Trends in premature avertable mortality from non-communicable diseases for 195 countries and territories, 1990–2017: a population-based study

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Summary

Background The reduction by a third of premature non-communicable disease (NCD) mortality by 2030 is the ambitious target of Sustainable Development Goal (SDG) 3.4. However, the indicator is narrowly defined, including only four major NCDs (cardiovascular diseases, cancer, diabetes, and chronic respiratory diseases) and only for people aged 30–70 years. This study focuses on premature avertable mortality from NCDs—premature deaths caused by NCDs that could be prevented through effective public policies and health interventions or amenable to high-quality health care—to assess trends at global, regional, and national levels using estimates from the Global Burden of Disease, Injuries, and Risk Factors Study (GBD) 2017.

Methods We reviewed existing lists of NCD causes of death that are either preventable through public health policies and interventions or amenable to health care to create a list of avertable NCD causes of death, which was mapped to the GBD cause list. We estimated age-standardised years of life lost (YLL) per 100 000 population due to premature avertable mortality from NCDs, avertable NCD cause clusters, and non-avertable NCD causes by sex, location, and year and reported their 95% uncertainty intervals (UIs). We examined trends in age-standardised YLL due to avertable and non-avertable NCDs, assessed the progress of premature avertable mortality from NCDs in achieving SDG 3.4, and explored specific avertable NCD cause clusters that could make a substantial contribution to overall trends in premature mortality.

Findings Globally, premature avertable mortality from NCDs for both sexes combined declined –1·3% (95% UI –1·4 to –1·2) per year, from 12 855 years (11 809 to 14 051) in 1990 to 9008 years (8329 to 9756) in 2017. However, the absolute number of avertable NCD deaths increased 49·3% (95% UI 47·3 to 52·2) from 23·1 million (22·0–24·1) deaths in 1990 to 34·5 million (33·4 to 35·6) in 2017. Premature avertable mortality from NCDs reduced in every WHO region and in most countries and territories between 1990 and 2017. Despite these reductions, only the Western Pacific and European regions and 25 countries (most of which are high-income countries) are on track to achieve SDG target 3.4. Since 2017, there has been a global slowdown in the reduction of premature avertable mortality from NCDs. In 2017, high premature avertable mortality from NCDs was clustered in low-income and middle-income countries, mainly in the South-East Asia region, Eastern Mediterranean region, and African region. Most countries with large annual reductions in such mortality between 1990 and 2017 had achieved low levels of premature avertable mortality from NCDs by 2017. Some countries, the most populous examples being Afghanistan, the Central African Republic, Uzbekistan, Haiti, Mongolia, Turkmenistan, Pakistan, Ukraine, Laos, and Egypt, reported both an upward trend and high levels of premature avertable mortality from NCDs. Cardiovascular diseases, cancers, and chronic respiratory diseases have been the main drivers of the global and regional reduction in premature avertable mortality from NCDs, whereas premature mortality from substance use disorders, chronic kidney disease and acute glomerulonephritis, and diabetes have been increasing.

Interpretation Worldwide, there has been a substantial reduction in premature avertable mortality from NCDs, but progress has been uneven across populations. Countries vary substantially in current levels and trends and, hence, the extent to which they are on track to achieve SDG 3.4. By accounting for premature avertable mortality while avoiding arbitrary age cutoffs, premature avertable mortality from NCDs is a robust, comprehensive, and actionable indicator for quantifying and monitoring global and national progress towards NCD prevention and control.

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See **Comment** page e456

For the Spanish translation of the abstract see **Online** for appendix 1

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Introduction

In response to resolutions made at the 2011 UN High-Level Meeting on non-communicable diseases (NCDs), the WHO Global Action Plan for the Prevention and Control of NCDs urges member states to reduce mortality from four major NCDs (cardiovascular diseases, cancers, diabetes, and chronic respiratory diseases) among people aged 30–70 years by 25% between 2010 and 2025.[1] Sustainable Development Goals (SDGs) target 3.4 aims to reduce mortality from NCDs

Research in context

Evidence before this study

We did not do a formal literature review. National and global progress towards the Sustainable Development Goal (SDG) target 3.4—a one-third reduction, relative to 2015 levels, in the probability of dying aged 30–70 years from any major non-communicable disease (NCD), including cancers, cardiovascular diseases, chronic respiratory diseases, and diabetes, by 2030—has been reported in other studies. However, the standard indicator is narrowly defined to include only four major NCDs and only for people aged 30–70 years. The NCD Countdown 2030 report proposed a more comprehensive indicator, but it still excludes people aged 80 years and over. A comprehensive and actionable measure of premature mortality from NCDs is needed for the informed analysis of epidemiological trends, health system performance, and effect of policies.

Added value of this study

This study develops a new measure to quantify the premature avertable mortality from NCDs. It combines a novel list of NCD causes accounting for deaths preventable through public policies and population-based health interventions and amenable to health care, with a health gap measure: years of life lost (YLLs) due to premature mortality. It presents a trend analysis for premature avertable mortality from NCDs at global, regional, and national levels based on 2017 data from the Global Burden of Diseases, Injuries, and Risk Factors Study, and assesses progress towards SDG target 3.4, as measured by premature avertable mortality from NCDs. To our knowledge, this is the first study to apply a metric of premature avertable NCD mortality without arbitrary restrictions by age or disease category.

Implications of all the available evidence

This study describes levels and trends for premature avertable mortality from NCDs globally, for WHO regions, and 195 countries and territories from 1990 to 2017. Between 1990 and 2017 premature avertable mortality from NCDs fell substantially worldwide, in all regions, and in all but 14 countries. Yet, only two WHO regions and 25 countries are on track to reach the SDG target 3.4. Most clusters of avertable NCDs contributed to the overall reduction in premature avertable mortality from NCDs. However, substance use disorders, chronic kidney disease and acute glomerulonephritis, and diabetes attenuated the overall reduction in many countries and regions. Globally in 2017, 8423 years of life per 100 000 people were still lost to conditions that could be averted with effective policies and interventions. YLLs due to premature avertable NCD mortality should become a key indicator to shape policy and identify priorities for interventions.

by one third by 2030 relative to its 2015 level.[2] Both measure premature NCD mortality as the unconditional probability of dying aged 30–70 years from the aforementioned four NCDs. However, the exclusion of deaths at ages younger than 30 years and older than 70 years or from NCDs other than the four major ones has been controversial.[3–5] Many excluded NCD causes are amenable to prevention and treatment, and some NCD deaths among people aged 70 years and older can be postponed. Hence, the *Lancet* NCD Countdown 2030 Collaborators[5] and others[4] have called for a more inclusive and comprehensive approach, better aligned with the WHO goal of "leaving no one behind".

In response, we developed a new measure: years of life lost (YLLs) due to premature avertable mortality from NCDs (hereafter referred to as premature avertable mortality from NCDs). This measure combines a new list of all NCD mortality causes that are preventable through public policies and health programmes or are amenable to health care, with a calculation of YLLs due to premature mortality. Our approach draws on the notion of "unnecessary, untimely deaths", introduced in the 1970s by Rutstein and colleagues,[6] who proposed a list of causes from which death would not occur in the presence of timely and effective medical care. This concept—termed amenable mortality—was modified and extended, accounting for advances in medical care and improved knowledge of cause-specific epidemiology.[7–9] It has been used in different populations,[10–13] including countries of the EU and the Organisation for Economic Co-operation and Development, and in comparisons between states and health systems in the USA and European countries.[12,13] Other studies extended the set of amenable conditions to include ones targeted by public health programmes,[13] coining the concept of avoidable mortality. To date, the most widely cited list of causes amenable to health care is that of Nolte and McKee,[14] which has been used extensively in countries belonging to the Organisation for Economic Co-operation and Development,[12,13] and by the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) to create the Health Access and Quality Index.[15] A study[16] of mortality attributable to low-quality health systems extended this list to a total of 61 conditions for which the risk of death could be reduced by personal health care not requiring advanced technology. In our approach, avertable mortality refers to mortality that is avertable by public policies and health interventions to prevent the condition in the first place, as well as mortality that can be avoided or postponed by good quality personal health care (panel). We calculate YLLs with reference to standardised life expectancy at age of death, thus avoiding arbitrary age cutoffs.

We aimed to estimate premature avertable mortality from NCDs globally, regionally, and nationally by sex, age, location and year, examine trends from 1990 to 2017, assess progress towards SDG target 3.4, analyse the

contribution of NCD clusters to overall trends, and discuss policy implications.

