BMJ Open

Burden of cancer attributable to sedentary behaviour in Germany: an epidemiological analysis of survey data

Katharina Schaber,[1] Michael Leitzmann,[1] Tobias Pukrop,[2,3] Wilm Quentin,[4] Michael J Stein [ID],[1] Carmen Jochem [ID] [1,4]

¹Department of Epidemiology and Preventive Medicine, University of Regensburg, Regensburg, Germany
²Department of Internal Medicine III, University Hospital Regensburg, Regensburg, Germany
³Bavarian Cancer Research Center (BZKF), Regensburg, Germany
⁴Department of Planetary & Public Health, University of Bayreuth, Bayreuth, Germany

Correspondence to
Dr Michael J Stein;
michael.stein@ukr.de

ABSTRACT

Objectives Sedentary behaviour (SB) is associated with increased risks of breast, colorectal, endometrial, ovarian and rectal cancers. However, the number of cancer cases attributable to SB in Germany and the associated costs are unknown.

Setting Numbers and proportions (population-attributable fractions, PAF) of new cancer cases attributable to SB with published risk estimates for Germany for the years 2024, 2030 and 2040.

Participants Sex-specific and age-specific population projections, national cancer incidence and exposure data. Primary and secondary outcome measures: new cancer cases attributable to SB and healthcare costs associated with cancer cases attributable to SB in Germany for the year 2024.

Results Estimated numbers of cancers attributable to SB are projected to be up to 7612 cases (6% of total cancer cases) in 2024, up to 7899 cases (6%) in 2030 and up to 8245 cases (6%) in 2040. The PAF attributable to SB in women is 3% for breast cancer, 8% for colon cancer, 9% for both endometrial and ovarian cancers and 2% for rectal cancer. In men, the PAF is 9% for colon cancer and 3% for rectal cancer. In 2024, the estimated costs of SB-attributable cancers are €270 million for colon cancer, €51 million for rectal cancer, €234 million for breast cancer and €242 million for female genital cancers.

Conclusions A considerable number of cancer cases can be attributed to SB, which also imposes a large health economic burden. Implementing effective prevention measures, such as workplace, school or commuting interventions, is needed to reduce the incidence of cancer attributable to this modifiable risk factor.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study relied on sedentary behaviour prevalences from a broad German population survey.
⇒ Insights into confounding factors are limited due to the non-availability of such measures in German cancer registry data.
⇒ The study assumed constant cancer incidence rates and SB prevalences, potentially underestimating the future cancer burden.

INTRODUCTION

Western lifestyles are characterised by prolonged sedentary behaviour (SB). SB is defined as any waking behaviour characterised by an energy expenditure of ≤1.5 metabolic equivalents of task while in a sitting, reclining or lying posture.[1] Worldwide, adults spend more than 6 hours per day engaged in SB,[2] with even more time observed in high-income countries like Germany, where 70% of adults spend 4 hours or more per day in sedentary behaviours.[3] High levels of SB are associated with increased risks of various chronic diseases, including cardiovascular disease, type 2 diabetes and cancer.[4–6]

Specifically, high levels of SB are associated with increased risks of developing breast, colorectal, endometrial, ovarian and rectal cancers.[7] Globally, when focusing on these cancer types for both sexes combined, breast cancer is the most common, accounting for 15% of cancer cases, followed by colon (6%), rectum (4%) endometrial (2%) and ovarian (2%) cancers.[8] In Germany, cancer is the second leading cause of death, responsible for 230 292 deaths in 2023, representing 22% of all deaths.[9] Given the high prevalence of SB and its associations with chronic diseases, the WHO has included specific recommendations to reduce SB in its latest guidelines on physical activity and SB.[10]

Given the positive association between SB and cancer, previous studies have estimated country-specific cancer incidence attributable to SB, such as the UK and Canada.[11 12] In Germany, previous studies have calculated the proportion of cancer cases attributable to various lifestyle habits, including smoking, alcohol consumption, overweight, physical inactivity and unhealthy diet.[13 14] However, the number of cancer cases attributable to SB has not yet been calculated for Germany. Moreover, the extent to which this cancer burden contributes to healthcare costs in Germany is unknown.

In the present study, we estimate the proportion and number of cancer cases attributable to SB in Germany for the years 2024, 2030 and 2040 among adults aged 35–84. Additionally, we estimate the direct healthcare costs associated with SB-related cancers in Germany.

