

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

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16

17 Word count, excluding title page, abstract, references, figures and tables, contributors and
18 funding statements: 2875

19

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.

1

2 **ABSTRACT**

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

7 **Methods:** National Health Service (NHS) costs associated with prolonged sedentary behaviour
8 (≥ 6 hours/day) were estimated over a one-year period in 2016-17 costs. We calculated a
9 population attributable fraction (PAF) for five health outcomes (type 2 diabetes, cardiovascular
10 disease [CVD], colon cancer, endometrial cancer, and lung cancer). Adjustments were made
11 for potential double counting due to co-morbidities. We also calculated the avoidable deaths
12 due to prolonged sedentary behaviour using the PAF for all-cause mortality.

13 **Results:** The total NHS costs attributable to prolonged sedentary behaviour in the UK in 2016-
14 17 were £0.8 billion, which included expenditure on CVD (£424 million), type 2 diabetes (£281
15 million), colon cancer (£30 million), lung cancer (£19 million), and endometrial cancer (£7
16 million). After adjustment for potential double-counting, the estimated total was £0.7 billion.
17 If prolonged sedentary behaviour was eliminated, 69,276 UK deaths might have been avoided
18 in 2016.

19 **Conclusions:** In this conservative estimate of the direct healthcare costs in the UK, prolonged
20 sedentary behaviour causes a considerable burden to the NHS. This estimate may be used by

1 decision makers when prioritising healthcare resources and investing in preventative public
2 health programmes.

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

5

1 INTRODUCTION

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

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

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

26 METHODS

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

30 Quantifying the increased risk to health due to sedentary behaviour

1 We selected the most suitable meta-analyses cited in a recent report of the relationship between
2 sedentary behaviour and health[6] in order to extract the relative risks (RRs). Appropriate
3 studies employed a prospective design, non-diseased participants at baseline, and adjusted for
4 levels of physical activity in their statistical model. Furthermore, the researchers had
5 investigated the association by comparing the most sedentary individuals with the least
6 sedentary, and we preferred studies which had used sedentary time as an exposure. Two studies
7 were appropriate for the outcome of CVD[9,10]: we chose the more recent meta-analysis by
8 Pandey et al. as it had included three additional applicable studies. After examining data from
9 the primary studies, we excluded those that did not meet the exact criteria above and re-pooled
10 the risk estimate using Review Manager (RevMan version 5.3).

11 **Estimating the extent of sedentary behaviour in the UK population**

12 The Health Survey for England (HSE) 2012[5] reported that 30% of adults in England spent at
13 least six hours/day sedentary on weekdays, and 37% of adults at the weekend. We used these
14 figures to estimate the percentage of UK adults who are sedentary on any given day of the week
15 ($\frac{(\text{weekday prevalence}) * 5 + (\text{weekend day prevalence}) * 2}{7}$).

16 The PAF formula we have used requires the prevalence of sedentary behaviour at baseline in
17 those who went on to become cases (i.e., experiencing the adverse outcome). This information
18 is not readily available. Therefore, we calculated prevalence “adjustment factors”[11] using
19 data from cohort studies (Table 1). We searched for cohort studies on Pubmed that fitted the
20 same criteria mentioned in the previous section and had specifically measured and reported
21 sedentary behaviour for the total population and for cases only at baseline. We preferred
22 European-based studies and larger studies with longer follow-up times to give more reliable
23 adjustment factors. The proportion of cases in the highest reported category of sedentary
24 behaviour was divided by the proportion of people at baseline in the highest category to
25 produce an adjustment factor. For example, Stamatakis et al.[12] reported that 34.1% of all
26 study participants and 38.3% of diabetes cases were sedentary at baseline. The adjustment
27 factor was 1.12 (38.3/34.1). We then multiplied the adjustment factor by the prevalence of
28 sedentary behaviour in the general population in order to estimate the additional prevalence
29 among cases.

