Current Diabetes Reports (2019) 19: 44
https://doi.org/10.1007/s11892-019-1161-2

MACROVASCULAR COMPLICATIONS IN DIABETES (VR ARODA AND A GETANEH, SECTION EDITORS)

Global Updates on Cardiovascular Disease Mortality Trends and Attribution of Traditional Risk Factors

Ram Jagannathan[1] · Shivani A. Patel[2] · Mohammed K. Ali[2] · K. M. Venkat Narayan[2]

Published online: 20 June 2019

Abstract

Purpose of Review The last 2–3 decades have witnessed a decline in age-standardized cardiovascular mortality rates in high-income regions, whereas this has only slightly decreased or even increased in most of the low- and middle-income countries. A systematic comparison of global CVD mortality by regions attributable to various modifiable risk factors such as diabetes, obesity, hypertension, poor diet, and physical inactivity is not available.

Recent Findings We present a summary of time trends and heterogeneity in the distribution of global CVD mortality and the attribution of risk factors between 1990 and 2017 using the Global Burden of Disease (GBD) 2017 study. Globally, an estimated ~ 17.8 million (233.1 per 100,000) people died of CVD in 2017. The rate of CVD death was decreased in high-income countries (1990: 271.8 (95% UI (uncertainty interval), 270.9–273.5); 2017: 128.5 (95% UI, 126.4–130.7) per 100,000)) whereas it remained the same in lower- and middle-income countries (1990: 368.2 (95% UI, 335.6–383.3); 2017: 316.9 (95% UI, 307.0–325.5) per 100,000). Among the various traditional risk factors, high systolic blood pressure, unhealthy diet, high fasting plasma glucose, and high low-density lipoprotein levels were attributed to most of the CVD death and disability-adjusted life year lost. We also observed gender variations in tobacco and increased alcohol consumption. In addition to the traditional risk factors, poor air quality is associated with increased CVD burden in developing countries.

Summary Surveillance, country-specific guidelines, evidence-based policies, reinforcement of multisectoral health systems, and innovative solutions are urgently needed in resource-challenged settings to curb CVD risk factors and overall burden.

Keywords Global burden of diseases · Non-communicable diseases · Cardiovascular diseases · Risk factors · The epidemiological transition · Disparities · Body mass index · Type 2 diabetes · Hypertension · Evidence-based medicine

Abbreviations

NCD	Non-communicable diseases
CVD	Cardiovascular diseases
HIC	High-income countries
LMIC	Low-middle income countries
WHO	World Health Organization
GBD	Global Burden of Diseases
UI	Uncertainty intervals
DALYs	Disability-adjusted life years
CRA	Comparative risk assessment

This article is part of the Topical Collection on *Macrovascular Complications in Diabetes*

✉ Ram Jagannathan
ram.jagannathan@emory.edu

Shivani A. Patel
s.a.patel@emory.edu

Mohammed K. Ali
mkali@emory.edu

K. M. Venkat Narayan
knaraya@emory.edu

1 Division of Hospital Medicine, Emory University School of Medicine, 5206 Woodruff Memorial Research Building, 101 Woodruff Circle, Atlanta, GA 30322, USA

2 Rollins School of Public Health, Emory University, Atlanta, GA, USA

Introduction

Non-communicable diseases (NCDs) are recognized as "the dominant public health challenge of the 21st-century" [1] and a "public health emergency in slow motion." NCDs account for nearly two-thirds of all global deaths. These estimates had been steadily increasing over time from ~ 26.8 million deaths due to NCDs in 1990 to 41.1 million deaths worldwide in 2017 and ~ 74% in 2017 [2••]. Importantly, NCDs are not only a high-income country problem: ~ 80% of premature deaths attributed to NCDs occur in low- and middle-income regions. Cardiovascular disease (CVD) is the leading NCD, accounting for ~ 50% of the world's NCD-related deaths and a significant barrier to sustainable human development. In substantial part, CVD is preventable, closely linked to a range of perilous albeit modifiable behaviors such as unhealthy dietary pattern, tobacco consumption, physical inactivity, social stressors, and harmful use of alcohol.

A natural question of scientific and public health importance is to address the disparities in global CVD mortality and how traditional cardiovascular behavioral risk factors have affected the global burden of CVD. Notably, the risk attribution and trends of behavioral risk factors such as unhealthy diet, physical inactivity, and tobacco smoking and metabolic risk factors such as increased levels of body mass index, fasting plasma glucose, cholesterol levels, and systolic blood pressure have been sparingly studied. Therefore, in this *report*, we summarize global and regional trends and variations in the number of CVD deaths attributed to traditional cardiovascular risk factors using data from the Global Burden of Disease (GBD) 2017 study.

Global Burden of Diseases: an Overview

The GBD 2017 study is an endeavor to continuously document disease burden by integrating the available data on disease incidence, prevalence, and mortality to create harmonized, transparent, and up-to-date global, regional, and national estimates (Table 1). Detailed descriptions of the study and updated methodology used for CVD burden estimation have been explained in previous publications [3–5].

Overall Trends: Changes in Number Affected and Rates of Disease

The absolute numbers of CVD-related deaths increased globally and in most regions between 1990 and 2017 (Fig. 1a, b). For instance, in 1990, the global age-standardized CVD death rate was 379.4 per 100,000 (95% uncertainty interval (UI), 372.5–386.9) for men which had fallen to per 275.5 per 100,000 (95% UI, 270.5–280.6) by 2017, a 27.4% decline. Despite the rate reduction, however, the absolute number of CVD deaths over the same period increased from 5.9 (95% UI, 5.8–6.1) million to 9.3 million (95% UI, 9.2–9.5), a 54% increase (Fig. 1a). Similarly, the age-standardized rates of CVD death for women decreased from 297.4 per 100,000 in 1990 (95% UI, 292.4–305.6) to 196.1 per 100,000 (95% UI, 192.0–200.0), a 34% decrease, whereas the number of deaths increased from 6.0 million (95% UI, 5.9–6.2) to 8.4 million (95% UI, 8.3–8.6) in 2017, a 40% increase (Fig. 1b).

Table 1 Global Burden of Diseases overview

The GBD is a multinational collaborative research project with the aim of producing harmonized estimates of health loss due to 359 causes of disease and injuries and 3484 sequelae in 195 countries and territories. In total, 68,781 data sources were used in the estimation process for GBD 2017. The GBD was commissioned in the early 1990s and featured in the landmark World Development Report 1993. In 2000, the comparative risk assessment (CRA) module of the GBD database was launched which includes 26 risk factors, about one-third of which were linked with CVD. The results of the CRA study formed the basis for the World Health Report 2002: *Reducing Risks, Promoting Healthy Life.* A wide range of data sources and methods were employed to produce age-, sex-, and country-specific results for the years 1990–2017 (time points (years): 1990, 1995, 2000, 2005, 2006, 2010, 2016, and 2017).
In the GBD 2017 study, the burden of CVD was estimated for the ten most common global causes of CVD-related deaths and an additional category that combined all other CVD and circulatory conditions. Deaths due to each underlying CVD cause were identified using the categorization of International Classification of Diseases (ICD) codes. Results are updated annually for the entire time-series, and these results supersede preceding versions of GBD findings. As of 2017, the database captures 84 different risk factors. Even though the GBD study is the most extensive database to date, it only provides modeled estimates rather than observed data.

