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Potential impact of increasing physical activity on NCD mortality in the EU: pathways to SDG 3.4.1 by 2030

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ABSTRACT

Background Physical inactivity affects 36.2% of adults in the European Union (EU), contributing substantially to the burden of non-communicable diseases (NCDs). The WHO's Global Action Plan on Physical Activity 2018–2030 targets a 15% relative reduction in physical inactivity by 2030, supporting Sustainable Development Goal (SDG) 3.4.1 to achieve over 30% reduction in premature NCD mortality. This study estimates the number of averted deaths, premature deaths and cause-specific NCD deaths averted if physical activity targets are achieved across EU countries.

Methods We applied the WHO Preventable Risk Integrated ModEl using baseline physical activity and body mass index from waves 2 and 3 of the European Health Interview Survey. The counterfactual scenario modelled a 15% increase in metabolic equivalent of task hours/week of moderate-to-vigorous physical activity and a 15% relative reduction in the proportion of adults who are physically inactive across the EU.

Findings Increased physical activity is associated with an estimated 24 178 premature deaths averted by 2030 (95% uncertainty interval (UI): 23 253–25 103), equivalent to 3.3% of premature NCD mortality. Overall, 107 108 deaths (95% UI: 102 479–111 737) across all ages could be prevented, representing 4.7% of total NCD deaths in EU member states.

Interpretation Increasing physical activity alone is unlikely to achieve the SDG 3.4.1 target of reducing premature NCD deaths by 2030. However, when combined with other WHO 'best buy' interventions, such as improved diet and reduced tobacco and alcohol use, this target could be attainable across the EU.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Physical inactivity is a major contributor to premature non-communicable disease (NCD) mortality.

⇒ A PubMed search (1 September 2015–31 August 2025) using the MeSH terms "Sustainable Development"[MeSH Terms] AND "mortality, premature"[MeSH Terms] AND ("Exercise"[MeSH Terms] OR "Sedentary Behavior"[MeSH Terms]) found no population-based studies quantifying the potential impact of achieving Sustainable Development Goal (SDG)-aligned physical activity targets on NCD deaths across the European Union (EU).

WHAT THIS STUDY ADDS

⇒ This EU-wide scenario analysis is the first to estimate the impact of increased physical activity on NCD mortality, allowing for consistent comparisons across countries through 2030.

⇒ The study provides a comprehensive, region-specific estimate of how an increase in physical activity affects NCD mortality, filling a critical evidence gap for policymakers.

INTRODUCTION

Non-communicable diseases (NCDs) account for over 91% of all deaths in the European Union (EU).[1] The major conditions that contribute most to this burden are cardiovascular diseases (CVDs) (37.4%), cancer (29%), chronic respiratory diseases (5.1%) and diabetes and kidney diseases (4.5%).[1] Sustainable Development Goal (SDG) target 3.4.1 calls for a 30% relative reduction in premature mortality from NCDs by 2030 compared with 2015.[2] Achieving this target will require stronger primary prevention and action on key modifiable risk factors, including tobacco use, harmful alcohol consumption, unhealthy diets and physical inactivity.[3]

Physical inactivity significantly contributes to the NCD burden in the EU. In 2019, it was responsible for about 125 000 deaths.[1] If current trends continue, physical inactivity is expected to cause nearly 85 million new cases of preventable NCDs and mental health conditions across the EU between 2020 and

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ Increased population-level physical activity is associated with a substantial reduction in premature NCD mortality, and when combined with interventions targeting diet, tobacco, alcohol and social determinants of health, it could help achieve the SDG 3.4.1 target.
- ⇒ Findings support embedding physical activity promotion into cross-sectoral EU policies (transport, urban planning, education) with equitable access across regions and socioeconomic groups.
- ⇒ Future research should evaluate real-world implementation, cost-effectiveness and robust monitoring systems to track progress towards SDG 3.4.1.

2030.[4] The estimated economic cost is US$96.58 billion, representing 32% of the global total.[4] Physical inactivity leads to overweight and obesity, which are major risk factors for NCDs.[5] Evidence indicated that physical inactivity is associated with a 52% increased odds of obesity in adults.[5] Large cohort studies report that high sedentary time (>6 hours/day) is linked to higher risks of multiple NCDs, such as ischaemic heart disease, diabetes, chronic liver and kidney diseases and depression.[6] Strong evidence also shows that regular physical activity can significantly reduce the burden of NCDs. A meta-analysis found that regular exercise lowers the risk of CVD, cancer and diabetes by 14%–26%.[7]

In the EU, 36.2% (95% CI 35.1 to 37.3) of adults are physically inactive.[8] Additionally, 45% of individuals across the 27 EU member states reported never engaging in exercise or sports.[9] Recognising the global threat posed by inactivity, the WHO, through the Global Action Plan on Physical Activity (GAPPA), set a target in 2013 to achieve a 10% relative reduction in the prevalence of physical inactivity by 2025.[10] However, a recent study of global progress revealed these efforts have been insufficient.[2] Progress may have been further disrupted by the COVID-19 pandemic and associated economic challenges.[9] Consequently, the target was revised to a 15% reduction by 2030.[2] Evaluating progress towards these goals requires reliable methods of assessing the effectiveness of health interventions, programmes or policies. Randomised controlled trials are often used, but they have several important limitations. These include short follow-up periods, high resource needs and limited generalisability.[11] Modelling can address these gaps by providing long-term projections of outcomes and costs. This offers valuable evidence to guide health policy decision-making.[11]

Macrosimulation models, such as the WHO Preventable Risk Integrated ModEl (PRIME), play a crucial role in public health policy by quantifying the potential impact of changes in modifiable risk factors. The WHO PRIME model, a widely used macrosimulation tool, estimates the number of deaths that could be prevented or delayed under alternative scenarios.[12,13] Researchers have used the WHO PRIME models to estimate the effects of reducing risk factors on disease burden in specific countries.[14–20] These applications include salt intake (Portugal, Eurasia, Paraguay, South Africa and Türkiye),[14–18] saturated fat (Denmark),[19] sugar intake and fruit and vegetable consumption (South Africa and the UK),[17,20] smoking and alcohol consumption (South Africa and Türkiye)[17,18] and physical inactivity (Türkiye).[18] To our knowledge, no previous study has estimated the impact of reducing physical inactivity on the burden of NCD across the EU. To address this gap, we estimated the number of averted deaths, averted premature deaths and cause-specific NCD deaths averted associated with increased physical activity levels across EU Member States.

METHODS

Modelling tool

We applied the WHO PRIME model, an openly available comparative risk assessment tool to estimate NCD mortality attributable to modifiable risk factors under alternative exposure or counterfactual scenarios (ie, if risk factors were reduced).[12] The model incorporates (1) demographic characteristics, (2) cause-specific mortality rates and (3) established dose–response relationships between behavioural risk factors and health outcomes. The empty WHO PRIME model was obtained from the toolkits section of the WHO Regional Office for Europe website,[21] and baseline parameters were entered into its Excel interface.

