American Journal of Preventive Cardiology 17 (2024) 100633

Contents lists available at ScienceDirect

American Journal of Preventive Cardiology

journal homepage: www.journals.elsevier.com/american-journal-of-preventive-cardiology

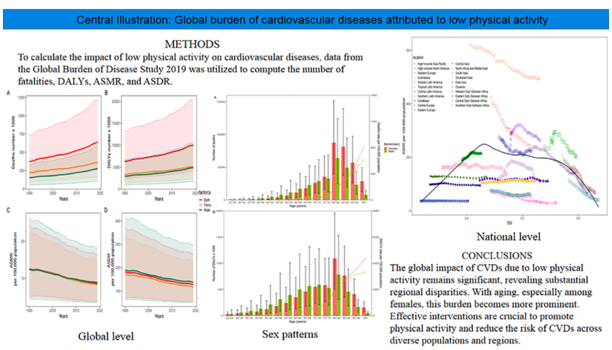
Original Research

Global burden of cardiovascular diseases attributed to low physical activity: An analysis of 204 countries and territories between 1990 and 2019

Yanfang Luo, Jinguang Liu, Jinshan Zeng, Hailin Pan *

Department of Cardiology, Huizhou Municipal People's Hospital, Huizhou, 516001, PR China

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Global burden of disease
Cardiovascular diseases
Low physical activity
Disability-adjusted life years

ABSTRACT

Background: Low physical activity is a major risk factor for cardiovascular diseases (CVDs). This study aimed to estimate the global, regional, national, and sex-age-specific burden of CVDs attributed to low physical activity from 1990 to 2019.

Methods: We leveraged data from the Global Burden of Disease Study 2019 to compute the number of fatalities, disability-adjusted life years (DALYs), age-adjusted mortality rates (ASMR), and age-adjusted DALY rates (ASDR) attributed to CVDs resulting from low physical activity. Furthermore, we scrutinized the trends and correlations of these metrics in connection with the socio-demographic index (SDI) across 21 regions and 204 countries and territories.

Results: The global deaths and DALYs due to CVDs caused by low physical activity increased from 371,042.96 [95 % UI: 147,621.82–740,490] and 6,282,524.95 [95 % UI: 2,334,970.61–13,255,090.08] in 1990 to 639,174.92 [95 % UI: 272,011.34–1,216,528.4] and 9,996,080.17 [95 % UI: 4,130,111.16–20,323,339.89] in 2019, respectively. The corresponding ASMR and ASDR decreased from 12.55 [95 % UI: 5.12–24.23] and 181.64 [95 % UI: 71.59–374.01] in 1990 to 8.6 [95 % UI: 3.68–16.28] and 127.52 [95 % UI: 53.07–256.55] in 2019, respectively. Deaths and DALYs attributed to low physical activity were initially higher in males but shifted to females after 70–74 age group. Both genders had increasing death rates, peaking at 80–84 age group. Most CVDs deaths and DALYs number are caused by ischemic heart disease. The highest burden of CVDs attributed to low physical activity was observed in North Africa and the Middle East. The lowest burden was observed in Oceania

* Corresponding author. Department of Cardiology, Huizhou Municipal People's Hospital, Huizhou, 516001, PR China.
E-mail address: panhailin2445@163.com (H. Pan).

https://doi.org/10.1016/j.ajpc.2024.100633
Received 13 October 2023; Received in revised form 14 December 2023; Accepted 6 January 2024
Available online 6 February 2024

and High-income Asia Pacific. There was a distinctive 'n-shape' relationship between the regional SDI and the ASDR of CVDs attributed to low physical activity from 1990 to 2019.
Conclusion: The global impact of CVDs stemming from low physical activity remains substantial and demonstrates substantial regional disparities. As individuals age, this burden becomes more prominent, particularly among females. Efficacious interventions are imperative to promote physical activity and mitigate the risk of CVDs across diverse populations and regions.

