	14.9%	£199,534,693	8.4%	311773 (1041520)	153845 (56515-227202)	287	8.7%
Immunology (inc. biologics)	451	10.5%	£194,086,617	8.1%	430347 (760955)	240052 (125669-466250)	212	6.5%
Radiotherapy	112	2.6%	£88,262,353	3.7%	788056 (2413445)	243333 (106175-439419)	209	6.4%
Psychosocial	117	2.7%	£23,445,835	1.0%	200391 (352410)	87463 (27317-239059)	122	3.7%
Men's Health	111	2.6%	£143,392,908	6.0%	1291828 (5617919)	285203 (126037-700353)	120	3.7%
Paediatrics	175	4.1%	£62,641,938	2.6%	357953 (547484)	183099 (89522-322261)	118	3.6%
Surgery	72	1.7%	£37,900,334	1.6%	526393 (684908)	235413 (97890-761651)	95	2.9%
Infection-associated	129	3.0%	£56,819,379	2.4%	440460 (798013)	231836 (134693-439378)	48	1.5%
Global Health	12	0.3%	£6,434,960	0.3%	536246 (1089118)	129738 (77519-459274)	12	0.4%
Geriatrics	7	0.2%	£1,616,394	0.1%	230913 (254925)	121623 (76421-262167)	8	0.2%
Occupational Health	18	0.4%	£2,576,841	0.1%	143157 (116928)	137103 (33857-199998)	8	0.2%
Total	**4299**		**£2,388,152,318**		**555513 (1429510)**	**231559 (114619-487063)**	**3284**	

Table 3: Cancer research investment awards and funding by type of science. All investment reported in 2013 UK pounds.

	All funders where investment data was available						Cancer Research UK	
Type of science	**Number of awards**	**Percentage of total**	**Sum investment (£)**	**Percentage of total**	**Mean award, £ (SD)**	**Median award, £ (IQR)**	**Number of awards**	**Percentage of all oncology research awards**
Pre-clinical	2845	66.2%	£1,485,997,379	62.2%	522318 (1006600)	240974 (132188-490872)	1809	55.1%
Phase I-III	303	7.0%	£223,060,276	9.3%	736172 (3361312)	178535 (70934-502399)	647	19.7%
Product development	172	4.0%	£104,214,364	4.4%	605897 (2213394)	193051 (75270-360813)	52	1.6%
Cross-disciplinary	441	10.3%	£315,145,351	13.2%	714615 (1586882)	238523 (126589-703764)	328	10.0%
Public health	512	11.9%	£254,333,282	10.6%	496744 (1000757)	209364 (82870-383623)	443	13.5%
Unable to specify	26	0.6%	£5,401,666	0.2%	n/a	n/a	5	0.2%
Total	**4299**		**£2,388,152,318**		**555513 (1429510)**	**231559 (114619-487063)**	**3284**	

Table 4: Cancer research investment awards and funding by funding agency (excluding CRUK). All investment reported in 2013 UK pounds.

	All funders where investment data was available					
Funder	**Number of awards**	**Percentage of total**	**Sum investment (£)**	**Percentage of total**	**Mean award, £ (SD)**	**Median award, £ (IQR)**
MRC	768	17.9%	£837,649,875	35.1%	1090690 (1770533)	504606 (305375-1153374)
Charity (excluding Wellcome and CRUK)	1,699	39.5%	£415,189,093	17.4%	244372 (391813)	151912 (81000-223244)
Department of Health	586	13.6%	£413,421,823	17.3%	705498 (2675223)	232173 (102391-471236)
BBSRC	511	11.9%	£223,651,002	9.4%	437673 (388793)	373356 (267848-501592)
EPSRC	356	8.3%	£201,861,623	8.5%	567027 (972696)	306906 (144056-604016)
Wellcome	193	4.5%	£140,425,805	5.9%	727594 (1679370)	226761 (164547-427455)
European Commission (inc ERC)	50	1.2%	£78,757,447	3.3%	1575149 (731858)	1409678 (1252574-1830017)
Other	136	3.2%	£77,195,650	3.2%	567615 (1901202)	129944 (69309-263613)
Total	**4299**		**£2,388,152,318**		**555513 (1429510)**	**231559 (114619-487063)**

Table 5: Compound ranking score for cancer research investment against 2013 global disease burdens, across mortality, YLDs, and DALYs, by cancer site.

	Research investment (UK pound) by burden observed, 2013			
Disease	**Mean ranking across all burden metrics**	**Mortality**	**Years lived with disability**	**Disability-adjusted life years**
Prostate	**2.7**	2	4	2
Ovarian	**3.0**	4	2	3
Mesothelioma	**4.0**	6	1	5
Breast	**4.0**	3	5	4
Testicular	**4.7**	1	3	10
Skin	**5.0**	5	9	1
Colorectal	**6.7**	7	7	6
Renal	**8.3**	8	10	7
Cervical	**9.7**	9	12	8
Pancreatic	**10.0**	12	6	12
Brain	**11.0**	11	11	11
Thyroid	**11.3**	10	15	9
Liver	**11.3**	13	8	13
Lung	**13.7**	14	13	14
Upper GI	**14.7**	15	14	15
Bladder	**16.0**	16	16	16

Supplementary Table 1: Investment per mortality observed for all site-specific cancers

	Number of deaths			Investment per mortality observed		
	2005	2010	2013	**2005**	**2010**	**2013**
Bladder	156385	170700	173900	£0.03	£0.26	£0.49
Brain	177191	195500	203900	£0.00	£2.02	£2.76
Breast	407108	438700	471000	£5.35	£18.20	£20.30
Cervical	221578	225400	235700	£2.93	£5.63	£4.50
Colorectal	644648	714600	771000	£3.54	£5.45	£6.77
Liver	715141	752100	818000	£0.04	£1.00	£1.45
Lung	1391577	1527100	1639600	£0.15	£0.57	£1.08
Mesothelioma	22128	n/a	33700	£0.81	?	£8.33
Ovarian	134354	160500	157800	£23.00	£20.98	£19.79
Pancreatic	276753	310200	352400	£0.56	£0.86	£1.67
Prostate	225081	256000	292700	£53.92	£45.19	£34.22
Renal	113048	162100	133800	£0.00	£2.27	£5.96
Skin	?	79700	96100	?	£14.20	£16.30
Testicular	7547	7700	8300	£7.27	£44.69	£55.14
Thyroid	29092	36000	33700	£0.00	£1.70	£3.14
Upper GI and oesophageal	1229320	1130100	1281200	£0.93	£1.18	£1.03