PRIME estimated the number of NCD-attributable deaths that could potentially be averted or postponed under certain scenarios, including premature deaths (<75 years).[2] The PRIME model is not designed to predict future events but rather to simulate potential outcomes based on established associations between risk factors such as physical activity and health outcomes. It assumes these associations remain stable under hypothetical scenarios, making it a valuable tool for scenario analysis and policy evaluation. For further methodological details on the PRIME model, see the WHO PRIME technical documentation.[12,21]

Data sources

In the WHO PRIME, baseline input parameters included physical activity divided into two components: moderate-to-vigorous physical activity (MVPA) among the active population, expressed as metabolic equivalent of task (MET) hours/week, and sedentary proportion. Additional inputs included body mass index (BMI), population size by age and sex and cause-specific mortality.[12] The input parameters for MET hours/week, sedentary proportion and BMI are derived from waves 2 and 3 of the European Health Interview Survey (EHIS).[22] The EHIS is a population-based survey that collects data on health status, healthcare use and health determinants across European countries.[22]

EHIS wave 2 was conducted between 2013 and 2015 and included 251 512 individuals from 24 EU countries: Austria (15 771), Bulgaria (6410), Croatia (5446), Cyprus

(4958), Czechia (6737), Denmark (5811), Estonia (5452), Finland (6183), Germany (24 824), Greece (8223), Hungary (5826), Ireland (10 323), Italy (25 325), Latvia (7077), Lithuania (5205), Luxembourg (4004), Malta (4086), Poland (24 156), Portugal (18 204), Romania (16 605), Spain (22 842), Slovakia (5490), Slovenia (6262) and Sweden (6292).

EHIS wave 3 was conducted primarily in 2019, with supplementary data from 2018 and 2020 in some countries, and included 286 414 individuals from 26 EU countries: Austria (15 461), Belgium (9644), Bulgaria (7540), Croatia (5461), Cyprus (6156), Czechia (7993), Denmark (6629), Estonia (4881), Finland (6251), Germany (23 001), Greece (8125), Hungary (5603), Ireland (7621), Italy (45 962), Latvia (6034), Lithuania (4923), Luxembourg (4504), Malta (4413), the Netherlands (8194), Poland (19 959), Portugal (14 617), Romania (16 186), Spain (22 072), Slovakia (5527), Slovenia (9900) and Sweden (9757). Detailed methodology of the EHIS is described elsewhere.[22]

The WHO PRIME model also required cause-specific mortality and population data as input parameters, which we obtained from the 2019 Global Burden of Disease (GBD) study.[23]

Measurement of physical activity

Physical activity was quantified using two indicators: MVPA, measured in MET hours/week among the active population, and the proportion of the population classified as sedentary. One MET corresponds to the energy expenditure at rest, with higher values indicating more intense activity.[9] Moderate-intensity activities typically have a MET value of approximately 3–5.9 (mean value of 4.5 MET), while vigorous-intensity activities have a MET value of 6 MET or higher.[24] Physical activity in the active population was assessed through self-reported data from the EHIS. Respondents reported the frequency and duration (in a typical week) of aerobic physical activities performed for at least 10 continuous minutes. These included walking or cycling for transport and sport or recreational activities that caused at least a slight increase in breathing or heart rate. The weekly duration in minutes was calculated by multiplying the reported frequency by the average daily duration, then converted to MET hours using standard values from the 2024 Compendium of Physical Activities.[24] Average MET values were 4.08 for walking, 6.86 for cycling and 6.32 for sports activities.

Activity levels were classified according to WHO guidelines, which recommend at least 150 min of moderate-intensity or 75 min of vigorous-intensity aerobic activity per week for adults.[9] We applied the WHO cut-off of at least 600 MET min/week from moderate-intensity and vigorous-intensity activities.[8] For further analysis, physical activity levels were classified into three groups: (1) insufficiently active <600 MET min/week (<10 MET hours/week), (2) moderately active 600–3000 MET min/week (10–50 MET hours/week) and (3) highly active >3000 MET min/week (>50 MET hours/week).[8]

We excluded questions on sitting behaviour from EHIS wave 3, as no comparable measure was available in wave 2. This ensured consistency across datasets for projection purposes. As PRIME does not provide an explicit definition of 'sedentary' in the model, we operationalised sedentary behaviour based on data availability, defined as the percentage of individuals who were insufficiently active (<600 MET min/week, equivalent to 10 MET hours/week), ie, not meeting the WHO minimum recommendation. Hereafter, we used the term 'physical inactivity' instead of 'sedentary'.

Counterfactual scenario and projection for 2030

Our model simulated a counterfactual scenario in which, among the active population, activity levels (MET hours/week of MVPA) increased by 15%, and the proportion of insufficiently active individuals decreased by 15%. These changes were applied as an equal proportional shift across all age and sex groups. The 15% relative reduction in physical inactivity is aligned with the WHO GAPPA 2018–2030 targets.[2]

Three PRIME models were constructed for 2015, 2019, and 2030. The 2015 model used input parameters from EHIS wave 2, and the 2019 model used data from EHIS wave 3. Input parameters for 2030 were projected using data from both waves. MET hours/week, the proportion of physically inactive individuals and mean BMI for 2030 were estimated using multilevel models fitted to log-transformed means from EHIS waves 2 and 3. Cause-specific mortality for 2030 was estimated using negative binomial regression, with case counts modelled using the log of the population as an offset, based on historical data from GBD 2010 to 2019. The PRIME model was then rerun to generate modelled output for 2030. Further details are provided in the online supplemental methods.

Model output and statistical analyses

The model was used to estimate (1) averted deaths, (2) averted premature deaths and (3) cause-specific deaths avoided for each country in both years.

In PRIME, impacts on NCDs were modelled via direct effects and BMI-mediated effects, using steady-state body weight equations and meta-analysed relative risks adjusted for body weight.[12] PRIME outputs included averted or delayed deaths due to NCDs.[12] These included CVDs such as ischaemic heart disease (I20–I25), hypertensive disease (I10–I15) and cerebrovascular disease (I60–I69), as well as cancers including colorectal (C18–C20), lung (C34), kidney (C64), pancreatic (C25), endometrial (C54.1), gallbladder (C23), breast (C50) and stomach cancer (C16). Additional conditions analysed included diabetes (E11, E14) and chronic renal failure (N18).[12]

Analyses were stratified by sex and 5-year age groups (15–19 to ≥85 years). Missing values affecting estimates of the proportion of inactive individuals in specific age groups within member states were imputed using beta regression, adjusted for sex and age. Missing values for mean MET hours/week and BMI, stratified by age group and country, were imputed using multiple imputation by chained equations with predictive mean matching. The imputation model included sex and age group, and five imputations were performed. Estimates of BMI, physical inactivity prevalence and MET were obtained using the EHIS estimation individual weights. Although our analysis is conducted at the macro level (eg, aggregate mortality rates, prevalence estimates), these estimates are informed by microlevel survey data on individual behaviours.