30 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[12]	UK	0.34	0.38	1.12
CVD incidence	Bjork Petersen et al., 2014[13]	Denmark	0.13	0.16	1.23
All-cause mortality	van der Ploeg et al., 2012[14]	Australia	0.06	0.12	1.87
Lung cancer	Ukawa et al., 2013[15]	Japan	0.25	0.28	1.10
Colon cancer	Simons et al., 2013[16]	Netherlands	0.26	0.32	1.22
Endometrial cancer	Gierach et al., 2009[17]	USA	0.08	0.10	1.20

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

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2 Calculating PAFs for each health outcome

3 The PAF estimates the contribution of a risk factor to the total burden of a disease in a given
 4 population. Here, PAFs estimate the reduction in disease that would occur if prolonged
 5 sedentary behaviour was eliminated. The following formula from Rockhill, Newman and
 6 Weinberg[18] was used:

$$7 \quad PAF(\%) = \frac{p_1(RR_{adj} - 1)}{RR_{adj}} \times 100$$

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

10 It integrates the pooled adjusted RR (RR_{adj}) estimates and the proportion of sedentary
 11 individuals who became cases (p_1). It is appropriate to use when confounding is present.[18]
 12 We calculated Wald confidence intervals (CIs) for each of the PAFs using Monte Carlo
 13 simulation methods (250,000 simulations) on Microsoft Excel (2016).[19] These techniques
 14 accounted for random error and uncertainty in confounding from the pooled RR estimates and
 15 the prevalence of sedentary behaviour (see supplementary file 1 for further details).

16 Estimating NHS expenditure for each disease

1 Healthcare budgets for specific disease groupings was available for the NHS in England for
2 the nearest financial year 2012-13,[20] Wales for 2016-17,[21] and Scotland 2011-12.[22]
3 Costs were standardised to the year 2017 by adjusting costs for inflation using the hospital and
4 community health services (HCHS) index, a weighted average of annual increases in pay and
5 prices in healthcare services.[23] Healthcare budget data for Northern Ireland was unavailable,
6 thus we estimated costs for this region based on the number of diagnoses compared to the rest
7 of UK. Further details are reported in supplementary file 2. All costs are in pounds sterling
8 (GBP).

9 **Calculating costs attributable to sedentary behaviour**

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

13 Thirty percent of Europeans with type 2 diabetes are also affected by CVD.[24] Therefore,
14 30% of the type 2 diabetes expenditure attributable to sedentary behaviour was subtracted from
15 the total costs to adjust for double-counting caused by this co-morbidity. This is consistent with
16 the approach used by Ding et al.[7]

17 **Estimating the avoidable deaths due to sedentary behaviour**

18 In addition, we multiplied the PAF for all-cause mortality by the total number of UK deaths in
19 2016 to estimate the number of deaths that would have been avoided if prolonged sedentary
20 behaviour was completely eliminated. As complete elimination is unrealistic, the number of
21 avoidable deaths was also estimated for 10%, 30%, and 50% potential reductions in the
22 proportion of sedentary individuals (i.e., sedentary ≥ 6 hours/day).

23 **RESULTS**

24 The health outcomes that we considered most relevant for this analysis were type 2 diabetes,
25 CVD, and all-cause mortality (strong evidence), and endometrial, colon, and lung cancers
26 (moderate evidence).[6] Pooled analyses of crude or age-adjusted estimates were not available
27 in the literature. The PAF formula given required a pooled risk estimate and so we extracted
28 RRs from the least adjusted models and pooled them to give an unadjusted RR estimate. Most
29 models were age-adjusted only, however several of the least-adjusted models were already
30 adjusted for more variables. Crucially, none of the models had adjusted for physical activity
31 level, an important confounder in the association between sitting time and health.[25] Table 2

1 presents the prevalence of sedentary behaviour for each health outcome with the associated
 2 RRs and PAFs.

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

Strength of evidence¹	Health outcome	Proportion of prolonged sedentary adults in cases(%)²	RR (95% CI)	PAF (95% CI)
Strong	Type 2 diabetes	36%	1.88 (1.62, 2.17)	16.9% (14.0%, 19.6%)
	CVD incidence	40%	1.14 (1.09, 1.19)	4.9% (4.2%, 5.5%)
	All-cause mortality	60%	1.25 (1.16, 1.34)	11.6% (10.3%, 12.9%)
Moderate	Lung cancer	35%	1.27 (1.06, 1.52)	7.5% (3.9%, 11.0%)
	Colon cancer	39%	1.30 (1.12, 1.49)	9.0% (7.3%, 10.7%)
	Endometrial cancer ⁵	37%	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.

¹Strength of evidence as reported by 2018 Physical Activity Guidelines Advisory Committee (2018).

²Estimated from weekday and weekend proportions available from Health Survey for England[5] and multiplied by the prevalence adjustment factor for each outcome.