1. Introduction

Cardiovascular diseases (CVDs) are a group of disorders that affect the heart and blood vessels. According to estimates from the World Health Organization (WHO), CVDs accounted for 17.9 million fatalities in 2019, constituting 32 % of all global deaths [1]. It is projected that the burden of CVDs will increase in the next years as a result of population aging, urbanization, and lifestyle changes [2]. At the moment, physical inactivity is thought to be the fourth leading cause of mortality worldwide [3]. Numerous studies have shown that regular physical activity reduces the incidence of coronary heart disease, stroke, and cardiovascular risk [3,4]. The most recent meta-analysis found that older persons who walk more often each day gradually reduce their risk of CVD [5]. Huge portions of the world's population do not meet the recommended levels of physical activity, despite the fact that over 1.4 billion people are believed to be at risk of developing or worsening diseases associated to inactivity [6]. According to WHO recommendations, people between the ages of 18 and 64 should exercise for at least 150 min per week at a moderate to vigorous level, or an equal combination of the two [3]. The degree of physical inactivity is one of the most important CVD risk factors that can be modified [7,8].

Previous studies have reported on the disease burden associated with low physical activity [6,9,10]. Roth et al. evaluated the global burden of CVDs and their risk factors as a whole, but they did not further analyze them from a national level or specific etiology perspective [9]. Xu et al. conducted an assessment of the worldwide impact of insufficient physical activity using the global burden of disease (GBD) database. Their findings revealed that the global burden stemming from low physical activity remained substantial, with a notable increase in the incidence of diabetes among individuals aged 15 to 49. However, their study did not delve into a detailed analysis of the specific burdens associated with each cause attributed to insufficient physical activity, particularly cardiovascular diseases (CVDs), were not specifically addressed [6]. Few studies have comprehensively examined the global, regional and national trends and specific etiology perspective in CVD burden due to low physical activity.

Therefore, based on the GBD 2019 study, this study sought to explore the global, regional, and national burden of CVDs owing to poor physical activity in terms of mortality and disability-adjusted life years (DALYs) from 1990 to 2019. The specific goals were to: (i) Examine long-term trends in the burden of CVDs associated with low physical activity on a global and national scale over the past three decades; and (ii) Compare geographic disparities among the 21 regions defined by the GBD study and five categories based on socio-demographic index (SDI) quintiles; (iii) Examine differences by age and gender; (iv) Compare how different causes were distributed in 1990 and in 2019. The results of this study might be used to track progress and guide global policy to stop the growing CVD epidemic caused by physical inactivity.

2. Materials and methods

2.1. Study data

The study's data were sourced from GBD 2019. GBD 2019 offers the latest and most extensive assessments of 369 diseases and 87 associated risk factors globally, spanning from 1990 to 2019. Data on deaths, age-standardized mortality rates (ASMR), DALYs, and age-standardized DALY rates (ASDR) related to low physical activity in the context of CVDs were obtained from the online website (https://vizhub.healthdata.org/gbd-results/). To delve into the connection between CVD burden attributed to low physical activity and the developmental status of individual countries, we utilized the SDI. This composite measure of development status is closely intertwined with health outcomes. The SDI data for the 21 GBD 2019 regions were acquired from (https://ghdx.healthdata.org/record/ihme-data/gbd-2019-socio-demographic-index-sdi-1950–2019).

2.2. Definitions

According to the International Classification of Diseases (ICD) system, there are 11 main categories that make up CVDs: arterial, aortic aneurysm, and a miscellaneous category that includes cardiopulmonary disease, capillary or venous disorders, atrial fibrillation, cardiomyopathy, stroke, ischemic heart disease, peripheral artery disease, hypertension, endocarditis, rheumatic heart disease, non-rheumatic valvular heart [11–13]. CVDs are categorized using ICD-10 codes and ICD-9 classification codes. Using the SDI, five groupings of nations and regions are categorized. By computing the mean years of education, per capita income, and total fertility for a given country and aggregating them, this index, ranging from 0 to 1, serves as a measure of a country's level of development. A value of 0 indicates the lowest level of development, while a value of 1 signifies the highest [14]. The five classes are high SDI (> 0.81), high-middle (0.70–0.81), middle (0.61–0.69), low-middle (0.46–0.60), and low SDI (0.46). These characteristics were then used to split the countries into 21 separate geographic GBD zone. Mortality alone does not provide a comprehensive understanding of the burden of disease experienced by individuals across diverse populations. The comprehensive evaluation of disease burden relies on DALYs. DALYs attributed to a particular cause are determined by adding the years of life lost due to premature mortality (YLLs) from that cause and the years of healthy life lost due to disability (YLDs) for individuals residing in states of less than good health resulting from the specific cause [15].

