Physical inactivity-attributable deaths and disability-adjusted life years in Switzerland

Estimates for the year 2022

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Abstract

English

Objective: The aim of this study was to estimate the number of deaths and the number of disability-adjusted life years (DALYs) attributable to physical inactivity (PIA) in Switzerland for the year 2022.

Methods: We modelled these estimates using a population attributable fraction (PAF) approach that combines estimates of prevalence (of physical inactivity) and the associated relative risk (RR) of PIA-related diseases. PIA was defined as failing to meet the recommended guidelines established by the WHO/HEPA Switzerland, which specify a minimum of 150 minutes of moderate-intensity or 75 minutes of high-intensity physical activity per week. Age- and sex-specific prevalences of PIA were taken from the Swiss Health Survey 2022. A systematic literature search was conducted to extract relevant RRs from meta-analyses. Age-, sex- and disease-specific deaths were extracted from the Swiss death statistic 2022. Age- sex- and disease-specific DALYs were extracted from the Global Burden of Disease Results Tool. Subsequently, stratified PIA-attributable deaths and DALYs were calculated by multiplying the PAFs with the total number of deaths and DALYs respectively. Uncertainty of the results was assessed via parametric bootstrapping.

Results: In 2022, a quarter of the adult population in Switzerland was physically inactive. Our estimations suggest that 1621 deaths (95% CI = [1460; 1770]) could be attributed to PIA during that year. Cardiovascular diseases, cancers, dementia, and Alzheimer's disease emerged as the primary contributors to PIA-related mortality. When quantifying the burden of PIA in terms of DALYs, we found that 52'689 DALYs (95% CI = [49'119; 57'991]) were attributed to PIA. Cardiovascular diseases, cancers, and dementia and Alzheimer's disease were the major contributors. The age group 75 years and older contributed most to the number of deaths and DALYs attributable to PIA and women contributed substantially more deaths and DALYs as men. Compared to the last investigation of PIA in the Swiss population in 2017, PIA-attributable deaths further decreased, while PIA-attributable DALYs remained stable.

Conclusion: This study underlines the significant impact of PIA on public health in Switzerland and highlights the urgent need for targeted interventions to promote physical activity, particularly among females and individuals aged 75 years and older.

Deutsch

Zielsetzung: Das Ziel dieser Studie war es, die Anzahl Todesfälle und die Anzahl *disability-adjusted life years* (DALYs) zu schätzen, die 2022 in der Schweiz auf körperliche Inaktivität (PIA) zurückzuführen waren.

Methoden: Die Schätzungen wurden anhand eines *Population Attributable Fraction* (PAF) Ansatzes modelliert, bei welchem Prävalenzdaten (von PIA) mit relativen Risiken (RR) von PIA-bedingten Krankheiten kombiniert werden. PIA wurde als das Nichterfüllen der von der WHO/HEPA Schweiz empfohlenen Bewegungsrichtlinien definiert, die ein Minimum von 150 Minuten moderater oder 75 Minuten intensiver körperlicher Aktivität pro Woche vorsehen. Die alters- und geschlechtsspezifischen Prävalenzen von PIA wurden anhand der Daten der Schweizerischen Gesundheitsbefragung 2022 berechnet. Eine systematische Literaturrecherche wurde durchgeführt, um relevante RRs aus Meta-Analysen zu extrahieren. Alters-, geschlechts- und krankheitsspezifische Todesfälle wurden der schweizerischen Todesursachenstatistik 2022 entnommen. Die alters-, geschlechts- und krankheitsspezifischen DALYs wurden mit Hilfe des Global Burden of Disease Results Tool berechnet. Die stratifizierten PIA-bedingten Todesfälle und DALYs wurden durch Multiplikation der PAFs mit der entsprechenden Gesamtzahl der Todesfälle bzw. DALYs berechnet. Die Unsicherheit der Resultate wurde durch parametrisches Bootstrapping quantifiziert.

Ergebnisse: Im Jahr 2022 war ein Viertel der erwachsenen Bevölkerung in der Schweiz körperlich inaktiv. Laut unseren Berechnungen waren in diesem Jahr 1621 Todesfälle (95% CI = [1460; 1770]) auf PIA zurückzuführen. Herz-Kreislauf-Erkrankungen, Krebs, Demenz und die Alzheimer-Krankheit trugen am stärksten zur PIA-bedingten Sterblichkeit bei. Die Quantifizierung der PIA bedingten Krankheitslast in Form von DALYs zeigte, dass 52'689 DALYs (95% CI = [49'119; 57'991]) auf PIA zurückgeführt werden konnten. Herz-Kreislauf-Erkrankungen, Krebserkrankungen sowie Demenz und die Alzheimer-Krankheit waren die Hauptverursacher. Die Altersgruppe 75 Jahre und älter trug am meisten zu Todesfällen und DALYs bei, die auf PIA zurückzuführen sind. Frauen trugen wesentlich mehr Todesfälle und DALYs bei als Männer. Im Vergleich zur letzten Untersuchung von PIA in der Schweizer Bevölkerung im Jahr 2017 ist die Anzahl PIA-bedingter Todesfälle weiter gesunken, während die PIA-bedingten DALYs gleich geblieben sind.

Schlussfolgerung: Diese Studie unterstreicht die erheblichen Auswirkungen von PIA auf die Gesundheit der Bevölkerung in der Schweiz und verdeutlicht den dringenden Bedarf an gezielten Interventionen zur Förderung der körperlichen Aktivität, insbesondere bei Frauen und Personen im Alter von 75 Jahren und älter.

Français

Objectif: Le but de cette étude était d'estimer le nombre de décès et le nombre d'années de vie corrigées de l'incapacité (plus connu en anglais sous le terme DALYs pour disability-adjusted life years) attribuables à l'inactivité physique en Suisse pour l'année 2022.

Méthodes: Nous avons modélisé ces estimations en utilisant une approche de fraction attribuable à la population (FAP) qui combine les estimations de la prévalence (de l'inactivité physique) et le risque relatif (RR) associé des maladies liées à l'inactivité physique. Les prévalences de l'inactivité physique spécifiques à l'âge et au sexe ont été tirées de l'Enquête suisse sur la santé 2022. Une recherche systématique de la littérature a été menée pour extraire les RR pertinents des méta-analyses. Les décès spécifiques à l'âge, au sexe et à la maladie ont été extraits de la statistique suisse de la mortalité 2022. Les DALYs spécifiques à l'âge, au sexe et à la maladie ont été extraites du Global Burden of Disease Results Tool. Les décès et les DALYs stratifiés attribuables à l'inactivité physique ont ensuite été calculés en multipliant les FAP par le nombre total de décès et de DALYs, respectivement. L'incertitude des résultats a été évaluée par le bootstrap paramétrique.

Résultats: En 2022, un quart de la population adulte en Suisse était physiquement inactive. Nos estimations suggèrent que 1621 décès (IC 95% = [1460 ; 1770]) pourraient être attribués à l'inactivité physique au cours de cette année. Les maladies cardiovasculaires, les cancers, la démence et la maladie d'Alzheimer sont ressortis comme les principaux facteurs de mortalité liés à l'inactivité physique. Lorsque l'on quantifie la charge de l'inactivité physique en termes de DALYs, on constate que 52'689 DALYs (IC à 95 % = [49 8119 ; 57 991]) ont été attribuées à l'inactivité physique. Les maladies cardiovasculaires, les cancers, la démence et la maladie d'Alzheimer sont les principales causes. Le groupe d'âge des 75 ans et plus a contribué le plus au nombre de décès et de DALYs attribuables à l'inactivité physique, et les femmes ont contribué à un nombre de décès et de DALYs nettement plus élevé que les hommes.

Conclusion: Cette étude souligne l'impact significatif de l'inactivité physique sur la santé publique en Suisse et met en évidence le besoin urgent d'interventions ciblées pour promouvoir l'activité physique, en particulier chez les femmes et les personnes âgées de 75 ans et plus.

Italiano

Obiettivo: Lo scopo di questo studio era di stimare il numero di decessi e il numero di disability-adjusted life years (DALYs) attribuibili all'inattività fisica (PIA) in Svizzera per l'anno 2022.
Metodologia: Le stime sono state modellizzate utilizzando un approccio di Population attributable Fraction (PAF), il quale integra dati di prevalenza (dell'inattività fisica) con rischi relativi (RR) di malattie correlate alla PIA. La PIA è stata definita come mancata adesione alle linee guida raccomandate stabilite dall'OMS/HEPA Svizzera, che prevedono un minimo di 150 minuti di attività fisica di intensità moderata o 75 minuti di attività fisica ad alta intensità per settimana. Le prevalenze specifiche per età e sesso della PIA sono state calcolate utilizzando i dati del sondaggio sulla salute svizzero del 2022. È stata eseguita una ricerca bibliografica sistematica per estrarre i RR rilevanti da meta-analisi. I decessi specifici per età, sesso e malattia sono stati ottenuti dalle statistiche sulla mortalità svizzere del 2022. I DALYs specifici per età, sesso e malattia sono stati calcolati utilizzando lo strumento Global Burden of Disease Results. I decessi e i DALYs attribuibili alla PIA, stratificati per gruppo, sono stati calcolati moltiplicando i PAF per il numero totale corrispondente di decessi e DALYs. L'incertezza dei risultati è stata valutata tramite bootstrap parametrico.
Risultati: Nel 2022, un quarto della popolazione adulta in Svizzera era fisicamente inattiva. Le nostre stime suggeriscono che 1621 decessi (95% CI = [1460; 1770]) potrebbero essere attribuiti alla PIA durante quell'anno. Le malattie cardiovascolari, i tumori, la demenza e la malattia di Alzheimer sono emerse come i principali contributori alla mortalità correlata alla PIA. Quantificando l'impatto della PIA in termini di DALYs, abbiamo riscontrato che 52'689 DALYs (95% CI = [49'119; 57'991]) sono attribuibili alla PIA. Le malattie cardiovascolari, i tumori e la demenza e la malattia di Alzheimer sono stati i principali contributori.
Il gruppo di età 75+ ha contribuito maggiormente al numero di decessi e DALYs attribuibili alla PIA. Le donne hanno registrato un maggior numero di decessi e DALYs rispetto agli uomini. Rispetto all'ultima indagine sulla PIA nella popolazione svizzera nel 2017, i decessi attribuibili alla PIA sono ulteriormente diminuiti, mentre i DALY attribuibili alla PIA sono rimasti stabili.
Conclusioni: Questo studio sottolinea l'impatto significativo della PIA sulla salute pubblica in Svizzera e evidenzia l'urgente necessità di interventi mirati per promuovere l'attività fisica, in particolare tra le donne e gli individui di età pari o superiore a 75 anni.