Methods

Estimation of premature avertable mortality

We reviewed lists of causes accounting for deaths considered to be either preventable by public policies and health programmes or amenable to good quality health care. These included lists developed by Nolte and McKee,[13,14] Eurostat's Working Group on Public Health Statistics,[17] the Canadian Institute for Health Information and Statistics Canada,[18] and the health ministries of Mexico, Brazil, and New Zealand.[19–21] From this review, we created a new list of fatal and non-fatal conditions. We included conditions after evaluating evidence that deaths due to the corresponding cause can be averted in the presence of effective health care, public health interventions, or other policies. We mapped each cause category to the GBD cause list[22] based on the International Classification of Diseases codes and created a list of 90 causes (appendix 2 p 7). A few conditions from our list could not be mapped, usually because GBD includes them within larger groups of causes that are not considered avertable. Where GBD provides separate categories, we disaggregated our categories accordingly.

To quantify premature avertable mortality from NCDs, we considered eight disease clusters based on the avertable cause list (cardiovascular diseases, neoplasms [cancers], chronic respiratory diseases, digestive diseases, neurological disorders, substance use disorders, diabetes and chronic kidney disease, and other NCDs) covering 43 fatal conditions (table 1). For comparison, causes of non-avertable mortality from NCDs are given in table 2. Rather than impose arbitrary age limits, we used a widely used health gap metric—YLLs due to premature mortality—derived from the standard life expectancy at each age.

Our analysis draws on GBD 2017 estimates.[23,24] The GBD study is a multinational research collaboration designed to produce consistent and comparable estimates of health effects related to more than 328 diseases and injuries in 195 countries and territories. Its methods have been described previously[23,24] and are summarised in appendix 2 (p 10).

YLLs measure premature death, calculated as the sum of each death observed at each specific age in a certain year multiplied by the standard life expectancy at each age, estimated from life tables.[25] Standard life expectancy was taken from the lowest observed risk of death for each 5-year age group in all populations greater than 5 million (appendix 2 p 14). GBD 2017 includes new assessments of population, fertility, migration, and all-cause mortality.[26] These components were used to generate population estimates by age, sex, and year.

We extracted estimates of numbers of deaths and YLLs, with 95% uncertainty intervals (UIs), for every cause of death from the GBD cause list, by sex, age group, location (global, six WHO regions, and 195 countries and territories [appendix 2 p 17]), and annually from 1990 to 2017 using the GBD Results Tool.

We used GBD 2017 population estimates by sex, age, location, and year from 1990 to 2017,[27] which we extracted from the Global Health Data Exchange.[27]

We estimated age-standardised YLL per 100 000 population with 95% UIs for all avertable deaths from NCDs, and clusters thereof, for non-avertable NCD deaths and all-NCDs deaths by sex, location, and year. First, we computed the number of deaths and YLLs by sex, age group, location, and year from each category of causes by aggregating separately the number of deaths and the number of YLLs, based on the cause list of avertable NCD mortality (table 1). Second, we calculated age-specific and sex-specific YLLs per 100 000 population for each cause group (avertable NCDs, avertable NCD clusters, non-avertable NCDs, and all NCDs) by location for 1990–2017. Third, we calculated age-standardised YLL per 100 000 population by cause, sex, location, and year by direct method using the world standard population,[28] as shown in appendix 2 (p 16). We computed the 95% UIs for age-specific and sex-specific YLL and age-standardised YLL by propagating the uncertainty from the GBD estimates of YLLs and population (appendix 2 p 12).

Assessment of trends from 1990 to 2017

We did Joinpoint regression analysis29 to assess trends in premature avertable mortality from NCDs, for each NCD cluster, and for non-avoidable NCDs for 1990–2017. We estimated inflexion points (joinpoints) from trends and the average (mean) annual percentage change (AAPC) by regressing a log-linear function of

***Panel:* Key concepts and terminology**

Here we present some concepts and terminology used in this Article, which are frequently used in the literature focused on assessing public health interventions and health-care quality, and the Global Burden of Diseases, Injuries, and Risk Factors Study.

Avertable mortality refers to mortality from diseases where death could be prevented in the presence of effective health policies and population-based interventions, in addition to mortality that can be avoided or postponed in the presence of access to high-quality personal health care once the condition occurs.

Preventable mortality refers to disease mortality that can be avoided through public health programmes or policies focused on wider determinants of health, such as behavioural, biological, and environmental risk factors, and socioeconomic status.[9,10]

Amenable mortality refers to mortality from diseases where death can be avoided or postponed by high-quality personal health care.[9,10]

With some conditions, premature mortality can be reduced by both personal health care and public health programmes and policies.[14]

For this study, we use the concept of avertable mortality to quantify the levels of premature avertable mortality from non-communicable diseases. This study does not differentiate between preventable and amenable mortality from such diseases.

See Online for appendix 2

For the **GBD Results Tool** see http://ghdx.healthdata.org/gbd-results-tool?params=gbd-api-2017-permalink/15af25bc634e7e0514f7fb287db5085e

	ICD-10	ICD-9
Neoplasms		
Lip and oral cavity cancer	C00–C08·9, D10·0–D10·5, D11–D11·9, Z85·81–Z85·810	140–145·9, 210·0–210·6, 235·0, V76·42
Nasopharynx cancer	C11–C11·9, D10·6	147–147·9, 210·7–210·9
Other pharynx cancer	C09–C10·9, C12–C13·9, D10·7	146–146·9, 148–148·9
Oesophageal cancer	C15–C15·9, D00·1, D13·0, Z85·01	150–150·9, 211·0, 230·1
Stomach cancer	C16–C16·9, D00·2, D13·1, D37·1, Z12·0, Z85·02–Z85·028	151–151·9, 211·1, 230·2, 209·23, V10·04
Colon and rectum cancer	C18–C21·9, D01·0–D01·3, D12–D12·9, D37·3–D37·5	153–154·9, 209·1–209·17, 209·5–209·57, 211·3–211·4, 230·3–230·6
Liver cancer	C22–C22·9, D13·4	155–155·9, 211·5
Larynx cancer	C32–C32·9, D02·0, D14·1, D38·0, Z85·21	161–161·9, 212·1, 231·0, 235·6, V10·21
Tracheal, bronchus, and lung cancer	C33–C34·9, D02·1–D02·3, D14·2–D14·3, D38·1, Z12·2, Z80·1–Z80·2, Z85·1–Z85·20	162–162·9, 212·2–212·3, 231·1–231·2, 235·7, 209·21, V10·1–V10·20, V16·1–V16·2, V16·4–V16·40
Malignant skin melanoma	C43–C43·9, D03–D03·9, D22–D23·9, D48·5, Z85·82–Z85·828	172–172·9
Non-melanoma skin cancer (squamous-cell carcinoma)	C44–C44·99, D04–D04·9, D49·2	173–173·99, 222·4, 232–232·9, 238·2
Breast cancer	C50–C50·929, D05–D05·92, D24–D24·9, D48·6–D48·62, D49·3, N60–N60·99	174–175·9, 217–217·8, 233·0, 238·3, 239·3, 610–610·9
Cervical cancer	C53–C53·9, D06–D06·9, D26·0	180–180·9, 219·0, 233·1
Uterine cancer	C54–C54·9, D07·0–D07·2, N87–N87·9	182–182·8, 233·2
Testicular cancer	C62–C62·92, D29·2–D29·8, D40·1–D40·8	186–186·9, 222·0, 222·3, 236·4
Bladder cancer	C67–C67·9, D09·0, D30·3, D41·4–D41·8, D49·4	188–188·9, 223·3, 233·7, 236·7, 239·4
Thyroid cancer	C73–C73·9, D09·3, D09·8, D34–D34·9, D44·0, Z85·850	193–193·9, 226–226·9
Mesothelioma	C45–C45·9	..
Hodgkin lymphoma	C81–C81·99	201–201·98
Leukaemia	C91–C95·92	204–208·92
Cardiovascular diseases		
Rheumatic heart disease	I01–I01·9, I02·0, I05–I09·9	391–391·9, 392·0, 393–398·99
Ischaemic heart disease	I20–I25·9	410–414·9
Cerebrovascular disease	G45–G46·8, I60–I61·9, I62·0–I62·03, I63–I63·9, I65–I66·9, I67·0–I67·3, I67·5–I67·6, I68·1–I68·2, I69·0–I69·398	430–435·9, 437·0–437·2, 437·5–437·8
Hypertensive heart disease	I11–I11·9	402–402·91
Alcoholic cardiomyopathy	I42·6	425·5
Aortic aneurysm	I71–I71·9	441–441·9
Chronic respiratory diseases		
Classifications	D86–D86·2, D86·89–D86·9, G47·3–G47·39, J30–J35·9, J37–J47·9, J60–J63·8, J65–J68·9, J70–J70·1, J70·8–J70·9, J82, J84–J84·9, J91–J92·9	135–135·9, 136·6, 327·2–327·8, 470, 470·9–474·9, 476–476·1, 477–479, 490–504·9, 506–506·9, 508–509, 515, 516–517·8, 518·6, 518·9, 519·1–519·4, 780·57, 786·03
Digestive diseases		
Cirrhosis and other chronic liver diseases due to hepatitis B	B18·0, B18·1	702–703
Cirrhosis and other chronic liver diseases due to hepatitis C	B18·2	704–705
Cirrhosis and other chronic liver diseases due to alcohol use	K70·0–K70·3	571·0–571·2
Peptic ulcer disease	K25–K28·9, K31, K31·1–K31·6, K31·8, K31·82–K31·89	531–534·91
Appendicitis	K35–K37·9, K38·3–K38·9	540–542·9
Inguinal, femoral, and abdominal hernia	K40–K42·9, K44–K46·9	550–551·1, 551·3–552·1, 552·3–553·03, 553·6
Gallbladder and biliary diseases	K80–K83·9, K87–K87·1	574–576·9
Pancreatitis	K85–K86·9	577–577·9, 579·4
Neurological disorders		
Alzheimer's disease and other dementias	F00–F03·9, G30–G31·1, G31·8–G31·9	290–290·9, 294·1–294·9, 331–331·2
Epilepsy	G40–G41·9	345–345·91
Substance use disorders		
Alcohol use disorders	F10–F10·9, G31·2, G72·1, P04·3, Q86·0, R78·0, X45–X45·9, X65–X65·9, Y15–Y15·9	291–291·9, 303–303·9, 305·0, 357·5, 790·3, E860
Drug use disorders	F11–F16·9, F18–F19·9, P04·4, P96·1, R78·1–R78·5	292–292·9, 304·0–304·8, 305, 305·1–305·9, 760·7, E850