METHODS
Prevalence of sedentary behaviour in Germany
We obtained data on SB prevalence from national surveys.[3] Among the German adult population, 69.7% reported sitting for 4 hours or more per day, 36.3% for 6 hours or more and 19.5% for 8 hours or more. In our analyses, we used SB prevalence rates of 67.0%, 32.8% and 16.7% for women who sat for ≥4 hours, ≥6 hours and ≥8 hours per day, respectively. For men, the SB prevalence rates were 72.5%, 39.9% and 22.3% for sitting times of ≥4 hours, ≥6 hours and ≥8 hours per day, respectively. To further assess the number of cancer cases attributable to SB, we additionally assessed mutually exclusive SB prevalences (women: 33.1%, 50.3%, 16.7%; men: 27.5%, 50.2%, 22.3%, for <4 hours, 4–8 hours and ≥8 hours of SB, respectively).

Cancer risk
To assess the association between SB and cancer risk, we referred to a 2022 umbrella review and meta-analysis,[7] which found that high SB levels were associated with a 25% higher risk of colon cancer and a 7% higher risk of rectal cancer. We used gender-combined risk ratios, as the analysis reported no significant heterogeneity by sex.[7] For female-specific cancers, the study reported an 8% higher risk of breast cancer and a 29% higher risk of both endometrial and ovarian cancers.

Estimation of incident cancer cases
To estimate the number of cancer cases attributable to SB, we used 2018 data from the German Cancer Registry[15] for cancers of the colon, rectum, breast, endometrium and ovary. The crude incident rates for both genders and each cancer type were obtained. To estimate the age-specific and gender-specific population sizes up to 2040, we used population projection variants from the Federal Statistical Office. We assumed moderate birth rates, life expectancy and migration balance, using the model 'variant 2' (G2-L2-W2).[16]

Estimation of costs attributable to sedentary behaviour
Healthcare costs for cancers were obtained from the Federal Statistical Office of Germany for the year 2020.[17] In that year, the total annual healthcare costs in Germany were €412 341 million. We estimated the costs attributable to SB for specific cancers for 2020, assuming that the proportion of cancer costs attributable to SB in 2020 corresponds to the percentage of cases attributable to SB in 2024. However, for female-specific cancers, cost data

Table 1 Estimated cancer cases attributable to sedentary behaviour for 2024

Group	Men			Women		
Sedentary behaviour time	≥4 hours	≥6 hours	≥8 hours	≥4 hours	≥6 hours	≥8 hours
Prevalence	**72.5%**	**39.9%**	**22.3%**	**67.0%**	**32.8%**	**16.7%**
Colon (C18-C20)	4787	2839	1656	3140	1654	880
PAF	15.3%	9.1%	5.3%	14.4%	7.6%	4.0%
Percentage of the population	0.0268%	0.0289%	0.0302%	0.0180%	0.0193%	0.0202%
Rectum (C21)	36	20	12	63	32	17
PAF	4.9%	2.7%	1.6%	4.5%	2.2%	1.2%
Percentage of the population	0.0002%	0.0002%	0.0002%	0.0004%	0.0004%	0.0004%
Breast (C50)				3259	1612	816
PAF				5.1%	2.5%	1.3%
Percentage of the population				0.0187%	0.0188%	0.0187%
Endometrium (C54-C55)				1670	892	471
PAF				16.2%	8.7%	4.6%
Percentage of the population				0.0096%	0.0104%	0.0108%
Ovary (C56)				1055	563	297
PAF				16.2%	8.7%	4.6%
Percentage of the population				0.0060%	0.0066%	0.0068%
All above cancer cases combined	4823	2859	1668	9188	4753	2481
PAF	10.1%	5.9%	3.4%	11.3%	5.9%	3.1%
Percentage of the population	0.0270%	0.0291%	0.0304%	0.0526%	0.0556%	0.0570%