Introduction

Physical inactivity (PIA) remains a significant risk factor for numerous non-communicable diseases (NCDs), mental health conditions, and premature mortality (Katzmarzyk, 2023; Santos et al., 2023). Recent research by Santos et al. (2023) indicates a projected increase of 499.2 million new cases of preventable major NCDs and mental health conditions globally between 2020 and 2030 if the prevalence of PIA persists. It is estimated that each year, nearly 16 million disability-adjusted life years (DALYs) and 830'000 deaths are attributable to PIA (Xu et al., 2022).
In 2017, 24.4% of the Swiss population aged 15 years and older failed to meet the recommended level of physical activity (PA) set by the World Health Organization (WHO) (Bundesamt für Statistik, 2023). Moreover, PIA was estimated to be responsible for 1'278 deaths in Switzerland in 2017 (Syleouni et al., 2020).
The aim of this study was to estimate the number of deaths attributable to PIA for the year 2022. We incorporated newly published data on the association between PIA and the risk of several NCDs. Our analysis employed PIA prevalence estimates from the recent Swiss Health Survey 2022[1] (SHS 2022) along with current mortality statistics for Switzerland. Additionally, we estimated the disease burden attributed to PIA in terms of DALYs.

Methods

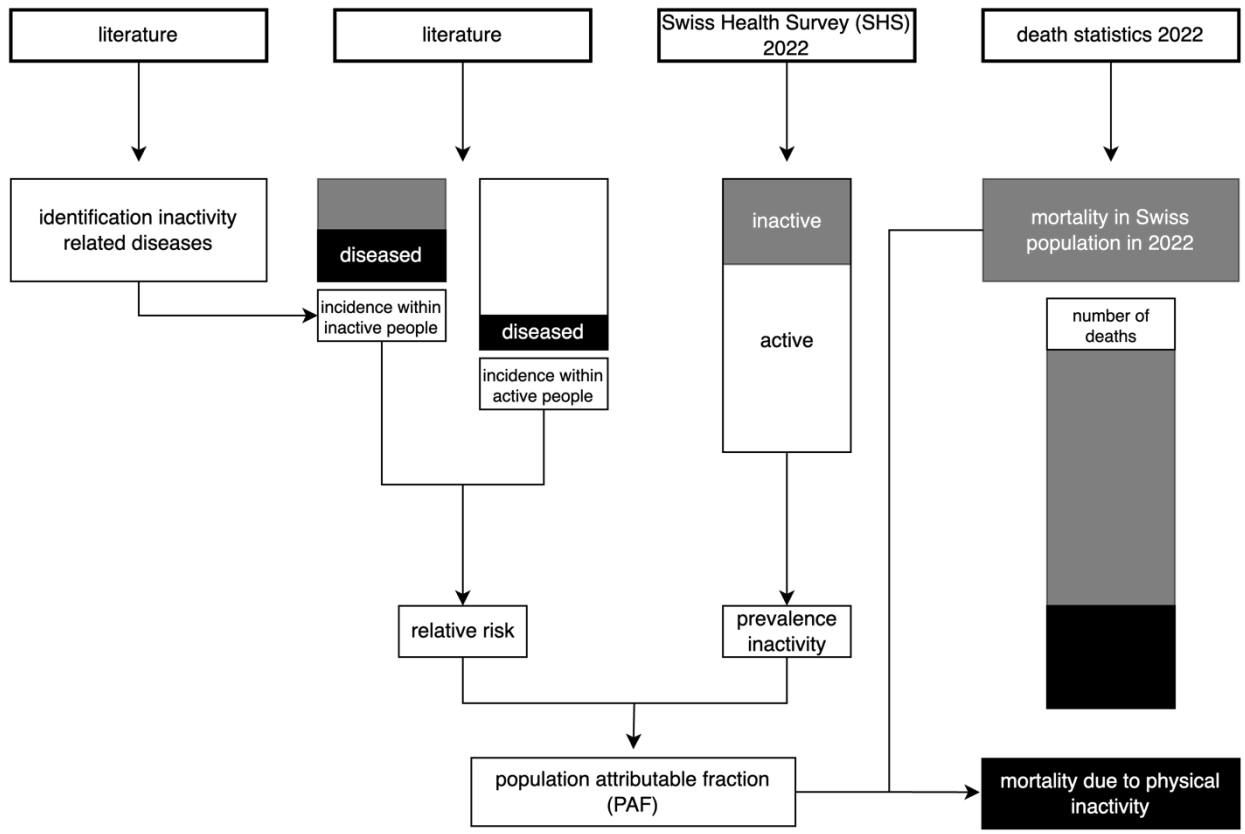

Figure 1: Overview of the methods to estimate physical inactivity-attributable deaths, based on Mattli et al. (2019). The same approach was used for physical inactivity-attributable disability-adjusted life years.

To ensure comparability with prior studies, we adopted the methodological framework outlined in the final report for the year 2017 (Syleouni et al., 2020), which builds upon previous investigations evaluating the impact of PIA (Ding et al., 2016; Mattli et al., 2019; Santos et al., 2023). Figure 1 presents a synthesis of both data sources and methodologies used for quantifying PIA-attributable deaths and DALYs. Initially, we conducted a systematic literature search to identify diseases associated with PIA. Subsequently, we extracted corresponding relative risks (RRs) for these diseases, which were then

[1] Schweizerische Gesundheitsbefragung:
https://www.bfs.admin.ch/bfs/de/home/statistiken/gesundheit/erhebungen/sgb.html

integrated with PIA prevalences to compute population attributable fractions (PAFs). Ultimately, the PAFs were multiplied by the total number of deaths or DALYs to estimate age- and sex-specific PIA-attributable deaths or DALYs respectively. Each of these procedural steps is elaborated upon below.

Prevalence of physical activity in Switzerland

The WHO recommends that adults engage in a minimum of 150 minutes of moderate-intensity PA, 75 minutes of high-intensity PA, or an equivalent combination per week (WHO, 2024). These guidelines, endorsed by the Swiss Federal Office of Sport / HEPA Switzerland [2] (Bundesamt für Sport BASPO, 2023; HEPA, 2023), serve as a reference PA standard. According to data from the SHS 2022, individuals classified as "inactive" or "partially active" failed to meet these WHO guidelines and were thus categorised as physically inactive in our study. 95% Wald confidence intervals (CIs) were estimated for all age- (35-44, 45-54, 55-64, 65-74, 75+ years old) and sex-specific prevalences. People younger than 35 years were not considered in our study as this population causes a very low number of deaths related to PIA.

Physical inactivity related diseases and corresponding relative risks

Diseases possibly affected by PIA were identified through the report 2017, the WHO global action plan on PA 2018–2030 and through highly cited research articles in this domain (Geidl et al., 2020; Katzmarzyk, 2023; Katzmarzyk et al., 2022; Ramírez Varela et al., 2021; Santos et al., 2023). We conducted a systematic literature search in PubMed (9/28/2023) to identify meta-analyses reporting RRs for each disease comparing physically active with inactive individuals. The detailed search strategy can be found in the appendix. All search results were stored in reference management software. After removing duplicates, titles and abstracts were screened for relevance. Full-texts were retrieved for all relevant references and assessed for eligibility. If more than one meta-analysis was available per disease, the following criteria were critical for selection:

- Representativeness for Switzerland
- Quality of the meta-analysis (e.g. adjusted estimates were preferred, study selection process)
- Quality of the primary studies (e.g. large cohort studies with long follow-ups were preferred)

RRs and corresponding 95% CIs were extracted from full-texts and sometimes from supplementary documents of the included meta-analyses. In this study, we considered PIA as a risk factor. If the RRs were reported considering physical activity as a protective factor, they were converted accordingly.
For dose-response meta-analyses, RRs comparing inactive individuals with those just meeting PA guidelines were extracted, rather than, for example, comparing the lowest versus highest PA levels.

Population attributable fractions

The PAF can be interpreted as the proportion of cases that could have been avoided if the risk factor (i.e. PIA) was eliminated. We used the following formula to estimate the PAF for each disease and each age-sex-group:

$$PAF_{ijk} = \frac{Prevalence_{ij}(RR_k - 1)}{RR_k}$$

For $i = 1, \dots, n$ age groups, $j = 1, \dots m$ sex groups and $k = 1, \dots p$ diseases.

There are other formulas to calculate the PAF (e.g. Santos et al., 2023). However, the formula presented above is preferred when there is confounding (Ding et al., 2016). Confounding is likely in the field of PIA and included studies adjusted for various confounding factors. For our model, we assumed that the RRs are constant across age- and sex-groups and over time.

Deaths attributable to physical inactivity

The number of deaths attributed to each disease under examination in this study was extracted from the Swiss Death Statistics for the year 2022, as provided by the Swiss Federal Statistical Office (FSO).

[2] HEPA Schweiz, Bewegungsempfehlungen: https://www.hepa.admin.ch/de/bewegungsempfehlungen

Death counts were disaggregated by age and gender. For identification of diseases, the International Classification of Diseases, 10th Revision (ICD-10) codes were applied as outlined in Table 1. Consistency with the ICD-10 codes reported in the 2017 study was maintained for diseases included therein. For diseases not covered in the 2017 report, we referenced the ICD-10 codes reported in studies investigating RRs. The number of deaths within each age-sex group was then multiplied by the corresponding PAF to estimate the number of deaths attributable to PIA.