The table was generated using publicly available web-based data visualization tools

Income Group Disparities in Total CVD Mortality and Absolute Burden in 2017

Globally, an estimated ~ 17.8 million people (95% UI, 17.5–18.0 million) worldwide died of CVD in 2017. The rate of CVD death was ~ 3 times higher in lower- and middle-income countries than in high-income countries, with lower-middle-income countries experiencing the highest rates of the four groups. Correspondingly, the estimated global age-standardized CVD mortality rates in 2017 were 233.1 per 100,000; 128.5 (95% UI, 126.4–130.7) per 100,000 in high-income countries; 254.1(95% UI, 249.4–258.6) in upper-middle-income countries; 316.9 (95% UI, 307.0–325.5) in lower-middle-income countries; and 285.3 (95% UI, 270.5–300.2) in low-income countries. In high-income countries, the largest burden tended to occur in older age groups (> 70 years), while in low- and middle-income countries, the largest burden was noted in the middle-aged groups (e.g., 40 to 59 years) which are the most economically productive years.

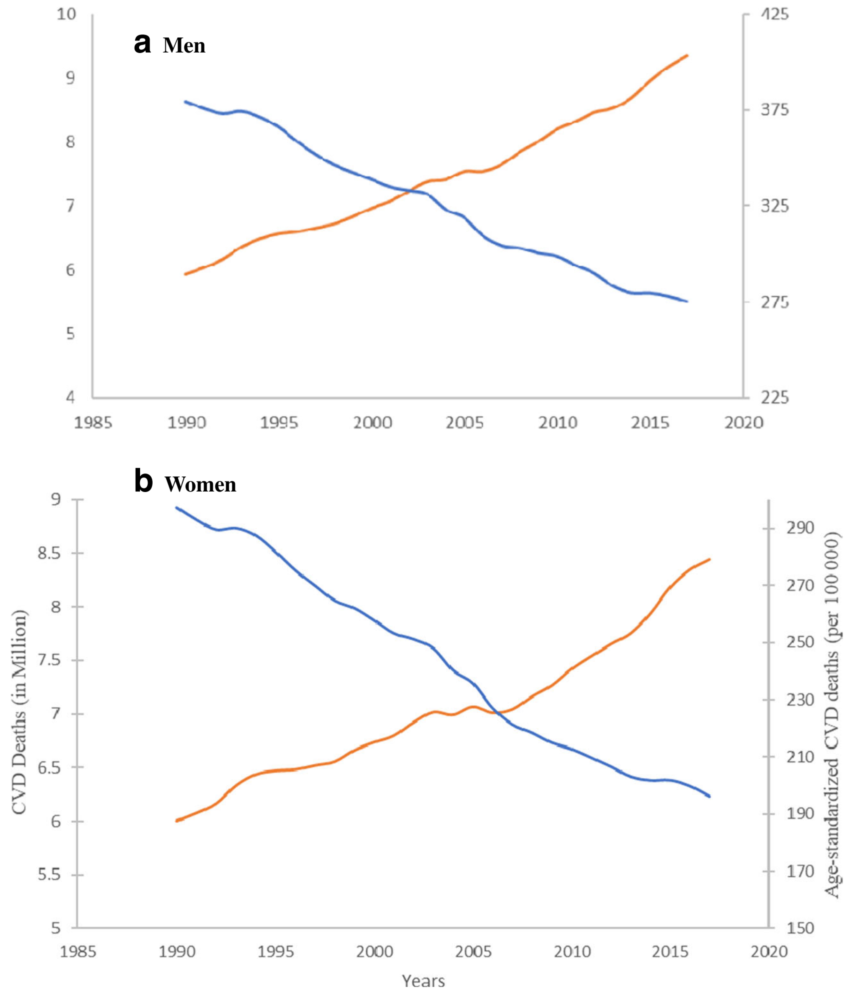

Fig. 1 Age-standardized CVD deaths (per 100,000) over the same period of men (**a**) and women (**b**)

Regional Shifts in CVD Mortality from 1990 to 2017

In 1990, the lowest age-standardized CVD mortality (< 250 deaths per 100,000) was observed in predominantly high-income regions (15 countries provided data on men, and 48 countries provided data for women; Figs. 2 and 3). The highest age-standardized CVD mortality rates (> 725 per 100,000) were in Bulgarian and Estonian men and Afghani women. By 2017, 116 countries in women and 83 countries in men had an age-standardized CVD mortality rate of < 250 per 100,000, with the lowest mortality rates estimated in most of the high-income countries such as Taiwan, Japan, Singapore, Spain, Switzerland, and France. At the other extreme, age-standardized CVD mortality rates in 2017 were > 700 per 100,000 in men and women living low- and middle-income countries in Europe and Central Asia, and Eastern-Mediterranean countries such as Uzbekistan, Azerbaijan, Ukraine, Turkmenistan, and Afghanistan.

Explaining the High and Rising Burden of CVD Mortality in LMICs

Sociodemographic change over the past three decades was associated with dramatic CVD decline in high- and middle-income regions, but only explains a gradual decrease or no change in most of the low- and middle-income countries. This sociodemographic change is related to the concept of the "epidemiologic transition," which describes the population-level shift in morbidity from largely infectious diseases and nutritional disorders over to morbidity largely due to chronic diseases [6]. The epidemiologic transition is one way of examining the growth of CVD in low- and middle-income countries. The stage of transition and causes for each region differ considerably and may consequentially impact the timing and magnitude of regional mortality and economic burdens. This transition stems from various "upstream" factors such as industrialization, unplanned urbanization, changes in lifestyle, medical innovation, changes in screening and diagnostic criteria, and the improved understanding of diseases [7]. The factors impact more proximal risk factors, as discussed below.

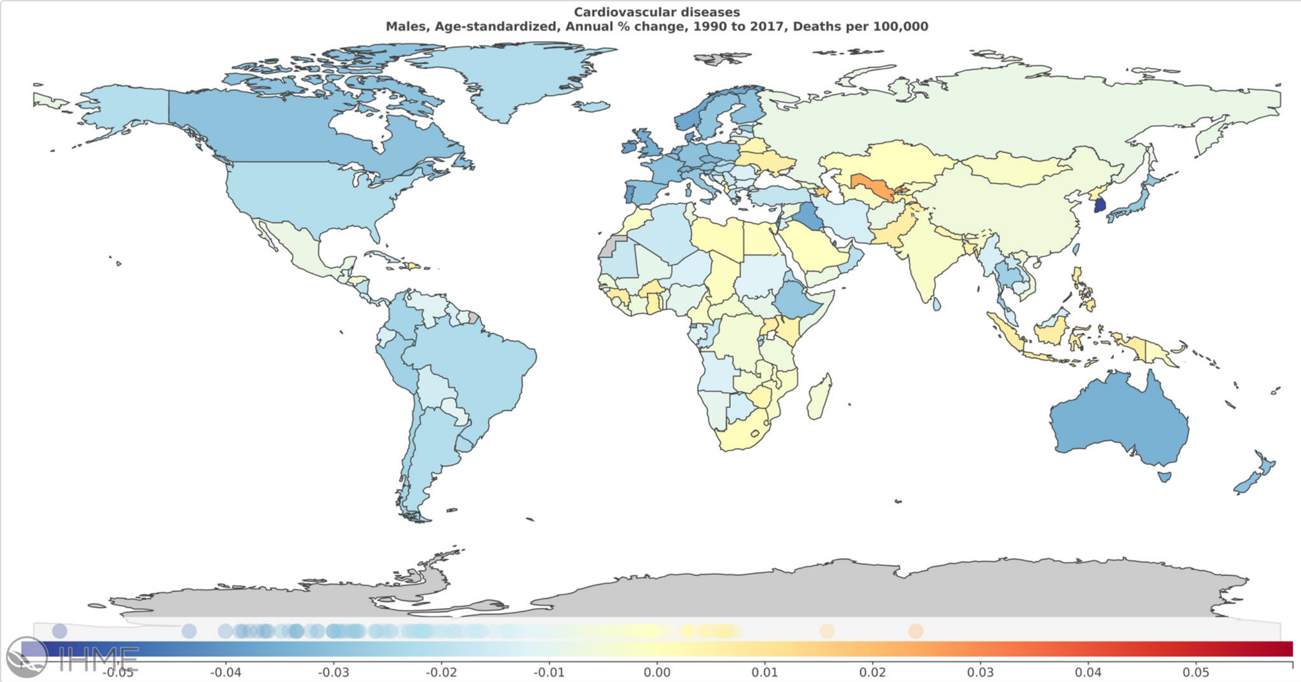

Fig. 2 Male percent change in the age-standardized CVD mortality rate map from 1990 to 2017