Cancer types were classified according to International Classification of Diseases (ICD)–10.
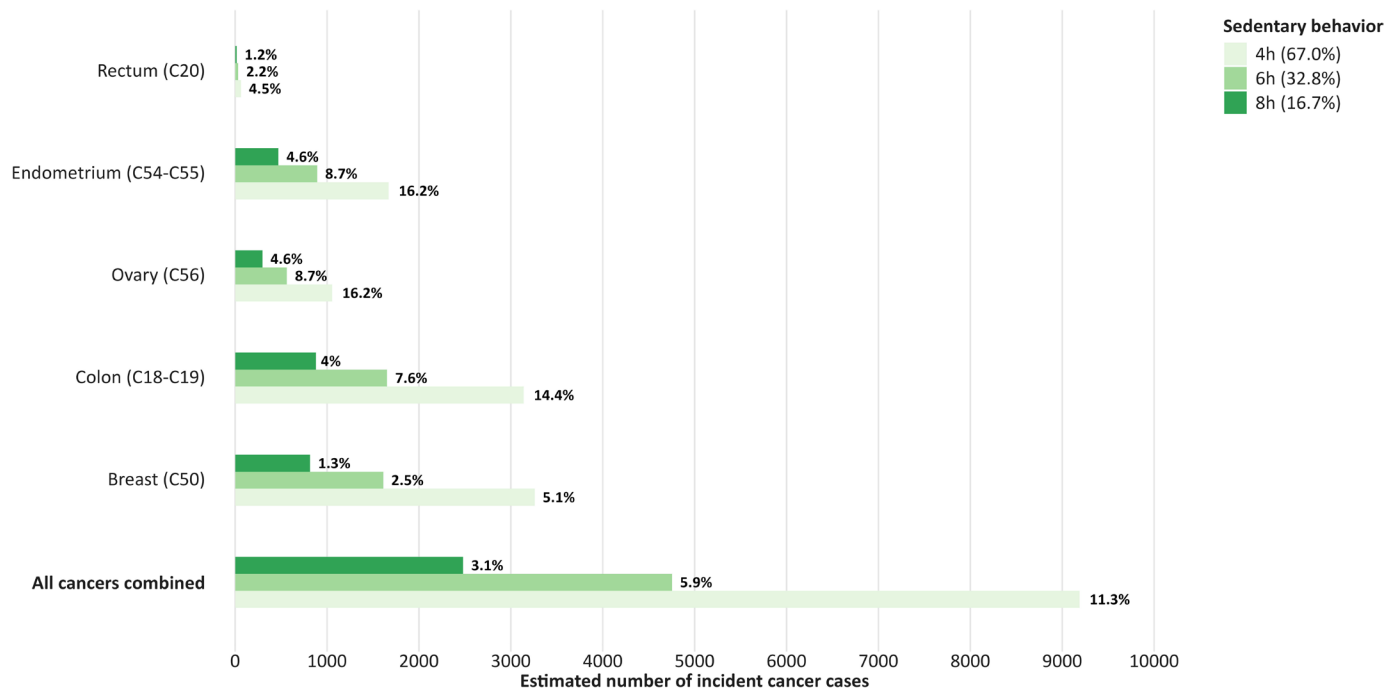PAF, population-attributable fraction.

Figure 1 Estimated number and population-attributable fraction (PAF) of site-specific incident cancer cases attributable to sedentary behaviour among women in Germany for the year 2024, by different levels of sedentary behaviour prevalence (≥4 hours, ≥6 hours, ≥8 hours). Cancer types were classified according to International Classification of Diseases (ICD)–10.

were only available for breast cancer and a combined category of all gynaecological cancers (excluding cervical cancer). Therefore, the costs related to endometrial and ovarian cancers are summarised and approximated in our study. Total annual costs in Germany in 2020 were €1818 million, €1099 million, €4423 million and €1439 million related to cancers of the colon, rectum, breast and gynaecological cancers, respectively. All costs are reported in euros (€).

Statistical analysis

We calculated the population-attributable fractions (PAFs) to estimate the number of cancer cases attributable to SB among men and women aged 35–84 in Germany. The PAF provides a summary measure of the extent to which the incidence or prevalence of a disease could be reduced if a specific risk factor were eliminated in a given population. We applied the commonly used Levin's formula for calculating the PAF[14]:

$$PAF = \frac{\Sigma(p x \times ERR x)}{1 + \Sigma(p x \times ERR x)}$$

In this formula, p_x represents the proportion of the population with exposure level x (ie, the prevalence of SB) and ERR_x is the excess relative risk associated with exposure level x, calculated as relative risk minus one.

We report results separately for population groups with different levels of SB, that is, ≥4 hours, ≥6 hours and ≥8 hours, for both men and women as well as proportions of cancer cases relative to the population size of those groups. Additionally, we estimate the number of cancer cases attributable to SB for the years 2024, 2030 and 2040,

Lastly, healthcare costs for 2024 were estimated by multiplying the PAFs with the total cancer-specific healthcare costs in Germany.

All calculations were performed using Microsoft Excel (Microsoft, Redmond, Washington, USA) and R V.4.2.3.[18]

Patient and public involvement

Neither patients nor the public were involved in this study.

RESULTS

We estimated 135 598 cancer cases among adults aged 35–84 years in Germany in 2024, of which 14 010 were attributable to SB of ≥4 hours per day. Specifically, we estimated 9188 cancer cases attributable to SB (PAF=11.3%) among women and 4823 cases (limited to colon and rectal cancers, PAF=10.1%) among men (table 1, figures 1 and 2).