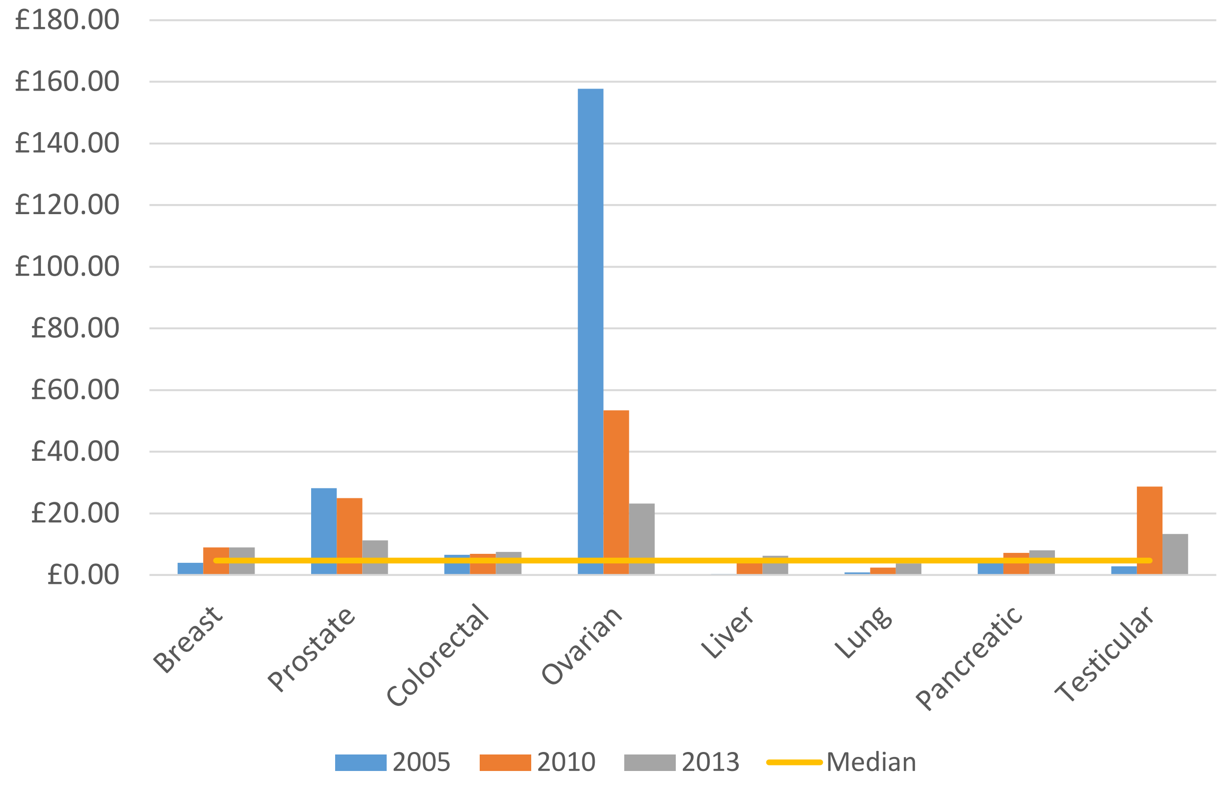
Supplementary Table 2: Investment per YLD observed for all site-specific cancers

	YLD			Investment per YLD observed		
	2005	2010	2013	2005	2010	2013
Bladder	153647	125000	179800	£0.05	£0.35	£0.47
Brain	105126	94000	121900	£0.00	£4.20	£4.61
Breast	885550	898000	1068200	£3.93	£8.89	£8.95
Cervical	242359	111000	243800	£4.28	£11.44	£4.35
Colorectal	561019	564000	701900	£6.50	£6.91	£7.44
Liver	160071	140000	190600	£0.29	£5.39	£6.24
Lung	388206	355000	467400	£0.86	£2.44	£3.78
Mesothelioma	7109	n/a	10800	£4.04	?	£25.98
Ovarian	31339	63000	134900	£157.75	£53.44	£23.15
Pancreatic	57317	37000	73600	£4.35	£7.18	£8.01
Prostate	690602	464000	893700	£28.12	£24.93	£11.21
Renal	112449	79000	139200	£0.00	£4.66	£5.72
Skin	?	300000	264100	?	£3.77	£5.93
Testicular	31339	12000	34300	£2.80	£28.67	£13.34
Thyroid	109078	48000	127600	£0.00	£1.27	£0.83
Upper GI and oesophageal	382757	304000	416100	£4.77	£4.39	£3.17

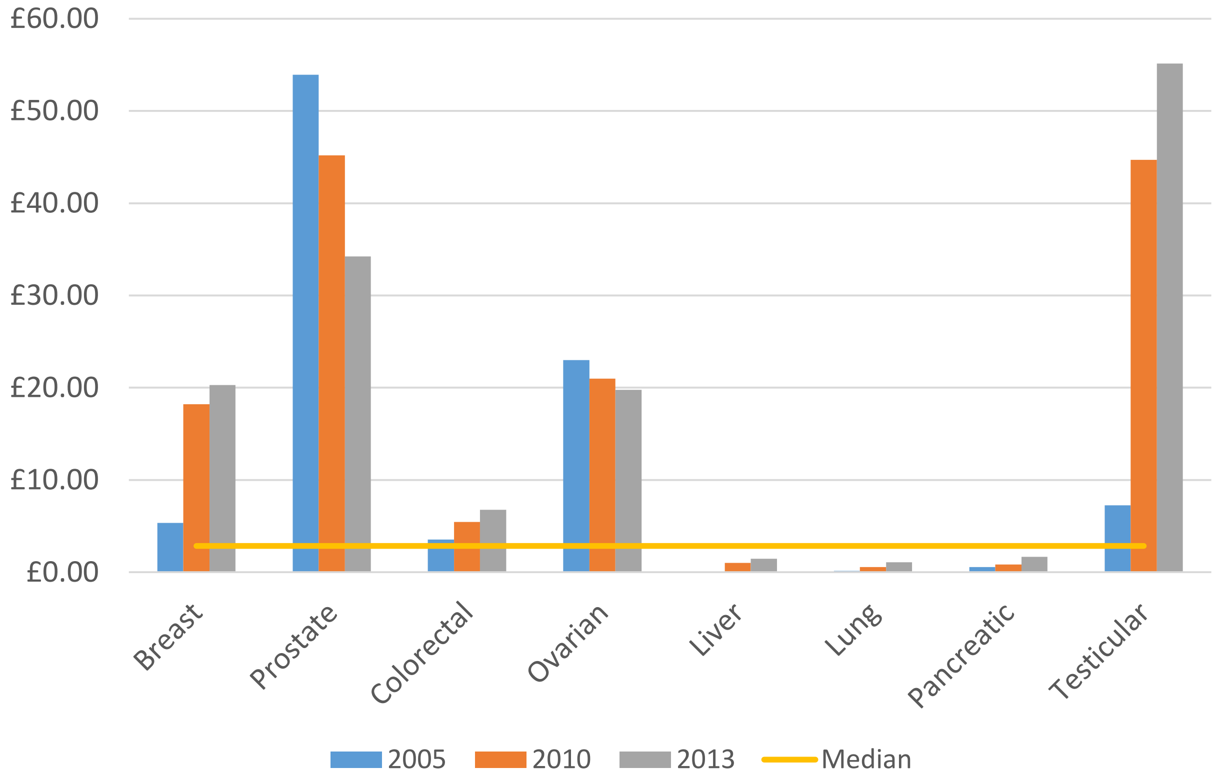
Supplementary Table 3: Investment per DALY observed for all site-specific cancers

	Global DALYs			Investment per DALY observed		
	2005	2010	2013	2005	2010	2013
Bladder	2987377	3015000	3139900	£0.00	£0.01	£0.03
Brain	6163358	6060000	6692200	£0.00	£0.07	£0.08
Breast	11762493	12018000	13258700	£0.19	£0.66	£0.72
Cervical	6775622	6440000	6914700	£0.10	£0.20	£0.15
Colorectal	13747947	14422000	15794100	£0.17	£0.27	£0.33
Liver	19175329	19111000	20888700	£0.00	£0.04	£0.06
Lung	30791630	32405000	34732900	£0.01	£0.03	£0.05
Mesothelioma	504037	n/a	763500	£0.04	?	£0.37
Ovarian	3541657	4118000	4056500	£0.87	£0.82	£0.77
Pancreatic	5704661	6161000	7029100	£0.03	£0.04	£0.08
Prostate	3812057	3787000	4768800	£3.18	£3.05	£2.10
Renal	2810156	3676000	3150300	£0.00	£0.10	£0.25
Skin	?	1967000	237200	?	£0.58	£6.61
Testicular	354875	313000	3787700	£0.15	£1.10	£0.12
Thyroid	764526	836000	851900	£0.00	£0.07	£0.12
Upper GI and oesophageal	27964269	25356000	27749600	£0.04	£0.05	£0.05