(Table 1 continues on next page)

	ICD-10	ICD-9
(Continued from previous page)		
Diabetes, urogenital, blood, and endocrine diseases		
Diabetes	E10–E10·11, E10·3–E11·1, E11·3–E12·1, E12·3–E13·11, E13·3–E14·1, E14·3–E14·9, P70·0–P70·2, R73–R73·9	250–250·39, 250·5–250·99, 357·2, 775·0–775·1, 790·2–790·22
Acute glomerulonephritis	N00–N01·9	580–580·9
Chronic kidney disease	D63·1, E10·2–E10·29, E11·2–E11·29, E12·2, E13·2–E13·29, E14·2, I12–I13·9, N02–N08·8, N15·0, N18–N18·9	250·4–250·49, 403–404·93, 581–583·9, 585–585·9, 589–589·9
Other non-communicable diseases		
Congenital birth defects	P96·0, Q00–Q07·9, Q10·4–Q18·9, Q20–Q28·9, Q30–Q36, Q37–Q45·9, Q50–Q60·6, Q63–Q86, Q86·1–Q87·8, Q89–Q89·8, Q90–Q93·9, Q95–Q99·8	740–749·0, 749·2–752·9, 753·4–758·9, 759·0–759·8

ICD=International Statistical Classification of Diseases and Related Health Problems.

Table 1: **Causes of avertable mortality from non-communicable diseases**

	ICD-10	ICD-9
Neoplasms		
Nasopharynx cancer	C11–C11·9, D10·6	147–147·9, 210·7–210·9
Others pharynx cancer	C09–C10·9, C12–C13·9, D10·7	146–146·9, 148–148·9
Gallbladder and biliary tract cancer	C23–C24·9, D13·5	156–156·9
Pancreatic cancer	C25–C25·9, D13·6–D13·7	157–157·9, 211·6–211·7
Ovarian cancer	C56–C56·9, D27–D27·9, D39·1	183–183·0, 220–220·9, 236·2
Prostate cancer	C61–C61·9, D07·5, D29·1, D40·0	185–185·9, 222·2, 236·5
Kidney cancer	C64–C65·9, D30·0–D30·1, D41·0–D41·1	189·0–189·1, 189·5–189·6, 223·0–223·1
Brain and nervous system cancer	C70–C72·9	191–192·9
Non-Hodgkin lymphoma	C82–C86·6, C96–C96·9	200–200·9, 202–202·9
Multiple myeloma	C88–C90·9	203–203·9
Other malignant neoplasms	C17–C17·9, C30–C31·9, C37–C38·8, C40–C41·9, C47–C4A, C51–C52·9, C57–C57·8, C58–C58·0, C60–C60·9, C63–C63·8, C66–C66·9, C68·0–C68·8, C69–C69·9, C74–C75·8, D07·4, D09·2, D13·2–D13·3, D14·0, D15–D16·9, D28·0–D28·1, D28·7, D29·0, D30·2, D30·4–D30·8, D31–D31·9, D35–D35·2, D35·5–D36, D36·1–D36·7, D37·2, D38·2–D38·5, D39·2, D39·8, D41·2–D41·3, D44·1–D44·8, D48·0–D48·4	152–152·9, 158–158·9, 160–160·9, 163–164·9, 170–171·9, 181–181·9, 183·2–183·8, 184·0–184·4, 184·8, 187·1–187·8, 189·2–189·4, 189·8, 190–190·9, 194–194·8, 209·0, 209·4, 211·2, 211·8, 212·0, 212·4–212·8, 213–213·9, 221·0–221·8, 222·1, 222·8, 223·2, 223·8, 224–224·9, 227–228·9, 229·0, 229·8, 230·7–230·8, 233·4–233·5, 234·0–234·8, 235·4, 235·8, 236·1, 238·0–238·1, 239·2
Other neoplasms	D32–D33·9, D35·3–D35·4, D42–D43·9, D45–D47·9, D49·6, K62·0–K62·1, K63·5, N60–N60·9, N84·0–N84·1, N87–N87·9	225–225·9, 237–237·3, 237·5–237·9, 238·4–238·9, 239·6
Cardiovascular diseases		
Non-rheumatic valvular heart disease	I34–I37·8	424·0–424·3, 424·8
Myocarditis	B33·2, I40–I41·9, I51·4	422–422·9
Other cardiomyopathy	I42·1–I42·5, I42·7–I42·8, I43–I43·9	425·0–425·3, 425·7–425·8, 429·0
Atrial fibrillation and flutter	I48–I48·9	427·3
Peripheral artery disease	I70·2–I70·8, I73–I73·9	440·2, 440·4, 443·0–443·9
Endocarditis	I33–I33·9, I38–I39·9	421–421·9, 424·4–424·5, 424·9
Other cardiovascular and circulatory diseases	I28–I28·8, I30–I31·1, I31·8–I32·8, I47–I47·9, I51·0–I51·3, I68·0, I72–I72·9, I77–I83·9, I86–I89·0, I89·9, I98, K75·1	036·4, 417–417·9, 420–420·9, 423, 423·1–423·9, 427–427·2, 427·6–427·8, 442–443, 447–454·9, 456, 456·3–457, 457·1, 457·8–457·9, 459, 459·1–459·3
Digestive diseases		
Cirrhosis due to non-alcoholic steatohepatitis	K75·81	573·8
Cirrhosis and other chronic liver diseases due to other causes	B18·8–B18·9, K71·7, K73, K75·2–K75·8, K75·89, K75·9, K76·1–K76·2, K76·4–K76·9, K77·8	571·4–571·9, K72·2, 573·0, 573·4, 573·9
Gastritis and duodenitis	K29–K29·9	535–535·9
Paralytic ileus and intestinal obstruction	K56–K56·9	560–560·3, 560·8–560·9
Inflammatory bowel disease	K50–K52·9, M09·1	555–556·9, 558–558·9, 569·5
Vascular intestinal disorders	K55–K55·9	557–557·9

(Table 2 continues on next page)