Monte Carlo simulation was used in the PRIME model for sensitivity analysis to quantify uncertainty around deterministic point estimates when multiple risk factors were altered simultaneously. We performed 5000 iterations to derive 95% uncertainty interval (UI) for estimates of preventable deaths.[12] Results are presented across EU member states, grouped into Central and Eastern, Northern, Southern and Western regions according to the EuroVoc classification.[25] Analyses were conducted in Stata IC (V.13.0) and R (V.4.4.0), following the Guidelines for Accurate and Transparent Health Estimates Reporting (online supplemental Table S1).[26] Further methodological details are provided in the online supplemental methods.

RESULTS

The analysis included 26 EU countries. However, only 24 countries were analysed for 2015 and 2030 due to data availability. Belgium and the Netherlands were excluded because physical activity data were missing in EHIS wave 2 and France was excluded due to missing data in EHIS wave 3 (tables 1 and 2).

Physical activity levels and BMI distributions

Table 1 shows the mean physical activity across EU regions and countries. Western European countries are likely to have the highest average levels of physical activity among active individuals, while Central and Eastern Europe tend to have the lowest. In 2015, mean physical activity ranged from 49.6 MET hours/week (SD 36.8) in Central and Eastern Europe to 62.1 MET hours/week (SD 52.0) in Western Europe, with Southern Europe recording the lowest levels in 2019 (46.9 MET hours/week; SD 37.5). By 2030, physical activity is projected to increase in Northern (60.3 MET hours/week; SD 80.8) and Western Europe (65.2 MET hours/week; SD 82.1) and decline in Central and Eastern (47.6 MET hours/week; SD 58.2) and Southern Europe (50.4 MET hours/week; SD 55.7). Overall, 15 of the 24 countries analysed are likely to experience increases in physical activity, including Austria, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, Germany, Greece, Hungary, Luxembourg, Malta, Spain and Sweden.

Younger adults (15–24 years) and males generally tend to have higher activity levels, which decline with age, particularly among older adults (online supplemental figures S1–S3). In most countries, active individuals tend to have moderate activity levels (10–50 MET hours/week), although regional variations persist. Austria, Germany, Luxembourg and Sweden are likely to have relatively higher MET hours/week, whereas Cyprus, Greece and Romania tend to have persistently lower levels (online supplemental figures S1–S3).

BMI values varied by age, sex and region. BMI is estimated to remain in the overweight range (25–27 kg/m²), with modest increases by 2030 (table 1). Males typically have higher BMI than females. BMI rises with age up to 60–64 years, then plateaus or declines. Regional disparities persist, with Central, Eastern and Southern Europe (eg, Croatia, Malta, Hungary, Portugal, Romania) estimated to have higher BMI values, while Western Europe (eg, Belgium, the Netherlands) tends to have lower values (online supplemental figures S4–S6).

Prevalence of physical inactivity

Baseline projections show a decline in adult physical inactivity across the EU, from 44.3% in 2015 to 37.2% in 2030 (table 1). By 2030, physical inactivity is expected to decline in most countries. Southern European countries are projected to have the highest proportions of insufficient physical activity, despite declining trends, with 58.1% in 2015, 52.7% in 2019 and around 51.9% in 2030. Malta recorded the highest level in 2015 (70.5%), while Cyprus is projected to remain the highest in 2019 (66.1%) and 2030 (64.8%). Portugal is also expected to retain comparatively elevated levels, decreasing from 60.4% in 2015 to 54.2% in 2030. Under a counterfactual scenario, the share of physically inactive adults exceeded 50% in Romania, Finland, Cyprus and Malta in 2015 and in Cyprus and Malta in 2019. By 2030, Cyprus is projected to be the only country above this threshold (table 1 and online supplemental tables S2 and S3).

Females tend to be less physically active than males, though patterns may vary by age. Inactivity prevalence remains high in Cyprus, Greece, Italy, Malta, Portugal and Romania, and lowest in Austria, Denmark, Estonia, Germany, the Netherlands and Sweden. Among adults aged 20–39 years, inactivity is likely more prevalent in Southern Europe (Cyprus, Greece, Italy, Malta, Portugal) and parts of Central and Eastern Europe (Poland, Romania) (figure 1 and online supplemental figures S7–S9).

Averted NCD-related mortality

If the target for increased physical activity were achieved across the EU, it may contribute to preventing a substantial number of deaths from NCDs. Model estimates suggest that it would avert approximately 24 309 (95% UI: 23 384–25 234) premature deaths in 2015 and 24 523 (95% UI: 23 598–25 448) in 2019 (table 1). By 2030, it would avert 24 178 (95% UI: 23 253–25 103), equivalent to a 3.3% decline in mortality under 75 years (table 1 and online supplemental table S4). Considering mortality at all ages, the number of NCD-related deaths prevented is

Table 1 Baseline input parameters

Country	MET hours/week in active population						Proportion of physically inactive individuals (%)			BMI					
	2015		2019		2030		2015	2019	2030	2015		2019		2030	
	Mean	SD	Mean	SD	Mean	SD	%	%	%	Mean	SD	Mean	SD	Mean	SD
EU	53.7	41.5	53.0	42.6	54.2	66.7	44.3	38.0	37.2	25.9	4.8	25.8	4.6	25.3	5.5
Central and Eastern Europe	49.6	36.8	53.1	39.6	47.6	58.2	47.2	37.8	39.3	26.1	4.4	26.1	4.1	24.5	5.1
Bulgaria	43.3	28.6	47.0	30.8	48.4	39.4	51.9	35.5	39.9	25.5	4.9	25.5	3.7	25.5	3.7
Croatia	43.3	34.2	53.0	40.8	51.8	58.6	51.3	44.9	45.5	26.0	4.6	26.7	4.4	27.1	5.3
Czechia	48.0	36.4	49.3	37.1	51.8	41.6	34.8	34.1	34.5	26.1	4.1	25.7	4.2	26.5	5.3
Hungary	52.6	34.9	51.4	44.8	52.8	43.0	47.0	34.2	36.0	27.1	5.9	26.6	4.8	27.1	5.9
Poland	50.4	34.1	43.9	33.7	45.0	33.7	51.9	41.4	43.3	26.2	4.2	26.2	4.2	26.8	5.2
Romania	44.3	25.9	37.0	25.5	38.6	31.1	59.2	46.5	42.6	25.6	3.2	25.6	3.2	26.3	4.1
Slovakia	55.5	38.7	53.2	41.0	53.4	53.9	41.3	32.0	35.5	26.4	4.2	26.3	4.5	27.0	5.5
Slovenia	66.4	68.2	58.7	64.9	62.7	148.8	40.3	33.7	37.0	26.3	4.5	26.4	4.2	27.1	5.2
Northern Europe	55.7	40.0	53.9	42.3	60.3	80.8	38.9	31.8	28.5	26.0	4.6	26.0	4.7	22.1	5.5
Denmark	56.2	42.9	58.2	43.6	62.4	61.5	24.2	24.0	20.6	25.4	4.6	25.6	4.9	26.3	5.9
Estonia	54.4	38.9	56.8	39.9	60.0	107.6	26.5	26.2	28.2	26.1	4.6	26.3	4.5	27.0	5.7
Finland	41.5	23.9	34.1	23.6	61.1	59.8	61.4	46.4	25.2	26.5	5.4	26.5	5.4	26.5	5.4
Latvia	53.5	34.4	47.8	34.6	53.1	92.1	42.6	32.8	32.2	26.4	4.6	26.4	4.6	27.1	5.6
Lithuania	52.2	33.6	45.7	33.7	46.9	61.1	49.8	39.1	44.0	26.1	4.3	26.1	4.3	26.8	5.1
Sweden	75.9	57.6	70.2	57.5	77.0	69.4	29.1	22.2	21.0	25.6	4.3	25.6	4.3	26.2	5.2
Southern Europe	51.2	38.3	46.9	37.5	50.4	55.7	58.1	52.7	51.9	25.7	4.5	25.5	4.4	26.4	5.2
Cyprus	38.5	26.6	36.7	24.5	40.2	88.4	64.7	66.1	64.8	25.7	4.5	26.2	4.1	26.9	5.1
Greece	43.0	33.5	39.7	27.7	43.6	33.5	58.5	52.2	52.3	26.0	4.5	26.0	4.2	26.8	5.2
Italy	52.6	39.6	47.4	39.5	49.0	36.8	57.4	50.3	51.4	24.9	3.9	24.9	3.9	25.5	4.6
Malta	46.7	34.0	38.8	33.4	48.6	141.5	70.5	61.9	54.3	27.7	5.6	27.7	5.6	28.3	6.9
Portugal	50.6	33.9	44.6	33.8	46.3	55.6	60.4	53.0	54.2	25.9	4.3	25.9	4.3	26.6	5.2
Spain	56.6	44.3	54.6	42.3	60.1	41.7	36.8	32.6	34.7	25.8	4.3	25.8	4.3	26.6	5.3
Western Europe	62.1	52.0	61.2	52.0	65.2	82.1	32.8	29.7	29.1	25.9	6.1	25.9	5.7	26.7	6.4
Austria	65.3	56.0	59.5	48.4	66.9	92.3	23.2	27.6	26.0	25.4	4.2	25.8	4.4	26.4	5.2
Belgium	–	–	44.7	29.8	–	–	–	43.6	–	–	–	25.5	4.9	–	–
Germany	59.6	54.3	63.8	53.9	66.9	39.4	27.5	23.1	25.1	25.8	4.7	26.0	4.8	26.7	5.9