DALYs attributable to physical inactivity

The Global Burden of Disease Study (2019) provides the most comprehensive estimation of the global burden of 369 diseases by country from 1990 to 2019 (Vos et al., 2020). Age-, sex- and disease-specific DALYs were extracted via the Global Health Data Exchange GBD Results Tool[3]. As the GBD Results Tool only provides DALYs for cancers and cardiovascular diseases in an aggregated form, we were not able to model individual cancer types and cardiovascular diseases. Furthermore, DALYs for osteoporosis are not available through GBD and were thus omitted in our analysis.
Population statistics from the FSO were employed to account for disparities in the total number of individuals within each age-sex group between 2019 and 2022. Age-, sex- and disease-specific PIA-attributable DALYs were computed by multiplying the number of DALYs within the respective group by the corresponding PAF.

Dealing with uncertainty

We estimated 95% (percentile) CIs for all quantities of interest (PAFs, PIA-attributable deaths, PIA-attributable DALYs) via parametric bootstrapping with $R = 5000$ replications. We used the following distributions for the simulations:

- Log-normal distributions for DALYs
- Log-normal distributions for RRs
- Beta distributions for prevalences

Parameter estimates were retrieved from the literature and from the SHS 2022 respectively as described above.

Sensitivity analyses

In a sensitivity analysis, we conducted an aggregated analysis that encompassed all cancer types and cardiovascular diseases, as opposed to solely considering those identified through literature search. The corresponding RRs were sourced from the literature (Garcia et al., 2023). This sensitivity analysis was undertaken based on the assumption that most deaths were attributed to cancers or cardiovascular diseases.
In another sensitivity analysis, we employed a RR for all-cause mortality instead of segregating PIA-related diseases to estimate deaths attributable to PIA (Ramakrishnan et al., 2021).

Trend over time

To examine the temporal trajectory, we computed PAFs, PIA-related deaths and DALYs for the preceding years in which the SHS was conducted – namely, 2002, 2007, 2012 and 2017. We employed the same methodologies and data sources outlined earlier for each of these years. Consequently, we addressed the same spectrum of diseases and assumed consistent RRs across time, Additionally, alongside the mortality and DALY figures, we calculated age- and sex-adjusted death rates based on demographic data provided by the FSO of Switzerland.

Results

Prevalence of physical inactivity in Switzerland

Figure 2 illustrates age-and sex-specific prevalences of PIA in Switzerland for the year 2022. Prevalences of PIA are higher in women (28%) than in men (23%). Across both genders, a negative correlation is

[3] Global Health Data Exchange GBD Results Tool: http://ghdx.healthdata.org/gbd-results-tool

observed between prevalence rates and age, except for the oldest age group (75+ years), where the prevalence notably peaks. Detailed data can be found in the appendix.

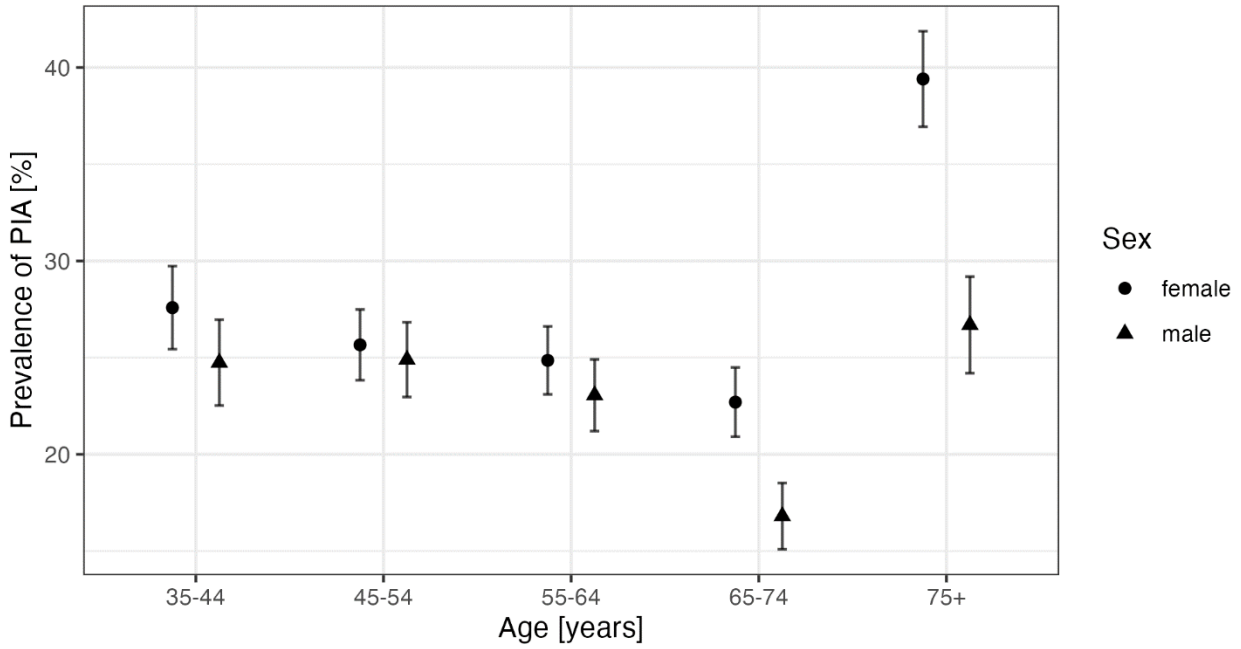

Figure 2: Age- and sex-specific prevalences of not meeting the HEPA physical activity guidelines in Switzerland for the year 2022. The error bars indicate 95% confidence intervals.

Physical inactivity related diseases and corresponding relative risks

Figure 3 illustrates the search strategy. We retrieved a total of 705 unique records, leading to the assessment of 98 full-texts. As depicted in Table 1, our selection process led to the inclusion of seven meta-analyses, which collectively offered RRs for 19 distinct diseases (Alzahrani et al., 2019; Fang et al., 2018; Garcia et al., 2023; Iso-Markku et al., 2022; Katzmarzyk & Janssen, 2004; Kyu et al., 2016; Pearce et al., 2022). One of these meta-analyses also presented RRs for all cancers and all cardiovascular diseases in an aggregated manner (Garcia et al., 2023), which we used for the sensitivity analysis. Furthermore, an additional meta-analysis was identified, providing the RR for all-cause mortality; this measure was used for the second sensitivity analysis (Ramakrishnan et al., 2021).

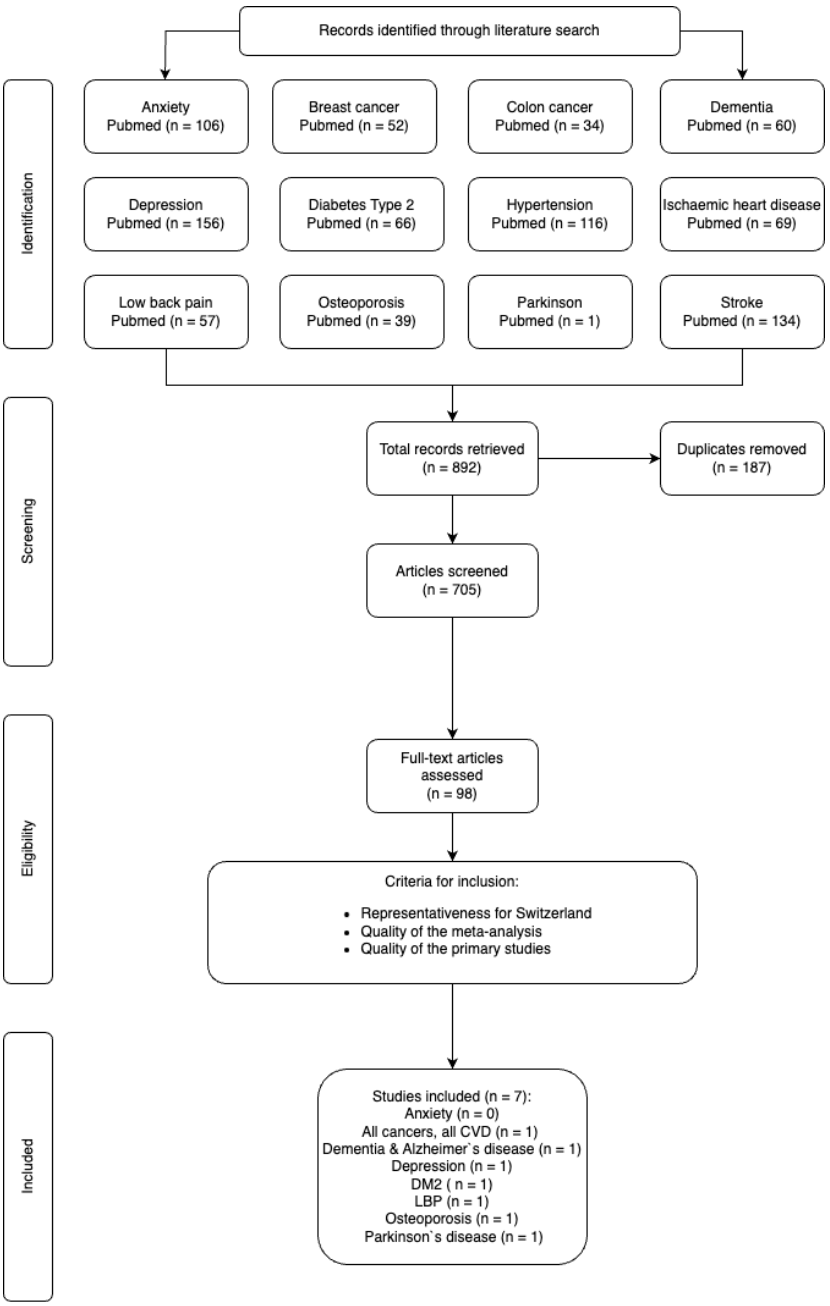

Figure 3: Flow diagram of the systematic literature search. No study could be included for anxiety. Estimates for cancers and CVDs were reported in the same study. CVD: cardiovascular disease, DM2: diabetes mellitus type 2, LBP: low back pain.