	ICD-10	ICD-9
(Continued from previous page)		
Other digestive diseases	I84–I84·9, K20–K20·9, K22–K22·6, K22·8–K24, K31·0, K31·7, K38–K38·2, K57–K62, K62·2–K62·6, K62·8–K62·9, K64–K64·9, K66·8, K67, K68–K68·9, K77, K90–K90·9, K92·8, K93·8	455–455·9, 530–530·0, 530·2–530·7, 530·9, 536–536·1, 537–537·6, 537·8, 538, 543–543·9, 553·1–553·3, 562–562·1, 564–564·1, 564·5–564·7, 565–566·9, 569·1–569·4, 569·7, 579–579·2, 579·8–579·9
Neurological disorders		
Parkinson's disease	G20–G20·9	332–332·0
Multiple sclerosis	G35–G35·9	340–340·9
Motor neuron disease	G12·2–G12·9	335–335·2, 335·8–335·9
Other neurological disorders	G10–G12·1, G13–G13·8, G23–G24, G24·1–G25·0, G25·2–G25·3, G25·5, G25·8–G26·0, G36–G37·9, G61–G61·9, G70–G72, G72·2–G73·7, G90–G90·9, G95–G95·9, M33–M33·9	330–330·9, 331·5–331·9, 333–334·9, 335·3, 336–337·9, 341–341·9, 349, 349·2–349·8, 353·6–353·9, 356–356·9, 357·0–357·1, 357·3–357·4, 357·7, 358–359·9, 775·2
Mental disorders		
Eating disorders	F50·0–F50·5	307·1
Skin and subcutaneous diseases		
Bacterial skin diseases	A46–A46·0, A66–A67·9, I89·1–I89·8, L00–L05·9, L08–L08·9, L88, L97–L98·4, M72·5–M72·6	035–035·9, 102–103·9, 457·2–457·3, 680–689
Decubitus ulcer	L89–L89·9	707–707·9
Other skin and subcutaneous diseases	D86·3, L10–L14·0, L51–L51·9	694–695·3
Musculoskeletal disorders		
Rheumatoid arthritis	M05–M06·9, M08·0–M08·8	714–714·3, 714·8–714·9
Other musculoskeletal disorders	I27·1, I67·7, L93–L93·2, M00–M03·0, M03·2–M03·6, M07–M08, M08·9–M09·0, M09·2–M09·8, M30–M32·9, M34–M36·8, M40–M43·1, M65–M65·0, M71·0–M71·1, M80–M82·8, M86·3–M86·4, M87–M87·0, M88–M89·0, M89·5, M89·7–M89·9	416·1, 437·4, 446–446·9, 695·4–695·5, 710–711·9, 730·1, 732–732·9, 733·0–733·1
Other non-communicable diseases		
Urinary tract infections	N10–N12·9, N15, N15·1–N16·8, N30–N30·9, N34–N34·3, N39·0–N39·2	590–590·9, 595–595·9, 597–597·9, 599·0
Urolithiasis	N20–N23·0	592–592·9, 594–594·9, 788·0
Other urinary diseases	N25–N28·1, N29–N29·8, N31–N32·0, N32·3–N32·4, N36–N36·9, N39, N41–N41·9, N44–N44·0, N45–N45·9, N49–N49·9	588–588·9, 593–593·8, 596–596·9, 598–598·1, 598·8–599, 599·1–599·6, 599·8, 601–602·9, 604–604·9, 608·2
Gynaecological diseases	D25–D26, D28·2, E28·2, N72–N72·0, N75–N77·8, N80–N81·9, N83–N83·9	218–219, 219·1–219·9, 236·0, 256·4, 617–618·9, 620–620·9, 621·4–621·9, 622·3–622·6, 629–629·8
Haemoglobinopathies and haemolytic anaemias	D55–D58·9, D59·1, D59·3, D59·5, D60–D61·9, D64·0	282–284·9
Endocrine, metabolic, blood, and immune disorders	D52·1, D59·0, D59·2, D59·6, D66–D67, D68·0–D69·8, D70–D75·8, D76–D78·8, D86·8, D89–D89·3, E03–E07·1, E09–E09·9, E15·0, E16·0–E16·9, E20–E28·1, E28·3–E34·8, E36–E36·8, E65–E68, E70–E85·2, E88–E89·9, G24·0, G25·1, G25·4, G25·6–G25·7, G72·0, G93·7, G97–G97·9, I95·2–I95·3, I97–I97·9, I98·9, J70·0–J70·5, J95–J95·9, K43–K43·9, K62·7, K91–K91·9, K94–K95·8, M87·1, N14–N14·4, N65–N65·1, N99–N99·9, P96·2, P96·5, R50·2	240–243·9, 244·0–244·1, 244·3–244·8, 245–246·9, 251–256·3, 256·8–259·9, 270–273·9, 275–276, 277–277·2, 277·4–277·9, 278·0–278·8, 286–286·5, 286·7–289·7, 357·6, 518·7, 519·0, 536·4, 539–539·9, 551·2, 552·2, 564·2–564·4, 569·6, 579·3, 598·2, 775·3, 779·4–779·5
Sudden infant death syndrome	R95–R95·9	798–798·0

ICD=International Statistical Classification of Diseases and Related Health Problems.

Table 2: **Causes of non-avertable mortality from non-communicable diseases**

age-standardised YLL per 100 000 population on year. We configured the model to detect a maximum of five joinpoints and avoid segments comprising only two datapoints. We calculated AAPCs and 95% UI for 1990–2017 and subperiods (1990–99, 2000–09, and 2010–17), by sex (male, female, and both) at global, regional, and country levels. The AAPC is a summary measure of the trend over a prespecified fixed interval, computed as a weighted average (mean) of the annual percentage change of each time segment from the Joinpoint model, with weights equal to the length of each segment over time. We used the Monte Carlo method[30] with 4499 randomly permuted datasets to calculate the 95% UIs of the AAPCs, and the overall asymptotic significance level was maintained through a Bonferroni correction. We assumed constant variance (homoscedasticity) in age-standardised YLL over time. However, these tests also consider situations with non-constant variance, Poisson variation, and possible autocorrelation errors. AAPC is considered significant when it is different from zero at $\alpha=0\cdot05$. A constant trend was considered when the zero value was within both 95% UI limits for the AAPC, an increasing trend when both 95% UI limits were positive, and a decreasing trend when both 95% UI limits were negative.

Figure 1: **Global deaths by broad group of causes (A) and avertable and non-avertable deaths due to non-communicable diseases (B) by age group and sex, 2017**

Assessment of progress towards SDG target 3.4

We assessed progress towards SDG target 3.4 by estimating AAPC and 95% UI for 2010–17. Countries were considered on track if the upper 95% UI of the AAPC was –2·22% or lower (equivalent to a one-third reduction by 2030 relative to 2015 levels). Countries whose lower and upper 95% UI for AAPC exceeded –2·22% were categorised as progressing with a high chance of reaching the target. Countries with lower and upper 95% UIs of AAPC between –2·22% and 0% were categorised as progressing, but not on track. Countries in which the upper 95% UI of the AAPC was 0 or above were categorised as stagnating or deteriorating.

We did a decomposition analysis[31] of AAPC for premature avertable mortality from NCDs and NCD clusters by location and sex for 2010–17 to determine which causes of death drove overall trends. We calculated the change in premature avertable mortality from NCDs for each disease cluster using counterfactual scenarios: allowing premature avertable mortality from NCDs for each disease cluster to change as they did from 2010 to 2017, while keeping premature mortality constant at 2010 levels for other causes. We then calculated the fraction of change for each disease cluster relative to the sum of change of all nine clusters, and multiplied this fraction by the AAPC for all premature avertable mortality from NCDs—ie, making