Similar patterns were noted for longer durations of SB, with lower numbers of cancer cases due to the lower prevalence of extended SB. However, the proportion of cases at the population level increased with extended SB. For example, considering ≥8 hours of SB, 4149 cancer cases were estimated (men: n=1668, PAF=3.4%; women: n=2481, PAF=3.1%) (table 1). For 2024, we estimated the cancer cases attributable to mutually exclusive prevalences of SB separately for men and women (table 2). For example, 50.2% of men were in the group of 4–8 hours of daily SB which resulted in a total of n=3520 attributable cancer cases (PAF=7.3%). With a prevalence of 50.3% of women in the same group of daily SB, a total of n=7074 cancer cases (PAF=8.8%) were attributable to SB. We also projected cancer cases for the years 2030 and 2040,
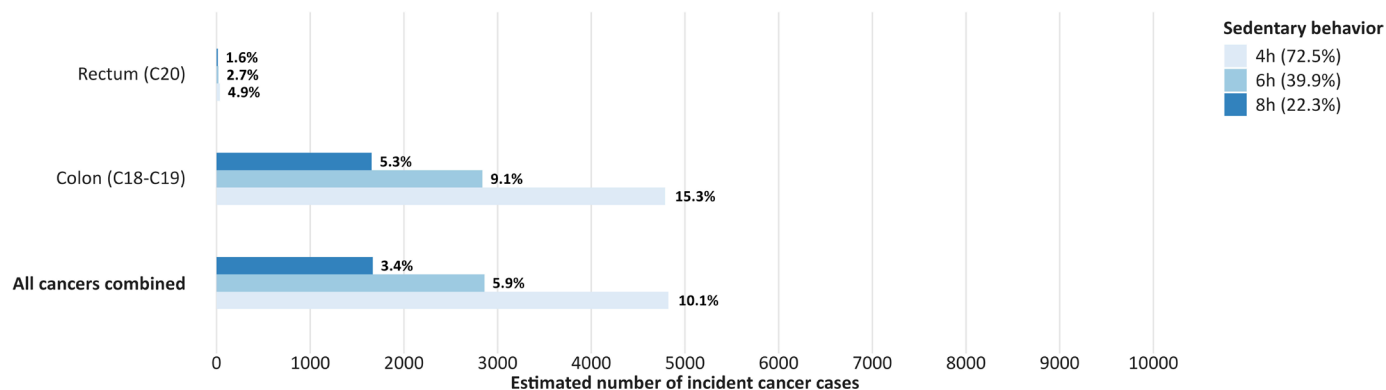
Figure 2 Estimated number and population-attributable fraction (PAF) of site-specific incident cancer cases attributable to sedentary behaviour among men in Germany for the year 2024, by different levels of sedentary behaviour prevalence (≥4 hours, ≥6 hours, ≥8 hours). Cancer types were classified according to International Classification of Diseases (ICD)–10.

noting a slight increase in numbers. For example, based on ≥4 hours of SB, we estimated 5066 total cancer cases for men and 9461 for women in 2030, and 5386 for men and 9756 for women in 2040 (table 3).

Specific cancer risk

Based on a prevalence of ≥4 hours of SB, we estimated 7927 colon cancer cases (PAF=5.8%) and only 99 rectal cancers (PAF=0.1%) for 2024. Estimates for colon cancer were higher for men (n=4787, PAF=15.3%) than for women (n=3140, PAF=14.4%), while the estimates for rectal cancer were fairly low (men: n=36, PAF=4.9%; women: n=63, PAF=4.5%). For breast cancers associated with ≥4 hours of SB, we estimated 3259 cases (PAF=5.1%) for 2024. Although more endometrial cancer cases (n=1670) were estimated than ovarian cancer cases (n=1055), the PAFs were equally high at 16.2%.

Similar patterns were noted for longer durations of SB (table 1, figures 1 and 2). For example, with ≥8 hours

of SB, 2536 colon cancer cases were estimated (men: n=1656, PAF=5.3%; women: n=880, PAF=4.0%).

Regarding projections for 2030 and 2040, the estimated number of cancer cases has increased. For example, with ≥4 hours of SB, colon cancer cases were projected to increase to 5029 for men and 3263 for women in 2030, and further to 5349 for men and 3481 for women in 2040 (table 3).

Healthcare costs

We estimated the total cancer-specific costs attributable to SB. For cancers attributable to SB (>4 hours), the costs were €270 million for colon cancer, €51 million for rectal cancer, €234 million for breast cancer and €242 million for female genital cancers (excluding cervical cancer). These costs represent 0.2% of the total annual healthcare costs. Detailed estimates for all levels of SB are provided in table 4.