Population attributable fractions

The variation in PAFs is only attributed to differences in PIA prevalence as we assumed RRs to be constant across age groups and gender. Therefore, highest PAFs were found for osteoporosis and head and neck cancer and lowest PAFs were found for breast and colon cancer. For the same reason, there are only minimal differences in PAFs among the 35-64 years age groups for both genders. Notably, women in the 65-74 years and 75+ years age groups show higher PAFs than men.

Disease	ICD-10 code	RR	Lower	Upper	Studies	Source
All cancers	C00 - D48.9	1.136	1.087	1.176	31	Garcia et al. (2023)
Breast cancer	C50	1.053	1.031	1.087	29	Garcia et al. (2023)
Colon cancer	C18	1.075	1.010	1.149	20	Garcia et al. (2023)
Head and neck cancer	C76.0	1.538	1.099	2.174	4	Garcia et al. (2023)
Myeloid leukaemia	C92	1.333	1.053	1.667	4	Garcia et al. (2023)
Myeloma	C90	1.333	1.087	1.639	4	Garcia et al. (2023)
Gastric cancer	C16.0	1.282	1.099	1.515	5	Garcia et al. (2023)
Lung cancer	C34	1.190	1.136	1.235	16	Garcia et al. (2023)
Liver cancer	C22-C24	1.190	1.042	1.370	6	Garcia et al. (2023)
Endometrial cancer	C54	1.111	1.031	1.190	13	Garcia et al. (2023)
All cardiovascular diseases	I00 - I99	1.370	1.266	1.449	37	Garcia et al. (2023)
Coronary heart disease	I20 - I25	1.266	1.190	1.351	26	Garcia et al. (2023)
Heart failure	I11.0, I13.0, I13.2, I50	1.190	1.075	1.333	11	Garcia et al. (2023)
Stroke	I60 - I66	1.250	1.176	1.333	25	Garcia et al. (2023)
Diabetes type 2	E11-E14 but not E11.2, E12.2, E13.2*	1.167	1.109	1.225	55	Kyu et al. (2016)
Depression	F32-F33, F34.1*	1.333	1.220	1.471	15	Pearce et al. (2022)
Low back pain	M46.9, M47, M48.0-M48.2, M48.8-M48.9, M51-M54, but not M53*	1.111	1.042	1.176	7	Alzahrani et al. (2019)
Osteoporosis	M80-M85*	1.590	1.400	1.800	9	Katzmarzyk et al. (2004)
Alzheimer's disease	G30	1.333	1.136	1.563	16	Iso-Markku et al. (2022)
Dementia	F00, F01, F03	1.220	1.149	1.316	20	Iso-Markku et al. (2022)
Parkinson disease	G20	1.266	1.099	1.471	7	Fang et al. (2018)
All-cause mortality	all	1.351	1.205	1.493	33	Ramakrishnan et al. (2021)

Table 1: Identified physical inactivity-associated diseases with corresponding relative risks. The limits of the 95% confidence intervals are given by the columns “Lower” and “Upper”. The column "Studies" indicates the number of studies, the estimates are based on. ICD-10 codes with * were defined according to the report for 2017 (Syleouni et al, 2020).

Deaths attributable to physical inactivity

In 2022, a total of 73’338 deaths (females = 37’589, males = 35’749) occurred in Switzerland in adults older than 35 years (see appendix for more details on total deaths). Of these, 1621, 95% CI = [1460; 1770] were attributable to PIA, which is about 2.2% of all deaths. Coronary heart disease (26%), dementia (20%), heart failure (12%), stroke (10%) lung cancer (9%) and Alzheimer’s disease (7%) contributed together more than 80% to the total PIA-attributable deaths (Figure 4). The number of PIA-attributable deaths was significantly higher for women (1040, 95% CI = [895; 1176]) than for men (581, 95% CI = [517; 642]). The gender differences were largest for dementia, heart failure, stroke, and Alzheimer’s disease (Figure 5). Detailed estimates and corresponding CIs are provided in the appendix.

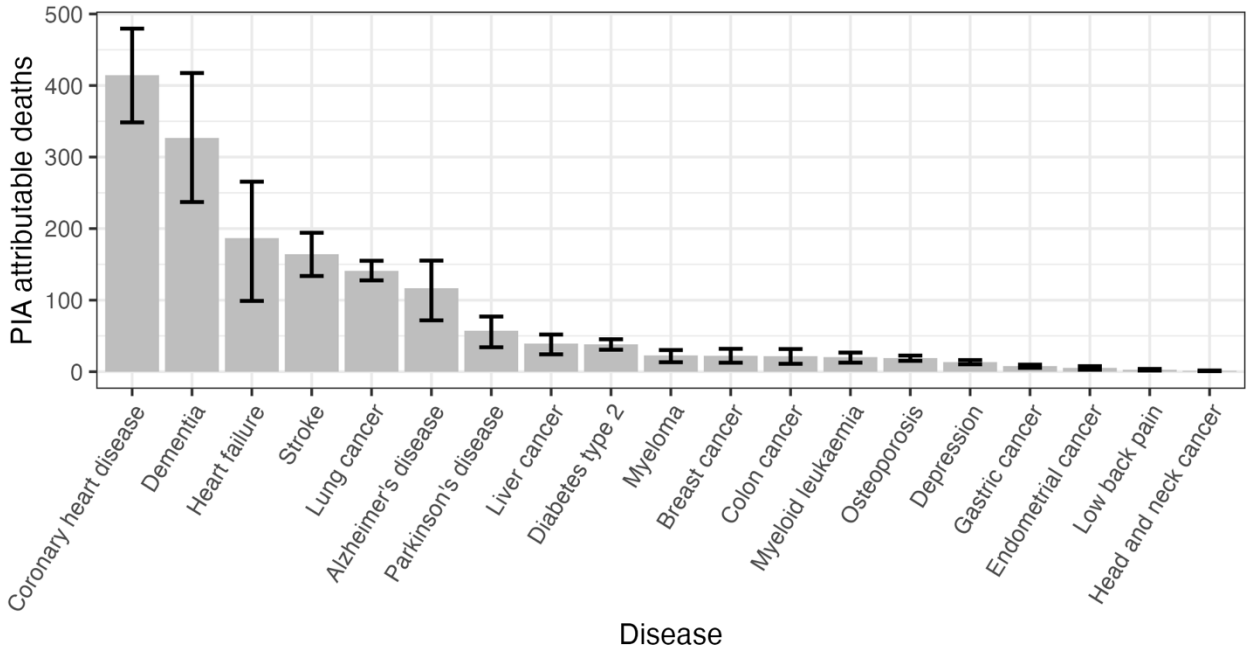

Figure 4: Physical inactivity-attributable deaths per disease (both sexes). The error bars indicate 95% confidence intervals.

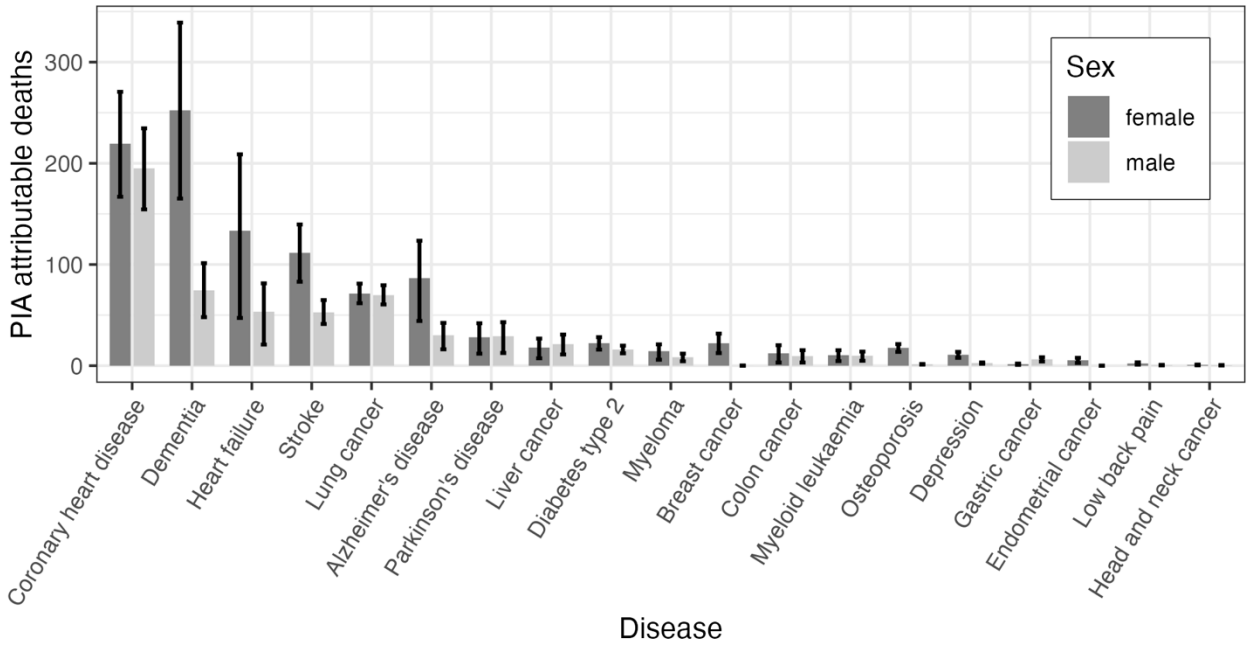

Figure 5: Physical inactivity-attributable deaths per disease and by sex. The error bars indicate 95% confidence intervals.

DALYs attributable to physical inactivity

In 2022, Switzerland experienced a total of 1'054'582 DALYs due to the included diseases (refer to the appendix for further breakdown of total DALYs). Among these, 52'689 (95% CI = [49'118; 57'990]) were attributed to PIA. Major contributors to PIA-related DALYs included cardiovascular diseases (49%) and cancers (23%) (Figure 6). The number of PIA-attributed DALYs was higher among females (30'265, 95% CI = [27'188; 34'709]) compared to males (22'424, 95% CI = [20'673; 24'728]). Gender disparities were most pronounced in cases of cardiovascular diseases and dementia (Figure 7). Detailed estimations and corresponding CIs are available in the appendix.