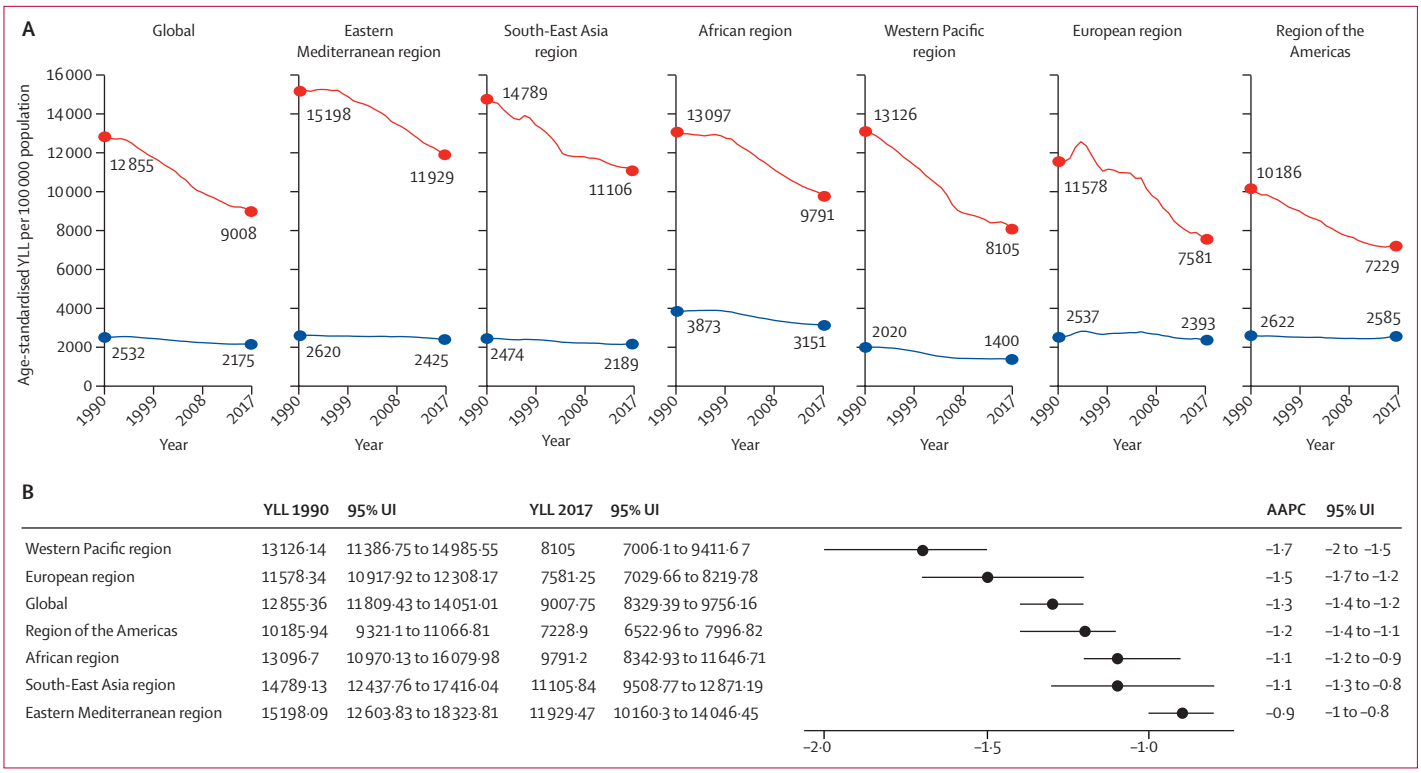

Figure 2: **Global and regional trends in age-standardised YLL lost due to premature avertable and non-avertable mortality from NCDs, 1990–2017**
(A) Avertable and non-avertable mortality from NCDs. Red=premature avertable mortality from NCDs. Blue=premature non-avertable mortality from NCDs. (B) Avertable mortality from NCDs. AAPC=average (mean) annual percentage change. NCDs=non-communicable diseases. YLL=years of life lost.

the fraction of change proportional to the rate of the change that would occur if each disease cluster alone had changed.

This analysis adheres to the Guidelines for Accurate and Transparent Health Estimates Reporting standards[32] developed by WHO and others (appendix 2 p 52).

Role of the funding source

No funding was received for this study. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

Globally, NCDs accounted for an estimated 41·1 million (95% UI 40·4–41·5) deaths in 2017, representing 73·5% (70·8–75·7) of all deaths. They caused a small proportion of deaths in childhood, but their share of all deaths increased rapidly with age until about 60 years, when the proportion plateaued at over 80% (figure 1A). Avertable NCDs accounted for the largest share of these deaths, 34·5 million (95% UI 33·4–35·6), or 83·9% (80·4–88·1) of all NCD deaths worldwide. In all age groups, more than 50% of NCD deaths are avertable, with the share increasing with age once individuals are older than 5 years (figure 1B).

The number of avertable global NCD deaths increased by 49·3% (95% UI 47·3 to 52·2) from 23·1 million (22·0 to 24·1) deaths in 1990 to 34·5 million (33·4 to 35·6) in 2017. Global age-standardised YLL per 100 000 population due to avertable NCDs declined substantially for both sexes combined, at an average (mean) annual rate of –1·3% (95% UI –1·4 to –1·2) from 12 885 years (95% UI 11 809 to 14 051) in 1990 to 9008 years (8329–9756) in 2017 (figure 2). In 2017, premature avertable mortality from NCDs was more than four times the rate for non-avertable NCDs, both globally (–0·5% [95% UI –0·6 to –0·5]) and for every WHO region.

For men, global premature avertable mortality from NCDs declined by –1·2% (95% UI –1·4 to –1·0) per year from 14 092 years (12 981 to 15 375) in 1990 to 10 187 years (9318 to 11 132) in 2017. It declined slightly faster among women, with an AAPC of –1·4% (95% UI –1·5 to –1·3), from 9997 years (8902 to 11 064) in 1990 to 6811 years (6186 to 7510) in 2017. However, this difference between sexes is not significant (appendix 2 pp 27–33).

This decline in global premature avertable mortality from NCDs changed over time in five segments: beginning slowly in 1990–94 (–0·27%), accelerating in 1994–2003 (–1·5%), further accelerating in 2003–07 (–2·26%), but decelerating in 2007–13 (–1·33%) and 2013–17 (–0·72%), when there were significant reductions (appendix 2 p 18). Trends were similar for both sexes.

Between 1990 and 2017, premature avertable mortality from NCDs fell substantially in every WHO region, with

AAPC ranging from –1·7 (95% UI –2·0 to –1·5) in the Western Pacific region to –0·9% (–1·0 to –0·8) in the Eastern Mediterranean region (figure 2). As with the global picture, these reductions were substantially higher for avertable than for non-avertable mortality from NCDs. In 2017, premature avertable mortality from NCDs was highest in the Eastern Mediterranean, followed by South-East Asia, and African regions with