5 We re-pooled the adjusted RR for the association between sedentary behaviour and type 2
 6 diabetes presented by Biswas et al.[9] to exclude a cross-sectional study.[26] The updated
 7 pooled RR estimate was 1.88 (95% CI 1.62, 2.17). Based on the PAF calculations, 16.9%
 8 (14.0%, 19.6%) of cases of type 2 diabetes were associated with sedentary behaviour. Pandey
 9 et al.[10] reported an adjusted RR of 1.14 (95% CI 1.09, 1.19) for the association between CVD
 10 and sedentary behaviour. Just under five per cent (4.9% [4.2%, 5.5%]) of CVD could be
 11 attributable to sedentary behaviour. The adjusted RR for the association between sedentary
 12 behaviour and all-cause mortality[10] was reanalysed in order to exclude four studies. The
 13 studies were inappropriate for the following reasons: their baseline populations were not free
 14 of disease;[27] they reported a per-hour association,[28] rather than comparing individuals in

1 the most and least sedentary categories; the definition of prolonged sedentary behaviour was
 2 not compatible (≥ 4 hours instead of ≥ 6 hours);[29] or they reported an inapplicable association
 3 (one study reported the association between those who were ‘consistently nonsedentary’ vs.
 4 ‘consistently sedentary’).[30] The sedentary time definition that they used, reported ranges,
 5 and estimated median sedentary time are reported in supplementary file 3.

6 The new pooled RR estimate was 1.25 (95% CI 1.16, 1.33) and the corresponding PAF for this
 7 association was 11.6% (10.3%, 12.9%). Shen et al.[31] investigated the risk of cancer
 8 associated with higher sedentary behaviour. They reported adjusted RRs for lung cancer (1.27
 9 [95% CI 1.06, 1.52]), colon cancer (1.30 [95% CI 1.12, 1.49]), and endometrial cancer (1.28
 10 [95% CI 1.08, 1.53]). The PAF calculations showed that 7.5% (3.9%, 11.0%) of lung cancer;
 11 9.0% (7.3%, 10.7%) of colon cancer; and 8.0% (6.0%, 10.0%) of endometrial cancer could be
 12 attributable to sedentary behaviour.

13 If sedentary behaviour was eliminated in the UK, 69,276 deaths in 2016 might have been
 14 avoided. More realistically, if levels of sedentary behaviour were 10%, 30%, or 50% lower in
 15 2016, we might have avoided 4,802, 12,006, or 24,012 deaths respectfully.

16 It is also important to note that the total budgets adjusted for inflation to 2016/17 costs were
 17 considerably lower than reported total budgets for 2016/17 for England[32] and Scotland.[33]
 18 Individual healthcare budgets were not available for these years and so costs had to be inflated.
 19 Table 3 provides the NHS costs attributable to sedentary behaviour and 95% CIs. CVD is
 20 associated with the greatest cost attributable to sedentary behaviour of £424 million (£367,
 21 £480 million), followed by £281 million (£233, £327 million) for type 2 diabetes. Costs for
 22 specific cancers attributable for sedentary behaviour were much lower; £19 million (£10, £28
 23 million) for lung cancer, £30 (£24, £35 million) for colon cancer, and £7 million (£5, £9
 24 million) for endometrial cancer. Together, the total costs attributable to sedentary behaviour
 25 are £762 million (£639, £879 million). Total UK NHS health expenditure is estimated to be
 26 £65.7 billion for 2016/17, indicating that sedentary behaviour accounted for 1.2% of total
 27 expenditure.

28 Table 3. Costs Attributable to Diseases Associated with Sedentary Behaviour

Disease	Costs Attributable to Sedentary Behaviour by UK region (£million, 2016-17)				Total UK NHS costs attributable to sedentary behaviour (£million, 2016-17 [95% CI])
	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.

1

2 After adjustment for double-counting, the NHS costs attributable to sedentary behaviour is
3 £677 million. An alternative method[7] was also used as a sensitivity analysis. A meta-analysis
4 reported the RR of having CVD as being 206% higher for people with type 2 diabetes compared
5 to those without type 2 diabetes.[34] Based on the prevalence of CVD in the general population
6 (4.28%, as reported by the British Heart Foundation),[35] we estimate that 8.82% of people
7 with type 2 diabetes have CVD. After subtracting 8.82% of type 2 diabetes expenditure, the
8 total costs attributable to sedentary behaviour were £737 million.

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

14

15 **DISCUSSION**

16 This cost-of-illness analysis found that prolonged sedentary behaviour costs the UK NHS £0.8
17 billion in the financial year 2016-17. After adjustments for double-counting, this estimate was
18 slightly reduced to £0.7 billion. The results suggested that 11.6% of all-cause mortality was
19 associated with sedentary behaviour. Therefore, 69,276 deaths might have been avoided in
20 2016 if sedentary behaviour was eliminated in the UK.