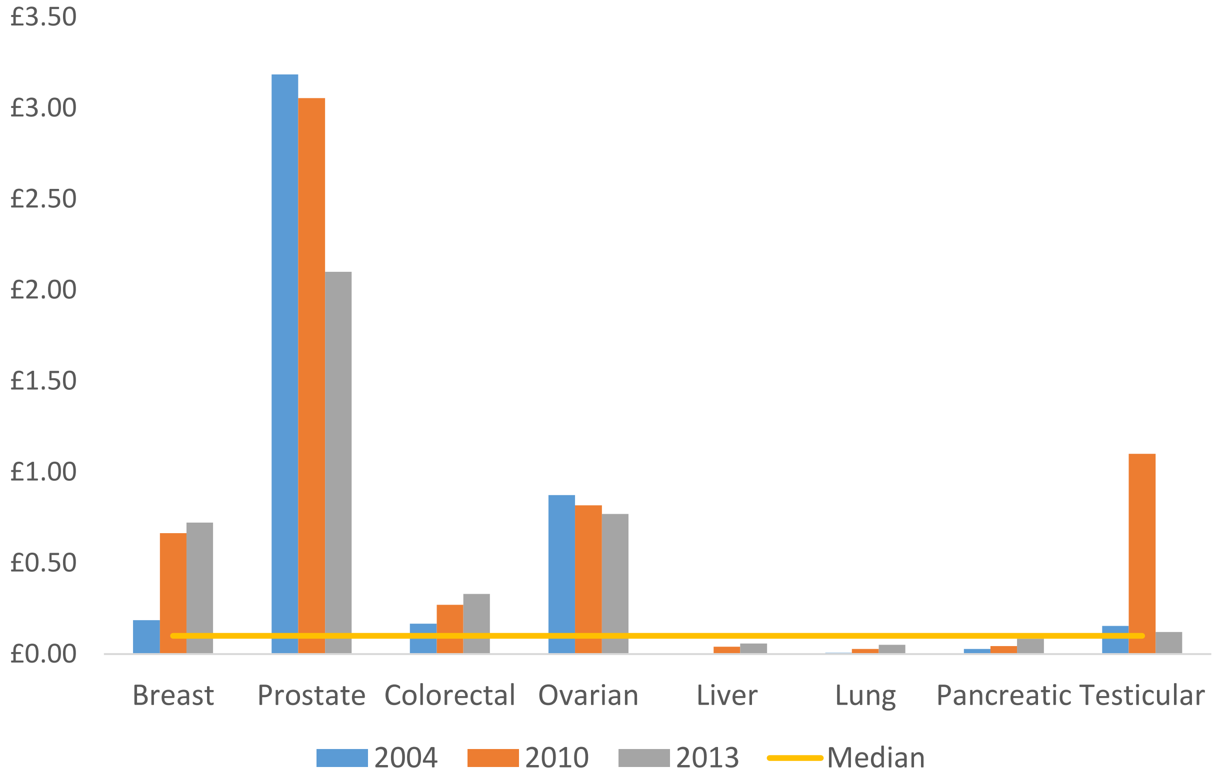
Supplementary Figure 1: Investment per YLD (£/YLD) for 8 indicator site-specific cancers



Supplementary Figure 1: Investment per death (£/death) for 8 indicator site-specific cancers



Supplementary Figure 1: Investment per DALY (£/DALY) for 8 indicator site-specific cancers



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Investments in cancer research awarded to UK institutions and the global burden of cancer 2000-2013: a systematic analysis

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Investments in cancer research awarded to UK institutions and the global burden of cancer 2000-2013: a systematic analysis

Mahiben Maruthappu[a],* Michael G Head[b],* Charlie Da Zhou[c], Barnabas J Gilbert[d], Majd A El-Harasis[e], Rosalind Raine[f], Joseph R Fitchett[g], Rifat Atun[g]

a Public Health Specialty Registrar, Epidemiology and Public Health, University College London, 1-19 Torrington Place, London, WC1E 6BT, UK

b Senior Research Fellow, Global Health Research Institute, Institute for Life Sciences, Faculty of Medicine, University of Southampton, Southampton, SO17 1BJ, UK

c Doctor, Medical Sciences Division, University of Oxford, Oxford OX1 2JD, UK

d Doctor, Harvard University, Cambridge, MA 02138, USA.

e Doctor, Faculty of Medicine, Imperial College London, London, SW7 2AZ, UK.

f Professor, Department of Applied Health Research, UCL, London, WC1E 7HB

g Professor, Harvard T. H. Chan School of Public Health, Harvard University, Boston, MA 02115, USA

* Authors Maruthappu and Head to be recognised as joint first-author

Corresponding author

Charlie Zhou

chazhou@gmail.com

New College, Holywell Street, Oxford, OX1 3BN, UK

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ABSTRACT

Objectives

We sought to systematically categorise cancer research investment awarded to UK institutions in the period 2000-2013 and to estimate research investment relative to disease burden as measured by mortality, disability-adjusted life years (DALYs), and years lived with disability (YLDs).

Design

Systematic analysis of all open access data.

Setting and participants

Public and philanthropic funding to all UK cancer research institutions, 2000-2013

Main outcome measures

Number and financial value of cancer research investment reported in 2013 UK pounds. Mortality, DALYs and YLDs data was acquired from the Global Burden of Diseases Study. A compound metric was adapted to estimate research investment relative to disease burden as measured by mortality, DALYs, and YLDs.

Results

We identified 4,299 funded studies with a total research investment of UK£2.4 billion. The highest funding by sites were haematological, breast, prostate, colorectal, and ovarian cancers. Relative to disease burden as determined by a compound metric combining mortality, DALYs and YLDs, gender-specific cancers were found to be highest funded - the five sites that received the most funding were prostate, ovarian, breast, mesothelioma, and testicular cancer; the least well-funded sites were liver, thyroid, lung, upper GI and bladder. Pre-clinical science accounted for 66.2% of award numbers and 62.2% of all funding. The top five areas of primary research focus by funding were pathogenesis, drug therapy, diagnostic, screening and monitoring, women’s health, and immunology. The largest

individual funder was the Medical Research Council. In combination, the five lowest funded site specific cancers relative to disease burden account for 47.9%, 44.3% and 20.4% of worldwide cancer mortality, DALYs and YLDs.

Conclusions

The cancer sites which we identify as receiving higher levels of funding relative to disease burden are broadly consistent with those reported in previous studies. Funding agencies and industry need to openly document their research investment to enable the development of transparent and objective methods to allocate funding.

Strengths and limitations of this study:

- We systematically analyse UK investment in cancer research and describe trends by cancer site and type of science along the research pipeline.
- We consider cancer research investments alongside the global burden of disease to provide pragmatic commentary about areas of UK research strength and relative neglect to inform funder strategy and contribute towards policy discussions.
- Our study is dependent on the accuracy of original investment data from the funding bodies
- We could not openly access date of private sector research funding, nor were we able to obtain disaggregated award data from CRUK, which impedes discussion around the equity of investment decisions.
- Disease burden measures are typically an estimate and are subject to the potential introduction of bias; other variable influence funding decisions beyond the burden of disease.

Introduction

Cancers account for a high burden of morbidity and mortality worldwide. The Global Burden of Disease (GBD) Study estimates that cancer of all types resulted in 8,235,700 deaths in 2013[1]. Being predominantly a disease of older age, prevalence of cancers has historically fallen among high-income countries. However as low-income countries experience economic maturation, we are seeing an expanded distribution of this disease burden. Further deaths from cancer are projected due to global population growth and ageing[2,3]. Between 1990 and 2013, the proportion of all deaths that was attributable to cancer rose from 11.9% to 15.0%, largely among low- and middle-income countries and site-specific cancers accounted for 9 of the 50 leading causes of death, worldwide[1].

The socioeconomic impact of cancer, both in terms of direct costs involved in medical management as well as indirect costs resulting from productivity loss, on patients and caregivers are substantial. Direct health-related costs of cancer have been estimated to incur €51.0 billion within in the European Union[4] and $124.5 billion in the United States[5]. Indirect costs are estimated to account for additional losses of €75.2 billion and $115.8 billion, respectively. Economic evaluation of the impact of cancer outside of these two geographical regions has been lacking.