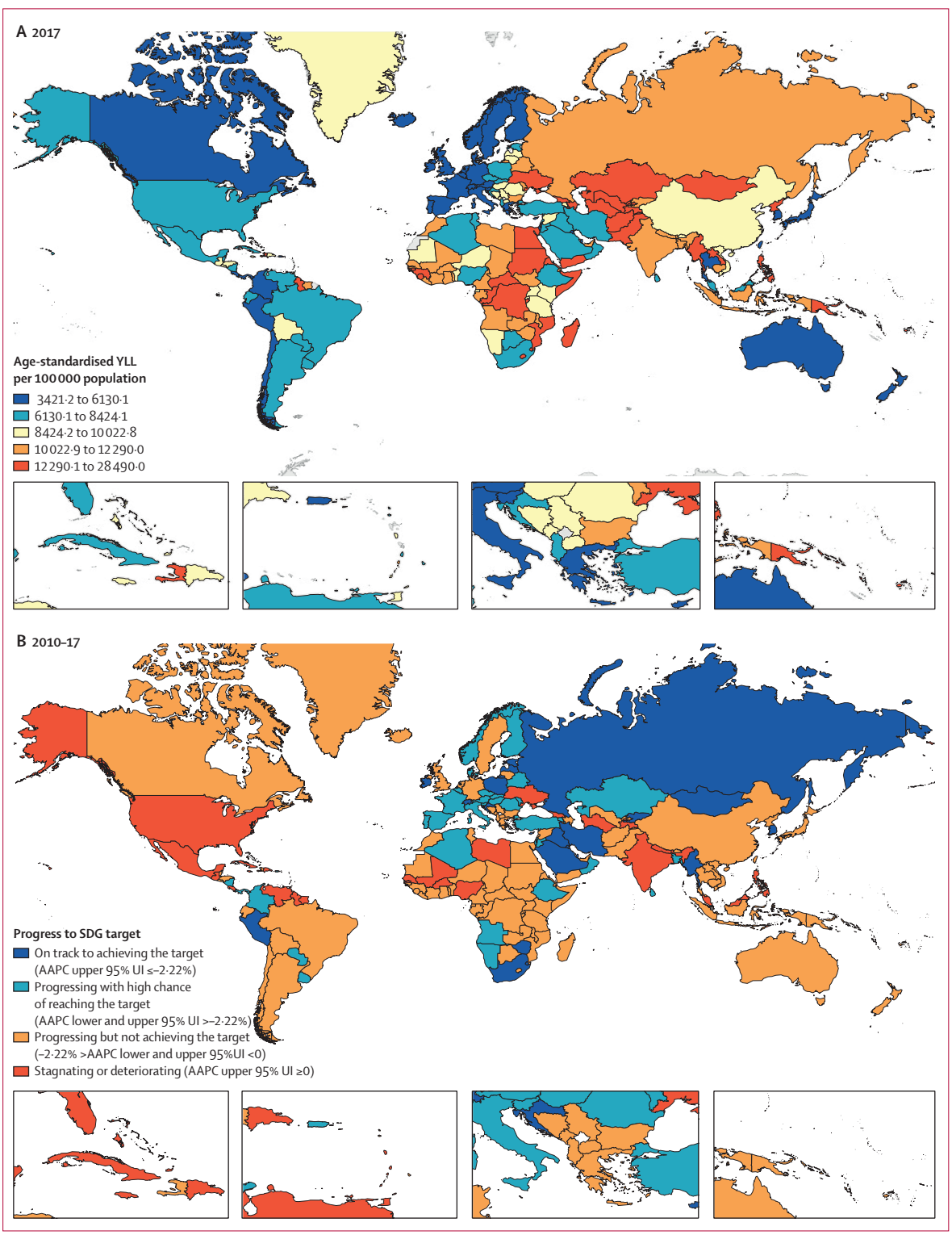

Figure 3: **Level and trends in premature avertable mortality from non-communicable diseases**
(A) Age-standardised YLL due to premature avertable mortality from NCDs for both sexes combined in 2017. Countries are colour coded on the basis of quintiles of the age-standardised YLL rates due to premature avertable mortality from NCDs. (B) AAPC in age-standardised YLL due to premature avertable mortality from non-communicable diseases for both sexes combined, 2010–17. Countries are colour coded by level of progress towards SDG target 3.4, as described in the Methods. Appendix 2 includes the distribution by sex (pp 34, 43) and numerical values (p 24). NCDs=non-communicable diseases. SDG=Sustainable Development Goal. AAPC=Average (mean) annual percentage of change. UI=uncertainty intervals. YLL=years of life lost.

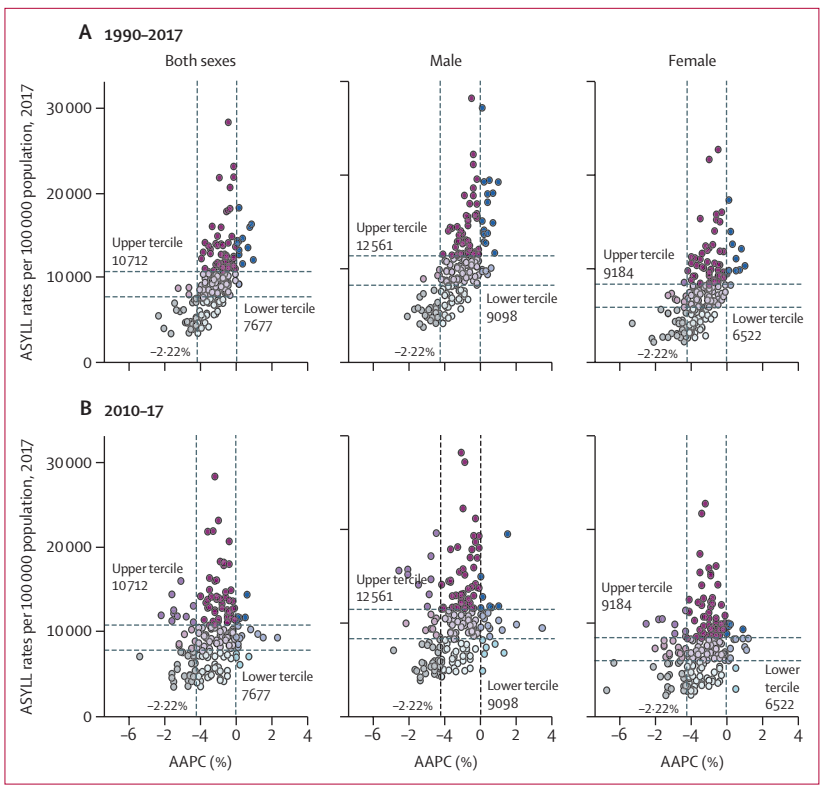

Figure 4: **ASYLL due to premature avertable mortality from NCDs in 2017 versus AAPC in 1990–2017 (A) and 2010–17 (B)**

Horizontal lines are the upper (67%) and lower (33%) terciles in age-standardised YLL due to premature avertable mortality from NCDs. Vertical lines represent the one-third reduction in AAPC by 2030, equivalent to –2·22%, and constant trend (zero value). Countries are colour coded according to nine quadrants created by the combination of age-standardised YLL rate terciles and AAPC cutoffs (–2·22% and 0). ASYLL=age-standardised years of life lost. AAPC=average (mean) annual percentage change. NCDs=non-communicable diseases.

levels over those observed globally (figure 2). Since 2013, premature non-avertable mortality from NCDs decreased slightly or stagnated in most regions, and rose in the Region of the Americas.

78 (40%) of 195 countries with high levels of premature avertable mortality from NCDs (over 10 022·9 years per 100 000 population) are low-income and middle-income countries in the South-East Asia, Eastern Mediterranean, and African regions (figure 3A). In 2017, premature avertable mortality from NCDs for both sexes combined was below 6130 years per 100 000 population in 41 countries, mostly high-income economies (36 of 41) (figure 3A). Premature avertable mortality from NCDs by sex in 2017 is shown in appendix 2 (pp 34–39). The ten countries of more than 2 million people with the highest levels of premature avertable mortality from NCDs (all >18 300 years per 100 000 population) were Afghanistan, the Central African Republic, Uzbekistan, Haiti, Mongolia, Turkmenistan, Pakistan, Ukraine, Laos, and Egypt. Singapore, Japan, Switzerland, Italy, and Israel had the lowest levels of premature avertable mortality from NCDs, with values below 4000 years per 100 000 population (appendix 2 pp 37–39).

For the **NCD Results Tool** see https://ais.paho.org/phip/viz/nmh-pam-ncds-tool.asp

Premature avertable mortality from NCDs fell in most countries between 1990 and 2017, with 14 exceptions (appendix 2 pp 24–33, pp 40–42). 163 (84%) of 195 countries had significant reductions in the AAPC for premature avertable mortality from NCDs between 2010 and 2017 (AAPC upper 95% UI ≤0%). However, only 25 countries had rates of decline significantly lower than –2·22% (ie, the required rate to be on track for achieving SDG target 3.4) for both sexes combined. Sex-disaggregated data are shown in appendix 2 (pp 43–48).

Figure 4 compares premature avertable mortality from NCDs in 2017 with the AAPC for 1990–2017 (figure 4A) and 2010–17 (figure 4B). Countries with fast declines in age-standardised YLL between 1990 and 2017 had low premature avertable mortality from NCDs by sex in 2017 (figure 4A). In countries with high premature avertable mortality from NCDs in 2017 (>67th percentile) the pace of reduction accelerated between 2010 and 2017 in both sexes combined and in each sex (figure 4B). However, Ukraine, Libya, and Nepal are the top three countries with both high rates of premature avertable mortality from NCDs in 2017 and an increasing trend in 2010–17 in both sexes combined (figure 4B).

Figure 5 shows the contributions of NCD clusters to overall trends in premature avertable mortality from NCDs between 2010 and 2017 by sex and region. Data by sex and country are given in appendix 2 (pp 49–51). Globally, for both sexes combined, all clusters (except diabetes and substance use disorders) contributed to the reduction in premature avertable mortality from NCDs (figure 5). Cardiovascular diseases, cancer, chronic respiratory diseases, congenital birth defects, and digestive diseases are the largest contributors, accounting for more than 80% of the overall decline. By contrast, substance use disorders slightly offset the decline in most of the regions, except the Americas. In the Americas, substance abuse disorders accounted for a 6% increase in the annual rate of change. The Western Pacific and European regions are the only two regions that are on track for reaching SDG target 3.4, assuming sustained progress until 2030.

A comprehensive set of estimates and interactive visualisations from this study are available online via the premature avertable mortality NCD Results Tool.