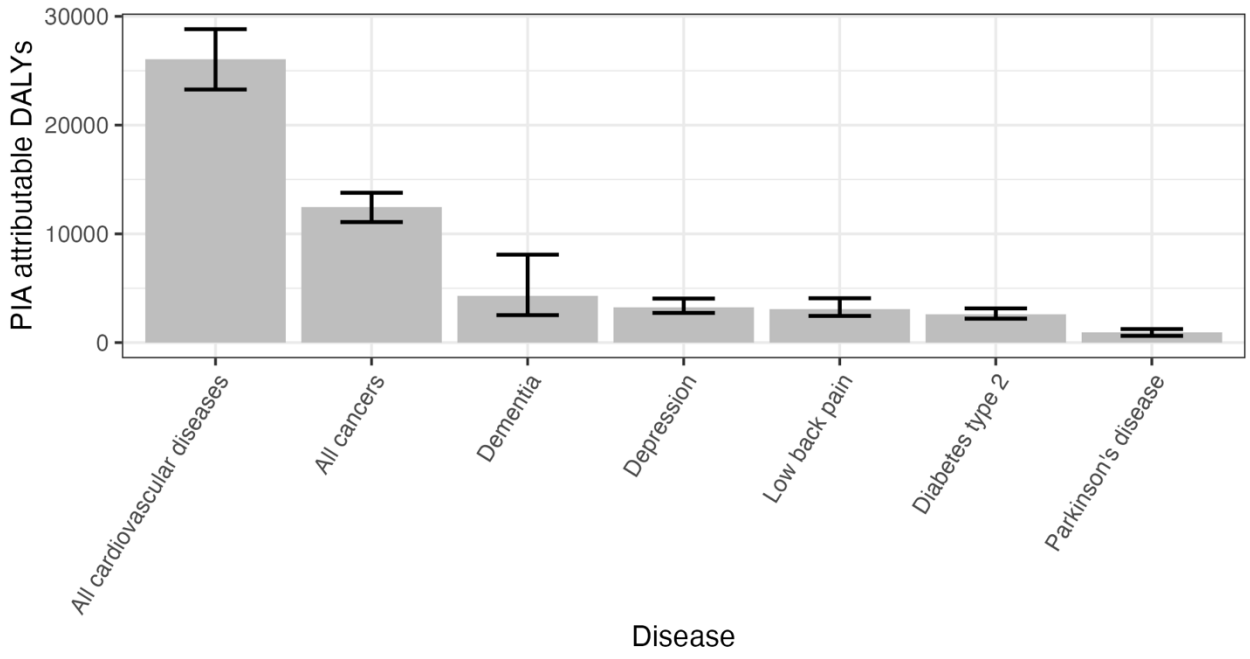

Figure 6: Physical inactivity-attributable disability-adjusted life years per disease (both sexes). The error bars indicate 95% confidence intervals. Dementia includes Alzheimer's disease.

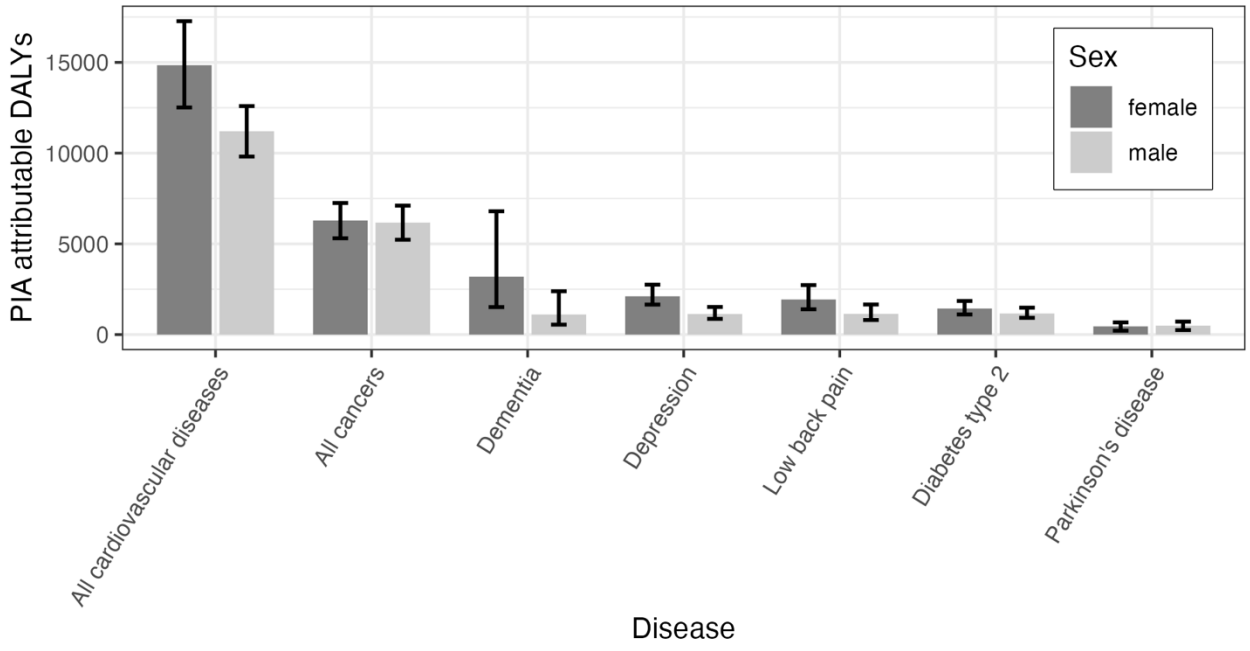

Figure 7: Physical inactivity-attributable disability-adjusted life years per disease and by sex. The error bars indicate 95% confidence intervals. Dementia includes Alzheimer's disease.

Sensitivity analyses

Considering all cardiovascular diseases and all cancers

When examining the collective impact of all cancers and cardiovascular diseases, the number of deaths attributable to PIA was significantly elevated (2944, 95% CI = [2691; 3176]). Among females, the estimated PIA-attributable deaths were 1872, 95% CI = [1648; 2072]), while among males, the figure was 1072, 95% CI = [955; 1183]). Together, cardiovascular diseases (60%) and cancers (20%) accounted for 80% of the total PIA attributable deaths (Figure 8). As for the main analysis, also in this sensitivity

analysis, total PIA attributable deaths were found to be higher among females for cardiovascular diseases and dementia, but not for cancers (Figure 9).

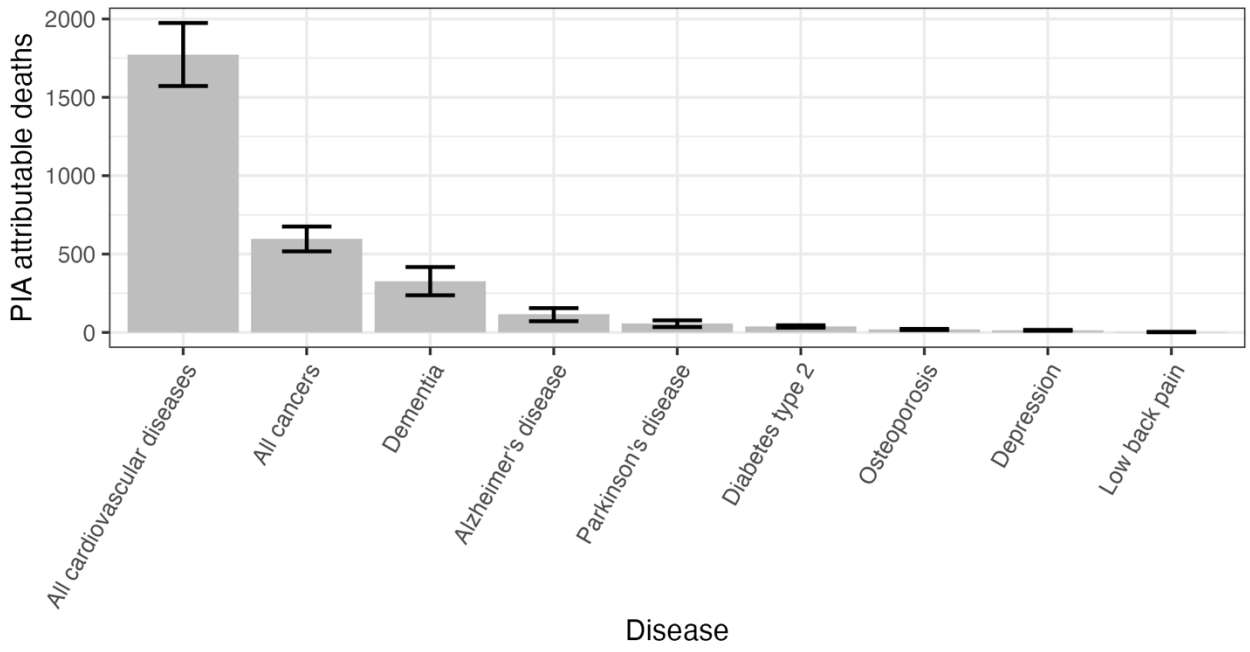

Figure 8 : Physical inactivity-attributable deaths per disease (both sexes) when considering all cardiovascular diseases and all cancers together. The error bars indicate 95% confidence intervals.