Table 2 Estimated cancer cases attributable to mutually exclusive prevalences of sedentary behaviour for 2024

Group	Men			Women		
Sedentary behaviour time	<4 hours	4–8 hours	≥8 hours	<4 hours	4–8 hours	≥8 hours
Prevalence	**27.5%**	**50.2%**	**22.3%**	**33.1%**	**50.3%**	**16.7%**
Colon (C18-C20)	2016	3495	1656	1673	2443	880
PAF	6.5%	11.2%	5.3%	7.7%	11.2%	4.0%
Rectum (C21)	12	25	12	32	48	17
PAF	1.6%	3.4%	1.6%	2.2%	3.4%	1.2%
Breast (C50)				1612	2447	816
PAF				2.5%	3.8%	1.3%
Endometrium (C54-C55)				900	1310	471
PAF				8.8%	12.7%	4.6%
Ovary (C56)				569	827	297
PAF				8.8%	12.7%	4.6%
All above cancer cases combined	2028	3520	1668	4786	7074	2481
PAF	4.0%	7.3%	3.4%	6.0%	8.8%	3.1%

Cancer types were classified according to International Classification of Diseases (ICD)–10.
PAF, population-attributable fraction.

Table 3 Gender-specific estimated cancer cases attributable to sedentary behaviour and population attributional fractions (PAF) for 2030 and 2040

	Men (cases/PAF)			Women (cases/PAF)		
	≥4 hours (72.5%)	≥6 hours (39.9%)	≥8 hours (22.3%)	≥4 hours (67.0%)	≥6 hours (32.8%)	≥8 hours (16.7%)
2030						
Colon (C18-C19)	5029 (15.3%)	2983 (9.1%)	1740 (5.3%)	3263 (14.4%)	1719 (7.6%)	914 (4.0%)
Rectum (C20-21)	36 (4.6%)	20 (2.7%)	12 (1.6%)	64 (4.5%)	32 (2.2%)	17 (1.2%)
Breast (C50)				3337 (5.1%)	1651 (2.5%)	836 (1.3%)
Endometrium (C54-C55)				1711 (16.2%)	913 (8.7%)	482 (4.6%)
Ovarian (C56)				1086 (16.2%)	580 (8.7%)	306 (4.6%)
All cancer cases combined	5066 (10.1%)	3004 (5.9%)	1752 (3.4%)	9461 (11.3%)	4895 (5.9%)	2556 (3.1%)
2040						
Colon (C18-C19)	5349 (15.3%)	3173 (9.1%)	1851 (5.3%)	3481 (14.4%)	1834 (7.6%)	976 (4.0%)
Rectum (C20-21)	37 (4.9%)	21 (2.7%)	12 (1.6%)	65 (4.5%)	32 (2.2%)	17 (1.2%)
Breast (C50)				3354 (5.1%)	1659 (2.5%)	840 (1.3%)
Endometrium (C54-C55)				1733 (16.2%)	925 (8.7%)	488 (4.6%)
Ovarian (C56)				1123 (16.2%)	600 (8.7%)	317 (4.6%)
All cancer cases combined	5386 (10.1%)	3194 (5.9%)	1863 (3.4%)	9756 (11.3%)	5051 (5.9%)	2638 (3.1%)

Cancer types were classified according to International Classification of Diseases (ICD)–10.

DISCUSSION

To the best of our knowledge, the incidence of cancer attributable to SB has not been previously investigated for Germany. Our study revealed that in 2024, more than 10% of cancer cases in Germany will be attributable to SB, which underscores the significant contribution of SB to the growing cancer burden in the country. Specifically, we estimated that 15% of male and 14% of female colon cancers, 5% of male and female rectal cancers, 16% of endometrial cancers, 16% of ovarian cancers and 5% of breast cancers were attributable to at least 4 hours of SB daily. Moreover, we estimated that at least 4 hours of SB per day is associated with cancer-specific healthcare costs of €797 million, representing 0.2% of total health expenditure in Germany.

Our results are broadly consistent with findings from other countries, but there are notable differences for specific cancer types. For example, the Canadian Cancer

Table 4 Estimated costs in Euro in millions for sedentary behaviour (SB)-attributable cancers for Germany for 2020

	≥4 hours of SB (69.7%)	≥6 hours of SB (36.3%)	≥8 hours of SB (19.5%)
Colon (C18-C19)	269.8	151.3	84.5
Rectum (C20-21)	51.1	27.2	14.8
Breast (C50)	233.6	124.8	67.9
Gynaecological cancers	242.0	137.1	77.0

Gynaecological cancers were classified according to International Classification of Diseases (ICD)–10 codes C51-C52, C54-C58.