Continued

Table 1 Continued

Country	MET hours/week in active population						Proportion of physically inactive individuals (%)			BMI					
	2015		2019		2030		2015	2019	2030	2015		2019		2030	
	Mean	SD	Mean	SD	Mean	SD	%	%	%	Mean	SD	Mean	SD	Mean	SD
Ireland	61.4	41.8	56.0	41.9	57.0	72.6	44.1	37.9	38.0	26.8	10.8	26.8	10.8	27.3	8.8
Luxembourg	67.1	44.2	62.3	44.7	68.6	189.2	36.6	30.1	27.4	25.7	4.7	25.7	4.7	26.6	6.4
The Netherlands	–	–	80.9	79.2	–	–	–	16.1	–	–	–	25.4	4.3	–	–

Physically inactive individuals are those who do not meet the threshold <600 MET min/week (<10 MET hours/week). MET hours/week, proportion of physical inactivity and BMI were derived from the EHIS and averaged across age groups and sex/gender.
*The active population is defined as individuals meeting the WHO recommendation of at least 600 MET min/week (10 MET hours/week).
BMI, body mass index; EHIS, European Health Interview Survey; EU, European Union; MET, metabolic equivalent of task.

estimated at 92 607 (95% UI: 87 978–97 236) in 2015 and 95 914 (95% UI: 91 286–100 542) in 2019. By 2030, this is projected to increase to 107 108 total averted deaths (95% UI: 102 479–111 737), corresponding to a 4.7% reduction in total mortality (table 2).

At the regional level, in 2030, Central and Eastern Europe are projected to have the highest number of premature deaths averted, followed by Southern Europe and Western Europe, with the lowest impact in Northern Europe. Across all regions, only Central and Eastern Europe are projected to experience a sustained increase in the total number of premature deaths averted from 10 710 (95% UI: 10 004–11 416) in 2015 to 12,287 (95% UI: 11 581–12 993) in 2030. In contrast, in Southern, Western and Northern Europe, the number of premature deaths averted is expected to decline slightly. For instance, in Northern Europe, the number is projected to decrease from 1858 (95% UI: 1795–1921) in 2015 to 1545 (95% UI: 1482–1608) in 2030 (table 2).

The number of premature deaths averted is projected to be higher in 11 countries under the increased physical activity scenario. These countries include Bulgaria, Cyprus, Czechia, Finland, Greece, Hungary, Luxembourg, Malta, Poland, Romania and Slovakia (table 2 and figure 2). The most significant gains expected in Poland, from 3488 (95% UI: 3039–3937) in 2015 to 4618 (95% UI: 4106–5138) in 2030, and in Romania, from 2156 (95% UI: 1858–2461) to 2398 (95% UI: 2107–2696). Across both years, nearly two times as many premature deaths could be averted among males as females (figure 2 and online supplemental figure S10).

Cardiovascular diseases (CVDs)

CVDs, based on our results, accounted for the largest share of averted NCD deaths, comprising over 68% in 2030. Bulgaria (85.7%), Romania (84.8%) and Slovakia (81.1%) are expected to retain the highest share of averted deaths attributable to CVD by 2030. In 2015, the absolute number of CVD deaths averted ranged from 45 (95% UI: 38–52) in Luxembourg to 15 434 (95% UI: 13 195–17 559) in Germany. By 2030, these numbers are projected to reach 62 (95% UI: 54–70) in Luxembourg and 15 408 (95% UI: 13 460–17 387) in Germany.

Ischaemic heart disease accounted for the largest proportion of CVD deaths prevented, averaging 36.6% in 2030, with the highest proportions observed in Lithuania and Slovakia (54.0% and 56.5%, respectively). In most countries, cerebrovascular disease was projected to contribute the second-largest proportion of CVD deaths averted, ranging from 9.7% (Estonia) to 34.8% (Romania) in 2015 and from 7.7% (Estonia) to 35.7% (Latvia) in 2030. By comparison, deaths averted due to hypertensive disease ranged widely from 2.2% (Denmark) to 34.5% (Estonia) in 2015, and from 2.3% to 42.4% in 2030 (online supplemental tables S5 and S6).