21 The total costs presented are likely to be a conservative estimate of the true burden of sedentary
22 behaviour. There are reported links between sedentary behaviour and several other cancers,
23 musculoskeletal disorders, and mental health disorders.[36-38] However, the evidence remains
24 limited, hence they were excluded from this study. Moreover, the analysis used a PAF-

1 approach which typically produces lower estimates than alternative econometric
2 approaches.[39]

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

13 This study had several strengths. We have calculated PAFs for sedentary behaviour in the UK
14 using the best data available, and we have included all conditions reported as having moderate
15 to strong evidence of an association.[6] The analysis followed several suggestions from a
16 checklist for reporting estimates of the economic costs of risk factors by Ding et al.[39]
17 Importantly, all extracted RRs had been adjusted for physical activity. We provided uncertainty
18 limits in the form of 95% CIs for the PAFs and the subsequent cost estimates. Finally, we
19 subtracted a proportion of costs to account for the strong likelihood of double-counting due to
20 co-morbidities.

21 However, the study was limited by the evidence available for sedentary behaviour and health
22 outcomes. We included a non-European study[15] in order to estimate the prevalence of
23 sedentary behaviour in lung cancer cases, which may not fully reflect a UK population.
24 Individual studies included in the meta-analyses which were used in this analysis varied in their
25 choice of cut-off values for each category, definition of sedentary behaviour, and in the
26 questionnaire used. Crucially, six hours/day was the minimum median time spent in sedentary
27 behaviour in the highest categories (supplementary file 3). Nevertheless, theoretically the
28 definition used for the prevalence of sedentary behaviour should match the RR when
29 calculating the PAF. We believe that since the minimum median sedentary time in the most
30 sedentary class is 6 hours, and our definition of sedentary behaviour is spending at least six
31 hours sedentary, that the RRs reported are reasonable estimations. Therefore, the PAFs are also
32 reasonable estimations. There were insufficient studies with appropriate data to investigate a

1 dose-response association for sedentary behaviour. We were further limited by self-reported
2 data for sedentary behaviour, which may have either underestimate or overestimate sedentary
3 behaviour[40] and could subsequently bias the results in either direction.

4 Future research is still needed to elucidate the complex relationship between sedentary
5 behaviour and health, and which of these are truly independent of physical activity.[28] Ideally,
6 prospective studies could use a combined method of both accelerometry and behaviour logs,
7 repeated over time, when measuring this behaviour. Consensus on how many hours/day of
8 sedentary behaviour is harmful would be helpful in research, in line with the more specific
9 guidelines for physical activity.[3]

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

15 There are several barriers that cause a gap between evidence and practice. Evidence may be
16 non-existent or arrive too late for policymakers. They may prefer uncomplicated papers and a
17 wide range of evidence to inform their decisions.[41] We have been explicit about the strengths
18 and weakness of this straightforward cost estimation for the benefit of other academics and
19 policymakers. We hope that these results can be easily understood and synthesized with other
20 evidence on sedentary behaviour. An economic case could be made for investment in reducing
21 the prevalence of sedentary behaviour in the UK. These cost estimates can be compared with
22 those of other risk factors in order to inform decision-making and prioritise preventative health
23 programmes. Many individuals in the UK spend their leisure time in sedentary behaviour, but
24 the workplace represents a significant proportion of unavoidable daily sitting time for many
25 people. Measures should be taken to reduce sedentary behaviour with the aim of improving
26 population health and reducing the financial burden to the health service.

27 This analysis presents the first estimate of direct healthcare costs due to prolonged sedentary
28 behaviour in the UK. After adjustment for co-morbidities, diseases associated with prolonged
29 sedentary behaviour cost the NHS £0.7 billion in 2016-17 costs. Furthermore, 69,276 deaths
30 could have potentially been avoided in 2016 if prolonged sedentary behaviour in the UK was
31 eliminated. It is hoped that these estimates will help policymakers prioritise resources to
32 address a major public health issue.

1 **Contributors**

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

5 **Funding**

6 Leonie Heron is funded by a Department for the Economy (Northern Ireland) studentship.

7 The Corresponding Author has the right to grant on behalf of all authors and does grant on
8 behalf of all authors, an exclusive licence (or non exclusive for government employees) on a
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13 Competing Interest: None declared.

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