CVD Risk Factors: Overview

There is an overwhelming consensus that the so-called conventional or lifestyle risk factors such as unhealthy dietary habits (higher intake of sodium and meat and lower consumption of fruits, nuts, and vegetables), physical inactivity, and tobacco use are strongly linked with growing CVD burdens. There is incontrovertible evidence that these lifestyle risk factors are strongly related to metabolic diseases such as hypertension, obesity, dyslipidemia, and dysglycemia (prediabetes and type 2 diabetes) which are independent precursors of CVD. There are other non-modifiable risk factors such as increasing age, male sex, genetics, and parental history of CVD which may be considered when considering screening and intervention for potential CVD.

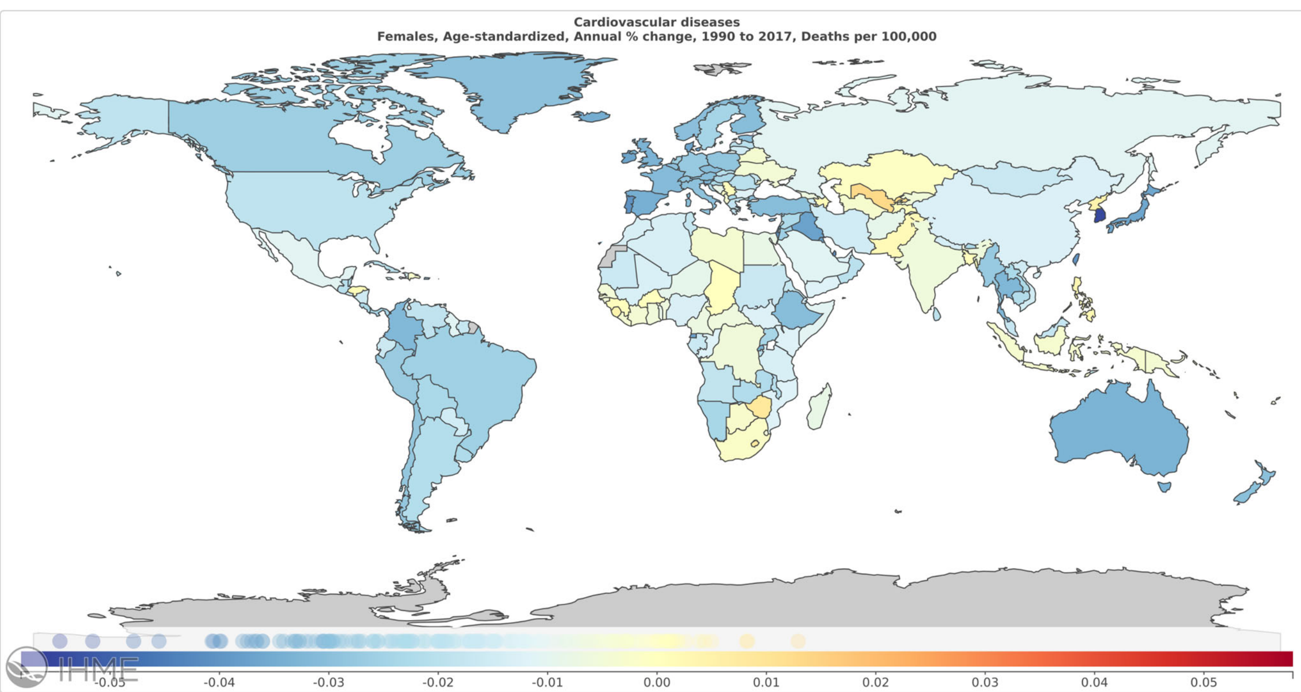

Fig. 3 Female percent change in the age-standardized CVD mortality rate map from 1990 to 2017

CVD Mortality and Disability-Adjusted Life Years Attributable to Traditional Risk Factors by Gender

Table 2 and Fig. 4 show the contribution of these selected behavioral and metabolic risk factors for CVD mortality and disability-adjusted life years (DALYs) between 1990-2017 stratified by sex and region respectively. The preponderance levels of CVD risk factors such as high systolic blood pressure, high fasting plasma glucose, high lipoprotein cholesterol, poor diet, and low physical activity in most of the low- and middle-income countries indicate that CVD burden can be expected to increase further as populations age.

Diabetes Prevalence and Management

Since 1980, age-standardized type 2 diabetes prevalence and overall fasting plasma glucose levels increased in each country [8•]. The International Diabetes Federation projected that ~425 million adults had diabetes worldwide in 2017, and by 2045, this estimate is expected to rise to 629 million. The most substantial disease burden (~80%) will occur in regions undergoing economic transitions from low-income to middle-income countries [9]. While the burden of diabetes is rising, associated CVD mortality from diabetes has been declining in most (but not all) of the high-income regions, probably because of the improved management of diabetic macrovascular complications. Systematic efforts to screen for dysglycemia (prediabetes and diabetes) were implemented in high-income countries and may have increased awareness and action in patients but can be resource-intensive [10–13]. Improvement in diabetes and blood pressure management by clinical interventions can be useful, although there are recent debates on the appropriate treatment targets to reduce CVD events [14, 15]. Furthermore, in the majority of the low- and middle-income countries, adequate health care delivery models that achieve goals identified in diabetes management guidelines are not yet available and implemented. Recently, studies in India and Hong Kong have shown that implementation of scalable, multicomponent quality improvement care models can improve diabetes management in resource-challenged settings [16, 17].

Systolic Blood Pressure

Globally, high systolic blood pressure is the leading cause of CVD deaths and the second leading cause of DALYs in 2017 (9.7 million deaths and 200.5 million DALYs). The increase in the prevalence of hypertension and corresponding poor management especially in low- and middle-income regions represents a significant missed opportunity for health systems in these countries. According to the recently published global data from 90 countries, the prevalence of hypertension decreased by 2.6% in high-income countries but increased by 7.7% in low- and middle-income regions. Almost three times as many people with hypertension live in low- and middle-income countries (~1.04 billion) than in high-income regions (~349 million) [18]. Our GBD 2017 analysis showed that, from 1990 to 2017, CVD deaths attributed to high systolic blood pressure decreased in 98 countries, while it is increased in many low- and middle-income regions especially in China [19], India [20], Pakistan [21], and Bangladesh [22]. Tackling hypertension is a global priority, but this is especially pivotal in those locations where rates are increasing. Emerging studies in low- and middle-income countries showed home-based health education [23, 24] and mobile-based text reminders [25, 26] as a cost-effective method to improve blood pressure control.