Table 2 Total averted death and averted premature death under a counterfactual scenario

Country	Total averted death (95% UI)						Total averted death (%)			Total averted death under 75 (95% UI)					
	2015		2019		2030		2015	2019	2030	2015		2019		2030	
EU	92 607	(87 978–97 236)	95 914	(91 286–100 542)	107 108	(102 479–111 737)	4.5%	4.6%	4.7%	24 309	(23 384–25 234)	24 523	(23 598–25 448)	24 178	(23 253–25 103)
Central and Eastern Europe	31 811	(29 569–34 053)	32 720	(30 478–34 962)	38 471	(36 229–40 713)	4.6%	4.8%	4.9%	10 710	(10 004–11 416)	11 113	(10 407–11 819)	12 287	(11 581–12 993)
Bulgaria	4672	(3923–5388)	4317	(3643–4969)	4578	(3882–5260)	5.0%	4.7%	4.9%	1666	(1456–1874)	1530	(1343–1717)	1695	(1493–1893)
Croatia	1620	(1393–1848)	1632	(1434–1831)	1851	(1631–2060)	4.8%	5.1%	5.1%	438	(385–492)	438	(389–487)	394	(351–438)
Czechia	2955	(2576–3338)	3045	(2669–3419)	3917	(3495–4327)	4.4%	4.5%	5.1%	931	(836–1034)	921	(827–1019)	1052	(950–1152)
Hungary	3921	(3393–4416)	3831	(3389–4264)	4210	(3743–4663)	4.7%	4.7%	5.0%	1340	(1194–1485)	1364	(1235–1500)	1351	(1215–1485)
Poland	9546	(8163–10 842)	10 139	(8803–11 454)	13 253	(11 664–14 766)	4.2%	4.3%	4.6%	3488	(3039–3937)	3692	(3242–4117)	4618	(4106–5138)
Romania	6924	(5707–8132)	7483	(6231–8705)	8212	(6970–9451)	4.1%	4.5%	4.5%	2156	(1858–2461)	2412	(2088–2737)	2398	(2107–2696)
Slovakia	1691	(1474–1898)	1741	(1521–1956)	1817	(1598–2034)	4.8%	5.0%	4.8%	562	(498–623)	641	(577–704)	669	(604–735)
Slovenia	482	(424–538)	532	(470–592)	633	(561–702)	4.9%	5.3%	5.2%	129	(106–132)	115	(102–128)	110	(97–123)
Northern Europe	6743	(6364–7122)	6598	(6219–6977)	7379	(7000–7758)	4.5%	4.6%	4.8%	1858	(1795–1921)	1671	(1608–1734)	1545	(1482–1608)
Denmark	790	(674–906)	820	(702–935)	877	(756–993)	3.4%	3.5%	3.6%	255	(223–287)	240	(212–269)	224	(198–251)
Estonia	475	(414–531)	495	(430–555)	715	(610–809)	4.9%	5.3%	5.8%	141	(126–155)	129	(116–141)	130	(116–142)
Finland	1294	(1133–1453)	1378	(1196–1551)	1584	(1418–1747)	4.6%	4.9%	4.6%	295	(266–325)	339	(299–378)	328	(298–360)
Latvia	901	(775–1025)	825	(705–938)	929	(809–1055)	4.9%	4.7%	5.0%	276	(246–307)	234	(209–260)	199	(180–218)
Lithuania	1317	(1117–1505)	1124	(963–1284)	1327	(1159–1491)	5.0%	4.6%	5.1%	389	(341–436)	327	(292–363)	297	(269–325)
Sweden	1966	(1675–2254)	1956	(1711–2197)	1947	(1708–2172)	4.5%	4.6%	4.6%	502	(415–582)	402	(363–442)	367	(331–402)
Southern Europe	29 319	(26 504–32 134)	29 948	(27 133–32 763)	33 833	(31 018–36 648)	4.5%	4.6%	4.6%	6389	(5952–6826)	5566	(5129–6003)	5908	(5471–6435)
Cyprus	203	(179–228)	202	(176–227)	228	(201–253)	4.7%	4.4%	4.6%	64	(57–72)	71	(63–79)	78	(69–86)
Greece	2808	(2356–3243)	2963	(2499–3399)	4096	(3440–4750)	4.3%	4.3%	3.8%	754	(651–854)	721	(621–820)	806	(697–917)
Italy	15 385	(13 084–17 598)	16 327	(14 014–18 522)	17 193	(14 828–19 536)	4.6%	5.0%	4.8%	3083	(2683–3476)	2377	(2089–2669)	2579	(2264–2902)
Malta	86	(77–95)	96	(86–105)	103	(92–113)	4.5%	5.0%	4.9%	27	(25–30)	26	(24–29)	29	(27–32)
Portugal	2287	(1933–2639)	2454	(2078–2799)	2617	(2262–2967)	4.4%	4.6%	4.7%	590	(517–666)	600	(528–672)	557	(492–621)
Spain	8550	(7508–9563)	7906	(6898–8866)	9596	(8400–10 791)	4.6%	4.3%	4.9%	1871	(1657–2091)	1771	(1570–1978)	1859	(1644–2083)
Western Europe	24 734	(21 611–27 857)	26 648	(23 064 –39 310)	27 425	(24 302–30 548)	4.2%	4.3%	4.6%	5352	(4882–5822)	6173	(5703 –6643)	4438	(3968–4908)
Austria	2068	(1794–2329)	1905	(1660–2143)	2249	(1965–2515)	4.7%	4.5%	4.9%	467	(420–512)	410	(368–452)	373	(335–413)
Belgium	–	–	1537	(1301–1765)	–	–	–	3.5%	–	–	–	442	(379–505)	–	–
Germany	22 030	(19 311–24 676)	19 607	(17 248–21 934)	24 477	(21 427–27 320)	4.7%	4.2%	4.8%	4694	(4214–5190)	4400	(3965–4859)	3885	(3473–4286)
Ireland	566	(489–641)	629	(554–707)	597	(526–665)	4.0%	4.4%	4.1%	171	(150–192)	165	(146–186)	158	(139–178)
Luxembourg	70	(62–79)	95	(84–105)	102	(88–114)	3.5%	4.7%	4.5%	20	(18–23)	21	(18–23)	22	(20–25)
The Netherlands	–	–	2875	(2492–3244)	–	–	–	4.4%	–	–	–	735	(652–819)	–	–

EU, European Union; UI, uncertainty interval.