Investment in research and development (R&D) for cancers produces global public benefits that have a positive effect both locally and worldwide, irrespective of the site of the work or the location of the institution receiving an award, bringing substantial health, social, and economic benefit.

There are several national and international funding bodies that make cancer research investments along the R&D pipeline, from population health research, pre-clinical studies through to clinical trials and applied research. The UK remains one of the world’s leading investors and producers of global biomedical and health research. Previous analyses by the Research Investments in Global Health study (ResIn, www.researchinvestments.org) has systematically analysed public and philanthropic awards totalling £3.7 billion to UK institutions for infectious disease from 1997 to 2013, and evaluated funding against global disease burden[6,7] and publications and citations as a marker of research output[8]. Tracking investments in R&D provides information and evidence to inform funding decisions and priority setting. Here, we present a systematic analysis of cancer-related research awarded by public and philanthropic funders to UK institutions from 2000 to 2013, categorise the data against a range of cancer-specific and cross-cutting disease areas, and assess the award data against global measures of mortality, disability-adjusted life years (DALYs), and years lived with disability (YLD) across three time points and in the wider literature.

Methods

Our methods build on those developed for the infectious disease research investment analysis, which are described in detail elsewhere[6,7] and adapted in subsequent peer-reviewed publications (www.researchinvestments.org/publications).

We systematically examined funding awards from a number of public and philanthropic funding bodies (including the Medical Research Council, Department of Health, Biotechnology and Biological Sciences Research Council, Engineering and Physical Science Research Council, Wellcome Trust, European Commission, as well as 9 members of the Association of Medical Research Charities) between 2000 and 2013. Information was obtained by downloading openly-accessible information on the funder website, contacting the funder to request the information, or searching existing funding databases. For each award, the title and abstract, where available, were individually screened for relevance to cancer research. We excluded awards that were i) not obviously or immediately relevant to oncology; ii) led by a non-UK institution; iii) not considered to be for R&D activity. Studies that were completed without funding were also excluded. Private sector data were not available to evaluate at the same level of detail as public and philanthropic research award data, and were therefore excluded from this analysis.

Cancer Research UK (CRUK) would not provide their funding data at individual award level and so could not be included in the main analysis. There is some description of individual CRUK awards without grant amounts available at https://europepmc.org/. We report total number of studies in this analysis.

Where awards were described in currencies other than UK pounds, these were converted to UK pounds using the mean exchange rate in the year of the award. All included awards were adjusted for inflation and reported in 2013 UK pounds.

Each study in the dataset was reviewed by one author (either CDZ, GJG, MAE-H, MGH) and assigned to as many of 14 cross-cutting categories as appropriate. The 14 association categories were paediatric, geriatric, infection-associated, women's health, men's health, occupational health, pathogenesis, diagnostic/screening/monitoring, drug therapy, radiotherapy, surgery, immunology, psychosocial and global health. Awards were defined as global health if they were considered to pursue a clear non-UK focus (e.g. 'thyroid cancer in Kenya'). The other category was only used when none of the aforementioned categories were deemed to be appropriate. Studies were also allocated to one of five categories along the R&D pipeline: pre-clinical; phase I, II, or III clinical trials; product development (including phase IV activity); public health; and cross-disciplinary research. The cross-disciplinary category was defined as an award containing significant components across two distinct areas along the R&D pipeline (such as pre-clinical research leading directly into a phase I trial). Provisional datasets were circulated to all authors for review and comment with checks by second authors on sections of the data and any disagreements settled by consensus. Final datasets were then again circulated for further review by all authors. Microsoft Excel 2010 and 2013 and Stata (V13) software were used for data analysis.

Global data on mortality, disability-adjusted life years (DALYs) and years lived with disability (YLDs) were available at time points 2005, 2010 and 2013. All burden data were sourced from the findings of the Global Burden of Disease (GBD) study, for 2013[1,9,10] and for 2010[11,12]. Burden data from

2005 were obtained directly from colleagues at the Institute for Health Metrics and Evaluation, USA. As defined by the GBD study, YLDs for a disease or injury are the sum of the YLDs for each sequela associated with the disease or injury[10]. DALYS are the sum of YLLs and YLDs for each age–sex–country group[9].

In order to allow direct comparison of relative investment with global health metrics across disease areas and between different time periods, metrics were adapted from the infectious disease analyses to estimate the ‘investment per mortality/DALY/YLD observed [7]’. The metrics were created using the following equation –

(Total research investment up to the year before the time point / number of deaths, DALYs or YLD at time point) / number of years of investment included

For example, for assessment of breast cancer mortality at the 2013 time point, we took the sum of breast cancer research investment 2000-2012 (£124,305,716) and divided that by number of deaths reported in 2013 (471000), and divided the result by the number of years of investment included (13) to get an ‘investment per mortality observed’ metric of £20.30.

These metrics were applied for research relating to 16 site-specific cancers, where there was comparable data in both the ResIn and GBD studies. We defined lung cancer by aggregating ‘tracheal, bronchus and lung cancer’ burden data from the GBD study. Similarly, we defined skin cancer by aggregating ‘malignant skin melanoma’ and ‘non-malignant skin cancer’, and we defined upper gastrointestinal (GI) cancer by aggregating ‘oesophageal’ and ‘stomach cancer’. The use of total investment and the division by number of years included aimed to reduce the impact of the volatility of annual research funding and the relatively short periods between time points. Ranking scores of the investment metrics were developed for the 16 sites of cancer against 2013 burdens. Cancers were ranked in order of relative investment against burden from high to low and assigned a score (from 1 to 16). The mean ranking scores across mortality, DALYs and YLDs were used to illustrate an overall relative level of investment against 2013 global disease burden.

Patient involvement

There was no patient involvement in this study.

Results

We identified 4,299 funded studies that met our inclusion criteria (Table 1). The funding for these studies represented a total research investment of almost £2.4 billion. The mean award amount for each study was £555,513 (standard deviation (SD) £1,429,510) and median was £231,559 (inter-quartile range £114,619 – 487,063. 2,416 awards (56.2% of total) were designated towards a named site-specific cancer (Table 1), equating to £1.0 billion (40.3% of total). The top five cancer sites in terms of award number were haematological, breast, colorectal, prostate, and skin; the bottom five were testicular, bone, bladder, thyroid, and cholangiocarcinoma (Table 1). The top five cancer sites in terms of total funding were haematological, breast, prostate, colorectal and ovarian; the bottom five were testicular, mesothelioma, thyroid, bladder and chlangiocarinoma. Mean funding per award varied greatly between sites with prostate cancer receiving the most (£1.47 million) and bladder cancer the least (£117,385).

The top five areas of primary research focus, by number of awards, were drug therapy, diagnostic, screening and monitoring, women's health, immunology, and pathogenesis; the bottom five areas were men's health, surgery, occupational health, global health and geriatrics (Table 2). In terms of net funding, the top five areas of research were pathogenesis, drug therapy, diagnostic, screening and monitoring, women's health, and immunology; the bottom five were surgery, psychosocial, global health, occupational health, and geriatrics.

The majority of awards were focused on pre-clinical science, accounting for 66.2% of award numbers and 62.2% of all funding (Table 3). In terms of award number, this was followed by public health, cross-disciplinary, phase I-III, and product development. This order was reflected in terms of net investment, although cross-disciplinary studies ranked ahead of public health studies. Phase I-III clinical trials received the highest mean funding per award, at £736,172 (SD £3,361,312), whilst public health research received the least, at £496,744 (SD £1,000,757).

The largest individual funder of cancer research of the studies identified was the Medical Research Council, accounting for 35.1% of all funding (Table 4). The charitable sector was responsible for 39.5% of all awards (excluding CRUK) but 17.4% of funding. The European Commission was responsible for the largest mean grant per award (£1.58 million).