2.3. Estimation methods

The GBD 2019 study utilized the comparative risk assessment framework that has been in use since 2002 to estimate the attributable burden of diseases [9,16]. The examination of physical activity among individuals aged 25 and older includes activities lasting at least 10 min that span a variety of life domains, such as leisure, employment, household chores, and transportation. The frequency, duration, and intensity of these activities were taken into account to compute the total metabolic equivalent of task (MET) minutes each week (MET-min/-week) [17]. MET, an abbreviation for metabolic equivalent, is a measure of cardiorespiratory fitness expressed as a ratio. One MET is equivalent to 1 kcal/kg/hour, representing the energy expenditure during quiet sitting. Alternatively, a MET can be defined as the oxygen intake measured in milliliters per kilogram per minute, with one MET equaling the oxygen consumption at rest, typically around 3.5 ml/kg/min. It is important to note that MET is a measure of cardiorespiratory fitness. The primary sources of information, as self-reported by participants, were the International Physical Activity Questionnaire (IPAQ) and the Global Physical Activity Questionnaire (GPAQ). Physical activity levels divided into four distinct categories. Level 0, represents individuals who engage in less than 600 MET-minutes per week and are considered inactive. Moving up the scale, level 1 encompasses those who engage in 600 to 3999 MET-minutes per week, categorized as low-active individuals. In level 2, individuals are considered moderately-active if they achieve a range of 4000 to 7999 MET-minutes per week. The highest category, level 3, includes those who engage in 8000 MET-minutes per week or more and are classified as highly active.

GPAQ results were predicted using machine learning for IPAQ estimates, and vice versa. the percentage of each nation, year, age, and gender inside each of the aforementioned four activity levels using 12 different Dismod models. Microdata on total MET-mins per week from individual-level surveys was harnessed for analysis. An ensemble approach to distribution fitting was then employed, drawing characteristics from individual distributions to tailor a unique distribution that aligns with the data, utilizing a weighting scheme. Subsequently, a dose-response meta-analysis of prospective cohort studies was conducted to estimate the effect size of changes in physical activity levels on cardiovascular diseases. Using a linear regression model that incorporated the relationship between the standard deviation and the mean activity levels in nationally representative IPAQ surveys, the standard deviation of activity within each community was computed.

All calculations were carried out with a 95 % uncertainty interval (UI) to account for potential variations. This 95 % UI was derived by generating 1000 simulations, utilizing the variance-covariance matrix and obtaining a random sample of the dispersion parameter from a gamma distribution. The results were subsequently summarized as the mean value across all simulations, along with a corresponding 95 % uncertainty interval defined by the 2.5th and 97.5th percentiles of the simulation outcomes [16].

2.4. Statistical analysis

The primary metrics used to assess the impact of low physical activity on CVDs included mortality rates, DALYs, ASMR, ASDR, and the estimated annual percentage change (EAPC) between 1990 and 2019. We created maps illustrating the geographical distribution of CVD burden attributed to low physical activity based on mortality rates, ASMR, and ASDR in the year 2019. In GBD 2019, only data for ischemic heart disease (IHD) and stroke were accessible regarding cardiovascular diseases. Consequently, we acquired the related data for etiological analysis. To examine the relationship between CVD burden and SDI by location and year, we employed the widely-used EAPC, a concise measure of age-standardized rate trends over a specified timeframe. The regression equation $y = \alpha + \beta x + \varepsilon$ was used to calculate the result. y stands for the natural logarithm of the rate, and x is the current year. The EAPC value was established as 100 (exp (β) - 1), and the regression model was used to estimate the EAPC's 95 % confidence interval (CI). It suggested a growing rate if the EAPC value and the lower limit of its 95 % CI were both positive, whereas it suggested a falling rate if the EAPC