Behavioral Risk Factors

Suboptimal intake of fruits, vegetables, and nuts and increased intake of salt, meat, sweetened beverages, and trans fat consumption were the second leading risk factor for women and the leading risk factor for men globally, accounting for 4.2 (3.9–4.6) million deaths (rate, 98.2 [89.9–106.3] per 100,000) and 82.0 (75.9−88.7 million) million DALYs (rate, 1930.9 [1785.4–2088.5] per 100,000) among women and 5.3 (4.9–5.7) million deaths (rate, 150.3 [138.3–161.9] per 100,000) and 125.1 million (116.0–134.1) (rate, 3253.1 [3013.5–3486] per 100,000) DALYs among men. Notably, high salt consumption in the diet was associated with ~2.7 million deaths in 2017. Alarmed by that, the United Nations General Assembly declared years 2016–2025 as the Decade of Action on Nutrition. It might be essential to planning a variety of public policies including food reformulation to reduce sodium content, taxation of sugar-sweetened beverages, and reforming agricultural and food subsidies [27]. A recent systematic review demonstrated that multicomponent strategies involving both upstream and downstream interventions achieved the substantial reductions in salt consumption and overall blood pressure reduction across an entire population, most notably in Finland, Japan, Turkey, and recently in the UK [27–29]. Smoking-attributable CVD deaths have decreased substantially in high-income countries, whereas it increased in developing countries since 1990, with most deaths occurring in low- and middle-income regions. Furthermore, GBD 2017 data show that poor air quality was responsible for the loss of ~2.1 million lives around the world, with more than one-third of those deaths occurring in fast-developing nations of Asia [30, 31]. More research and microeconomic development in these communities that help remove the exposure to indoor air pollution and policies that address macroeconomic reliance on carbon fuels may be important moving forward to reduce CVD burdens in polluted environments.

Table 2 Attributable risk for global CVD mortality: by selected risk factors

	Death (rate per 100,000) 1990			Death (rate per 100,000) 2017	
	Total	Men	Women	Total	Men
Behavioral risk factors					
Dietary risk factors	184.5 [170.3–198.2]	214.7 [197.6–231.3]	158.6 [146.6–170.5]	122.6 [112.7–132.3]	150.3 [138.3–161.9]
Physical inactivity	23.9 [12.5–37.7]	26.3 [13.6–42.2]	21.7 [11.4–34.4]	15.7 [8.2–25]	18.1 [9.4–29]
Tobacco use	67 [64.5–69.8]	102.2 [98.5–106.2]	37.9 [35.5–40.7]	38.4 [36.7–40.2]	62.7 [60.2–65.3]
Alcohol consumption	5.7 [−0.6-12.4]	19.5 [7.8–31.3]	− 4.6 [−11.1-2.2]	8.6 [4.4–12.7]	20.4 [11.9–28.6]
Metabolic risk factors					
High Systolic blood pressure	182.6 [161.5–202.7]	199.5 [176.3–223.1]	166.6 [147.7–185.2]	126.2 [112.3–140.4]	145.7 [129.1–161.9]
High fasting plasma glucose	60.6 [41.1–90.4]	70.8 [48.1–105.3]	52.6 [35.3–79.6]	46.6 [32.4–68.5]	56.7 [39.6–82.9]
High LDL-cholesterol	86.2 [65.8–109.6]	97.7 [75.9–122.4]	74.9 [56–95.9]	56.1 [42.6–71.4]	65.7 [50.5–82.8]
High body mass index	41.1 [22.1–65.3]	41.6 [20.8–68.9]	39.6 [22.8–60.9]	38.9 [24.1–56.2]	43 [25.5–63.3]

	Death (rate per 100,000) 2017	DALY (rate per 100,000) 1990			DALY (rate per 100,000) 2017
	Women	Total	Men	Women	Total
Behavioral risk factors					
Dietary risk factors	98.2 [89.9–106.3]	3741 [3486.2–4007.1]	4490 [4176.7–4814.2]	3048.6 [2830.8–3260.7]	2570.5 [2381.2–2753.8]
Physical inactivity	13.6 [7.1–21.6]	381.5 [199.1–610.2]	443.5 [229.6–713.7]	324.4 [170.2–516.5]	264.5 [137.1–428.8]
Tobacco use	17 [15.6–18.5]	1591.3 [1528.1–1659.8]	2421.2 [2333.1–2514.7]	839.9 [784.9–902.8]	947.2 [904.8–992]
Alcohol consumption	− 1.3 [−4.3-1.7]	211.4 [95.2–335.8]	494.3 [275.8–714.8]	− 32.8 [−133.6-73.9]	253.3 [170.9–336.6]
Metabolic risk factors					
High Systolic blood pressure	108.2 [96–121.1]	3451.3 [3118.6–3776.7]	3949.4 [3553.1–4332.5]	2974.3 [2687.1–3255.3]	2500.3 [2261.2–2736.3]
High fasting plasma glucose	38.1 [25.9–57.1]	1679.5 [1386.2–1996.8]	1211.9 [900.6–1688.6]	824.9 [614.3–1166.7]	841.2 [633.3–1158.7]
High LDL-cholesterol	46.8[34.8–60.5]	1004.7 [748.1–1390.9]	2058.5 [1718.1–2429.7]	1306.9 [1065.4–1578.4]	1176.9 [971.6–1403.7]
High body mass index	34.6[22.5–48.7]	970.7 [539.6–1501.5]	1033.2 [534.3–1662.1]	899.7 [534.8–1335.3]	992.4 [649.7–1363.9]

The table was generated using publicly available web-based data visualization tools