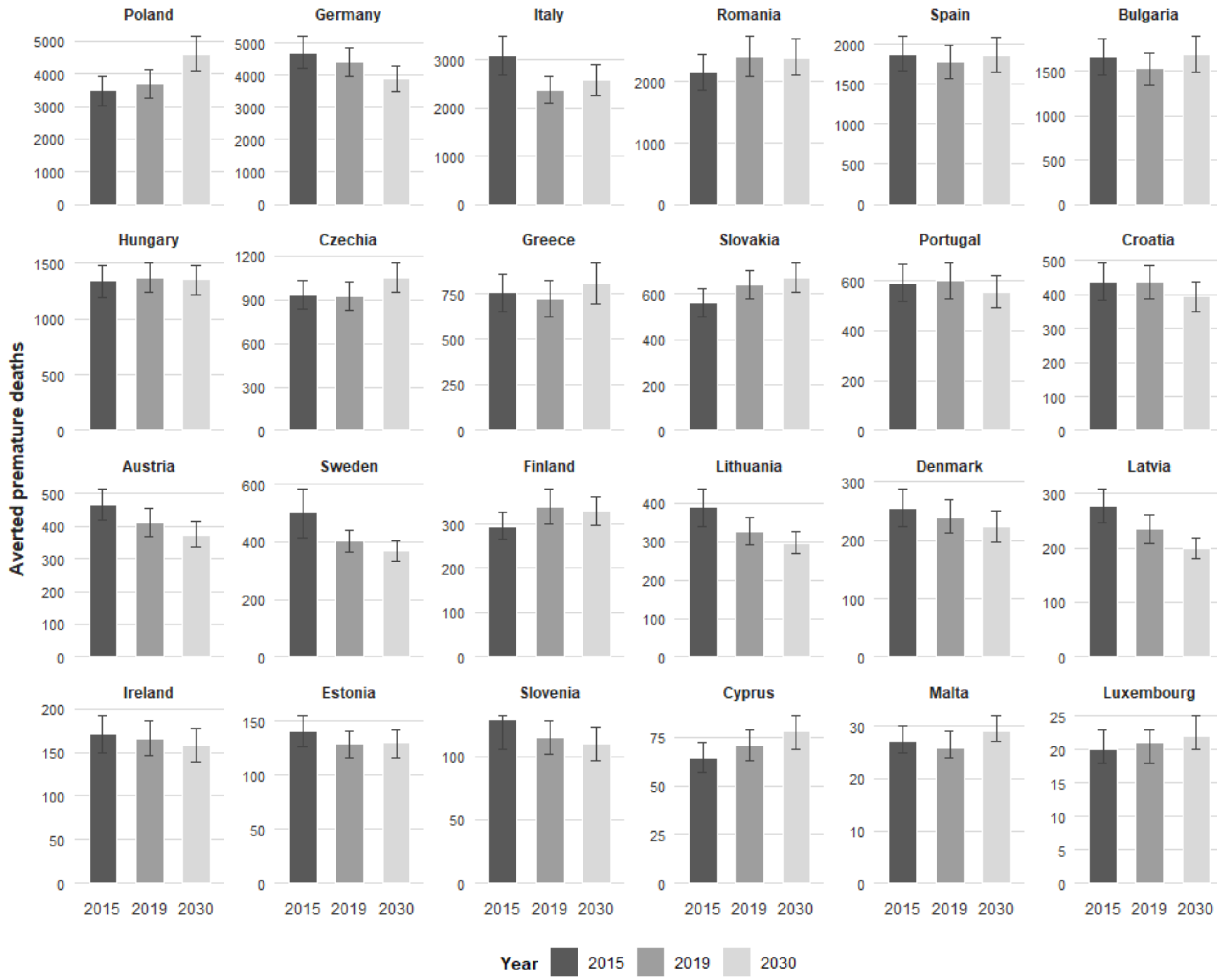

Figure 1 Estimated averted premature deaths across European Union countries for 2015, 2019 and 2030 under the counterfactual scenario. Data are presented as mean values with uncertainty intervals.

Cancer

Based on our outputs, cancer was the second leading cause of averted NCD deaths, accounting for an average of 14.3% in 2030. Germany is projected to have the highest number of cancer deaths prevented, with 3547 (95% UI: 2793–4321) in 2030, while Malta and Luxembourg are expected to have the lowest, at 16 (95% UI: 13–20) deaths averted by 2030. In most countries, lung cancer and colorectal cancer accounted for the largest proportions of cancer deaths averted. Reductions in gallbladder and endometrial cancers were projected to be minimal across all countries under the counterfactual scenario (online supplemental tables S5 and S6).

Diabetes

In 2030, diabetes is projected to account for 9.3% of total averted NCD deaths. The largest proportional reductions are projected for Czechia (20.1%) and the least for Romania (2.9%) (online supplemental tables S5 and S6).

DISCUSSION

Our model suggests that meeting the target for increased physical activity could have a substantial health impact, leading to around 3.3% of premature NCD deaths averted and approximately 4.7% of all deaths prevented by 2030 in the EU. Although modest compared with the SDG 3.4.1 target of a 30% reduction in premature NCD deaths, this still represents a meaningful contribution to broader prevention strategies.

A global evidence synthesis by Frieden *et al*[27] estimated that WHO 'best buy' interventions are associated with reductions in premature NCD deaths as follows: tobacco control (13%), treatment to reduce cardiovascular risk (5.7%), dietary sodium reduction (5.4%), reduction of household air pollution (5.0%), elimination of artificial trans fats (2.0%), reduction of alcohol use (1.4%) and cancer prevention, detection and treatment (0.6%), giving a combined reduction of approximately 33.1%, which exceeds the 30% SDG 3.4.1 target.[27] Although