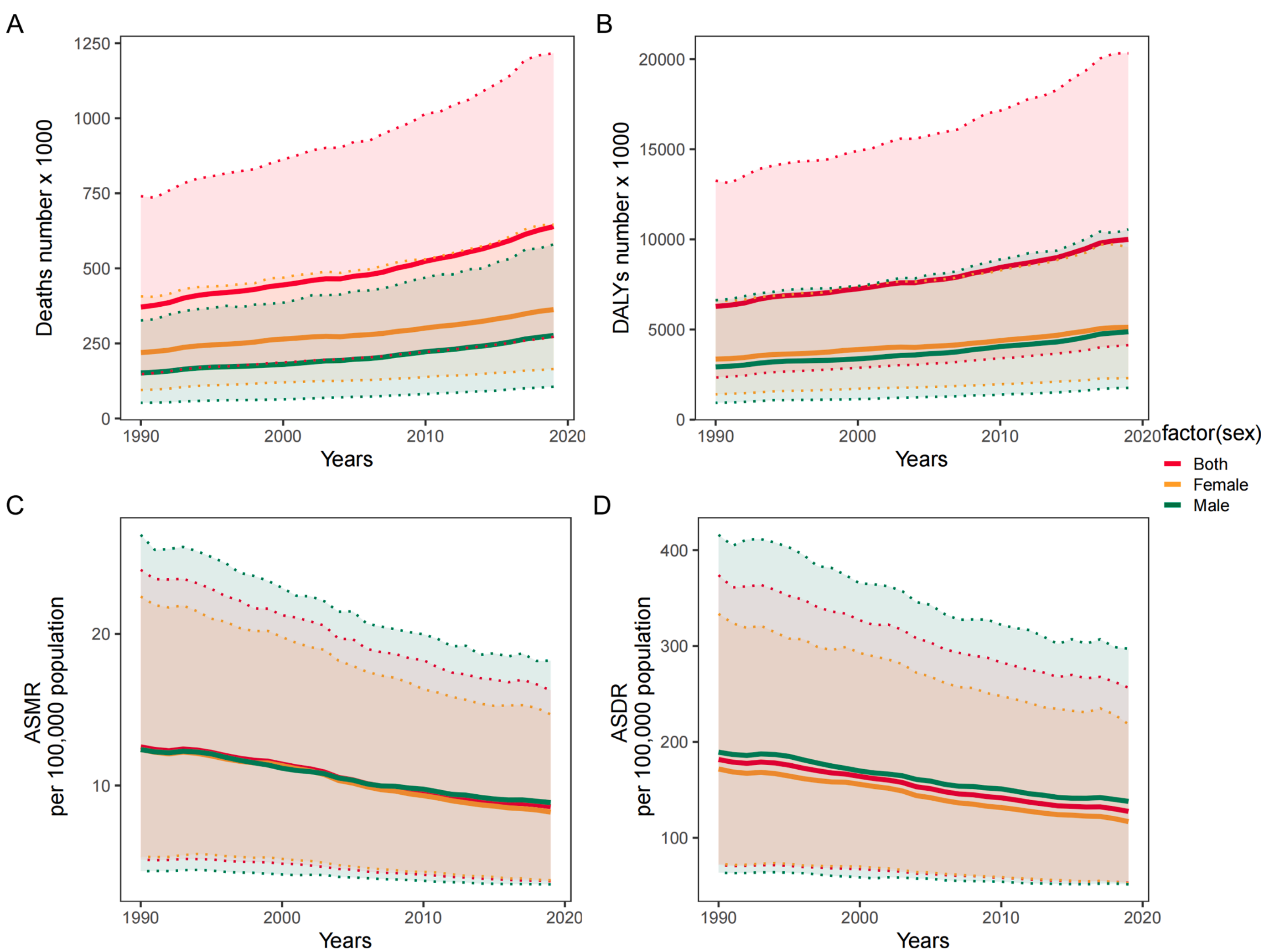


Fig. 1. The deaths number (A), DALYs number (B), ASMR per 100,000 population (C), ASDR per 100,000 population (D) of cardiovascular diseases attributed to low physical activity by sex, 1990–2019. ASMR = age-standardised mortality rate; ASDR = age-standardised DALYs rate; DALYs = disability-adjusted life years.

value and the upper limit of its 95 % CI were both negative. R statistical software (version 4.1.2) was used to analyze and display the data.

3. Results

3.1. Global burden of CVDs attributed to low physical activity

The global trends in CVD deaths and DALYs associated with poor physical activity are shown in Figs. 1A and 1B from 1990 to 2019. Both sexes, males and females, are showing a steady rise in these patterns, with females outnumbering males. Fig. 1C shows a similar steady fall in ASMR for both sexes, men and females. Finally, Fig. 1D illustrates the ASDR with a gradual downward trend, with males having slightly higher rates compared to both sexes and females.