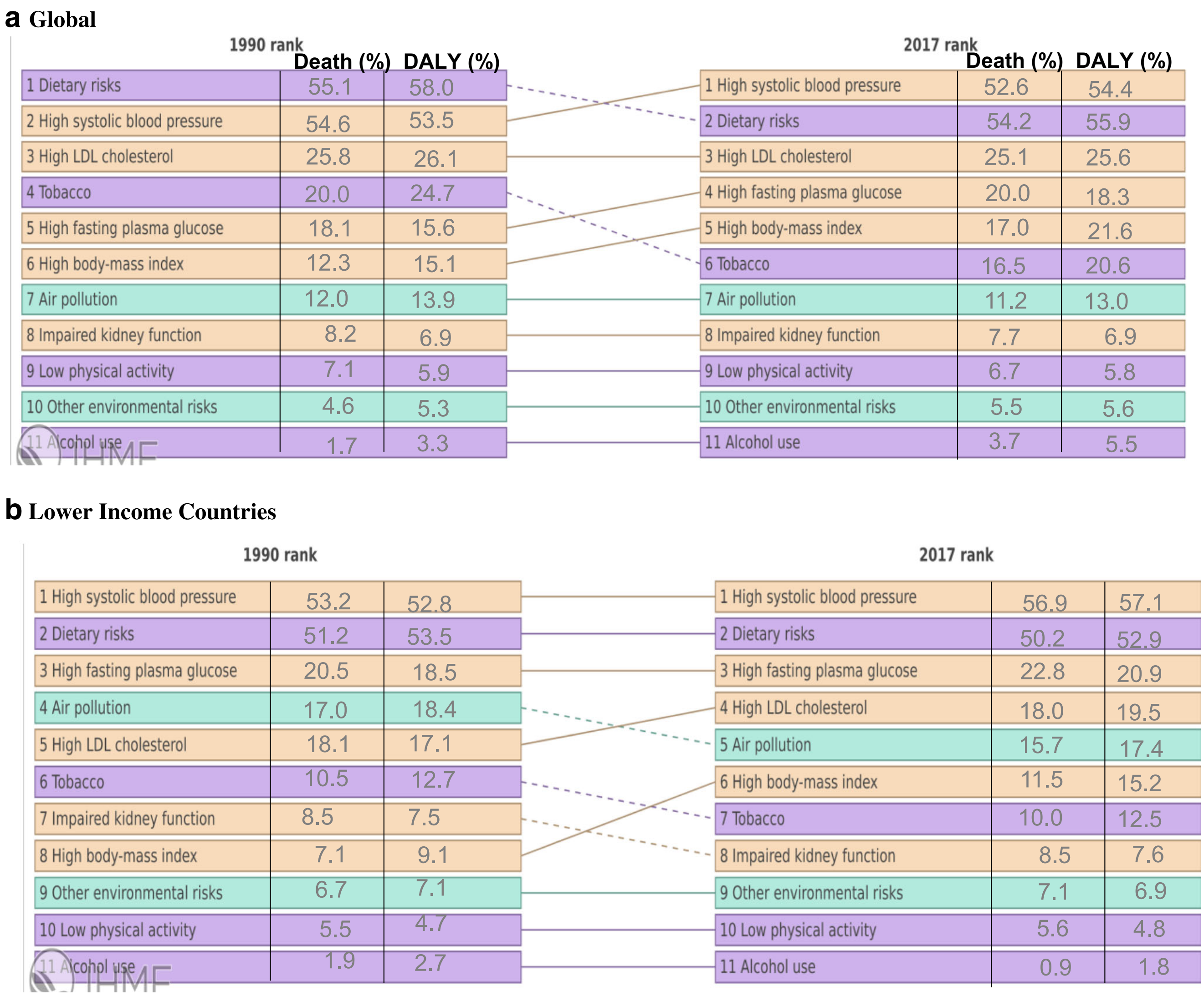

Fig. 4 **a**–**e** Change in death and disability-adjusted life year (DALY) rates attributed to risk factors, 1990–2017. Risks are connected by lines between time periods. Behavioral risk factors are shown in *lavender*, environmental risks in *green*, and metabolic risks in *orange*. For the time period of 1990 to 2016, percent change in the age-standardized mortality rate is shown. Statistically significant increases or decreases are shown in **bold** ($p < 0{\cdot}05$). The figures were generated using publicly available web-based data visualization tools

The Way Forward

The constitution of the World Health Organization (WHO) declared that "the highest attainable standard of health is one of the fundamental rights of every human being without distinction of race, religion, political belief, economic or social condition" [32]. The WHO also stated that population health is the "responsibility of governments." According to current evidence, some salient points must be considered both in surveillance and patient care:

a) *CVD risk factor screening and health behavior changes*: Many risk factors for CVD are treatable (e.g., high blood cholesterol, blood glucose, and blood pressure). Therefore, appropriate screening and treatment is an important primary prevention strategy. Multiple risk factors positively interact to exacerbate CVD risks [33]. A significant amount (~ 50%) of the reduction in CVD mortality has come from controlling risk factors [11]. Several landmark randomized controlled studies successfully demonstrated that healthy behavior changes could prevent or delay the development of diabetes and other cardiometabolic risk factors [34–36]. Despite the favorable benefits of behavior change interventions on CVD risk [12], lifestyle modification is a complicated process [37]. Importantly, due to cultural barriers, translation of successful lifestyle interventions into daily life settings is challenging especially in a low-resource and fragmented healthcare systems [38]. Major innovations are warranted at

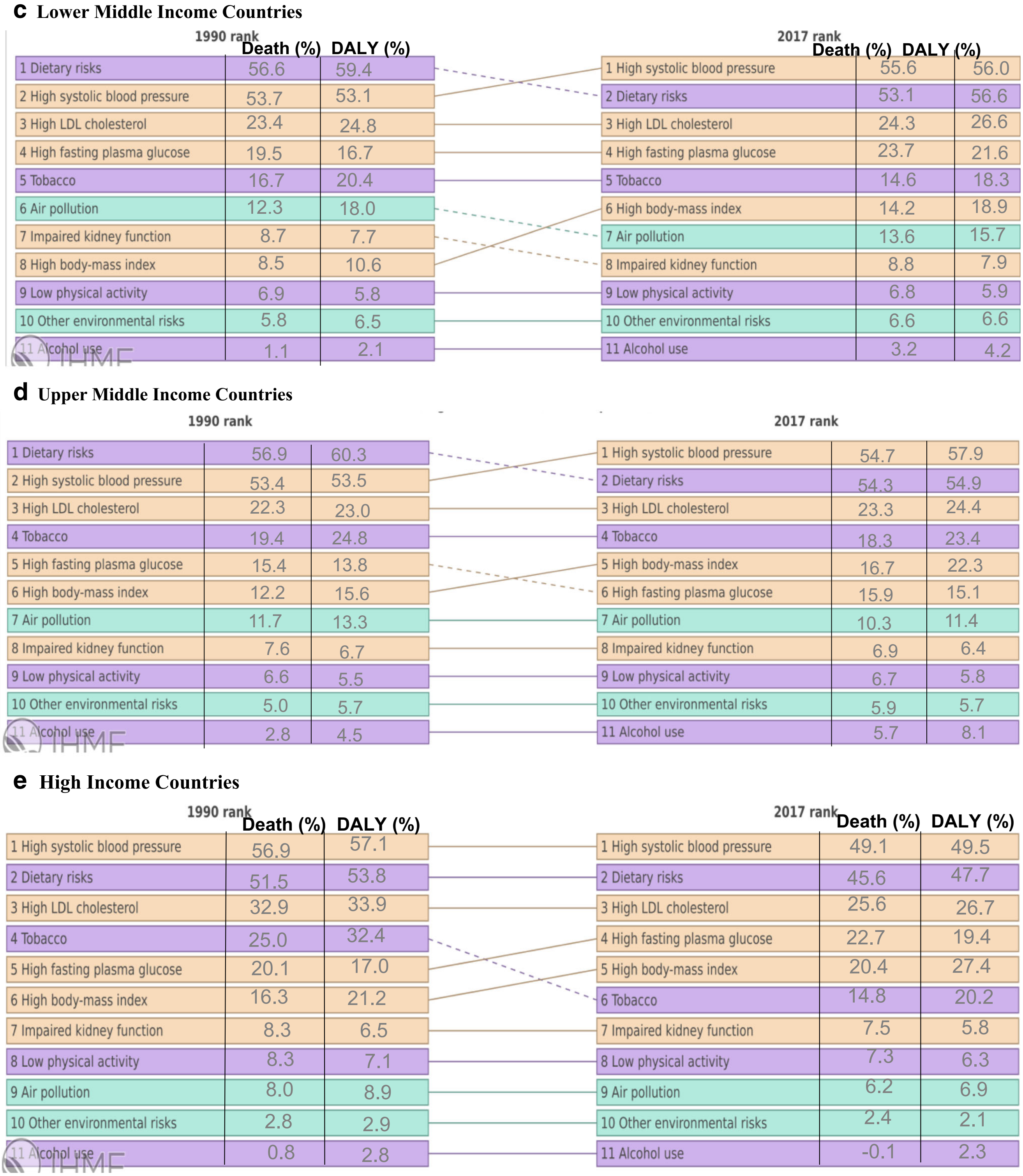

Fig. 4 (continued)

relevant personal, cultural, societal, and community levels for any prevention programs to be successful at a population level. Healthy behavior changes by mobile health are becoming a transformational tool for the population health management and a few well-designed "proof-of-principle" studies in South Asia and other low- and middle-income regions successfully showed its effectiveness in chronic care management [16, 39, 40], medication adherence [41], and diabetes prevention [42].