We generated a compound ranking score for the 16 sites of cancer against 2013 global disease burdens, across mortality, DALYs, and YLDs (table 5). The amount of investment per unit disease burden (£ per death/DALY/YLD) were used to compile this compound ranking score. The data for all site-specific cancers measured here are presented in the supplementary information (Supplemental Tables 1-3, Supplemental Figures 1-3). We identified the five sites that received the most funding relative to disease burden as prostate, ovarian, breast, mesothelioma and testicular cancer. The least well-funded sites relative to disease burden were cancers of the liver, thyroid, lung, upper GI, and bladder.

We were able to obtain some disaggregated data for 3,284 CRUK research grants during the period of interest but this excluded individual award data. Compared to the aggregation of all other funders, CRUK placed more of a focus on funding towards cancers of the prostate, ovary and liver – by study number these sites accounted for 6.9%, 3.4% and 2.7% of CRUK funded studies compared to 2.1%, 1.1% and 0.9% of all studies in our quantitative database, respectively. CRUK preferentially funded research investigating pathogenesis, which accounted for 51.0% of all grants awarded. In comparison, only 5.3% of all awards in our quantitative database were identified as primarily focused on pathogenesis.

Discussion

We identified 4,299 funded studies, with a total research investment of £2.4 billion. We performed qualitative analysis on a further 3,284 CRUK funded awards. The vast majority of all awards awarded were investigating at least one of pathogenesis, diagnosis, monitoring and screening and drug therapy. In the absence of CRUK data, the Medical Research Council and the Department of Health were the two leading funding sources. Preclinical research accounted for £1.5 billion (62.2%) of total R&D investment. Four of the five highest funded cancer sites relative to global disease burden were gender-specific – namely prostate, ovarian, breast, and testicular cancers. Cancer research with a clear focus on women's health accounted for 640 studies (14.9%) and £199.5 million (8.4%) of investment. In comparison, 111 studies (2.6%) and £143.3 million (6.0%) of investment had a clear link with men's health. This may reflect the successes of various institutions and charities that have sought to increase awareness of these sex-specific cancers. Breast cancer, the most commonly diagnosed cancer in the UK and the leading cause of cancer death in women, and prostate cancer, the second most frequently diagnosed cancer and the sixth leading cause of cancer death among men, were found to be relatively well funded[1,13].

We highlight several cancer sites where there might be underinvestment, namely that of liver, thyroid, lung, upper GI tract, and bladder. In our analysis cancer of the upper GI tract combines oesophageal and stomach cancer. These site-specific cancers identified to be relatively underfunded account for a substantial proportion of global cancer burden. Globally, these sites account for 47.9%, 44.3% and 20.4% of the global mortality[1], DALYs[9] and YLDs[10] of all cancers, respectively. The disparity between YLDs and DALYs demonstrates the poor prognosis and high mortality of these particular sites when compared against all neoplastic disease. Lung, liver, stomach and oesophagus are the first, second, third and fifth, leading sites of neoplastic mortality worldwide[1].

Two previous studies have compared UK cancer funding with years of life lost (YLLs). Burnett et al [14] reported the relative over-funding of breast cancers and leukaemia. Carter et al [15,16] likewise reported higher levels of funding than their burden suggests of testicular, leukaemia, Hodgkin's lymphoma, breast, cervical, ovarian, prostate cancer with relative underfunding of gallbladder, lung, nasopharyngeal, intestine, stomach, pancreatic, thyroid, oesophageal, liver, kidney, bladder, and brain/central nervous system. Furthermore, they show that these broad discrepancies between cancer burden and research investment are also reflected in US data. Over the past decade in the

UK, there has generally been a transition of increased funding towards previously underfunded cancers with one notable exception being breast cancer. Although our site-specific classifications differed slightly, our findings are broadly consistent with these previous studies with the identification of haematological and sex-specific cancers being relatively well-funded. We are unable to account exactly for the slight differences in our findings (such as cervical and colorectal cancers); however, they are likely due to our metrics which seek to capture mortality (global mortality and DALYs) and life burden (DALYs and YLDs) rather than just mortality, and also different included components in the respective datasets.

With regard to interventions research, there is heavy investment in drug-based modalities. £620.9 million (26.0%) was invested in novel drug therapies and £194.1 million (8.1%) was invested in the emergent role of immunomodulation. In comparison, funding towards radiotherapy and surgical interventions accounted for £88.2 million (3.7%) and £37.9 million (1.6%), respectively. In high-income settings, around half of new cancer diagnoses will undergo a course of radiotherapy treatment during their clinical management; roughly a quarter will receive two or more courses[17,18]. Globally, over 80% of cancer cases will warrant surgical intervention, where it has preventative, diagnostic, curative, supportive, palliative, and reconstructive roles[19].

Analysis by R&D pipeline showed that research investment in the UK places a heavy emphasis on pre-clinical research, but relatively little investment towards phase I-III clinical trials or product development, and this is line with previous research in infectious disease investment[6]. This may reflect the strengths of UK institutions in preclinical science, but also could suggest a need to strengthen research capacity further down the R&D chain. It would be useful to determine whether investment reflects the priorities of funding agencies and whether this is comparable to research investment in other countries. We noted a lack of readily available data from the pharmaceutical industry and this is likely to leave a data gap in particular for sum totals of investment in clinical trials of pharmaceutical products.

Our findings contribute to the development of transparent and objective methods to couple the allocation of limited research funds with disease burden. Previous studies have suggested that financial investment might appropriately be coupled with DALYs as a measure of burden[20–23]. In recent years, whilst net UK governmental and charitable cancer investment has increased [24], there has been a proportional reduction compared to that of total funding towards cancer, coronary heart disease, dementia and stroke – in keeping with the health and social care costs attributable to each disease [25]. Furthermore, previous UK research suggests that publicly funded research offers substantial rates of return in terms of both health and monetary benefit both in the case of cancer specifically [24] and biomedical sciences as a whole [26]. We have further sought to incorporate mortality rates and YLDs into the consideration of cancer research investment. These analyses, when considered together, provide convincing pragmatic evidence of UK research strength and types of cancer where research investment has been particularly lacking.

We have chosen to compare cancer research funding to global rather than domestic UK disease burden. Due to increasing globalization, the emergence of non-communicable disease burden in resource poor settings, the internationalization of healthcare, the flow of people across national borders and the role of the UK as an international centre of biomedical research, we believe this approach to be justified.

However, defining an appropriate amount of research investment for each site specific cancer is challenging since cancers of similar disease burdens may warrant different levels of investment to develop cost-effective interventions. Decisions may be influenced by any of a number of factors, for example due to exceptional need, as may be the case in mesothelioma, or due to public awareness and third-party lobbying, as may be the case with regards to the gender-specific cancers.

A variety of factors contribute towards the difficulty in tracking net cancer research investment within the UK. Fragmentation of data from a large number of diverse public and private sources of funding, poorly designed donor accounting structures and the paucity of disaggregated information from the private sector limit the quality of the evidence base and thus the ability to inform policy in real-time. In our study, we were unable to obtain disaggregated investment data from CRUK. Despite requests across 2014 and 2015, CRUK refused to make available disaggregated investment data. This is in spite CRUK policy and representatives seemingly welcoming and encouraging the expansion of data-sharing and promoting the availability, accessibility and discoverability of such data [27,28]. In our experience across the ResIn infection and cancer analyses, this reluctance to be transparent is unique amongst more than 200 high-profile research funders in the UK and USA [29]. The lack of data liberation across non-communicable diseases impedes open scrutiny and hinders timely and effective response to this growing global disease burden [29,30]. Transparency in the tracking and monitoring of cancer research financing is essential to enable accountability and equity in resource allocation and to facilitate further future research in this area. We would encourage CRUK to be more open in providing data on funding.