In 2019, there were 639,174.92 worldwide CVD-related fatalities due to insufficient physical activity, compared to 371,042.96 [95 % UI: 147,621.82–740,490] in 1990. With an EAPC of −1.44 (95 % CI: −1.5 to −1.37), the related ASMR showed a diminishing trend, falling from 12.55 [95 % UI: 5.12–24.23] in 1990 to 8.6 [95 % UI: 3.68–16.28] in 2019 (Table 1). However, from 6282,524.95 [95 % UI: 2334,970.61–13,255,090.08] DALYs in 1990 to 9996,080.17 [95 % UI: 4130,111.16–20,323,339.89] DALYs in 2019 (a rise from 2334,970.61 to 13,255,090.08) DALYs. With an EAPC of −1.3 (95 % CI: −1.35 to −1.25), the ASDR fell from 181.64 [95 % UI: 71.59–374.01] to 127.52 [95 % UI: 53.07–256.55] (Table 2).

3.2. National burden of CVDs attributed to low physical activity

China has the highest number of deaths attributed to CVDs attributed to low physical activity, with 126,992.2 (95 % UI: 48,095.2–255,579.8) fatalities, followed by Russia with 38,169.8 (95 % UI: 17,122.2–73,053.6) and India with 72,632.4 (95 % UI: 29,524.7–146,975.8) (Fig. 2A and Additional file 1). Sudan, Oman, and the Syrian Arab Republic had the highest ASMRs, with values of 54.47 (95 % UI: 33.18–81.52), 49.4 (95 % UI: 27.21–76.03), and 48.17 (95 % UI: 79.9–24.45), respectively (Fig. 2B and Additional file 2). With

Table 1
Death number and age-standardized mortality rates of cardiovascular diseases attributed to low physical activity for both sexes in 1990 and 2019.

