Direct Healthcare Costs of Sedentary Behaviour in the UK

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Title: The Direct Healthcare Costs of Sedentary Behaviour in the UK

Authors:

Leonie Heron[1], Professor Ciaran O'Neill[1], Dr Helen McAneney[1], Professor Frank Kee[1], Professor Mark A Tully[2]

[1]Centre for Public Health, Queen's University Belfast, Institute of Clinical Sciences, Block A, Royal Victoria Hospital, Belfast, BT12 6BA
[2]School of Health Sciences, Ulster University, Shore Road, Newtownabbey, Co. Antrim, BT37 0QB

Corresponding author:

Professor Mark Tully
Room 01D116, School of Health Sciences, Ulster University, Shore Road, Newtownabbey, Co. Antrim, BT37 0QB
Email: m.tully@ulster.ac.uk
Telephone: +44 28 9036 6977

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What is already known on this subject?

Recent evidence indicates that prolonged sedentary behaviour increases the risk of several non-communicable diseases. However, a large proportion of the UK population spend their lives in sedentary jobs and leisure activities, and official physical activity recommendations regarding sedentariness are vague.

What does this study add?

Diseases associated with prolonged sedentary behaviour cost the NHS £0.8 billion in the 2016-17 financial year. This estimate can inform decision-makers who are prioritising resources in healthcare and make a financial case for reducing sedentary behaviour in the UK.

ABSTRACT

Background: Growing evidence indicates that prolonged sedentary behaviour increases the risk of several chronic health conditions and all-cause mortality. Sedentary behaviour is prevalent among adults in the United Kingdom (UK). Quantifying the costs associated with sedentary behaviour is an important step in the development of public health policy.

Methods: National Health Service (NHS) costs associated with prolonged sedentary behaviour (≥6 hours/day) were estimated over a one-year period in 2016-17 costs. We calculated a population attributable fraction (PAF) for five health outcomes (type 2 diabetes, cardiovascular disease [CVD], colon cancer, endometrial cancer, and lung cancer). Adjustments were made for potential double counting due to co-morbidities. We also calculated the avoidable deaths due to prolonged sedentary behaviour using the PAF for all-cause mortality.

Results: The total NHS costs attributable to prolonged sedentary behaviour in the UK in 2016-17 were £0.8 billion, which included expenditure on CVD (£424 million), type 2 diabetes (£281 million), colon cancer (£30 million), lung cancer (£19 million), and endometrial cancer (£7 million). After adjustment for potential double-counting, the estimated total was £0.7 billion. If prolonged sedentary behaviour was eliminated, 48,024 UK deaths might have been avoided in 2016.

Conclusions: In this conservative estimate of the direct healthcare costs in the UK, prolonged sedentary behaviour causes a considerable burden to the NHS. This estimate may be used by decision makers when prioritising healthcare resources and investing in preventative public health programmes.

Keywords: public health; sedentary behaviour; sitting time; cost analysis; health expenditure; healthcare cost; physical activity.

INTRODUCTION

Adults in the United Kingdom (UK) have become increasingly sedentary as modern technology has changed everyday life.[1] Sedentary behaviour is distinct from physical inactivity and refers to sitting or lying while expending low amounts of energy (≤1.5 metabolic equivalents [METs]).[2] National guidelines recommend minimising time spent sedentary[3] without specifying how many hours/day of sitting might be harmful. A recent meta-analysis reported that spending 6-8 hours/day sedentary increases future risk of all-cause and cardiovascular disease (CVD).[4] This study defined sedentary behaviour as spending at least six hours of waking time sedentary. Thirty percent of adults in the UK are sedentary for a least six hours/day during the week, which rises to 37% at the weekend.[5] Consequently, many individuals in the UK are at greater risk of chronic disease.

Sedentary behaviour is an established risk factor for several non-communicable diseases. Strong evidence suggests that high levels of sitting time lead to increased risk of CVD, type 2 diabetes, and all-cause mortality (risk of mortality from all causes, not only those mentioned here).[6] Additionally, moderate evidence indicates an increased risk of colon, endometrial, and lung cancer.[6] These diseases all contribute considerably to morbidity and mortality in the UK. Thus, addressing the problem of sedentary behaviour could potentially reduce the burden of disease.

Awareness of the economic burden of sedentary behaviour could inform and motivate policymakers to address this risk factor. Estimates of the cost impacts allow decision makers to prioritise funding and make an economic argument for investment in prevention. Estimates for the financial impact of many lifestyle risk factors in the UK are available, such as obesity, smoking, and physical inactivity,[7, 8] however none exist thus far for sedentary behaviour. As a result, this study aims to estimate the direct healthcare costs of prolonged sedentary behaviour in the UK.