Society published data in 2015 on cancers attributable to SB, reporting population-attributable risks of 7% for colorectal cancer, 10% for endometrial cancer, 12% for ovarian cancer and 3% for breast cancer.[11] Their estimates for ovarian and colorectal cancers are lower than those in our study. Similarly, a study in the UK estimated that 9% of colon cancers and 8% of endometrial cancers were attributable to SB, accounting for 0.6% of the total expenditure of the National Health Service in 2016/2017.[12] In contrast, our cost estimates were higher; for example, we estimated approximately €151 million in healthcare costs attributable to SB for colon cancer, compared with the €35 million reported in the UK study. These differences may be due to variations in SB estimates, relative risks, reference years, inflation and the generally higher level of health expenditures in Germany compared with the UK. As a result, direct comparisons may not be appropriate. Nevertheless, our findings show that SB-attributable, and therefore potentially preventable, cancer cases contribute significantly to healthcare costs in Germany. Although we assumed constant cancer incidence rates and SB prevalences, demographic changes, including an ageing population, are expected to lead to an increase in SB-attributable cancer cases. Consequently, the healthcare system in Germany must prepare for a growing SB-associated cancer burden and its related costs.

There is a growing body of evidence that identifies the potential molecular mechanisms linking SB with increased cancer risk.[19] These mechanisms include slowed metabolism, which can lead to higher body weight, obesity and an increased proportion of body fat. SB is also positively associated with insulin resistance and altered levels of

growth factors (eg, insulin-like IGF-1 and VEGF), steroid hormones (eg, oestrogens and oestrogen metabolite) and adipokines (eg, leptin or adiponectin).[20 21] These changes can modulate the immune system, resulting in chronic low-grade inflammation, which may cause higher pain levels and reduced motivation to be physically active.[22] Additionally, prolonged sitting can alter blood flow to the organs, particularly in the pelvic area.[23] Several pathways associated with SB are thought to contribute to oxidative stress, DNA methylation, telomere length alterations, immune function changes and shifts in the gut microbiome.[24] Importantly, adiposity may serve as an intermediate variable linking sedentary behaviour to cancer through several of the above-mentioned biological mechanisms.[19] Notably, our risk estimates are slightly stronger or comparable compared with cancer risk estimates for adiposity or physical activity. However, the effect directions are largely comparable; only ovarian cancer is more strongly related to SB than to adiposity or physical activity.[25 26]

Policy implications

The findings of the present study highlight the importance of policy measures aimed at reducing the prevalence of SB from both a health promotion and economic perspective. Consistent with the WHO 2020 guidelines on physical activity and SB, it is crucial to limit the amount of time spent sedentary across all age groups and replace it with physical activity of any intensity.[10] The WHO specifically recommends reducing SB in various contexts, including occupational, educational, home and community settings, and transportation.

In the occupational context, while ergonomics has been a focus in workplace health promotion in Germany, SB has not been adequately addressed. A comprehensive umbrella review showed that workplace interventions, such as height-adjustable desks, could reduce SB by nearly 90 min per day.[27] However, most workplaces in Germany are not equipped with height-adjustable desks as standard.

The same concerns apply to the education system. While kindergartens are generally more activity-promoting environments, primary, secondary and tertiary educational institutions are predominantly characterised by sedentary activities. International recommendations exist for addressing school-related SB among children and youth.[28 29] According to these guidelines, a healthy school day should include both scheduled and unscheduled movement breaks to interrupt periods of SB, incorporate different types of movement into homework and replace sedentary learning activities with movement-based ones. Specifically, school-related screen time should be limited and interrupted at least once every 30 min.[29] The Sedentary Behaviour Research Network also offers recommendations for educators, school administrators, policymakers, parents/guardians, caregivers, physicians and healthcare providers on how to implement these school-related SB guidelines.[29]

In contrast to occupational and educational settings, addressing SB in the home environment requires more individual knowledge and initiative, particularly during leisure time or while working from home. Information campaigns about the negative health effects of SB and specific strategies for reducing it could help raise awareness at both the individual and population levels.

For community settings and transportation, the WHO's 'Global action plan on physical activity 2018–2030: more active people for a healthier world' provides guidance on reducing SB and promoting physical activity.[30] In the transportation sector, replacing SB during personal motorised transportation with active modes of transportation (eg, walking or cycling) would not only benefit human health but also positively impact the environment, contributing to sustainable development and planetary health.[31 32]

The high prevalence of SB in Germany, along with the associated cancer cases and healthcare costs, underscores the need for cross-sectoral prevention and health promotion strategies. Although SB is a lifestyle factor that significantly affects health and the healthcare sector, effectively addressing this risk factor requires coordinated efforts across multiple sectors.

Strengths and limitations

To our knowledge, this is the first study to present estimates of cancer cases attributable to SB and the associated healthcare costs in Germany. By using realistic SB prevalences, we provided results that closely reflect the actual situation in Germany. Additionally, we calculated the attributable cancer cases for multiple years and considered different scenarios based on varying SB prevalences. Moreover, we relied on published risk estimates from studies that accounted for various confounding factors such as body mass index, smoking and physical activity.