	1990		2019		
location	Deaths numbers (95 % UI)	ASMR per 100,000 No. (95 % UI)	Deaths numbers (95 % UI)	ASMR per 100,000 No. (95 % UI)	EAPC (95 % CI)
Global	371,042.96 [147,621.82–740,490]	12.55 [5.12–24.23]	639,174.92 [272,011.34–1216,528.4]	8.6 [3.68–16.28]	−1.44 [−1.5 to −1.37]
Socio-demographic index					
High SDI	124,199.15 [43,396.02–247,095.22]	12.09 [4.24–24.02]	115,979.49 [45,327.64–219,518.49]	5.04 [1.93–9.75]	−3.47 [−3.65 to −3.29]
High-middle SDI	121,121.99 [49,719.6–238,360.43]	15.26 [6.49–29.41]	199,973.9 [85,794.59–365,651.12]	10.4 [4.49–18.96]	−1.46 [−1.58 to −1.34]
Middle SDI	72,646.55 [30,245.12–147,038.79]	10.92 [4.73–21.32]	194,905.47 [82,238.54–384,845.15]	10.33 [4.49–19.58]	−0.19 [−0.26 to −0.11]
Low-middle SDI	40,225.5 [17,809.4–79,787.08]	10.45 [4.82–19.57]	100,586.46 [46,344.56–191,605.6]	9.79 [4.59–18.04]	−0.15 [−0.23 to −0.07]
Low SDI	12,586.9 [5137.48–26,526.62]	8.2 [3.57–16.11]	27,249.71 [11,570.83–55,671.2]	7.57 [3.4–14.7]	−0.1 [−0.2 to 0.01]
Regions					
Andean Latin America	817.38 [224.49–2002.35]	4.96 [1.39–11.87]	2013.01 [601.09–4537.85]	3.85 [1.17–8.69]	−0.79 [−1 to −0.59]
Australasia	3214.21 [1133.53–6371.87]	15.01 [5.33–29.48]	3735.4 [1512.87–6631.33]	6.36 [2.6–11.49]	−3.54 [−3.73 to −3.34]
Caribbean	4115.66 [1642.52–7512.79]	18.43 [7.62–33.16]	7237.31 [3223–12,772.57]	13.91 [6.2–24.54]	−1 [−1.2 to −0.8]
Central Asia	5905.84 [2373.22–12,052.22]	15.78 [6.5–31.84]	9106.35 [3671.57–18,773.31]	19.67 [8.24–39.29]	0.37 [−0.01 to 0.76]
Central Europe	20,656.74 [8530.91–42,750.82]	17.44 [7.42–34.7]	25,060.88 [11,179.12–47,677.25]	11.14 [4.95–21.18]	−1.88 [−2 to −1.77]
Central Latin America	3205.33 [961.79–7709.42]	5.01 [1.53–11.81]	9376.17 [2910.72–21,567.1]	4.28 [1.33–9.8]	−0.88 [−1.14 to −0.62]
Central Sub-Saharan Africa	1050.2 [368.3–2443.14]	7.75 [2.99–16.78]	2672.22 [980.7–5836.46]	8.08 [3.2–16.96]	0.07 [0.02 to 0.13]
East Asia	39,969.26 [15,143.64–84,555.32]	8.22 [3.25–16.07]	130,524.47 [49,619.39–262,600.43]	8.66 [3.44–17.06]	0.26 [0.06 to 0.46]
Eastern Europe	40,734.27 [17,006.91–83,670.85]	18.53 [7.8–36.59]	56,998.91 [24,753.53–108,459.27]	16.2 [7.09–30.76]	−0.65 [−1.05 to −0.25]
Eastern Sub-Saharan Africa	1063.41 [359.83–2894.42]	2.18 [0.77–5.62]	2465.57 [873.57–6609.98]	2.28 [0.81–5.68]	0.18 [0.15 to 0.21]
High-income Asia Pacific	13,124.86 [4545.5–27,647.08]	8.2 [2.93–17.16]	17,998.59 [6366.04–36,450.38]	2.78 [0.98–5.68]	−3.87 [−4.08 to −3.66]
High-income North America	40,407.78 [12,419.43–84,843.04]	10.9 [3.39–22.98]	31,498.14 [9910.48–69,390.43]	4.33 [1.33–9.71]	−3.65 [−3.97 to −3.33]
North Africa and Middle East	45,862.73 [22,040.94–81,176.21]	36.57 [18.63–61.57]	100,040.76 [51,420.1–168,303.4]	29.73 [15.72–48.05]	−0.8 [−0.85 to −0.74]
Oceania	198.26 [64.51–472.18]	10.82 [4.12–22.87]	563.57 [194.43–1308.92]	12.39 [4.89–25.88]	0.44 [0.36 to 0.51]
South Asia	34,867.22 [13,355.01–74,460.05]	10.16 [4.18–20.09]	93,596.4 [38,450.99–188,874.7]	9.28 [3.97–18.4]	−0.16 [−0.37 to 0.06]
Southeast Asia	11,411.08 [3823.82–27,366.58]	6.56 [2.24–14.62]	32,196.26 [11,271.78–70,490.75]	7.04 [2.5–15.04]	0.22 [0.12 to 0.33]
Southern Latin America	1346.32 [426.41–3539.04]	3.49 [1.1–8.97]	1762.72 [599.22–4058.26]	2.04 [0.69–4.71]	−1.6 [−1.86 to −1.34]
Southern Sub-Saharan Africa	1497.21 [616.22–2994.04]	6.95 [2.95–13.61]	3361.29 [1419.6–6699.72]	8.19 [3.51–15.91]	0.94 [0.35 to 1.53]
Tropical Latin America	17,252.99 [7898.96–28,886.66]	25.43 [12.25–40.36]	30,504.29 [16,843.93–46,671]	13.5 [7.45–20.55]	−2.07 [−2.21 to −1.93]
Western Europe	80,580.7 [29,731.44–154,833.47]	13.78 [5.08–26.19]	70,672.93 [28,147.02–127,129.33]	5.91 [2.35–10.85]	−3.41 [−3.63 to −3.18]
Western Sub-Saharan Africa	3761.51 [1302.72–8627.77]	6.27 [2.37–13.82]	7789.66 [2833.71–17,640.39]	6.15 [2.32–13.55]	−0.13 [−0.2 to −0.06]

Note: UI, uncertainty intervals; CI, confidence interval; EAPC, the estimated annual percentage changes.

Table 2
DALYs number and age-standardized DALYs rates of cardiovascular diseases attributed to low physical activity for both sexes in 1990 and 2019.