Discussion

To our knowledge, this is the first study that thoroughly assesses NCD mortality without arbitrary restrictions by age or disease category. Premature avertable mortality from NCDs shows the YLLs that could be averted if NCD risk factor exposures of populations were reduced to a theoretical minimum level and good quality health care was universally available. The high variation in premature avertable mortality from NCDs across countries in 2017 (range: 3421–28 490) indicates that levels in many countries can be considered excessively high. As such, we consider premature avertable mortality from NCDs to be a robust, comprehensive,

and actionable indicator for assessing performance in reducing NCD mortality and a powerful concept for informing public health and policy. For these reasons, and in the light of known concerns about the existing indicator set out by the *Lancet* NCD Countdown 2030 Collaborators[5] and others,[4] we argue that it should be adopted as the gold standard.

Our study includes two important innovations. First, we review, update, and apply a new list of avertable burden conditions, which is exhaustive, comprehensive, and globally applicable. Second, we decompose overall changes in premature avertable mortality from NCDs by NCD clusters, going beyond the four NCD clusters (cancer, cardiovascular diseases, respiratory disease, and all other NCDs) used by the NCD Countdown 2030 report[5] to include eight clusters that account for avertable mortality. This approach allows for the identification of causes contributing to change in premature avertable mortality from NCDs.

WHO regions represent a heterogeneous set of countries and their overall epidemiological profiles are strongly shaped by the most populous countries. For example, the reduction in premature avertable mortality from NCDs in the Western Pacific region is largely due to the rapid decline achieved by China.[33] Similarly, the early 1990s spike in such mortality in the European region is mainly driven by trends in formerly socialist economies in eastern Europe.[34] The deceleration in the decline and subsequent reversal in this measure in the Americas since 2013 is explained by the notable increase in premature mortality from substance use disorders in the USA (appendix 2 pp 49–51).[35]

Notably, the Eastern Mediterranean region—the worst performing region in terms of premature avertable mortality from NCDs—is facing numerous health challenges related to armed conflicts and political crises.[36] However, this is a descriptive study, which is not intended to assess the effects of specific public policies, interventions, or changing national circumstances. Interpretation of these trends in premature avertable mortality from NCDs should be done with great caution. For example, it is important to assess the relative contributions of NCD incidence and survival rates. Mortality attributable to premature avertable mortality from NCDs will be affected by competition from deaths from non-NCD causes, especially those at young ages, which is a particular concern in conflict situations. There might also be time lags between the reduction of amenable mortality and the introduction of interventions and policies. There is a need for more nuanced analysis of these effects in future studies of premature avertable mortality from NCDs.

Despite the global reduction in premature avertable mortality from NCDs, our analysis showed that only the Western Pacific and European regions and 25 countries (mostly high-income economies) are on track to achieve SDG target 3.4. This finding is consistent with values reported by NCD Countdown 2030,[5] and raises concerns about the global community's ability to meet the SDG commitments. Worldwide in 2017, 9008 years of life per 100 000 population were lost due to conditions amenable to effective public policies, health interventions, and health care. This global level is almost three times the best performing countries (3421 YLLs per 100 000 population), showing what can theoretically be achieved. 65 countries had what can be considered high levels of premature avertable mortality from NCDs in 2017 (over the upper tercile of the distribution by country, equivalent to 10 712 YLL per 100 000 population), the most populous examples being Afghanistan, the Central African Republic, Uzbekistan, Haiti, Mongolia, Turkmenistan, Pakistan, Ukraine, Laos, and Egypt. Some countries, including Ukraine, Libya, and Nepal, present both high rates of premature avertable mortality from NCDs and an increasing trend since 2010.

Most NCD clusters have contributed to the overall reduction in premature avertable mortality from NCDs,

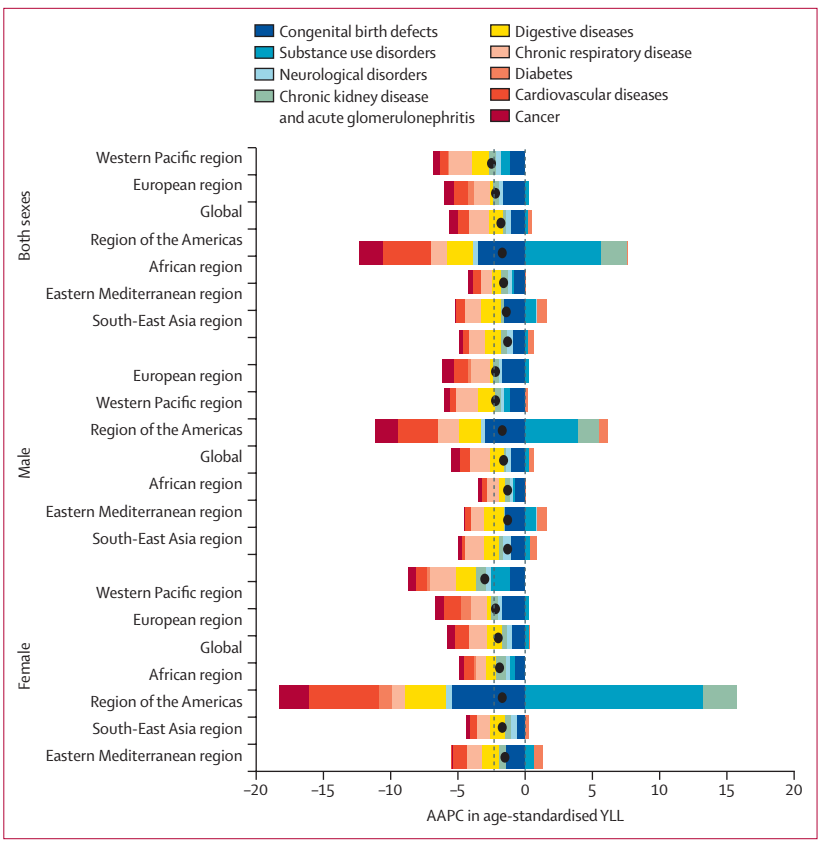

Figure 5: **Contributions of NCD clusters to the overall AAPC in the age-standardised YLL due to premature avertable mortality from NCDs by sex and region, 2010–17**

The black dot shows the overall AAPC in the age-standardised YLL due to premature avertable mortality from NCDs for 2010–17. Bars show the contribution to change due to constituent NCD clusters, calculated so that their net effect equals the overall AAPC. Vertical lines represent the one-third reduction in AAPC by 2030, equivalent to –2·22%, and constant trend (zero value). Contributions of avertable NCD clusters to the overall AAPC in age-standardised YLL due to premature avertable mortality from NCDs by sex and country are in appendix 2 (pp 49–51). AAPC=average (mean) annual percentage change. YLL=years of life lost. NCDs=non-communicable diseases.

but substance use disorders, chronic kidney disease and acute glomerulonephritis, and diabetes counteract this reduction in many countries and regions. Of these diseases, only diabetes is included as one of the four major NCDs promoted by global targets. Substance use disorders is an emerging and complex public health issue, now referred to as one of the so-called diseases of despair, which is especially marked in parts of the USA[35] and is an emerging concern for other countries, such as the UK.

Our approach has limitations associated with the use of GBD data,[23,24,26] especially when high-quality vital registration systems are lacking, in terms of completeness, coverage, and medical certification, or complete absence of vital registration, and estimates are mostly based on modelling. Although the method used by the GBD study to estimate deaths and death rates by cause, the Cause of Death Ensemble model (CODEm), outperforms previous approaches, it is inevitably subject to problems in capturing data on the covariates used in CODEm, the treatment of outliers, and the rules used for redistribution of garbage codes.[37] Nevertheless, the concept of YLL due to premature avertable mortality from NCDs offers a comprehensive and robust measure for monitoring NCD mortality. We used an alternative method to assess uncertainty to that applied by GBD. Although the point estimates of our comparison are identical to those derived from GBD methods, indicating that our comparison is valid, our method of assessing uncertainty is much more conservative than GBD (appendix 2 p 12). This difference is not surprising as the GBD method uses considerably more data. Our inferences based on the significance of differences between groups are also conservative, so we might have missed some significant findings (type 1 error) that are detectable by GBD methods. Re-running our analyses using GBD methods for assessing uncertainty would not result in any changes to the significant differences we have described, but might reveal further, smaller, differences that we would have rejected as non-significant.