METHODS

Costs were estimated from a healthcare payer perspective (UK National Health Service [NHS]) using a prevalence-based and population attributable fraction- (PAF) approach, following methodology employed by Ding et al.[7]

Quantifying the increased risk to health due to sedentary behaviour

We selected the most suitable meta-analyses cited in a recent report of the relationship between sedentary behaviour and health[6] in order to extract the relative risks (RRs). Appropriate studies employed a prospective design, non-diseased participants at baseline, and adjusted for levels of physical activity in their statistical model. Furthermore, the researchers had investigated the association by comparing the most sedentary individuals with the least sedentary, and we preferred studies which had used sedentary time as an exposure. Two studies were appropriate for the outcome of CVD[19,21]: we chose the more recent meta-analysis by Pandey et al. as it had included three additional applicable studies. After examining data from the primary studies, we excluded those that did not meet the exact criteria above and repooled the risk estimate using Review Manager (RevMan version 5.3).

Estimating the extent of sedentary behaviour in the UK population

The Health Survey for England (HSE) 2012[5] reported that 30% of adults in England spent at least six hours/day sedentary on weekdays, and 37% of adults at the weekend. We used these figures to estimate the percentage of UK adults who are sedentary on any given day of the week.

The PAF formula we have used requires the prevalence of sedentary behaviour at baseline in those who went on to become cases (i.e., experiencing the adverse outcome). This information is not readily available. Therefore, we calculated prevalence "adjustment factors"[9] using data from cohort studies. We searched for cohort studies on Pubmed that fitted the same criteria mentioned in the previous section and had specifically measured and reported sedentary behaviour for the total population and for cases only at baseline. We preferred European-based studies and larger studies with longer follow-up times to give more reliable adjustment factors. The proportion of cases in the highest reported category of sedentary behaviour was divided by the proportion of people at baseline in the highest category to produce an adjustment factor. For example, Stamatakis et al.[10] reported that 34.1% of all study participants and 38.3% of diabetes cases were sedentary at baseline. The adjustment factor was 1.12 (38.3/34.1). We then multiplied the adjustment factor by the prevalence of sedentary behaviour in the general population in order to estimate the additional prevalence among cases.

Table 1. Prevalence adjustment factors calculated from longitudinal study data

Disease	Study	Country	Prevalence of prolonged sedentary behaviour[1] at baseline	Prevalence of prolonged sedentary behaviour[1] in cases	Adjustment factor
Type 2 diabetes	Stamatakis et al., 2017[10]	UK	0.34	0.38	1.12
CVD incidence	Bjork Petersen et al., 2014[35]	Denmark	0.13	0.16	1.23
All-cause mortality	van der Ploeg et al., 2012[36]	Australia	0.06	0.12	1.87
Lung cancer	Ukawa et al., 2013[37]	Japan	0.25	0.28	1.10
Colon cancer	Simons et al., 2013[38]	Netherlands	0.26	0.32	1.22
Endometrial cancer	Gierach et al., 2009[39]	USA	0.08	0.10	1.20

CVD = cardiovascular disease. [1]Prolonged sedentary behaviour indicates spending at least six hours sedentary during waking hours.

Calculating PAFs for each health outcome

The PAF estimate the contribution of a risk factor to the total burden of a disease in a given population. Here, PAFs estimate the reduction in disease that would occur if prolonged sedentary behaviour was eliminated. The following formula from Rockhill, Newman and Weinberg[11] was used:

$$PAF(\%) = \frac{p_1(RR_{adj} - 1)}{RR_{adj}} x100$$

where p_1 is the prevalence of sedentary behaviour among cases and RR_{adj} is the pooled adjusted RR, comparing the most sedentary individuals with the least sedentary.

It integrates the pooled adjusted RR (RR_{adj}) estimates and the proportion of sedentary individuals who became cases (p_1). It is appropriate to use when confounding is present.[11] We calculated Wald intervals for each of the PAFs using Monte Carlo simulation methods (250,000 simulations) on Microsoft Excel (2016).[12] These techniques accounted for random error and uncertainty in confounding from the pooled RR estimates and the prevalence of sedentary behaviour (see supplementary file 1 for further details).