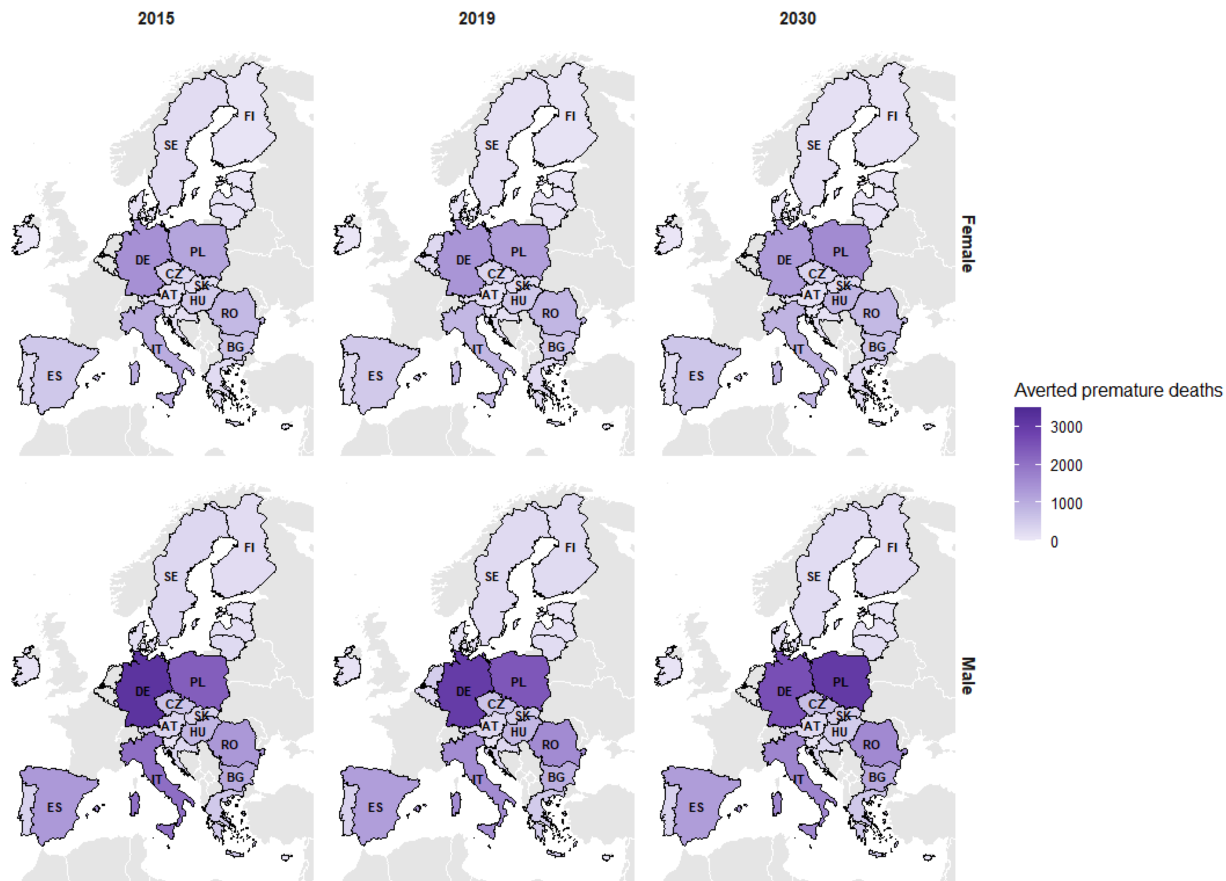

Figure 2 Maps showing estimated averted premature deaths by sex (male, female) across EU countries for 2015, 2019 and 2030 under the counterfactual scenario. AT, Austria; BG, Bulgaria; CZ, Czechia; DE, Germany; ES, Spain; FI, Finland; HU, Hungary; IT, Italy; PL, Poland; RO, Romania; SE, Sweden; SK, Slovakia.

these estimates are global rather than EU-specific, they provide a useful benchmark for interpreting the relative contribution of physical activity and suggest that combining interventions could help achieve the SDG 3.4.1 target.

The relatively modest reduction in NCD mortality observed in our study likely reflects the isolated effect of increased physical activity. Physical inactivity, however, is a cross-cutting risk factor affecting major NCD outcomes, including CVD, diabetes and certain cancers. Integrating physical activity promotion with other high-impact interventions, such as tobacco control, cardiovascular risk reduction and dietary improvements, is expected to produce synergistic effects and further reduce premature NCD mortality across European populations.

If the target of increased physical activity across sexes and age groups in the EU were achieved, more than 24 000 premature deaths could potentially be averted in 2030 alone. These findings are consistent with WHO estimates, which indicate that achieving the recommended 150 min of moderate-intensity physical activity per week is associated with over 10 000 prevented premature deaths annually in the EU.[9] This evidence further supports the well-established association between physical activity of any intensity and reduced all-cause mortality, as well as lower risks of CVD, hypertension and diabetes.[9 28]

Modelled estimates indicate substantial regional differences in physical activity across the EU. Central, Eastern and Southern Europe show lower levels than Northern and Western regions, in line with previous research.[8] These disparities may reflect socioeconomic factors, such as gross domestic product per capita, as higher-income groups typically engage in more leisure-time physical activity.[8] Environmental and urban factors, including urban planning, active transport infrastructure and the availability of recreational facilities, may further shape opportunities for physical activity, contributing to regional differences in activity levels.[8]

Variation in national-level public health investment and the policy emphasis on physical activity may also shape population behaviour.[8] For instance, Southern European countries tend to allocate a smaller share of total health expenditure to public funding than the EU average of around 80%, resulting in greater reliance on private and out-of-pocket payments.[29] Such reliance on private financing may limit equitable access to preventive services and structured opportunities for physical activity. Our findings, therefore, underline that physical activity is not only a behavioural choice but also the outcome of political, commercial and other structural determinants of health, including transport, housing as well as labour policies and corporate practices that shape opportunities for movement. Recognising these determinants is critical to avoid placing responsibility solely on individuals and to align SDG-oriented strategies with goals of equity and social justice.

The larger numbers of averted deaths in Central, Eastern and Southern EU countries reflect their higher baseline risk profiles, characterised by lower physical activity, higher physical inactivity and higher BMI. When baseline exposure to a harmful risk factor is high, a given relative improvement produces a larger absolute reduction in risk because more individuals are shifted out of high-risk categories. This results in higher population attributable fractions and more preventable deaths.[12] PRIME applies these fractions to baseline cause-specific mortality, so regions with higher NCD death burdens show larger absolute gains even under the same proportional increases in physical activity.[12] This effect may be amplified further by population ageing and population size in many Southern and Central/Eastern EU countries.[30] These findings suggest that physical activity promotion targeting populations at risk could potentially reduce disease burden. Although promoting physical activity in older and higher-risk populations is associated with more short-term deaths averted, it remains crucial among younger adults. Physical activity in early and mid-life prevents obesity, diabetes, CVD and functional decline, producing large lifetime health benefits that are not captured by mortality-based models such as PRIME.[31]

Across EU member states, increased physical activity is associated with more averted premature deaths among males than females. Sex and gender differences may reflect disparities in physical activity participation, with women generally engaging in slightly lower levels of activity than men. Previous studies have also reported that men are more likely to participate in vigorous activities.[32] Physical activity tends to decline with age. Among active individuals, levels (expressed in MET values) are likely to peak at ages 15–24 years, plateau in middle age and drop sharply from ages 64–69 years onwards. These patterns highlight the importance of targeted interventions for older adults, who may face greater barriers to regular exercise. Modelled estimates suggest that physical inactivity will remain more prevalent among older adults in Central, Eastern and Southern Europe, in line with previous research.[8,32]

Across levels of physical activity, men were projected to have a higher average BMI than women, with greater variability observed in older age groups. BMI tends to increase steadily with age, peaking at 60–64 years, then plateauing or declining slightly. No clear association was observed between higher BMI and the total number of deaths averted. This finding may, in part, be explained by the so-called ‘obesity paradox’, which has been documented in older adults. Systematic reviews have shown that overweight and obese older adults sometimes experience lower mortality risk compared with their normal-weight peers, particularly in the presence of comorbidities or acute illness, suggesting that excess body weight may confer a survival advantage in certain contexts.[33] This paradox may be driven less by fat itself and more by the preservation of muscle mass and strength among obese older individuals, which can reduce the risk of sarcopenia and frailty.[33]

Further investigation of body composition, including fat percentage and muscle mass, is therefore warranted to clarify the relationship between BMI and obesity, given that obesity remains a major risk factor for NCD-related mortality, including CVD and diabetes.[9,34] Furthermore, increases in BMI may also be attributed to other factors such as diet. Dietary patterns differ between countries and between males and females. They are known to influence NCD risk, particularly through low consumption of fruits and vegetables, and a diet high in salt, sugar and/or ultra-processed foods.[10] Such differences in diet may therefore contribute to the observed results. Addressing this issue will require integrated strategies that combine increased physical activity with healthier dietary patterns, as recommended by WHO.

Our findings resonate with several ongoing EU policy frameworks that place physical activity and NCD prevention high on the agenda. Europe’s Beating Cancer Plan[35] explicitly highlights the promotion of active lifestyles as a pillar of cancer prevention, while the Healthier Together–EU Non-Communicable Diseases Initiative[36] calls for integrated action across diet, alcohol, tobacco and physical activity, echoing our conclusion that activity alone will not achieve SDG 3.4.1. Promoting active transport and expanding access to green spaces are also consistent with the EU Green Deal and the Sustainable and Smart Mobility Strategy,[37] which recognise health and climate co-benefits of walking and cycling infrastructure. In addition, the Council of the EU Work Plan on Sport (2021–2024)[38] and the EU4Health programme (2021–2027)[39] prioritise investment in physical activity promotion as a means of improving public health and resilience. Embedding our scenario-based evidence into these initiatives could help EU member states target populations with persistently high inactivity, reduce regional inequalities and strengthen cross-sectoral collaboration for more effective NCD prevention.