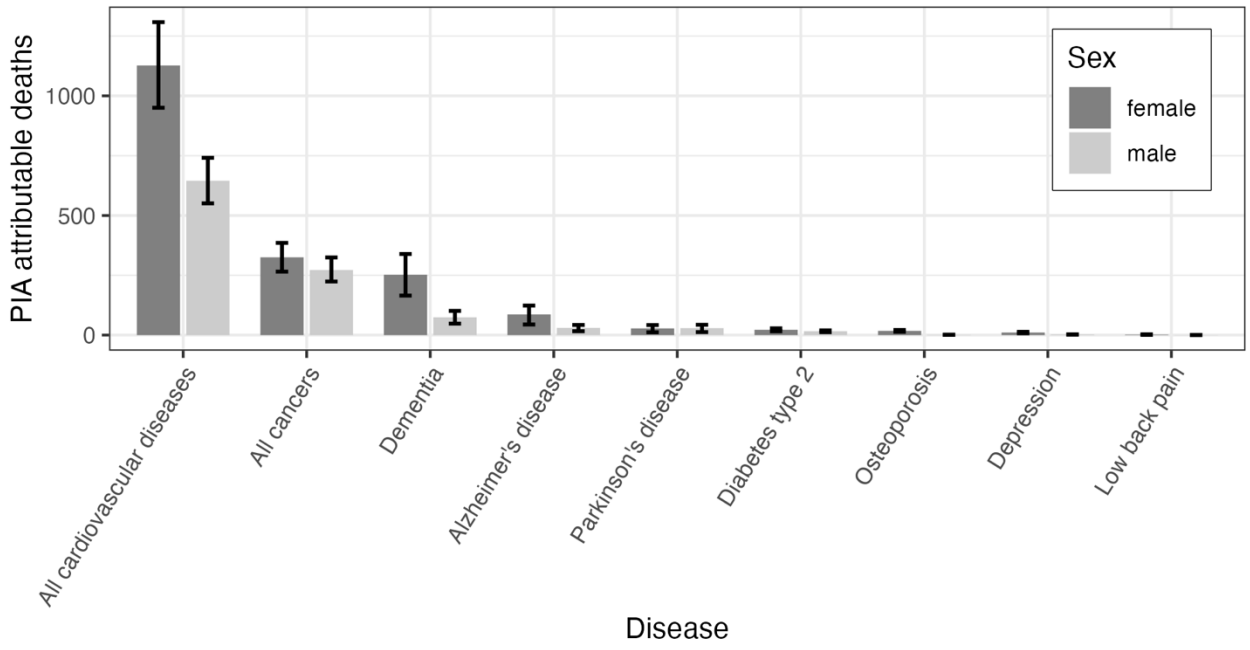

Figure 9 : Physical inactivity-attributable deaths per disease and by sex when considering all cardiovascular diseases and all cancers together. The error bars indicate 95% confidence intervals.

PIA attributable deaths using the relative risk for all-cause mortality

Based on the findings of this second sensitivity analysis, the estimates have shown an increase. The total number of deaths attributable to PIA is 5855, 95% CI = [4763; 6865]. Specifically, among females, the total PIA-attributable deaths amount to 3569, 95% CI = [2625; 4465], while among males, the figure stands at 2285, 95% CI = [1755; 2776].

Trend over time

Analysis of PIA over time across all age-sex groups showed a consistent downward trend in prevalences from 2002 to 2017, with stabilization observed between 2017 and 2022. There was even an increase in PIA among females aged 35 to 54 years during the latter period (Figure 10). As we kept RRs constant over time, the trend for PAFs is the same as for PIA.

For PIA-attributable death rates, our analysis revealed a consistent decrease for both genders from 2002 to 2022 (Figure 11). The total death rate more than halved over this period, with figures in 2002 at 68 deaths per 100,000 persons aged older than 35 years, in contrast to 30 deaths per 100,000 persons in 2022.

A similar pattern was observed for PIA-attributable DALY rates (Figure 12). There was a decline in DALY rates from 2002 (1946 DALYs per 100,000 persons older than 35 years) to 2017 (1012 DALYs per 100,000 persons older than 35 years). Notably, unlike the pattern observed in death rates, DALY rates remained stable between 2017 and 2022 (975 DALYs per 100,000 persons older than 35 years). Further insights into these trends are presented in the appendix.

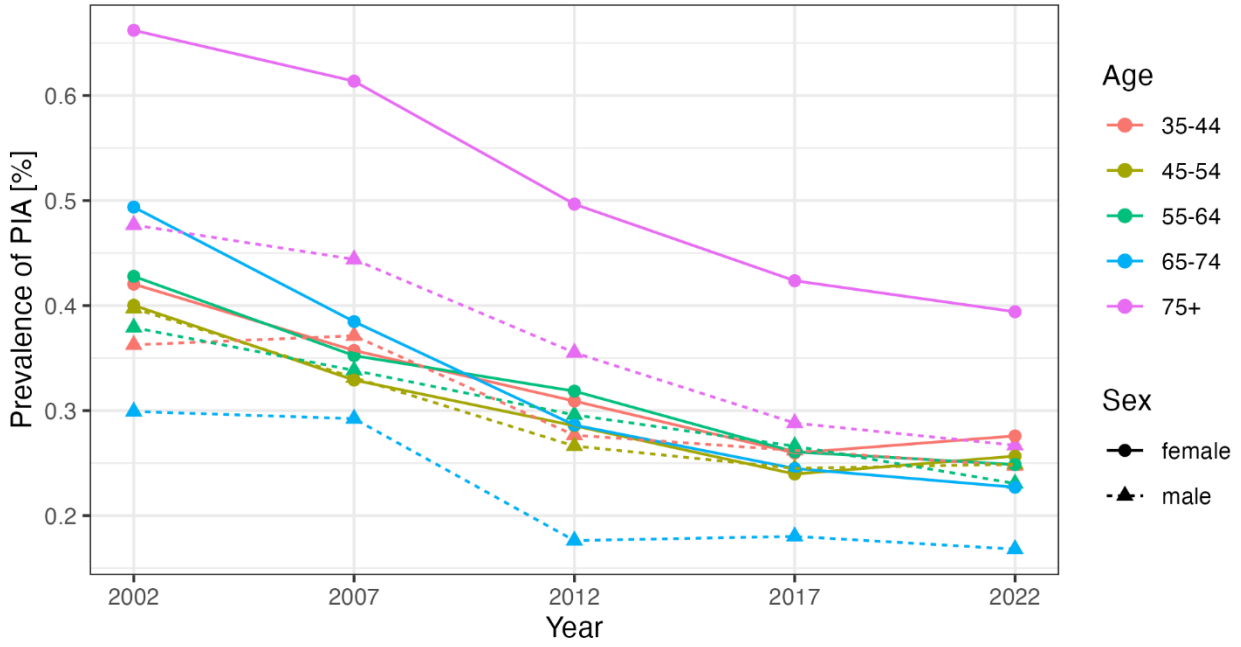

Figure 10 : Physical inactivity per age-group and sex from 2002 to 2022

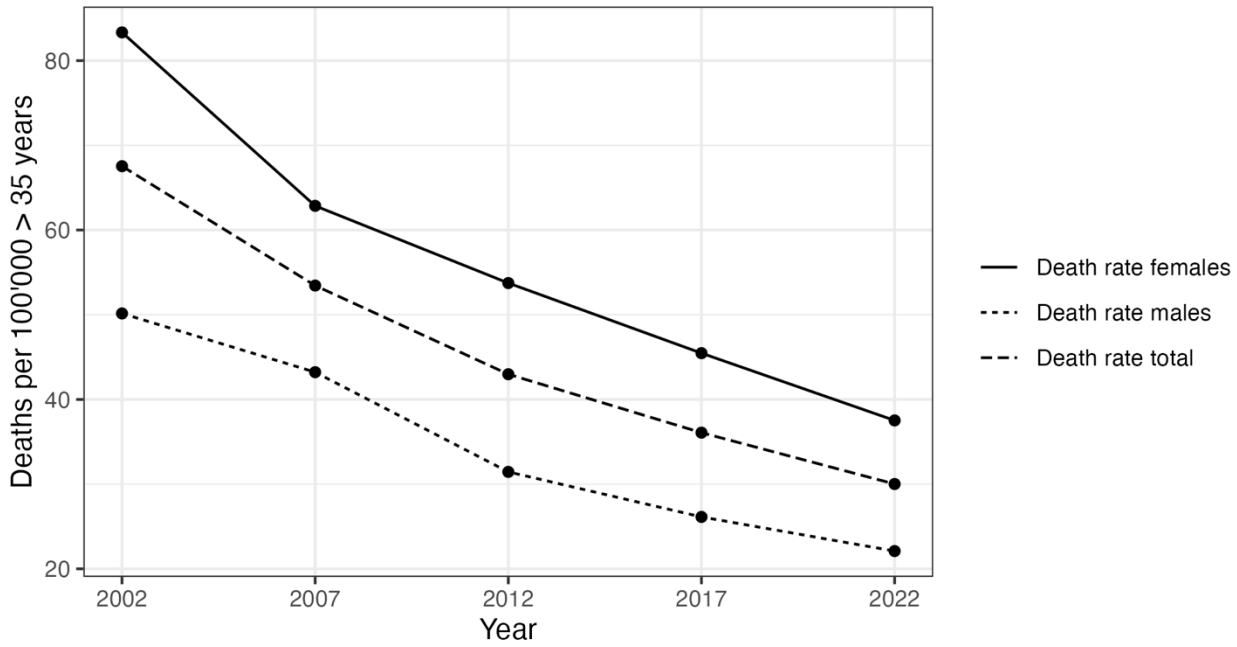

Figure 11 : Physical inactivity death rates per 100'000 persons older than 35 years from 2002 to 2022.