b) *Health promotion in the workplace*: Wellness programming in the workplace has been recognized as an essential approach to prevent and treat NCDs as > 50% of the world population spends one-third of their adult lives at work [43]. It is especially vital for low- and middle-income countries, as the risk and onset of metabolic diseases happen at working age groups. Therefore, workplace-based health promotion is one innovative strategy to improve health outcomes [44]. Currently, our group is conducting a feasibility study in 11 public and private sector worksites in India to reduce cardiovascular risk factors [45]. This kind of collaboration will pave the way for the identification of effective intervention solutions among a highly vulnerable population. It is to be understood that the availability of a workplace wellness program alone does not guarantee its effectiveness, and the results are highly variable with intervention design, implementation, and evaluation [46].

c) *National CVD registries and surveillance*: Although NCDs and especially CVD mortality contribute to ~ 80% of the death and tremendous strain in the healthcare systems, the best strategies and tools for monitoring the changing patterns of diseases and risk factors are not available in most of the low- and middle-income regions [47]. Accordingly, only 49 out of 242 countries track NCD mortality and risk factor trends over three decades [48•]. Comprehensive and standardized surveillance for NCDs was recommended at the United Nations High-Level meeting in 2011. A CVD surveillance framework, encompassing a set of exposures and outcomes, is imperative for policy development and evaluation and monitoring of disease trends [49]. Currently, only a handful of well-standardized, longitudinal NCD surveillance studies are available in low- and middle-income regions [50–54]. Promoting both the coverage and the accuracy of mortality documentation in populous low- and middle-income regions is a priority.

d) *Evidence-practice gaps in the management of CVD and its risk factors*: According to the recent estimates, ~ 1 billion people have uncontrolled hypertension and glycemic control worldwide [18, 55]. Importantly, most individuals who receive hypotensive treatments use only one medication [56]; meanwhile, the evidence base suggests that two different classes of antihypertensive agents are routinely necessary to control hypertension [57]. Similar evidence-practice gaps are observed in dyslipidemia management, with suboptimal use of statins. Notably, due to the lack of awareness and education, individuals with known CVD remain exposed to significant risk factors, with 19% continuing to smoke, 65% physically inactive, and 61% consume an unhealthy diet [58].

e) *Unique challenges*: Low- and middle-income regions face unique challenges in combating chronic metabolic diseases. This includes lack of (a) funding [59, 60], (b) few context-specific guidelines [61, 62], (c) availability of essential medications [63], and (d) geographical inequalities [64, 65]. Because of these challenges, chronic metabolic diseases have a significant impact on CVD morbidity and mortality in low- and middle-income regions than the rest of the world [13].

Conclusions

The last 2–3 decades have seen dramatic declines in age-standardized CVD mortality rates in high-income regions, whereas this has only slightly decreased or even increased in most low- and middle-income countries. This age-adjusted decline in high-income regions is primarily driven by preventive interventions that enable people to thwart disease; optimal management of diabetes, blood pressure, and dyslipidemia [61, 66]; treatments to prevent death during an acute manifestation of illness (especially stroke or myocardial infarction); availability of CVD medications [67]; and medical interventions that prolong life expectancy once CVD manifests. Importantly, the secular trends in CVD risk factors are highly heterogeneous in low- and middle-income regions. Therefore, understanding country-specific nuances contributing to CVD burdens can help guide policymakers and epidemiologists to design tailored interventions. There continues to be resistance to funding CVD interventions owing to the lack of sophisticated data documenting the burden in many regions of the world. As previous World Heart Foundation, President K. Srinath Reddy succinctly summed up, “we can spend time cataloging the catastrophe with greater and greater precision, or we can take action with a good if not perfect plan for what needs to be done” [68].

Acknowledgments Research reported in this publication was supported by the National Heart, Lung, And Blood Institute of the National Institutes of Health under award numbers: R01HL125442 (KMVN, JR, MKA) and U01HL138635 (SAP, KMVN) and the National Institute of Diabetes and Digestive and Kidney Diseases of the National Institutes of Health under award number P30DK111024 (SAP, MKA, KMVN). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:
• Of importance
•• Of major importance

1. WHO: Health situation and trend assessment. http://www.searo.who.int/entity/health_situation_trends/data/ncd_ncd-deaths/en/. Accessed on 3/11/2019.
2.•• James SL, Abate D, Abate KH, Abay SM, Abbafati C, Abbasi N, et al. Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990&2013;2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet. 2018;392(10159):1789–858. https://doi.org/10.1016/S0140-6736(18)32279-7. **Provides comprehensive updates on global disease trends**.
3. GBD 2016 Causes of Death Collaborators. Global, regional, and national age-sex specific mortality for 264 causes of death, 1980–2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet. 2017;390(10100):1151–210. https://doi.org/10.1016/S0140-6736(17)32152-9.
4. GBD 2016 DALYs, HALE Collaborators. Global, regional, and national disability-adjusted life-years (DALYs) for 333 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet. 2017;390(10100):1260–344. https://doi.org/10.1016/S0140-6736(17)32130-X.
5. GBD 2016 Risk Factors Collaborators. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet. 2017;390(10100):1345–422. https://doi.org/10.1016/S0140-6736(17)32366-8.
6. Omran AR. The epidemiologic transition: a theory of the epidemiology of population change. 1971. The Milbank quarterly. 2005;83(4):731–57. https://doi.org/10.1111/j.1468-0009.2005.00398.x.
7. Gulland A. Global life expectancy increases by five years.BMJ (Clinical research ed). 2016;353:i2883. https://doi.org/10.1136/bmj.i2883.
8.• NCD Risk Factor Collaboration (NCD-RisC). Worldwide trends in diabetes since 1980: a pooled analysis of 751 population-based studies with 4.4 million participants. Lancet (London, England). 2016;387(10027):1513–30. https://doi.org/10.1016/S0140-6736(16)00618-8. **Provides comprehensive updates on global diabetes disease trends**.
9. International Diabetes Federation. IDF Diabetes Atlas, 8th edn. Brussels, Belgium: International Diabetes Federation, 2017 http://www.diabetesatlas.org.[accessed on 3/25/2019].
10. Siu AL, U S Preventive Services Task Force. Screening for abnormal blood glucose and type 2 diabetes mellitus: US Preventive Services Task Force recommendation statement. Ann Intern Med. 2015;163(11):861–8.
11. Ford ES, Capewell S. Proportion of the decline in cardiovascular mortality disease due to prevention versus treatment: public health versus clinical care. Annu Rev Public Health. 2011;32:5–22. https://doi.org/10.1146/annurev-publhealth-031210-101211.
12. Mudaliar U, Zabetian A, Goodman M, Echouffo-Tcheugui JB, Albright AL, Gregg EW, et al. Cardiometabolic risk factor changes observed in diabetes prevention programs in US settings: a systematic review and meta-analysis. PLoS Med. 2016;13(7):e1002095. https://doi.org/10.1371/journal.pmed.1002095.
13. Pastakia SD, Pekny CR, Manyara SM, Fischer L. Diabetes in sub-Saharan Africa - from policy to practice to progress: targeting the existing gaps for future care for diabetes. Diabetes Metab Syndr Obes. 2017;10:247–63. https://doi.org/10.2147/DMSO.S126314.
14. Skyler JS, Bergenstal R, Bonow RO, Buse J, Deedwania P, Gale EAM, et al. Intensive glycemic control and the prevention of cardiovascular events: implications of the ACCORD, ADVANCE, and VA diabetes trials. A position statement of the American Diabetes Association and a scientific statement of the American College of Cardiology Foundation and the. American Heart Association. 2009;32(1):187–92. https://doi.org/10.2337/dc08-9026%JDiabetesCare.
15. Saiz LC, Gorricho J, Garjón J, Celaya MC, Erviti J, Leache L. Blood pressure targets for the treatment of people with hypertension and cardiovascular disease. Cochrane Database Syst Rev. 2018;7. https://doi.org/10.1002/14651858.CD010315.pub3.
16. Ali MK, Singh K, Kondal D, Devarajan R, Patel SA, Shivashankar R, et al. Effectiveness of a multicomponent quality improvement strategy to improve achievement of diabetes care goals: a randomized, controlled trial multicomponent quality improvement strategy to improve diabetes care goals. Ann Int Med. 2016;165(6):399–408. https://doi.org/10.7326/M15-2807.
17. Ko GT, So W-Y, Tong PC, Le Coguiec F, Kerr D, Lyubomirsky G, et al. From design to implementation–the Joint Asia Diabetes Evaluation (JADE) program: a descriptive report of an electronic web-based diabetes management program. BMC Med Inform Decis Mak. 2010;10:26. https://doi.org/10.1186/1472-6947-10-26.
18. Mills KT, Bundy JD, Kelly TN, Reed JE, Kearney PM, Reynolds K, et al. Global disparities of hypertension prevalence and control: a systematic analysis of population-based studies from 90 countries. Circulation. 2016;134(6):441–50. https://doi.org/10.1161/CIRCULATIONAHA.115.018912.
19. Wang Z, Chen Z, Zhang L, Wang X, Hao G, Zhang Z, et al. Status of hypertension in China: results from the China hypertension survey, 2012-2015. Circulation. 2018;137(22):2344–56. https://doi.org/10.1161/circulationaha.117.032380.
20. Gupta R, Gaur K, Ram SCV. Emerging trends in hypertension epidemiology in India. J Hum Hypertens. 2018. https://doi.org/10.1038/s41371-018-0117-3.
21. Shah N, Shah Q, Shah AJ. The burden and high prevalence of hypertension in Pakistani adolescents: a meta-analysis of the published studies. Archives of public health. 2018;76:20. https://doi.org/10.1186/s13690-018-0265-5.
22. Islam JY, Zaman MM, Haq SA, Ahmed S, Al-Quadir Z. Epidemiology of hypertension among Bangladeshi adults using the 2017 ACC/AHA Hypertension Clinical Practice Guidelines and Joint National Committee 7 Guidelines. J Hum Hypertens. 2018;32(10):668–80. https://doi.org/10.1038/s41371-018-0087-5.
23. Jafar TH, Islam M, Bux R, Poulter N, Hatcher J, Chaturvedi N, et al. Cost-effectiveness of community-based strategies for blood pressure control in a low-income developing country. Circulation. 2011;124(15):1615–25. https://doi.org/10.1161/CIRCULATIONAHA.111.039990.
24. Neupane D, McLachlan CS, Mishra SR, Olsen MH, Perry HB, Karki A, et al. Effectiveness of a lifestyle intervention led by female community health volunteers versus usual care in blood pressure reduction (COBIN): an open-label, cluster-randomised trial. Lancet Glob Health. 2018;6(1):e66–73.
25. Bobrow K, Farmer AJ, Springer D, Shanyinde M, Yu L-M, Brennan T, et al. Mobile phone text messages to support treatment adherence in adults with high blood pressure (SMS-text adherence support [StAR]). Circulation. 2016;133(6):592–600. https://doi.org/10.1161/CIRCULATIONAHA.115.017530.
26. Vargas G, Cajita MI, Whitehouse E, Han H-R. Use of short messaging service for hypertension management: a systematic review. J