Estimating NHS expenditure for each disease

Healthcare budgets for specific disease groupings was available for the NHS in England for the nearest financial year 2012-13,[13] Wales for 2016-17,[14] and Scotland 2011-12.[15] Costs were standardised to the year 2017 by adjusting costs for inflation using the hospital and community health services (HCHS) index, a weighted average of annual increases in pay and prices in healthcare services.[16] Healthcare budget data for Northern Ireland was unavailable, thus we estimated costs for this region based on the number of diagnoses compared to the rest of UK. Further details are reported in supplementary file 2. All costs are in pounds sterling (GBP).

Calculating costs attributable to sedentary behaviour

We multiplied the adjusted PAFs and their 95% CIs by the total disease expenditure to estimate the NHS costs attributable to sedentary behaviour in the UK. Since the timeframe for this analysis is one year, discounting was unnecessary.

Thirty percent of Europeans with type 2 diabetes are also affected by CVD.[17] Therefore, 30% of the type 2 diabetes expenditure attributable to sedentary behaviour was subtracted from the total costs to adjust for double-counting caused by this co-morbidity. This is consistent with the approach used by Ding et al.[7]

Estimating the avoidable deaths due to sedentary behaviour

In addition, we multiplied the PAF for all-cause mortality by the total number of UK deaths in 2016 to estimate the number of deaths that would have been avoided if prolonged sedentary behaviour was completely eliminated. As complete elimination is unrealistic, the number of avoidable deaths was also estimated for 10%, 30%, and 50% potential reductions in the proportion of sedentary individuals (i.e., sedentary ≥6 hours/day).

RESULTS

The health outcomes that we considered most relevant for this analysis were type 2 diabetes, CVD, and all-cause mortality (strong evidence), and endometrial, colon, and lung cancers (moderate evidence).[6] Pooled analyses of crude or age-adjusted estimates were not available in the literature. The PAF formula given required a pooled risk estimate and so we extracted RRs from the least adjusted models and pooled them to give an unadjusted RR estimate. Most models were age-adjusted only, however several of the least-adjusted models were already adjusted for more variables. Crucially, none of the models had adjusted for physical activity level, an important confounder in the association between sitting time and

health.[18] Table 2 presents the prevalence of sedentary behaviour for each health outcome with the associated RRs and PAFs.

Table 2. Estimates of prevalence, relative risk of disease, and population attributable fractions for sedentary behaviour in the UK.

Strength of evidence[1]	Health outcome	Proportion of prolonged sedentary adults in cases(%)[2]	RR (95% CI)	PAF (95% CI)
Strong	Type 2 diabetes	34%	1.88 (1.62, 2.17)	16.9% (14.0%, 19,6%)
	CVD incidence	38%	1.14 (1.09, 1.19)	4.9% (4.2%, 5.5%)
	All-cause mortality	57%	1.25 (1.16, 1.34)	11.6% (10.3%, 12.9%)
Moderate	Lung cancer	34%	1.27 (1.06, 1.52)	7.5% (3.9%, 11.0%)
	Colon cancer	37%	1.30 (1.12, 1.49)	9.0% (7.3%, 10.7%)
	Endometrial cancer[5]	40%	1.28 (1.08, 1.53)	8.0% (6.0%, 10.0%)

RR = relative risk; CI = confidence interval; PAF = population attributable fraction; CVD = cardiovascular disease.
[1]Strength of evidence as reported by 2018 Physical Activity Guidelines Advisory Committee (2018).
[2]Estimated from weekday and weekend proportions available from Health Survey for England.[5]

We re-pooled the adjusted RR for the association between sedentary behaviour and type 2 diabetes presented by Biswas et al.[19] to exclude a cross-sectional study.[20] The updated pooled RR estimate was 1.88 (95% CI 1.62, 2.17). Based on the PAF calculations, 16.9% (14.0%, 19.6%) of cases of type 2 diabetes were associated with sedentary behaviour. Pandey et al.[21] reported an adjusted RR of 1.14 (95% CI 1.09, 1.19) for the association between CVD and sedentary behaviour. Just under five per cent (4.9% [4.2%, 5.5%]) of CVD could be attributable to sedentary behaviour. The adjusted RR for the association between sedentary behaviour and all-cause mortality[21] was reanalysed in order to exclude four studies. The studies were inappropriate for the following reasons: their baseline populations were not free of disease;[22] they reported a per-hour association,[23] rather than comparing individuals in the most and least sedentary categories; their design was cross-sectional;[20] or they reported an inapplicable association (one study reported the association between those who were

'consistently nonsedentary' vs. 'consistently sedentary').[24] The sedentary time definition that they used, reported ranges, and estimated median sedentary time are reported in supplementary file 3.