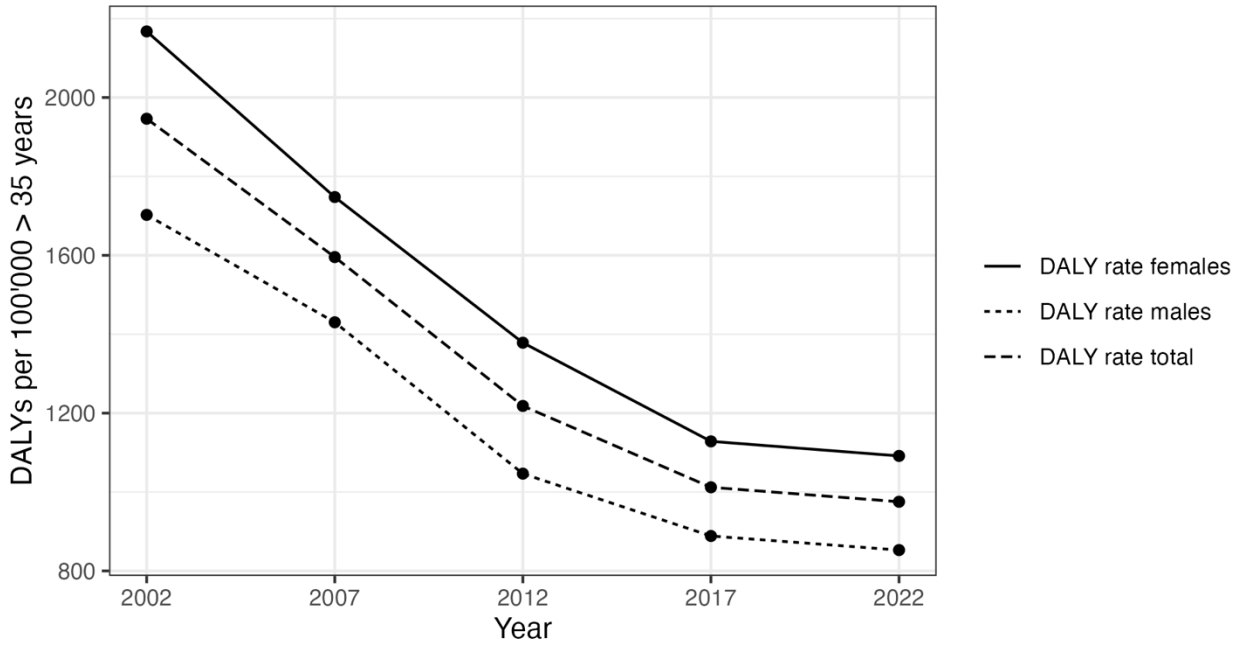

Figure 12 : Physical inactivity DALY rates per 100'000 persons older than 35 years from 2002 to 2022.

Discussion

Summary of the results

In 2022, a quarter of the adult population in Switzerland failed to meet the PA guidelines established by HEPA Switzerland. Our estimations suggest that 1621 deaths (95% CI = [1460; 1770]) could be attributed to PIA during that year. Cardiovascular diseases, cancers, dementia, and Alzheimer's disease emerged as the primary contributors to PIA-related mortality. Notably, the majority of these deaths occurred within the 75 years and older age group, which also showed the highest prevalence of PIA. Consequently, this demographic segment made the most significant contribution to the overall number of deaths attributable to PIA.

The advancement of medical science contributes significantly to the extended lifespans observed among individuals with NCDs, consequently resulting in increased prevalence rates of such conditions. To address this phenomenon, we also quantified the burden of PIA using DALYs. In 2022, 52'689 DALYs (95% CI = [49'119; 57'991]) were attributed to PIA. Like for deaths, cardiovascular diseases, cancers, and dementia (including Alzheimer's disease) were the major contributors and women caused substantially more DALYs attributable to PIA than men. As our longitudinal analysis over time reveals, a discrepancy exists in the trends observed between PIA-attributable deaths and DALYs. This disparity emphasizes the importance of incorporating DALYs into our assessment to attain a holistic understanding of the health burden associated with PIA.

Comparison with similar research

Physical inactivity-attributable deaths

The latest assessment of PIA-attributable deaths in Switzerland was conducted for the year 2017, revealing a total of 1287, 95% CI = [1095; 1483] deaths (Syleouni et al., 2020). Conversely, the current estimates for the year 2022 stand at 1621, 95% CI = [1460; 1770] deaths, indicating a higher figure (however, the CIs do overlap). Given that the prevalence of PIA remained relatively stable between 2017 and 2022, the increase in estimates between the two periods is likely attributable to two main reasons. Primarily, the inclusion of numerous new meta-analyses concerning PIA and associated diseases in recent years has enabled us to expand the spectrum of diseases considered, as compared to the 2017 report. Secondly, discrepancies arise from more recent studies reporting different RRs compared to earlier estimates. As depicted in Table 2, there exists a correlation between differences in estimates of deaths and differences for RRs. The most substantial deviations were observed concerning breast and colon cancer. Consequently, the number of PIA-attributable deaths is most sensitive to variations in RRs, particularly when the prevalence of PIA remains stable.

We further validated our estimates by comparing them with findings from the Global Burden of Disease (GBD) Study. The most recent GBD estimates, available for 2019, indicate 1808 deaths attributable to PIA (95% CI = [915; 2960]). Remarkably, our estimates of 1621 (95% CI = [1460; 1770]) attributable deaths, align with these figures. This convergence provides additional support for the credibility of our results.

Physical inactivity-attributable disability-adjusted life years

To the best of our knowledge, the most recent study employing a comparable methodology to estimate PIA-attributable DALYs in Switzerland was published in 2019 by Mattli et al. The authors reported 40'433 DALYs (95% CI = [34'935; 46'487]). In contrast, the estimates from our current study are higher, amounting to 52'689 DALYs (95% CI = [49'119; 57'991]). The primary reason for this disparity lies in our inclusion of all cardiovascular diseases and cancer types, as opposed to the aforementioned study, which focused solely on breast and colon cancer. In the current analysis, cancers and cardiovascular diseases collectively contributed to over 40'000 DALYs. However, the premise that PIA is associated with all types of cancer and cardiovascular diseases is supported by a recent high-quality meta-analysis encompassing a total of 25 million person-years of observation time (Garcia et al., 2023).

Disease	RR 2022	RR 2017	Attr. deaths 2022	Attr. deaths 2017
Breast cancer	1.053	1.33	22	134
Colon cancer	1.075	1.32	22	150
Head and neck cancer	1.538	Not included	1	NA
Myeloid leukaemia	1.333	Not included	20	NA
Myeloma	1.333	Not included	23	NA
Gastric cancer	1.282	Not included	8	NA
Lung cancer	1.190	Not included	141	NA
Liver cancer	1.190	Not included	39	NA
Endometrial cancer	1.111	Not included	5	NA
Coronary heart disease	1.266	1.16	414	355
Hypertension	Included in heart failure*	1.36	NA	369
Heart failure (with hypertension)	1.190	Not included	187	NA
Stroke	1.250	1.18	164	182
Diabetes type 2	1.167	1.20	38	67
Depression	1.333	1.2	13	9
Low back pain	1.111	1.16	3	2
Osteoporosis	1.590	1.57	19	20
Alzheimer's disease	1.333	Not included	117	NA
Dementia	1.220	Not included	327	NA
Parkinson disease	1.266	Not included	57	NA
All-cause mortality	1.351	1.28	5855	5522

Table 2: Differences between included diseases, relative risks, and corresponding physical inactivity-attributable deaths between the analyses for 2017 and 2022. Differences in sums are due to rounding. *In the analysis for 2022, hypertension was not considered as a separate disease as hypertension was included in the category heart failure.

Definition of physical activity

PA is typically quantified as a continuous variable, often expressed in metabolic equivalent of task (MET)-hours. However, for the purpose of our analysis, we dichotomised PA into "active" and "inactive" categories based on the recommendation by HEPA Switzerland, corresponding to 11.25 MET-hours per week. This categorisation aligns with studies reporting RRs concerning PIA. Nevertheless, during the study selection process, we observed that the relationship between PA and several NCDs follows a curvilinear dose-response association (e.g. Garcia et al., 2013). We adopted a conservative approach by exclusively using RRs comparing inactive individuals with those meeting just the WHO guidelines, rather than, for example, inactive versus very active individuals.

Typically, PA serves as a proxy for cardiorespiratory fitness due to its ease of measurement, often through questionnaires. However, the association between cardiorespiratory fitness and the risk for diseases is much stronger (Cheng et al., 2022; Qiu et al., 2019). For this reason and given the rapidly expanding body of evidence regarding the dose-response effect of PA, future analyses may explore this relationship further to elucidate the full protective potential of PA.

Strengths and limitations of this study

Strengths

We employed the latest, highest-quality data available to estimate the prevalence of PIA and the associated deaths and DALYs for specific diseases. We derived adjusted RRs from comprehensive meta-analyses, which predominantly drew upon studies with substantial sample sizes and extended follow-up periods. Ensuring precision and relevance, all estimates were stratified by age and sex. To maintain consistency, we aligned our disease categorisations with ICD-10 codes used in the meta-analyses reporting the RRs. Furthermore, to quantify uncertainty, Monte Carlo simulations were performed for all estimates, providing 95% CIs.

Limitations

Several limitations warrant consideration in the interpretation of our findings. The RRs used in our analysis were sourced from seven different studies. While efforts were made to align RRs with a consistent definition of PIA, slight discrepancies persisted.

Due to the unavailability of age- and sex-specific RRs, we applied the same RRs across different demographic groups.

The available DALY data pertained to 2019, necessitating adjustments to account for population disparities between 2019 and 2022. However, a more optimal approach would involve conducting the analysis with concurrent prevalence data and DALYs from the same year.

The presence of comorbidities, such as cardiovascular disease in patients with diabetes, may result in double counting of DALYs, potentially leading to an overestimation. Furthermore, we could only model DALYs for cancers and cardiovascular diseases in an aggregated form. As it can be seen from the first sensitivity analysis, this leads to higher estimates, possibly leading to an overestimation of PIA-attributable DALYs.

Our reliance on self-reported PA levels from the SHS 2022 may introduce bias, as studies have indicated discrepancies between self-reported and objectively measured activity levels, potentially leading to underestimation of PIA in Switzerland.

Conclusions

Our study underscores the significant impact of PIA on public health in Switzerland. We found that a substantial number of deaths, estimated at 1621 (95% CI = [1460; 1770]), were attributable to PIA in 2022. Notably, coronary heart disease, dementia, heart failure, stroke, lung cancer, and Alzheimer's disease emerged as the primary contributors to PIA-related mortality.

To provide a more comprehensive assessment of the burden of PIA, we also estimated PIA-attributable DALYs, which amounted to 52'689 (95% CI = [49'119; 57'991]). Cardiovascular diseases, cancers, dementia, and Alzheimer's disease were identified as the leading contributors to PIA-related DALYs.

Furthermore, our analysis revealed that estimates were generally higher for females compared to males. Additionally, nearly 90% of PIA attributable deaths occurred in individuals aged 75 years and older, where the prevalence of PIA was also highest.