In this study we systematically analyse UK investment in cancer research and identify areas of relative neglect. Although the competitive application process used by most funders to allocate research grants ensure a portfolio of high quality, the absence of explicit resource allocation criteria could contribute towards inequalities in R&D by disease burden. Funding agencies will have particular areas of focus, and UK funders may have considered the focus of international agencies in their own research strategies. As a result, international data is essential to complete the mapping of cancer research investment. Nevertheless, our findings will inform funders and contribute towards policy discussions that reduce inequities in the allocation of limited financial resources.

By demonstrating the relationship between disease burden and research funding, we enable the identification of potential investment gaps. However, it is not possible to fully equate gaps in funding with areas of neglect without consideration of other influences such as the feasibility of research, costs of technologies, infrastructure and skill requirements, political and social considerations, and the accuracy of disease burden estimates.

There are several potential limitations to our study. We are dependent on the accuracy of original investment data as sourced from the funding bodies. Although checks were made on any obvious discrepancies or errors, interpretation of these original data may contain errors. We made no attempt to investigate the contribution of any indirect or estate costs. Currency conversions were averaged across each financial year and any intra-year fluctuations may not have been captured. Unless clearly documented, we were unable to assess how funding was distributed from lead institutions to collaborative partners. We considered individual awards, rather than number of studies.

Furthermore, assignment of disease categories and allocation of studies according to these categories is subjective, and there might be disagreements regarding certain inclusion criteria. As YLLs were not included in our analysis, we may underrepresent the disease burden of cancers that occur disproportionately in the young and which are associated with poor survival, notably cancers of the ovary, cervix and CNS [14]. However, we would expect any additional information offered by YLL analysis to be predominantly captured by use of DALYs.

We could not openly access data of private sector research funding, nor were we able to obtain disaggregated award data from CRUK. Whilst our analysis did demonstrate that CRUK funding (with some exceptions) broadly reflected the findings of our quantitative database, it is likely that substantial awards towards particular areas of research could skew results; for example, CRUK are particularly keen to fund clinical trials, an area typically not covered to such an extent by other public and philanthropic funders. In 2014/15 CRUK invested £394 million into research or research-related activity, and we hypothesise that much of that would have met our inclusion criteria for this analysis [31]. Disease burden measures are typically an estimate and are subject to the potential introduction of bias from missing or unobtainable data as well as from differences in classification and diagnosis.

Our report presents the latest investment data on cancer research awarded to UK institution between 2000 and 2013. Cancers of the liver, thyroid, lung, upper GI tract, and bladder as well as research towards radiotherapy and surgical techniques in particular may warrant increased rates of investment. We will make the entire database and associated figures available online (www.researchinvestment.org) to assist policy makers, funding organisations, and researchers in the identification of investment gaps. We further encourage funding organisations to make their investment portfolios openly accessible to facilitate future research.

We hope that open funding data in this area can contribute to redressing the misalignments in investments for cancer research. Cancer research can improve the clinical course of disease and offer tangible improvements in health outcomes[24]. Access to open data across all funders, including CRUK is essential and transparency can assist policy makers and the scientific community in ensuring that limited resources are allocated appropriately and thus most effectively alleviate the extensive mortality and morbidity associated with cancer.

Contributions

MM and MGH are the guarantors of this study. MM, MGH, JRF and RA conceived and designed the study. MGH, CDZ, BJG and MAE-H obtained the data. MM and MGH conducted data formatting and statistical analysis. All authors helped interpret the findings. MM, MGH and CDZ wrote the first draft of the manuscript with input from RR, JRF and RA; all authors provided input to subsequent drafts. All authors had full access to all of the data in the study and take responsibility for its integrity and the accuracy of data analysis.

Transparency declaration

MM affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

Funding

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Competing interests

Rosalind Raine is supported by the National Institute for Health Research (NIHR) Collaboration for Leadership in Applied Health Research and Care (CLAHRC) North Thames at Bart's Health NHS Trust. The views expressed are those of the author(s) and not necessarily those of the NHS, the NIHR or the Department of Health. All other authors declare no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval

Not required

Data sharing

All data used is publicly available. Entire database and associated figures are permanently available with open access online (www.researchinvestment.org) to assist policy makers, funding organisations, and researchers.

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Table Legends

Table 1: Cancer research investment awards and funding by site. All investment reported in 2013 UK pounds.

	All funders where investment data was available						Cancer Research UK	
Site of cancer	**Number of awards**	**Percentage of total**	**Sum investment (£)**	**Percentage of total**	**Mean award, £ (SD)**	**Median award, £ (IQR)**	**Number of awards**	**Percentage of all oncology research awards**
Breast	571	13.3%	£137,960,107	5.8%	241611 (414584)	135752 (25000-216673)	273	8.3%
Haematological	1158	26.9%	£381,008,394	16.0%	329022 (476943)	186813 (120437-272324)	225	6.9%
Colorectal	147	3.4%	£77,279,857	3.2%	525713 (674881)	251800 (102078-819866)	205	6.2%
Prostate	92	2.1%	£135,290,779	5.7%	1470552 (6156372)	333757 (155227-721037)	123	3.7%
Ovarian	48	1.1%	£44,709,938	1.9%	931457 (3380145)	226764 (131990-627401)	112	3.4%
Lung	82	1.9%	£24,263,280	1.0%	295893 (556278)	146123 (66701-242934)	89	2.7%
Skin	87	2.0%	£22,179,011	0.9%	254931 (453726)	85406 (69629-248603)	84	2.6%
Brain	22	0.5%	£9,994,255	0.4%	454284 (498933)	401046 (196928-528008)	83	2.5%
Upper GI and	18	0.4%	£19,094,230	0.8%	1060791 (1448010)	788850 (80964-1296962)	80	2.4%
Head and neck	20	0.5%	£18,250,632	0.8%	912531 (1003091)	389751 (167358-1602465)	68	2.1%
Renal	19	0.4%	£13,885,496	0.6%	730815 (678732)	479197 (244075-1252574)	48	1.5%
Bladder	10	0.2%	£1,173,856	0.0%	117385 (106902)	94520 (29264- 173855)	48	1.5%
Cervical	26	0.6%	£14,328,402	0.6%	551092 (877250)	210179 (88934-368402)	43	1.3%
Pancreatic	16	0.4%	£9,453,577	0.4%	590848 (519850)	276237 (191804-1033948)	40	1.2%
Bone	13	0.3%	£17,242,183	0.7%	1326322 (1604685)	685853 (243559-1999907)	29	0.9%
Liver	37	0.9%	£25,037,541	1.0%	676690 (847151)	319082 (177974-776480)	20	0.6%
Mesothelioma	30	0.7%	£4,476,088	0.2%	149202 (101201)	137103 (95895-205500)	11	0.3%
Cholangiocarcinoma	2	0.0%	£582,405	0.0%	n/a	n/a	11	0.3%
Testicular	14	0.3%	£5,949,990	0.2%	424999 (507277)	242175 (102938-411010)	11	0.3%
Thyroid	4	0.1%	£1,375,881	0.1%	n/a	n/a	7	0.2%
Total	**4299**		**£2,388,152,318**		**555513 (1429510)**	**231559 (114619-487063)**	**3284**	

Table 2: Cancer research investment awards and funding by cross-cutting theme. All investment reported in 2013 UK pounds.