Cardiovasc Nurs. 2017;32(3):260–70. https://doi.org/10.1097/JCN.0000000000000336.

27. Hyseni L, Elliot-Green A, Lloyd-Williams F, Kypridemos C, O'Flaherty M, McGill R, et al. Systematic review of dietary salt reduction policies: evidence for an effectiveness hierarchy? PloS One. 2017;12(5):e0177535-e. https://doi.org/10.1371/journal.pone.0177535.
28. Laatikainen T, Critchley J, Vartiainen E, Salomaa V, Ketonen M, Capewell S. Explaining the decline in coronary heart disease mortality in Finland between 1982 and 1997. Am J Epidemiol. 2005;162(8):764–73. https://doi.org/10.1093/aje/kwi274.
29. Ezoe S, Noda H, Akahane N, Sato O, Hama T, Miyata T, et al. Trends in policy on the prevention and control of non-communicable diseases in Japan. Health Syst Reform. 2017;3(4):268–77. https://doi.org/10.1080/23288604.2017.1347125.
30. Uzoigwe JC, Prum T, Bresnahan E, Garelnabi M. The emerging role of outdoor and indoor air pollution in cardiovascular disease. N Am J Med Sci. 2013;5(8):445–53. https://doi.org/10.4103/1947-2714.117290.
31. Samet JM, Bahrami H, Berhane K. Indoor air pollution and cardiovascular disease: new evidence from Iran. Circulation. 2016;133(24):2342–4. https://doi.org/10.1161/CIRCULATIONAHA.116.023477.
32. World Health Organization: WHO Constitution. https://www.who.int/about/who-we-are/constitution. Accessed 03/23/2019.
33. Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet (London, England). 2012;380(9859):2224–60. https://doi.org/10.1016/s0140-6736(12)61766-8.
34. Gillies CL, Abrams KR, Lambert PC, Cooper NJ, Sutton AJ, Hsu RT, et al. Pharmacological and lifestyle interventions to prevent or delay type 2 diabetes in people with impaired glucose tolerance: systematic review and meta-analysis. BMJ. 2007;334(7588):299. https://doi.org/10.1136/bmj.39063.689375.55.
35. Zhang X, Devlin HM, Smith B, Imperatore G, Thomas W, Lobelo F, et al. Effect of lifestyle interventions on cardiovascular risk factors among adults without impaired glucose tolerance or diabetes: a systematic review and meta-analysis. PLoS One. 2017;12(5):e0176436. https://doi.org/10.1371/journal.pone.0176436.
36. Haw JS, Galaviz KI, Straus AN, Kowalski AJ, Magee MJ, Weber MB, et al. Long-term sustainability of diabetes prevention approaches: a systematic review and meta-analysis of randomized clinical trials. JAMA Intern Med. 2017;177(12):1808–17. https://doi.org/10.1001/jamainternmed.2017.6040.
37. Kelly MP, Barker M. Why is changing health-related behaviour so difficult? Public Health. 2016;136:109–16. https://doi.org/10.1016/j.puhe.2016.03.030.
38. Druetz T. Integrated primary health care in low- and middle-income countries: a double challenge. BMC Med Ethics. 2018;19(Suppl 1):48. https://doi.org/10.1186/s12910-018-0288-z.
39. Vargas G, Cajita MI, Whitehouse E, Han HR. Use of short messaging service for hypertension management: a systematic review. J Cardiovasc Nurs. 2017;32(3):260–70. https://doi.org/10.1097/JCN.0000000000000336.
40. Bobrow K, Farmer AJ, Springer D, Shanyinde M, Yu LM, Brennan T, et al. Mobile phone text messages to support treatment adherence in adults with high blood pressure (SMS-text adherence support [StAR]): a single-blind, randomized trial. Circulation. 2016;133(6):592–600. https://doi.org/10.1161/CIRCULATIONAHA.115.017530.
41. Thakkar J, Kurup R, Laba TL, Santo K, Thiagalingam A, Rodgers A, et al. Mobile telephone text messaging for medication adherence in chronic disease: a meta-analysis. JAMA Intern Med. 2016;176(3):340–9. https://doi.org/10.1001/jamainternmed.2015.7667.
42. Ramachandran A, Snehalatha C, Ram J, Selvam S, Simon M, Nanditha A, et al. Effectiveness of mobile phone messaging in prevention of type 2 diabetes by lifestyle modification in men in India: a prospective, parallel-group, randomised controlled trial. Lancet Diabetes Endocrinol. 2013;1(3):191–8.
43. WHO: global strategy on occupational health for all: the way to health at work. http://www.who.int/occupational_health/publications/globstrategy/en/index2.html. Accessed 03/25/2019.
44. Total WSH Services Centre: https://www.totalwshcentre.com/. Accessed 03/13/2019.
45. ClinicalTrials.gov: Worksite lifestyle program for reducing diabetes and cardiovascular risk in India. https://clinicaltrials.gov/ct2/show/NCT02813668?term=Mary+Beth+Weber&rank=1. Accessed 03/13/2019.
46. Fonarow GC, Calitz C, Arena R, Baase C, Isaac FW, Lloyd-Jones D, et al. Workplace wellness recognition for optimizing workplace health. Circulation. 2015;131(20):e480–e97. https://doi.org/10.1161/CIR.0000000000000206.
47. Echouffo-Tcheugui JB, Yaya S, Joshi R, Venkat Narayan KM, Kengne AP. Population surveillance of cardiovascular diseases in low-income to middle-income countries should leverage existing international collaborations. BMJ Global Health. 2018;3(5):e000866-e. https://doi.org/10.1136/bmjgh-2018-000866.
48.• Ali MK, Jaacks LM, Kowalski AJ, Siegel KR, Ezzati M. Noncommunicable diseases: three decades of global data show a mixture of increases and decreases in mortality rates. Health affairs (Project Hope). 2015;34(9):1444–55. https://doi.org/10.1377/hlthaff.2015.0570. **Trends in mortality rates caused by non-communicable diseases from 49 countries**.