Our study has some limitations. We relied on SB prevalences derived from self-reported survey data, which can introduce various types of bias. However, the German Health Update (GEDA) is generally considered representative of the population in Germany.[33] Moreover, we cannot draw any conclusions about dose-response relationships between SB and cancer cases because our SB prevalences were not mutually exclusive. While we reported sex-specific results, we were unable to account for additional confounding factors, such as genetic characteristics, previous illnesses or sociodemographic factors, due to the lack of stratified data in the German cancer registries as well as the lack of corresponding risk estimates in the literature. We assumed constant cancer incidence rates and SB prevalences in our projection due to a lack of corresponding estimates, which may have led to an underestimation of the future cancer burden attributable to SB. Lastly, it is important to acknowledge that SB is not a behaviour that can be completely avoided. Effective coping strategies

are needed, and our study provides some potential avenues to address this issue.

CONCLUSION

We estimated the number of cancer cases attributable to SB for breast, colon, rectal, endometrial and ovarian cancers in women and men aged 35–84 years in Germany. Our analysis suggests that over 14 000 new cancer cases in 2024 are attributable to SB, leading to significant costs for the German healthcare system. These findings underscore that SB is a major contributor to the cancer burden in Germany, highlighting the urgent need for cross-sectoral prevention strategies.

ORCID iDs
Michael J Stein http://orcid.org/0000-0002-1120-1751
Carmen Jochem http://orcid.org/0000-0002-2741-3759