	All funders where investment data was available						**Cancer Research UK**	
Cross-cutting theme	**Number of awards**	**Percentage of total**	**Sum investment (£)**	**Percentage of total**	**Mean award, £ (SD)**	**Median award, £ (IQR)**	**Number of awards**	**Percentage of all oncology research awards**
Pathogenesis (mechanism)	227	5.3%	£1,374,387,838	57.6%	543881 (955710)	248573 (135752-506232)	1674	51.0%
Drug Therapy	1104	25.7%	£620,961,060	26.0%	562464 (1910050)	202342 (105622-436559)	935	28.5%
Diagnostic, Screening and Monitoring	681	15.8%	£359,618,823	15.1%	528074 (1155156)	205728 (102672-513836)	404	12.3%
Women's Health	640	14.9%	£199,534,693	8.4%	311773 (1041520)	153845 (56515-227202)	287	8.7%
Immunology (inc. biologics)	451	10.5%	£194,086,617	8.1%	430347 (760955)	240052 (125669-466250)	212	6.5%
Radiotherapy	112	2.6%	£88,262,353	3.7%	788056 (2413445)	243333 (106175-439419)	209	6.4%
Psychosocial	117	2.7%	£23,445,835	1.0%	200391 (352410)	87463 (27317-239059)	122	3.7%
Men's Health	111	2.6%	£143,392,908	6.0%	1291828 (5617919)	285203 (126037-700353)	120	3.7%
Paediatrics	175	4.1%	£62,641,938	2.6%	357953 (547484)	183099 (89522-322261)	118	3.6%
Surgery	72	1.7%	£37,900,334	1.6%	526393 (684908)	235413 (97890-761651)	95	2.9%
Infection-associated	129	3.0%	£56,819,379	2.4%	440460 (798013)	231836 (134693-439378)	48	1.5%
Global Health	12	0.3%	£6,434,960	0.3%	536246 (1089118)	129738 (77519-459274)	12	0.4%
Geriatrics	7	0.2%	£1,616,394	0.1%	230913 (254925)	121623 (76421-262167)	8	0.2%
Occupational Health	18	0.4%	£2,576,841	0.1%	143157 (116928)	137103 (33857-199998)	8	0.2%
Total	**4299**		**£2,388,152,318**		**555513 (1429510)**	**231559 (114619-487063)**	**3284**	

Table 3: Cancer research investment awards and funding by type of science. All investment reported in 2013 UK pounds.

	All funders where investment data was available						Cancer Research UK	
Type of science	**Number of awards**	**Percentage of total**	**Sum investment (£)**	**Percentage of total**	**Mean award, £ (SD)**	**Median award, £ (IQR)**	**Number of awards**	**Percentage of all oncology research awards**
Pre-clinical	2845	66.2%	£1,485,997,379	62.2%	522318 (1006600)	240974 (132188-490872)	1809	55.1%
Phase I-III	303	7.0%	£223,060,276	9.3%	736172 (3361312)	178535 (70934-502399)	647	19.7%
Product development	172	4.0%	£104,214,364	4.4%	605897 (2213394)	193051 (75270-360813)	52	1.6%
Cross-disciplinary	441	10.3%	£315,145,351	13.2%	714615 (1586882)	238523 (126589-703764)	328	10.0%
Public health	512	11.9%	£254,333,282	10.6%	496744 (1000757)	209364 (82870-383623)	443	13.5%
Unable to specify	26	0.6%	£5,401,666	0.2%	n/a	n/a	5	0.2%
Total	**4299**		**£2,388,152,318**		**555513 (1429510)**	**231559 (114619-487063)**	**3284**	

Table 4: Cancer research investment awards and funding by funding agency (excluding CRUK). All investment reported in 2013 UK pounds.

	All funders where investment data was available					
Funder	**Number of awards**	**Percentage of total**	**Sum investment (£)**	**Percentage of total**	**Mean award, £ (SD)**	**Median award, £ (IQR)**
MRC	768	17.9%	£837,649,875	35.1%	1090690 (1770533)	504606 (305375-1153374)
Charity (excluding Wellcome and CRUK)	1,699	39.5%	£415,189,093	17.4%	244372 (391813)	151912 (81000-223244)
Department of Health	586	13.6%	£413,421,823	17.3%	705498 (2675223)	232173 (102391-471236)
BBSRC	511	11.9%	£223,651,002	9.4%	437673 (388793)	373356 (267848-501592)
EPSRC	356	8.3%	£201,861,623	8.5%	567027 (972696)	306906 (144056-604016)
Wellcome	193	4.5%	£140,425,805	5.9%	727594 (1679370)	226761 (164547-427455)
European Commission (inc ERC)	50	1.2%	£78,757,447	3.3%	1575149 (731858)	1409678 (1252574-1830017)
Other	136	3.2%	£77,195,650	3.2%	567615 (1901202)	129944 (69309-263613)
Total	**4299**		**£2,388,152,318**		**555513 (1429510)**	**231559 (114619-487063)**

Table 5: Compound ranking score for cancer research investment against 2013 global disease burdens, across mortality, YLDs, and DALYs, by cancer site.

	Research investment (UK pound) by burden observed, 2013			
Disease	**Mean ranking across all burden metrics**	**Mortality**	**Years lived with disability**	**Disability-adjusted life years**
Prostate	**2.7**	2	4	2
Ovarian	**3.0**	4	2	3
Mesothelioma	**4.0**	6	1	5
Breast	**4.0**	3	5	4
Testicular	**4.7**	1	3	10
Skin	**5.0**	5	9	1
Colorectal	**6.7**	7	7	6
Renal	**8.3**	8	10	7
Cervical	**9.7**	9	12	8
Pancreatic	**10.0**	12	6	12
Brain	**11.0**	11	11	11
Thyroid	**11.3**	10	15	9
Liver	**11.3**	13	8	13
Lung	**13.7**	14	13	14
Upper GI	**14.7**	15	14	15
Bladder	**16.0**	16	16	16

Supplementary Table 1: Investment per mortality observed for all site-specific cancers

	Number of deaths			Investment per mortality observed		
	2005	2010	2013	**2005**	**2010**	**2013**
Bladder	156385	170700	173900	£0.03	£0.26	£0.49
Brain	177191	195500	203900	£0.00	£2.02	£2.76
Breast	407108	438700	471000	£5.35	£18.20	£20.30
Cervical	221578	225400	235700	£2.93	£5.63	£4.50
Colorectal	644648	714600	771000	£3.54	£5.45	£6.77
Liver	715141	752100	818000	£0.04	£1.00	£1.45
Lung	1391577	1527100	1639600	£0.15	£0.57	£1.08
Mesothelioma	22128	n/a	33700	£0.81	?	£8.33
Ovarian	134354	160500	157800	£23.00	£20.98	£19.79
Pancreatic	276753	310200	352400	£0.56	£0.86	£1.67
Prostate	225081	256000	292700	£53.92	£45.19	£34.22
Renal	113048	162100	133800	£0.00	£2.27	£5.96
Skin	?	79700	96100	?	£14.20	£16.30
Testicular	7547	7700	8300	£7.27	£44.69	£55.14
Thyroid	29092	36000	33700	£0.00	£1.70	£3.14
Upper GI and oesophageal	1229320	1130100	1281200	£0.93	£1.18	£1.03