	1990		2019		
location	DALYs numbers (95 % UI)	ASDR per 100,000 No. (95 % UI)	DALYs numbers (95 % UI)	ASDR per 100,000 No. (95 % UI)	EAPC (95 % CI)
Overall	6282,524.95 [2334,970.61–13,255,090.08]	181.64 [71.59–374.01]	9996,080.17 [4130,111.16–20,323,339.89]	127.52 [53.07–256.55]	−1.3 [−1.35 to −1.25]
Socio-demographic index					
High SDI	1778,146.55 [591,504.93–3743,659.27]	169.67 [56.06–357.65]	1547,309.87 [591,461.02–3097,464.47]	78.52 [30.01–161.5]	−3.06 [−3.26 to −2.87]
High-middle SDI	1964,079.67 [759,343.89–4141,245.89]	211.98 [84.64–430.41]	2791,230.81 [1175,769.71–5461,182.25]	140.39 [59.39–274.78]	−1.59 [−1.71 to −1.47]
Middle SDI	1421,780.97 [552,260.85–3044,031.47]	166.56 [68.64–341.96]	3294,768.32 [1344,450.82–6944,407.97]	150.93 [62.57–310.6]	−0.34 [−0.39 to −0.28]
Low-middle SDI	839,679.38 [341,476.03–1791,853.4]	166.24 [72.72–332.32]	1805,923.78 [770,393.76–3678,280.79]	149.18 [66.98–297.34]	−0.22 [−0.29 to −0.15]
Low SDI	274,408.53 [98,157.8–607,116.28]	135.89 [55.04–288.03]	548,780.24 [208,490.73–1207,537.69]	121.16 [50.37–250.85]	−0.19 [−0.3 to −0.09]
Regions					
Andean Latin America	13,804.58 [3704.69–35,035.41]	73.65 [19.82–185.04]	30,422.69 [8627.77–70,766.82]	56.06 [16.12–129.15]	−0.89 [−1.12 to −0.67]
Australasia	47,342.35 [15,585.29–100,577.64]	208.37 [69.44–441.04]	44,346.13 [17,015.03–83,681.27]	82.99 [30.47–160.1]	−3.65 [−3.83 to −3.47]
Caribbean	67,703.56 [25,461.64–132,163.44]	275.47 [104.27–527.98]	114,737.51 [45,819.34–220,266.26]	222.4 [88.81–426.66]	−0.73 [−0.94 to −0.53]
Central Asia	88,901.77 [33,906.42–189,839.14]	216.6 [83.11–455.68]	145,945.57 [53,872.51–328,429.05]	262.11 [102.93–556.53]	0.24 [−0.15 to 0.64]
Central Europe	319,495.48 [124,959.3–692,087.5]	239.68 [96.18–510.96]	314,771.28 [134,834.68–620,006.68]	140.97 [60.21–288.46]	−2.19 [−2.32 to −2.07]
Central Latin America	57,472.98 [16,941.8–141,736.57]	75.61 [22.63–184.23]	140,260.87 [40,640.08–337,363.14]	61.72 [18.16–148.46]	−0.92 [−1.15 to −0.69]
Central Sub-Saharan Africa	24,248.63 [7881.67–57,297.25]	129.67 [46.96–293.43]	55,296.93 [18,542.86–132,461.57]	127.57 [47.27–287.73]	−0.14 [−0.2 to −0.08]
East Asia	728,327.64 [269,402.34–1661,799.83]	113.66 [43.25–239.45]	1917,269.54 [713,670.82–4107,169.64]	110.68 [42.79–231.46]	−0.1 [−0.24 to 0.03]
Eastern Europe	595,220.15 [240,754.6–1301,236.08]	240.34 [98.65–526.89]	725,601.15 [301,026.43–1489,927.12]	203.85 [85.15–425.82]	−0.78 [−1.19 to −0.37]
Eastern Sub-Saharan Africa	23,864.04 [7548.86–70,926.67]	37.07 [12.47–101.15]	50,417.21 [16,881.88–146,662.65]	36.56 [12.78–98.39]	−0.06 [−0.08 to −0.04]
High-income Asia Pacific	201,817.25 [64,208.77–447,303.13]	111.9 [36.37–244.67]	216,246.54 [74,212.18–461,366.9]	40.68 [13.9–89.9]	−3.59 [−3.78 to −3.41]
High-income North America	573,173.68 [173,260.52–1286,882.22]	158.25 [47.05–362.23]	430,179.56 [128,449.73–1005,311]	66.43 [19.29–158.41]	−3.38 [−3.61 to −3.15]
North Africa and Middle East	958,674.02 [415,159.51–1823,784.09]	618.9 [290.34–1116.85]	1984,195.15 [923,056.11–3607,537.77]	493.78 [241.44–856.21]	−0.9 [−0.96 to −0.84]
Oceania	4845.85 [1470.36–12,356.27]	188.79 [64.42–440.83]	13,265.27 [4133.25–32,997.73]	213.59 [76.01–490.45]	0.4 [0.29 to 0.52]
South Asia	750,164.54 [260,234.9–1736,410.08]	161.58 [62.08–341.88]	1629,943.9 [607,606.64–3594,943.61]	135.3 [54.09–282.99]	−0.24 [−0.43 to −0.04]
Southeast Asia	225,943.7 [72,364.99–548,645.24]	104.05 [34.2–245.88]	598,334.95 [196,909.86–1357,628.21]	111.46 [38.29–252.21]	0.22 [0.14 to 0.3]
Southern Latin America	21,800.02 [6929.3–58,967.66]	50.98 [16.24–136.69]	25,038.98 [8632.88–61,408.57]	29.61 [10.19–72.23]	−1.63 [−1.85 to −1.42]
Southern Sub-Saharan Africa	31,206.42 [11,686.84–66,331.33]	119.32 [46.5–242.73]	60,867.58 [23,713.33–127,851.52]	123.47 [50.02–252.87]	0.44 [−0.17 to 1.05]
Tropical Latin America	358,332.22 [149,758.62–633,590.3]	424.66 [188.35–730.73]	542,325.35 [269,401.66–878,673.59]	229.6 [116.1–370.11]	−2.02 [−2.12 to −1.92]
Western Europe	1116,774.27 [383,731.34–2260,111.18]	188.55 [65.1–382.79]	807,100.2 [305,556.58–1517,059.85]	76.51 [27.7–153.85]	−3.66 [−3.93 to −3.39]
Western Sub-Saharan Africa	73,411.81 [23,545.28–171,351.71]	98.34 [33.43–228.88]	149,513.8 [50,017.04–350,953.97]	94.7 [34.02–217.72]	−0.2 [−0.29 to −0.12]