The new pooled RR estimate was 1.25 (95% CI 1.16, 1.33) and the corresponding PAF for this association was 11.6% (10.3%, 12.9%). Shen et al.[25] investigated the risk of cancer associated with higher sedentary behaviour. They reported adjusted RRs for lung cancer (1.27 [95% CI 1.06, 1.52]), colon cancer (1.30 [95% CI 1.12, 1.49]), and endometrial cancer (1.28 [95% CI 1.08, 1.53]). The PAF calculations showed that 7.5% (3.9%, 11.0%) of lung cancer; 9.0% (7.3%, 10.7%) of colon cancer; and 8.0% (6.0%, 10.0%) of endometrial cancer could be attributable to sedentary behaviour.

Thus, if sedentary behaviour was eliminated in the UK, 48,024 deaths in 2016 might have been avoided. More realistically, if levels of sedentary behaviour were 10%, 30%, or 50% lower in 2016, we might have avoided 4,802, 12,006, or 24,012 deaths respectfully.

It is also important to note that the total budgets adjusted for inflation to 2016/17 costs were considerably lower than reported total budgets for 2016/17 for England[26] and Scotland.[27] Individual healthcare budgets were not available for these years and so costs had to be inflated. Table 3 provides the NHS costs attributable to sedentary behaviour and 95% CIs. CVD is associated with the greatest cost attributable to sedentary behaviour of £424 million (£367, £480 million), followed by £281 million (£233, £327 million) for type 2 diabetes. Costs for specific cancers attributable for sedentary behaviour were much lower; £19 million (£10, £28 million) for lung cancer, £30 (£24, £35 million) for colon cancer, and £7 million (£5, £9 million) for endometrial cancer. Together, the total costs attributable to sedentary behaviour are £762 million (£639, £879 million). Total UK NHS health expenditure is estimated to be £65.7 billion for 2016/17, indicating that sedentary behaviour accounted for 1.2% of total expenditure.

Table 3. Costs Attributable to Diseases Associated with Sedentary Behaviour

	Costs Attributable to Sedentary Behaviour by UK region (£million, 2016-17)				**Total UK NHS costs attributable to sedentary behaviour (£million, 2016-17 [95% CI])**
Disease	**England**	**Scotland**	**Wales**	**NI**	
Type 2 diabetes	£242.54	£14.86	£16.90	£7.03	£281.34 (£233.46, £326.85)
CVD	£348.95	£40.75	£22.80	£11.88	£424.38 (£366.61, £480.09)

Lung cancer	£13.54	£3.78	£1.32	£0.52	£19.16 (£9.92, £27.98)
Colon cancer	£22.74	£3.99	£2.90	£0.80	£29.64 (£23.96, £35.12)
Endometrial cancer	£5.72	£0.74	£0.63	£0.20	£7.29 (£5.44, £9.07)
Total costs	£633.49	£64.13	£44.55	£20.44	£761.80 (£639.40, £879.11)

NHS = National Health Service; CI = confidence interval; CVD = cardiovascular disease; NI = Northern Ireland.

After adjustment for double-counting, the NHS costs attributable to sedentary behaviour is £677 million. An alternative method[7] was also used as a sensitivity analysis. A meta-analysis reported the RR of having CVD as being 206% higher for people with type 2 diabetes compared to those without type 2 diabetes.[28] Based on the prevalence of CVD in the general population (4.28%, as reported by the British Heart Foundation),[29] we estimate that 8.82% of people with type 2 diabetes have CVD. After subtracting 8.82% of type 2 diabetes expenditure, the total costs attributable to sedentary behaviour were £737 million.

After an additional sensitivity analysis which excluded diseases for which only moderate evidence of an association was available, the total costs attributable to sedentary behaviour were £706 million (£600, £807 million), i.e., approximately eight per cent lower. The small change is due to the much lower incidence and prevalence of the individual cancers in comparison to CVD and type 2 diabetes expenditure.

DISCUSSION

This cost-of-illness analysis found that prolonged sedentary behaviour costs the UK NHS £0.8 billion in the financial year 2016-17. After adjustments for double-counting, this estimate was slightly reduced to £0.7 billion. The results suggested that 11.6% of all-cause mortality was associated with sedentary behaviour. Therefore, 48,024 deaths might have been avoided in 2016 if sedentary behaviour was eliminated in the UK.