These findings align with the latest estimates for Switzerland in 2017 and highlight the urgent need for targeted interventions to promote PA, particularly among females and individuals aged 75 years and older. Policymakers are encouraged to prioritise initiatives aimed at increasing population PA levels especially within females and those aged 75 years and more to mitigate the burden of PIA and improve public health outcomes in Switzerland.

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Abbreviations

PIA:	Physical inactivity
PA:	Physical activity
RR:	Relative risk
CI:	Confidence interval
FSO:	Federal Statistical Office
SHS 2022:	Swiss Health Survey 2022
DALY:	Disability-adjusted life years
WHO:	World Health Organization
NCD:	Non-communicable diseases
GBD:	Global Burden of Disease

Appendix

Search strategy for PubMed

A:
("Risk"[Mesh] OR Risks OR Risk OR "relative risk" OR "relative risks" OR "Odds Ratio"[Mesh] OR "Risk Ratio" OR "Risk Ratios" OR "RR" OR "PAF" OR "population attributable fraction")

B:
(Exercise[Mesh] OR exercis*[Title/Abstract] OR "physical activit*" [Title/Abstract] OR training[Title/Abstract] OR sport[Title/Abstract] OR sports[Title/Abstract] OR "physical inactivity" [Title/Abstract] OR "Physical Fitness"[Mesh])

C:

1. ("Anxiety"[Mesh] OR "Anxiety Disorders"[Mesh] OR "Anxiety" OR "Anxiety Disorders")

2. ("Breast Neoplasms"[Mesh] OR "Breast Cancer" OR "Breast Tumor" OR "Mammary Neoplasms" OR "Mammary Cancer" OR "Mammary Tumor" OR "Breast Carcinoma" OR "Mammary Carcinoma" OR "Breast Malignancy" OR "Mammary Malignancy" OR "Breast Oncology" OR "Mammary Oncology")

3. ("Colonic Neoplasms"[Mesh] OR "Colorectal Neoplasms"[Mesh] OR "Colonic Neoplasms"[Mesh] OR "Colon Cancer" OR "Colorectal Cancer" OR "Colonic Cancer" OR "Colon Tumor" OR "Colorectal Tumor" OR "Colonic Tumor" OR "Colon Carcinoma" OR "Colorectal Carcinoma" OR "Colonic Carcinoma" OR "Colon Malignancy" OR "Colorectal Malignancy" OR "Colonic Malignancy")

4. ("Dementia"[Mesh] OR "Dementia")

5. ("Depression"[MeSH] OR "Depression" OR "Depressive Disorder"[MeSH] OR "Depressive Disorder" OR "MDD")

6. ("Diabetes Mellitus, Type 2"[MeSH])

7. ("Hypertension"[MeSH] OR "Hypertension" OR "High Blood Pressure")

8. ("Myocardial Ischemia"[Mesh] OR "Ischemic Heart Disease" OR "Coronary Artery Disease"[MeSH] OR "Coronary Artery Disease" OR "Coronary Heart Disease" OR "CHD" OR "Coronary Disease")

9. ("Low Back Pain"[MeSH] OR "Low Back Pain" OR "Lumbago" OR "Lumbar Pain" OR "Lower Back Pain" OR "Lumbar Spine Pain" OR "LBP" OR "Back Pain"[Mesh])

10. ("Osteoporosis"[Mesh] OR "Bone Diseases, Metabolic"[Mesh] OR "Bone Density"[Mesh] OR "Osteoporosis" OR "bone mineral density" OR "bone density reduction")

11. ("Kidney Neoplasms"[Mesh] OR "kidney neoplasm" OR "kidney cancer" OR "kidney tumor" OR "renal cancer" OR "renal neoplasm")

12. ("Stroke"[Mesh] OR "Stroke" OR "Cerebrovascular Disorders"[Mesh] OR "Cerebrovascular Accident" OR "CVA" OR "Brain Infarction" OR "Cerebral Infarct" OR "Ischemic Stroke" OR "Hemorrhagic Stroke")

String: A AND B AND C_i; i = {1, …, 12}

The search was conducted 9/28/23.

Prevalence data on PIA

Sex	Age	Prevalence	Lower	Upper
Male	35-44	0.25	0.23	0.27
Male	45-54	0.25	0.23	0.27
Male	55-64	0.23	0.21	0.25
Male	65-74	0.17	0.15	0.19
Male	75+	0.27	0.24	0.29
Female	35-44	0.28	0.25	0.30
Female	45-54	0.26	0.24	0.27
Female	55-64	0.25	0.23	0.27
Female	65-74	0.23	0.21	0.24
Female	75+	0.39	0.37	0.42

Suppl. Table 1: Age- and sex-specific prevalences of physical inactivity in Switzerland for the year 2022. Limits of the 95% confidence interval are given by lower and upper.

Total deaths

Disease	Total deaths females	Total deaths males
All cancers	8197	9570
All cardiovascular diseases	10937	9494
All causes	37589	35749
Alzheimer	907	471
Breast cancer	1348	6
Colon cancer	512	561
Coronary heart disease	2749	3729
Dementia	3592	1576
Depression	118	42
Diabetes type II	415	459
Endometrial cancer	162	0
Gastric cancer	21	129
Head and neck cancer	7	6
Heart failure	2147	1277
Leukaemia	124	168
Liver cancer	338	581
Low back pain	57	23
Lung cancer	1430	1889
Osteoporosis	122	14
Parkinson disease	354	545
Skin cancer	164	142
Stroke	1481	1051

Suppl. Table 2 : Total deaths due to included diseases and disease-categories respectively in Switzerland, 2022.

PIA-attributable deaths

Disease	Total	Lower	Upper
Dementia	252	160	337
Coronary heart disease	219	167	270
Heart failure	133	50	207
Stroke	112	83	138
Alzheimer's disease	87	44	123
Lung cancer	71	62	81
Parkinson's disease	28	12	42
Diabetes type 2	22	16	28
Breast cancer	22	13	32
Liver cancer	18	7	27
Osteoporosis	18	13	21
Myeloma	14	6	21
Colon cancer	12	3	20
Depression	11	8	13
Myeloid leukaemia	10	5	15
Endometrial cancer	5	3	8
Low back pain	2	1	3
Gastric cancer	2	1	2
Head and neck cancer	1	0	1

Suppl. Table 3 : Physical inactivity-attributable deaths and corresponding 95% confidence intervals for females.

Disease	Total	Lower	Upper
Coronary heart disease	195	155	235
Dementia	74	48	100
Lung cancer	70	60	79
Heart failure	53	21	83
Stroke	53	41	65
Alzheimer's disease	30	16	42
Parkinson's disease	29	13	44
Liver cancer	21	11	30
Diabetes type 2	16	12	20
Myeloid leukaemia	10	5	14
Colon cancer	9	3	15
Myeloma	8	4	12
Gastric cancer	6	4	8
Depression	3	2	3
Osteoporosis	1	1	2
Low back pain	1	0	1
Head and neck cancer	0	0	1
Breast cancer	0	0	0
Endometrial cancer	0	0	0

Suppl. Table 4 : Physical inactivity-attributable deaths and corresponding 95% confidence intervals for males.

Total DALYs

Disease	Sex	Total
All cancers	Female	177468
All cardiovascular diseases	Female	153167
Low back pain	Female	69117
Dementia	Female	47400
Diabetes type 2	Female	32331
Depression	Female	30836
Parkinson's disease	Female	6073
All cancers	Male	226474
All cardiovascular diseases	Male	173563
Low back pain	Male	49213
Diabetes type 2	Male	35501
Dementia	Male	24445
Depression	Male	19379
Parkinson's disease	Male	9613

Suppl. Table 5: Total disability-adjusted life years by disease and sex.

PIA-attributable DALYs

Disease	Total	Lower	Upper
All cardiovascular diseases	14845	12514	17272
All cancers	6290	5310	7253
Dementia	3193	1517	6798
Depression	2112	1655	2752
Low back pain	1937	1395	2729
Diabetes type 2	1438	1112	1855
Parkinson's disease	451	216	673

Suppl. Table 6 : Physical inactivity-attributable disability-adjusted life years and corresponding 95% confidence intervals for females.

Disease	Total	Lower	Upper
All cardiovascular diseases	11210	9809	12594
All cancers	6172	5228	7107
Diabetes type 2	1163	926	1485
Low back pain	1144	803	1659
Depression	1135	867	1523
Dementia	1107	549	2389
Parkinson's disease	494	252	718

Suppl. Table 7 : Physical inactivity-attributable disability-adjusted life years and corresponding 95% confidence intervals for males.

PIA-attributable death rates, 2002 to 2022

Year	Sex	Rate	Lower	Upper
2002	Both	2847	2594	3086
2007	Both	2412	2199	2614
2012	Both	2065	1860	2242
2017	Both	1848	1674	2009
2022	Both	1621	1460	1770
2002	Female	1841	1604	2060
2007	Female	1477	1283	1654
2012	Female	1336	1159	1501
2017	Female	1198	1038	1347
2022	Female	1040	895	1176
2002	Male	1006	894	1113
2007	Male	935	834	1027
2012	Male	730	649	808
2017	Male	650	577	713
2022	Male	581	517	642

Suppl. Table 8 : Physical inactivity-attributable death rates per 100'000 persons > 35 years and corresponding 95% confidence intervals.

PIA-attributable DALY rates, 2002 to 2022

Year	Sex	Rate	Lower	Upper
2002	Both	82055	76936	88642
2007	Both	72017	67504	78387
2012	Both	58550	54655	63967
2017	Both	51847	48478	56722
2022	Both	52689	49119	57991
2002	Female	47891	43233	53886
2007	Female	41078	36832	46782
2012	Female	34264	30751	39054
2017	Female	29749	26646	34311
2022	Female	30265	27188	34709
2002	Male	34164	31714	36967
2007	Male	30939	28680	33660
2012	Male	24286	22296	26629
2017	Male	22098	20337	24193
2022	Male	22424	20673	24728

Suppl. Table 9: Physical inactivity-attributable DALY rates per 100'000 persons > 35 years and corresponding 95% confidence intervals.