The Organisation for Economic Co-operation and Development (OECD) and WHO/Europe report that a wide range of effective policy options exist to promote physical activity. These include setting-specific interventions, such as physical education in schools.[9] Evidence shows that physically active behaviours begin to develop early in childhood, with activity patterns tracking moderately to strongly from youth into adulthood.[9] Insufficient opportunities for physical activity in schools may therefore contribute to children growing into less active adults. Workplace initiatives to promote physical activity include, for example, standing desks, prompts to use stairs, active transportation and healthcare-based measures such as personalised physical activity prescriptions.[9] Policies that invest in sports infrastructure, improve road safety, expand access to green spaces and promote active mobility can support active lifestyles on a larger scale.[9]

Although 28 European member states have formal policies to promote physical activity, as reported by WHO, the extent of implementation and prioritisation remains inconsistent across the region.[25] While 78% of countries report having a national coordination mechanism to promote health-enhancing physical activity, significant gaps persist. Only 30% apply specific sports club health guidelines, and just 26% systematically use the European Guidelines for Improving Infrastructures for Leisure-Time Physical Activity in the Local Arena (IMPALA) to support leisure-time physical activity infrastructure.[32] National guidance or programmes for active travel to school are in place in only 59% of countries and 20% still lack workplace policies to encourage active commuting. In addition, 11% of countries have no mass media campaigns to promote physical activity and 26% lack national programmes for exercise prescription in healthcare.[32] These implementation gaps are concerning, given strong evidence that even modest increases in physical activity can reduce NCD-related morbidity and mortality.

Interventions should be tailored to regional and local contexts, especially in Southern, Central and Eastern Europe, where the prevalence of physical inactivity remains consistently higher than in other regions. Key barriers may include cultural norms, socioeconomic inequalities and limited access to safe, supportive environments.[40] Addressing these challenges requires a whole-of-society approach that integrates urban planning, education, transport and health systems into a coordinated policy response. Targeted interventions are also needed for high-risk populations, including sedentary adults, older individuals and people living with obesity. These groups would benefit most from structured support to achieve even modest increases in physical activity. Priorities should include structural changes in workplaces, community-based initiatives and the development of inclusive, accessible recreational infrastructure. Promoting physical activity should be embedded in national strategies to prevent NCDs.

A key strength of this study is the use of the PRIME model, which enables rapid estimation of the impact of changes in behavioural risk factors with minimal data inputs, making it accessible and adaptable across diverse policy settings. However, its simplicity limits the capacity to capture temporal dynamics or estimate more nuanced outcomes, such as life expectancy, years of life lost or quality-adjusted life years.[12] The relative risk parameters incorporated into the PRIME tool have been adjusted for key confounders, including age, sex, smoking status and social class. Nonetheless, residual confounding cannot be ruled out due to unmeasured or imperfectly measured variables. Additionally, as in many epidemiological models, interactions among risk factors are not taken into account. Reliance on self-reported data for physical activity may also introduce bias, as physical activity is often over-reported.

As PRIME does not use a consistent definition of 'sedentary', and EHIS wave 2 does not include questions on sedentary behaviour, we operationalised sedentary behaviour based on available data, defining it as the percentage of individuals who were insufficiently active. Consequently, the estimated prevalence of physical inactivity may not fully capture the true levels of sedentary behaviour in the population. Furthermore, the EHIS physical activity module did not differentiate between moderate and vigorous intensity activity and reported only duration. As a result, we assumed that reported activity could encompass both intensities and applied a combined threshold of 600 MET min/week for total walking, cycling and sports activities. However, this threshold may underestimate adherence to recommended physical activity guidelines and may not fully capture the increased mortality risk associated with insufficient physical activity.

Model predictions based on only two time points may not capture the whole trajectory of trends and are subject to greater uncertainty. Projections of epidemiological indicators such as disease prevalence may either overestimate or underestimate the actual burden. Additionally, COVID-19-related restrictions led to sudden changes in physical activity and sedentary patterns. These shifts are not fully captured in pre-pandemic data which may affect the accuracy of projections. Therefore, trends should be interpreted with caution given the potential disruptions related to the pandemic.

Our analysis shares limitations with GBD scenario studies including uncertainties in mortality estimates potential biases in self-reported data and assumptions about parameter stability. Finally, socioeconomic disparities in physical activity, which strongly influence health outcomes, were not explicitly modelled and should be addressed in future research.

CONCLUSION

While increased physical activity alone is unlikely to achieve the SDG 3.4.1 target of reducing premature NCD deaths by 2030, combining it with complementary measures such as improved diet and reduced tobacco and alcohol use could make this target attainable across the EU.

Public health initiatives should focus on reducing sedentary behaviour and promoting even modest increases in physical activity, especially among older adults and individuals with higher BMI. Effective promotion requires a multifaceted approach, recognising that lasting behaviour change cannot be achieved through one-size-fits-all solutions. A comprehensive, well-funded policy package is critical for achieving meaningful, lasting impact. Its success depends on cross-sectoral collaboration, sustained funding, continuous monitoring and adaptation to local needs. Achieving impact depends on translating policy into effective action.

This study does not aim to predict exact future outcomes but to explore potential impacts under plausible behavioural change scenarios, serving as a policy tool to inform effective interventions. These scenarios rely on assumptions about the stability of risk associations and behavioural responses, which should be considered when interpreting the results. The findings may also guide future cost-effectiveness evaluations of physical activity promotion policies.

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Contributors All authors had full access to the data, contributed to the study and take responsibility for its submission. Conceptualisation: OV, ANAM and NM. Data curation: ANAM and NM. Formal analysis: OV, ANAM, NM, CASA, JC-X, TAE, MB, ME, EAM, BU, CMB, AB, JS, JG, RJV, BL, RH, GT, SC, DR-R, HH, GC and GLT. Funding acquisition: OV. Methodology: OV, ANAM and NM. Project administration: OV. Resources: OV. Software: ANAM and NM. Validation: OV, ANAM, NM, CASA, JC-X, TAE, MB, ME, EAM, BU, CMB, AB, JS, JG, RJV, BL, RH, GT, SC, DR-R, HH, GC and GLT. Visualisation: ANAM. Writing – original draft: ANAM, NM and OV. Writing – review and editing: ANAM, NM, CASA, JC-X, TAE, MB, ME, EAM, BU, CMB, AB, JS, JG, RJV, BL, RH, GT, SC, DR-R, HH, GC, GLT and OV. Guarantor: OV. The first author used AI (ChatGPT) to improve the readability and language of the manuscript during its drafting. Afterwards, all authors carefully reviewed and revised the content as needed and accept full responsibility for the final published version.

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