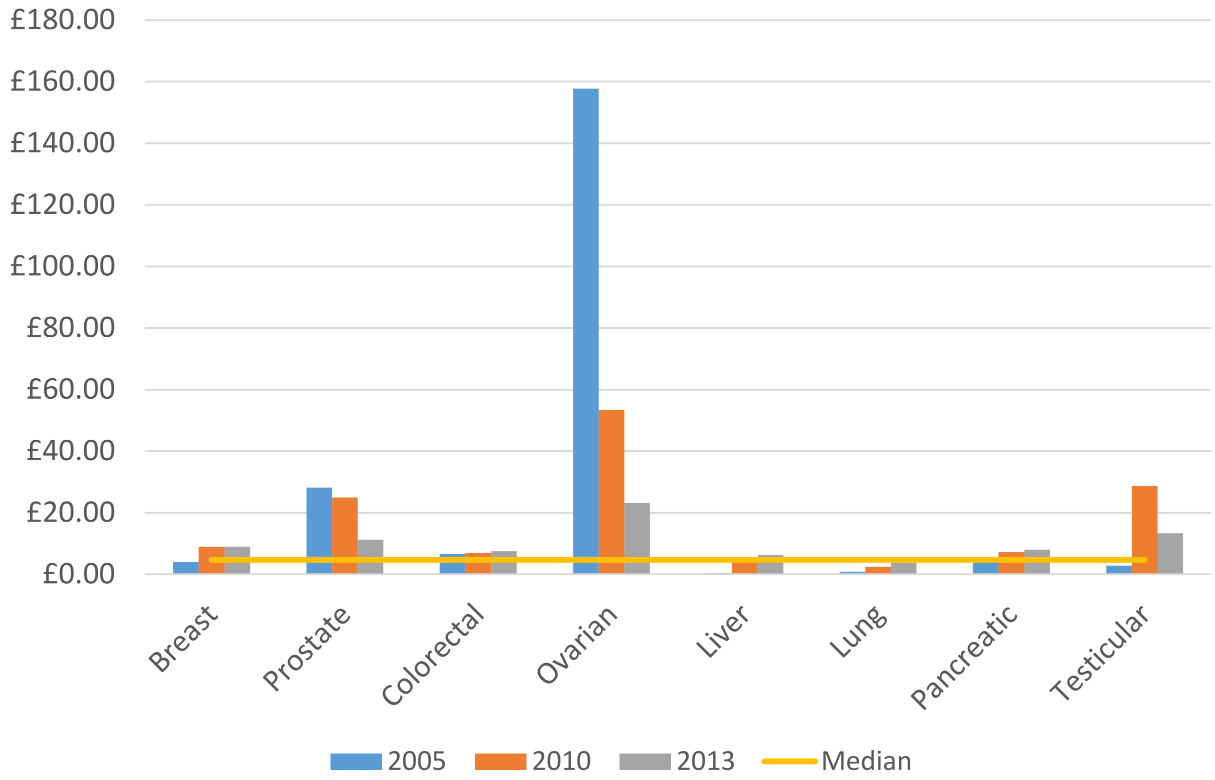
Supplementary Table 2: Investment per YLD observed for all site-specific cancers

	YLD			Investment per YLD observed		
	2005	2010	2013	2005	2010	2013
Bladder	153647	125000	179800	£0.05	£0.35	£0.47
Brain	105126	94000	121900	£0.00	£4.20	£4.61
Breast	885550	898000	1068200	£3.93	£8.89	£8.95
Cervical	242359	111000	243800	£4.28	£11.44	£4.35
Colorectal	561019	564000	701900	£6.50	£6.91	£7.44
Liver	160071	140000	190600	£0.29	£5.39	£6.24
Lung	388206	355000	467400	£0.86	£2.44	£3.78
Mesothelioma	7109	n/a	10800	£4.04	?	£25.98
Ovarian	31339	63000	134900	£157.75	£53.44	£23.15
Pancreatic	57317	37000	73600	£4.35	£7.18	£8.01
Prostate	690602	464000	893700	£28.12	£24.93	£11.21
Renal	112449	79000	139200	£0.00	£4.66	£5.72
Skin	?	300000	264100	?	£3.77	£5.93
Testicular	31339	12000	34300	£2.80	£28.67	£13.34
Thyroid	109078	48000	127600	£0.00	£1.27	£0.83
Upper GI and oesophageal	382757	304000	416100	£4.77	£4.39	£3.17

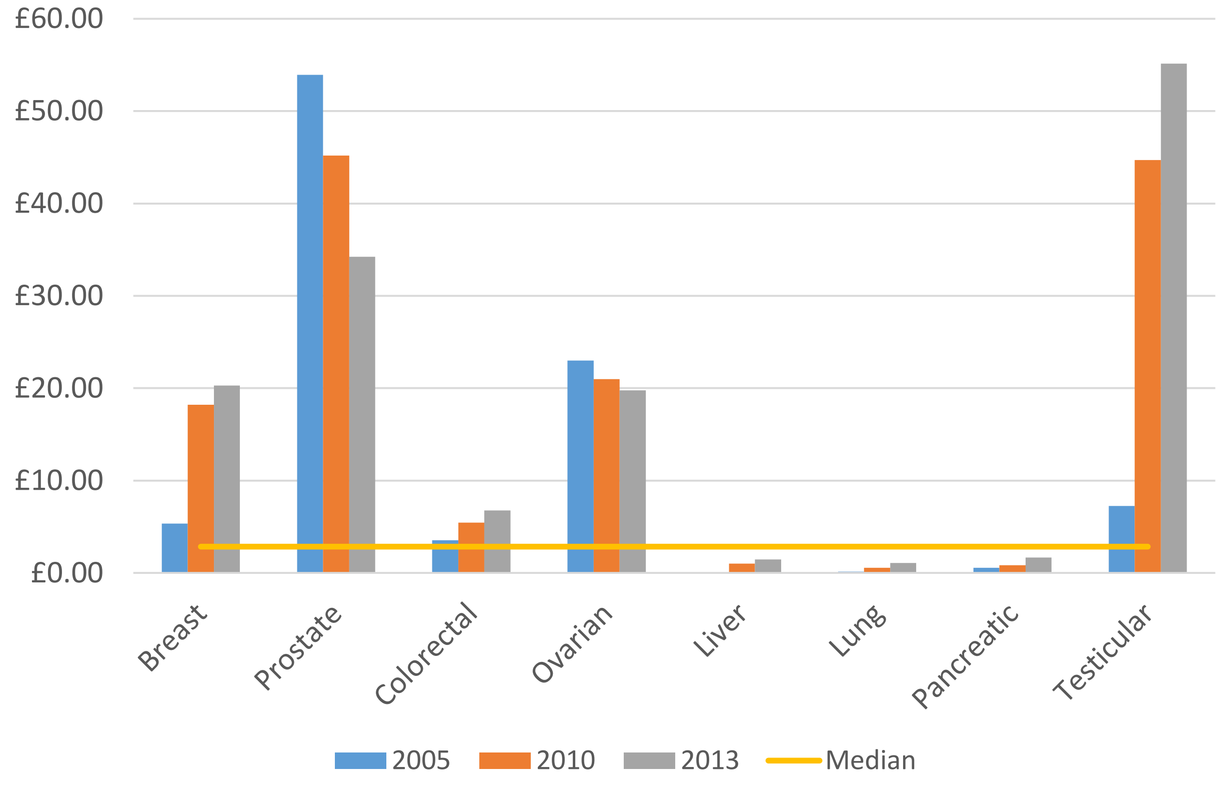
Supplementary Table 3: Investment per DALY observed for all site-specific cancers

	Global DALYs			Investment per DALY observed		
	2005	2010	2013	2005	2010	2013
Bladder	2987377	3015000	3139900	£0.00	£0.01	£0.03
Brain	6163358	6060000	6692200	£0.00	£0.07	£0.08
Breast	11762493	12018000	13258700	£0.19	£0.66	£0.72
Cervical	6775622	6440000	6914700	£0.10	£0.20	£0.15
Colorectal	13747947	14422000	15794100	£0.17	£0.27	£0.33
Liver	19175329	19111000	20888700	£0.00	£0.04	£0.06
Lung	30791630	32405000	34732900	£0.01	£0.03	£0.05
Mesothelioma	504037	n/a	763500	£0.04	?	£0.37
Ovarian	3541657	4118000	4056500	£0.87	£0.82	£0.77
Pancreatic	5704661	6161000	7029100	£0.03	£0.04	£0.08
Prostate	3812057	3787000	4768800	£3.18	£3.05	£2.10
Renal	2810156	3676000	3150300	£0.00	£0.10	£0.25
Skin	?	1967000	237200	?	£0.58	£6.61
Testicular	354875	313000	3787700	£0.15	£1.10	£0.12
Thyroid	764526	836000	851900	£0.00	£0.07	£0.12
Upper GI and oesophageal	27964269	25356000	27749600	£0.04	£0.05	£0.05

Supplementary Figure 1: Investment per YLD (£/YLD) for 8 indicator site-specific cancers



Supplementary Figure 1: Investment per death (£/death) for 8 indicator site-specific cancers



Supplementary Figure 1: Investment per DALY (£/DALY) for 8 indicator site-specific cancers