The total costs presented are likely to be a conservative estimate of the true burden of sedentary behaviour. There are reported links between sedentary behaviour and several other cancers, musculoskeletal disorders, and mental health disorders.[30–32] However, the evidence remains limited, hence they were excluded from this study. Moreover, the analysis

used a PAF-approach which typically produces lower estimates than alternative econometric approaches.[33]

CVD, type 2 diabetes, and colon, endometrial and lung cancers are all linked to sedentary behaviour (PAFs ranged from 4.9%-16.9%). Patterson et al.[4] also calculated PAFs for sedentary behaviour in a recent meta-analysis, where the exposure was TV viewing time and the methodology (using a Monte-Carlo micro-simulation) was somewhat different. Thus, it is difficult to compare these estimates. Nonetheless, it is interesting to note that the PAFs for type 2 diabetes, CVD and all-cause mortality are of the same order of magnitude (i.e., type 2 diabetes > all-cause mortality > CVD). The PAFs for CVD are similar (5% [95% CI: 1%, 8%] from Patterson vs. 4.9% (95% CI: 1.8%, 7.9%) in the present study). This indicates that although the studies differ in their definition of sedentary behaviour and in the methods used, there is considerable agreement in the observed pattern of the relationships.

This study had several strengths. We have calculated PAFs for sedentary behaviour in the UK using the best data available, and we have included all conditions reported as having moderate to strong evidence of an association.[6] The analysis followed several suggestions from a checklist for reporting estimates of the economic costs of risk factors by Ding et al.[33] Importantly, all extracted RRs had been adjusted for physical activity. We provided uncertainty limits in the form of 95% CIs for the PAFs and the subsequent cost estimates. Finally, we subtracted a proportion of costs to account for the strong likelihood of double-counting due to co-morbidities.

However, the study was limited by the evidence available for sedentary behaviour and health outcomes. We included a non-European study[37] in order to estimate the prevalence of sedentary behaviour in lung cancer cases, which may not fully reflect a UK population. Individual studies included in the meta-analyses which were used in this analysis varied in their choice of cut-off values for each category, definition of sedentary behaviour, and in the questionnaire used. Crucially, six hours/day was the minimum median time spent in sedentary behaviour in the highest categories (supplementary file 3). Nevertheless, theoretically the definition used for the prevalence of sedentary behaviour should match the RR when calculating the PAF. We believe that since the minimum median sedentary time in the most sedentary class is 6 hours, and our definition of sedentary behaviour is spending at least six hours sedentary, that the RRs reported are reasonable estimations. Therefore, the PAFs are also reasonable estimations. We were further limited by self-reported data for

sedentary behaviour, which may have either underestimate or overestimate sedentary behaviour[34] and could subsequently bias the results in either direction.

Future research is still needed to elucidate the complex relationship between sedentary behaviour and health, and which of these are truly independent of physical activity.[23] Ideally, prospective studies could use a combined method of both accelerometry and behaviour logs, repeated over time, when measuring this behaviour. Consensus on how many hours/day of sedentary behaviour is harmful would be helpful in research, in line with the more specific guidelines for physical activity.[3]

Indirect costs that incorporate the financial burden on society, such as productivity losses to the workforce, can be very high. Physical inactivity was responsible for an estimated $0.5 billion (international dollars) outside of the healthcare setting in 2013 in the UK.[7] There are no known estimates for the wider societal costs of sedentary behaviour. Economic estimates will need to be updated as further evidence on sedentary behaviour emerges.

There are several barriers that cause a gap between evidence and practice. Evidence may be non-existent or arrive too late for policymakers. They may prefer uncomplicated papers and a wide range of evidence to inform their decisions.[40] We have been explicit about the strengths and weakness of this straightforward cost estimation for the benefit of other academics and policymakers. We hope that these results can be easily understood and synthesized with other evidence on sedentary behaviour. An economic case could be made for investment in reducing the prevalence of sedentary behaviour in the UK. These cost estimates can be compared with those of other risk factors in order to inform decision-making and prioritise preventative health programmes. Many individuals in the UK spend their leisure time in sedentary behaviour, but the workplace represents a significant proportion of unavoidable daily sitting time for many people. Measures should be taken to reduce sedentary behaviour with the aim of improving population health and reducing the financial burden to the health service.

This analysis presents the first estimate of direct healthcare costs due to prolonged sedentary behaviour in the UK. After adjustment for co-morbidities, diseases associated with prolonged sedentary behaviour cost the NHS £0.7 billion in 2016-17 costs. Furthermore, 48,024 deaths could have potentially been avoided in 2016 if prolonged sedentary behaviour in the UK was eliminated. It is hoped that these estimates will help policymakers prioritise resources to address a major public health issue.

Contributors

CO, FK, LH, and MT developed the research question. LH did the analysis, with methodological guidance from CO. HM provided statistical expertise. LH drafted the manuscript. All authors read and approved the final manuscript.

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