REFERENCES

1 Tremblay MS, Aubert S, Barnes JD, *et al*. Sedentary Behavior Research Network (SBRN) - Terminology Consensus Project process and outcome. *Int J Behav Nutr Phys Act* 2017;14:75.
2 Ahrensberg H, Bjørk Petersen C, Jacobsen JNW, *et al*. The descriptive epidemiology of sedentary behaviour. In: Leitzmann MF, Jochem C, Schmid D, eds. *Sedentary Behaviour Epidemiology*. Cham: Springer International Publishing, 2023: 45–80.
3 Manz K, Domanska OM, Kuhnert R, *et al*. How much do adults sit? Results from the German Health Update (GEDA 2019/2020-EHIS). *J Health Monit* 2022;7:29–37.
4 de Rezende LFM, Rodrigues Lopes M, Rey-López JP, *et al*. Sedentary behavior and health outcomes: an overview of systematic reviews. *PLoS One* 2014;9:e105620.
5 Ekelund U, Tarp J, Steene-Johannessen J, *et al*. Dose-response associations between accelerometry measured physical activity and sedentary time and all cause mortality: systematic review and harmonised meta-analysis. *BMJ* 2019;366:l4570.
6 Guo C, Zhou Q, Zhang D, *et al*. Association of total sedentary behaviour and television viewing with risk of overweight/obesity, type 2 diabetes and hypertension: A dose-response meta-analysis. *Diabetes Obes Metab* 2020;22:79–90.
7 Hermelink R, Leitzmann MF, Markozannes G, *et al*. Sedentary behavior and cancer-an umbrella review and meta-analysis. *Eur J Epidemiol* 2022;37:447–60.
8 World Health Organization. Estimated number of prevalent cases (1-year), both sexes, age [0-74], in 2022. 2024. Available: https://gco.iarc.who.int/today/en/dataviz/pie-prevalence?mode=cancer&group_populations=1&key=total&age_end=14&types=2
9 Statistisches Bundesamt (Destatis). Todesursachen. 2023. Available: https://www-genesis.destatis.de/genesis/online?sequenz=tabelleErgebnis&selectionname=23211-0002#abreadcrumb
10 Bull FC, Al-Ansari SS, Biddle S, *et al*. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br J Sports Med* 2020;54:1451–62.
11 Canadian Cancer Society. Attributable cancer case(s) due to sedentary behaviour in Canada for all ages, 2015. 2015. Available: https://data.prevent.cancer.ca/current/risk-factors
12 Heron L, O'Neill C, McAneney H, *et al*. Direct healthcare costs of sedentary behaviour in the UK. *J Epidemiol Community Health* 2019;73:625–9.
13 Behrens G, Gredner T, Stock C, *et al*. Cancers Due to Excess Weight, Low Physical Activity, and Unhealthy Diet. *Dtsch Arztebl Int* 2018;115:578–85.
14 Mons U, Gredner T, Behrens G, *et al*. Cancers Due to Smoking and High Alcohol Consumption. *Dtsch Arztebl Int* 2018;115:571–7.
15 Zentrum für krebsregisterdaten. Berlin Robert Koch Institut; 2018. Available: https://www.krebsdaten.de/Krebs/DE/Content/Krebsarten/krebsarten_node.html
16 Statistisches Bundesamt. Bevölkerung deutschlands bis 2060 - 13. Koordinierte bevölkerungsvorausberechnung wiesbaden. 2015. Available: https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Bevoelkerung/Bevoelkerungsvorausberechnung/Publikationen/Downloads-Vorausberechnung/bevoelkerung-deutschland-2060-presse-5124204159004.pdf?__blob=publicationFile
17 Statistisches Bundesamt (Destatis). Krankheitskostenrechnung. 2023. Available: https://www-genesis.destatis.de/genesis/online?sequenz=tabelleErgebnis&selectionname=23631-0001&sachmerkmal=ICD10Y&sachschluessel=ICD10-C00-C97,ICD10-C00-C14,ICD10-C15-C26,ICD10-C16,ICD10-C18,ICD10-C20,ICD10-C25,ICD10-C30-C39,ICD10-C33-C34,ICD10C43-C44,ICD10-C50,ICD10-C51-C58,ICD10-C53,ICD10-C60-C63,ICD10-C61,ICD10-C64-C68,ICD10-C67,ICD10-C81-C96,ICD10-C91-C95#abreadcrumb
18 R Core Team. R: a language and environment for statistical computing. R Foundation for Statistical Computing: Vienna, Austria; 2022. Available: https://www.R-project.org/
19 Jochem C, Wallmann-Sperlich B, Leitzmann MF. The Influence of Sedentary Behavior on Cancer Risk: Epidemiologic Evidence and Potential Molecular Mechanisms. *Curr Nutr Rep* 2019;8:167–74.
20 Diaz KM, Goldsmith J, Greenlee H, *et al*. Prolonged, Uninterrupted Sedentary Behavior and Glycemic Biomarkers Among US Hispanic/Latino Adults: The HCHS/SOL (Hispanic Community Health Study/Study of Latinos). *Circulation* 2017;136:1362–73.
21 Leitzmann M, Powers H, Anderson AS, *et al*. European Code against Cancer 4th Edition: Physical activity and cancer. *Cancer Epidemiol* 2015;39 Suppl 1:S46–55.
22 Verdú E, Homs J, Boadas-Vaello P. Physiological Changes and Pathological Pain Associated with Sedentary Lifestyle-Induced Body Systems Fat Accumulation and Their Modulation by Physical Exercise. *Int J Environ Res Public Health* 2021;18:13333.
23 Aparicio VA, Ocón O, Padilla-Vinuesa C, *et al*. Effects of supervised aerobic and strength training in overweight and grade I obese pregnant women on maternal and foetal health markers: the GESTAFIT randomized controlled trial. *BMC Pregnancy Childbirth* 2016;16:290.
24 Friedenreich CM, Ryder-Burbidge C, McNeil J. Physical activity, obesity and sedentary behavior in cancer etiology: epidemiologic evidence and biologic mechanisms. *Mol Oncol* 2021;15:790–800.
25 Lauby-Secretan B, Scoccianti C, Loomis D, *et al*. Body Fatness and Cancer--Viewpoint of the IARC Working Group. *N Engl J Med* 2016;375:794–8.

26 Moore SC, Lee I-M, Weiderpass E, *et al*. Association of Leisure-Time Physical Activity With Risk of 26 Types of Cancer in 1.44 Million Adults. *JAMA Intern Med* 2016;176:816–25.

27 Lam K, Baurecht H, Pahmeier K, *et al*. How effective and how expensive are interventions to reduce sedentary behavior? An umbrella review and meta-analysis. *Obes Rev* 2022;23:e13422.

28 Kuzik N, da Costa BGG, Hwang Y, *et al*. School-related sedentary behaviours and indicators of health and well-being among children and youth: a systematic review. *Int J Behav Nutr Phys Act* 2022;19:40.

29 Sedentary Behaviour Research Network. International school-related sedentary behaviour recommendations. 2024. Available: https://www.sedentarybehaviour.org/school-related-sedentary-behaviour-recommendations

30 World Health Organization. Global action plan on physical activity 2018–2030: more active people for a healthier world. 2018.

31 Jochem C, Leitzmann M. A call for integrating active transportation into physical activity and sedentary behaviour guidelines. *Lancet Planet Health* 2023;7:e112–3.

32 Tittlbach S, Brockfeld A, Kindig S, *et al*. Maintaining health in daily life—is active travel the solution? *Ger J Exerc Sport Res* 2024;54:121–34.

33 Allen J, Born S, Damerow S, *et al*. German health update (GEDA 2019/2020-ehis) – background and methodology. 2021.66–79.