A one-third reduction of premature avertable mortality from NCDs by 2030 relative to its level in 2015 is a very ambitious goal, since it includes all preventable and treatable NCDs, and deaths at all ages. Measuring premature avertable mortality from NCDs allows for comparison of how countries succeed (or not) in preventing and delaying deaths from conditions amenable to public health interventions and health care. This goal and measure should spur countries that are currently off track to re-evaluate and strengthen their action plans, including those for universal health care. Our study sounds an alarm about the global slowdown of the reduction in premature avertable mortality from NCDs since 2007—calling for more robust, politically committed responses to the social determinants of NCDs, effective public health interventions, and universal good quality health care for all.

Contributors

RM, PL-S, SE, PO, and MM conceived the idea for the study and designed it. RM, PS, and PO created the list of avertable causes. RM and PO analysed the data and drafted the manuscript. All authors interpreted the findings and prepared the manuscript.

Declaration of interests

We declare no competing interests.

Acknowledgments

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References

1 WHO. NCD global monitoring framework. 2013. https://www.who.int/nmh/global_monitoring_framework/en/ (accessed July 20, 2019).
2 UN. Transforming our world: the 2030 agenda for sustainable development. 2015. https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E (accessed July 20, 2019).
3 Lloyd-Sherlock P, Ebrahim S, McKee M, Prince M. A premature mortality target for the SDG for health is ageist. *Lancet* 2015; **385:** 2147–48.
4 Lloyd-Sherlock P, Ebrahim S, Martinez R, McKee M, Ordunez P. Reducing the cardiovascular disease burden for people of all ages in the Americas region: analysis of mortality data, 2000–15. *Lancet Glob Health* 2019; **7:** e604–12.
5 NCD Countdown 2030 collaborators. NCD Countdown 2030: worldwide trends in non-communicable disease mortality and progress towards Sustainable Development Goal target 3.4. *Lancet* 2018; **392:** 1072–88.
6 Rutstein DD, Berenberg W, Chalmers TC, et al. Measuring the quality of medical care. A clinical method. *N Engl J Med* 1976; **294:** 582–88.
7 Charlton JR, Velez R. Some international comparisons of mortality amenable to medical intervention. *Br Med J (Clin Res Ed)* 1986; **292:** 295–301.
8 Rutstein DD, Berenberg W, Chalmers TC, Fishman AP, Perrin EB, Zuidema GD. Measuring the quality of medical care: second revision of tables of indexes. *N Engl J Med* 1980; **302:** 1146.
9 Tobias M, Yeh LC. How much does health care contribute to health gain and to health inequality? Trends in amenable mortality in New Zealand 1981–2004. *Aust NZ J Public Health* 2009; **33:** 70–78.
10 Gay JG, Paris V, Devaux M, de Looper M. Mortality amenable to health care in 31 OECD countries. Paris: Organisation for Economic Co-operation and Development. 2011. http://www.oecd-ilibrary.org/content/workingpaper/5kgj35f9f8s2-en (accessed Oct 10, 2019).
11 Nolte E, McKee M. Variations in amenable mortality—trends in 16 high-income nations. *Health Policy* 2011; **103:** 47–52.
12 Nolte E, McKee CM. Measuring the health of nations: updating an earlier analysis. *Health Aff (Millwood)* 2008; **27:** 58–71.
13 Nolte E, McKee CM. In amenable mortality—deaths avoidable through health care—progress in the US lags that of three European countries. *Health Aff (Millwood)* 2012; **31:** 2114–22.
14 Nolte E, McKee M. Does healthcare save lives? Avoidable mortality revisited. London: Nuffield Trust, 2004.
15 Fullman N, Yearwood J, Abay SM, et al. Measuring performance on the Healthcare Access and Quality Index for 195 countries and territories and selected subnational locations: a systematic analysis from the Global Burden of Disease Study 2016. *Lancet* 2018; **391:** 2236–71.
16 Kruk ME, Gage AD, Joseph NT, Danaei G, García-Saisó S, Salomon JA. Mortality due to low-quality health systems in the universal health coverage era: a systematic analysis of amenable deaths in 137 countries. *Lancet* 2018; **392:** 2203–12.
17 Weber A, Clerc M. Deaths amenable to health care: converging trends in the EU? *Health Policy* 2017; **121:** 644–52.
18 Canadian Institute for Health Information. Health Indicators 2012. 2012. https://secure.cihi.ca/estore/productFamily.htm?locale=en&pf=PFC1791 (accessed July 1, 2019).

19 Franco-Marina F, Lozano R, Villa B, Soliz P. La Mortalidad en México, 2000–2004 "Muertes Evitables: magnitud, distribución y tendencias". México: D F Dirección General de Información en Salud, Secretaría de Salud, 2006.

20 Carvalho Malta D, Duarte EC, Furquim de Almeida M, et al. List of avoidable causes of deaths due to interventions of the Brazilian Health System. *Epidemiol. Serv. Saúde, Brasília* 2007; **16:** 233–44.

21 Tobias M, Lewis C; New Zealand Ministry of Health. Defining amenable mortality. September, 2016. https://nsfl.health.govt.nz/system/files/documents/pages/defining_amenable_mortality_sept2016.docx (accessed July 1, 2019).

22 Global Burden of Disease Collaborative Network. Global Burden of Disease study 2017 (GBD 2017) causes of death and nonfatal causes mapped to ICD codes. 2018. http://ghdx.healthdata.org/record/ihme-data/gbd-2017-cause-icd-code-mappings (accessed June 2, 2019).

23 Roth GA, Abate D, Abate KH, et al. Global, regional, and national age-sex-specific mortality for 282 causes of death in 195 countries and territories, 1980–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* 2018; **392:** 1736–88.

24 GBD 2017 Mortality Collaborators. Global, regional, and national age-sex-specific mortality and life expectancy, 1950–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* 2019; **92:** 1684–735.

25 Martinez R, Soliz P, Caixeta R, Ordunez P. Reflection on modern methods: years of life lost due to premature mortality—a versatile and comprehensive measure for monitoring non-communicable disease mortality. *Int J Epidemiol* 2019; **48:** 1367–76.

26 GBD 2017 Population and Fertility Collaborators. Population and fertility by age and sex for 195 countries, 1950–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* 2018; **392:** 1995–2051.

27 Global Burden of Disease Collaborative Network. Global Burden of Disease study 2017 (GBD 2017) population estimates 1950–2017. 2018. http://ghdx.healthdata.org/record/ihme-data/gbd-2017-population-estimates-1950-2017 (accessed July 10, 2019).

28 Ahmad OB, Boschi-Pinto C, Lopez AD, et al. Age standardization of rates: a new WHO standard. 2001, http://www.who.int/healthinfo/paper31.pdf (accessed March 6, 2019).

29 National Cancer Institute. Joinpoint regression programme. Version 4.7.0.0. June, 2019. https://surveillance.cancer.gov/joinpoint/ (accessed June 16, 2019).

30 Kim HJ, Fay MP, Feuer EJ, Midthune DN. Permutation tests for joinpoint regression with applications to cancer rates. *Stat Med* 2000; **19:** 335–51.

31 Das Gupta P. Standardization and decomposition of rates: a user's manual. US Department of Commerce. Bureau of Census. 1993. https://www.census.gov/library/publications/1993/demo/p23-186.html (accessed Aug 18, 2019).

32 Stevens GA, Alkema L, Black RE, et al. Guidelines for Accurate and Transparent Health Estimates Reporting: the GATHER statement. *Lancet* 2016; **388:** e19–23.

33 Zhou M, Wang H, Zeng X, et al. Mortality, morbidity, and risk factors in China and its provinces, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* 2019; **394:** 1145–58.

34 Starodubov VI, Marczak LB, Varavikova E, et al. The burden of disease in Russia from 1980 to 2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet* 2018; **392:** 1138–46.

35 Nosrati E, Ash M, Marmot M, McKee M, King LP. The association between income and life expectancy revisited: deindustrialization, incarceration and the widening health gap. *Int J Epidemiol* 2017; **47:** 720–30.

36 GBD 2015 Eastern Mediterranean Region Collaborators. Danger ahead: the burden of diseases, injuries, and risk factors in the Eastern Mediterranean Region, 1990–2015. *Int J Public Health* 2018; **63** (suppl 1): S11–23.

37 Foreman KJ, Lozano R, Lopez AD, Murray CJL. Modeling causes of death: an integrated approach using CODEm. *Popul Health Metr* 2012; **10:** 1.