49. Alwan A, Maclean DR, Riley LM, d'Espaignet ET, Mathers CD, Stevens GA, et al. Monitoring and surveillance of chronic non-communicable diseases: progress and capacity in high-burden countries. Lancet (London, England). 2010;376(9755):1861–8. https://doi.org/10.1016/s0140-6736(10)61853-3.
50. Nair M, Ali MK, Ajay VS, Shivashankar R, Mohan V, Pradeepa R, et al. CARRS surveillance study: design and methods to assess burdens from multiple perspectives. BMC Public Health. 2012;12(1):701. https://doi.org/10.1186/1471-2458-12-701.
51. Al-Nsour M, Zindah M, Belbeisi A, Hadaddin R, Brown DW, Walke H. Prevalence of selected chronic, noncommunicable disease risk factors in Jordan: results of the 2007 Jordan Behavioral Risk Factor Surveillance Survey. Prev Chronic Dis. 2012;9:E25.
52. Bovet P, Viswanathan B, Shamlaye C, Romain S, Gedeon J. Addressing non-communicable diseases in the Seychelles: towards a comprehensive plan of action. Glob Health Promot. 2010;17(2 Suppl):37–40. https://doi.org/10.1177/1757975910363930.
53. Reed GJMR. New survey results enhance Cuba's NCD surveillance: Mariano Bonet, MD. Director, National Hygiene. Epidemiol Microbiol Inst. 2011;13(4):11–3.
54. Choi BC, Corber SJ, McQueen DV, Bonita R, Zevallos JC, Douglas KA, et al. Enhancing regional capacity in chronic disease surveillance in the Americas. Rev Panam Salud Publica. 2005;17:130–41.
55. Raccah D, Chou E, Colagiuri S, Gaal Z, Lavalle F, Mkrtumyan A, et al. A global study of the unmet need for glycemic control and predictor factors among patients with type 2 diabetes mellitus who have achieved optimal fasting plasma glucose control on basal insulin. Diabetes Metab Res Rev. 2017;33(3):e2858. https://doi.org/10.1002/dmrr.2858.
56. Chow CK, Teo KK, Rangarajan S, Islam S, Gupta R, Avezum A, et al. Prevalence, awareness, treatment, and control of hypertension in rural and urban communities in high-, middle-, and low-income countries. JAMA. 2013;310(9):959–68.
57. Working Group on the Summit on Combination Therapy for CVD, Yusuf S, Attaran A, Bosch J, Joseph P, Lonn E, et al. Combination

pharmacotherapy to prevent cardiovascular disease: present status and challenges. Eur Heart J. 2014;35(6):353–64. https://doi.org/10.1093/eurheartj/eht407.
58. Teo K, Lear S, Islam S, Mony P, Dehghan M, Li W, et al. Prevalence of a healthy lifestyle among individuals with cardiovascular disease in high-, middle-and low-income countries: the Prospective Urban Rural Epidemiology (PURE) study. JAMA. 2013;309(15):1613–21.
59. The Lancet Diabetes Endocrinology. Diabetes and NCD research: meeting the needs of the patient. Lancet Diabetes Endocrinol. 2016;4(11):873. https://doi.org/10.1016/S2213-8587(16)30291-1.
60. Geldsetzer P, Barnighausen T. Late-stage research for diabetes and related NCDs receives little funding: evidence from the NIH RePORTER tool. Lancet Diabetes Endocrinol. 2017;5(2):91–2. https://doi.org/10.1016/S2213-8587(16)30421-1.
61. Owolabi MO, Yaria JO, Daivadanam M, Makanjuola AI, Parker G, Oldenburg B, et al. Gaps in guidelines for the management of diabetes in low- and middle-income versus high-income countries-a systematic review. Diabetes Care. 2018;41(5):1097–105. https://doi.org/10.2337/dc17-1795.
62. Owolabi M, Olowoyo P, Miranda JJ, Akinyemi R, Feng W, Yaria J, et al. Gaps in hypertension guidelines in low- and middle-income versus high-income countries: a systematic review. Hypertension. 2016;68(6):1328–37. https://doi.org/10.1161/HYPERTENSIONAHA.116.08290.
63. Wirtz VJ, Kaplan WA, Kwan GF, Laing RO. Access to medications for cardiovascular diseases in low- and middle-income countries. Circulation. 2016;133(21):2076–85. https://doi.org/10.1161/CIRCULATIONAHA.115.008722.
64. Oyebode O, Pape UJ, Laverty AA, Lee JT, Bhan N, Millett C. Rural, urban and migrant differences in non-communicable disease risk-factors in middle income countries: a cross-sectional study of WHO-SAGE data. PLoS One. 2015;10(4):e0122747. https://doi.org/10.1371/journal.pone.0122747.
65. Victora CG, Barros AJ, Franca GV, da Silva IC, Carvajal-Velez L, Amouzou A. The contribution of poor and rural populations to national trends in reproductive, maternal, newborn, and child health coverage: analyses of cross-sectional surveys from 64 countries. Lancet Glob Health. 2017;5(4):e402–e7. https://doi.org/10.1016/S2214-109X(17)30077-3.
66. Hoerger TJ, Segel JE, Gregg EW, Saaddine JB. Is glycemic control improving in US adults? Diabetes Care. 2008;31(1):81–6.
67. Wirtz VJ, Kaplan WA, Kwan GF, Laing RO. Access to medications for cardiovascular diseases in low- and middle-income countries. Circulation. 2016;133(21):2076–85. https://doi.org/10.1161/CIRCULATIONAHA.115.008722.
68. Ralston J, Reddy KS, Fuster V, Narula J. Cardiovascular diseases on the global agenda: the United Nations high level meeting, sustainable development goals, and the way forward. Glob Heart. 2016;11(4):375–9. https://doi.org/10.1016/j.gheart.2016.10.029.