Note: ASDR, age-standardized DALYs rates; UI, uncertainty intervals; CI, confidence interval;EAPC, the estimated annual percentage changes.

979.12 (95 % UI: 556.55–1534.28), Sudan likewise has the highest ASDR, closely followed by Saudi Arabia, Egypt, the Syrian Arab Republic, and Oman (Fig. 2C and Additional file 3).

3.3. Regional burden of CVDs attributed to low physical activity

In 2019, among 21 regions, the highest number of deaths attributed to Cardiovascular Diseases attributed to low physical activity was in East Asia, with 130,524.47 [95 % UI: 49,619.39–262,600.4], followed closely by North Africa and the Middle East, with 100,040.76 [95 % UI: 51,420.1–168,303.4]. In contrast to 1990, there was a decrease in the number of deaths in High-income North America and Western Europe. The highest ASMR in 2019 was observed in North Africa and the Middle East at 29.73 [95 % UI: 15.72–48.05], followed by Central Asia at 19.67 [95 % UI: 8.24–39.29]. The region with the most significant decrease in EAPC was High-income Asia Pacific at −3.87 [95 % CI: −4.08 to −3.66], while the highest increase was observed in Southern Sub-Saharan Africa at 0.94 [0.35 to 1.53]. Six regions had increase EAPCs (Central Asia 0.37 [95 % CI: −0.01 to 0.76], Central Sub-Saharan Africa 0.07 [95 % CI: 0.02 to 0.13], East Asia 0.26 [95 % CI: 0.06 to 0.46], Eastern Sub-Saharan Africa 0.18 [95 % CI: 0.15 to 0.21], Oceania 0.44 [95 % CI: 0.36 to 0.51], Southeast Asia 0.22 [95 % CI: 0.12 to 0.33]), while the rest of the regions showed decrease trends (Table 1).

The highest DALYs number attributed to CVDs attributed to low

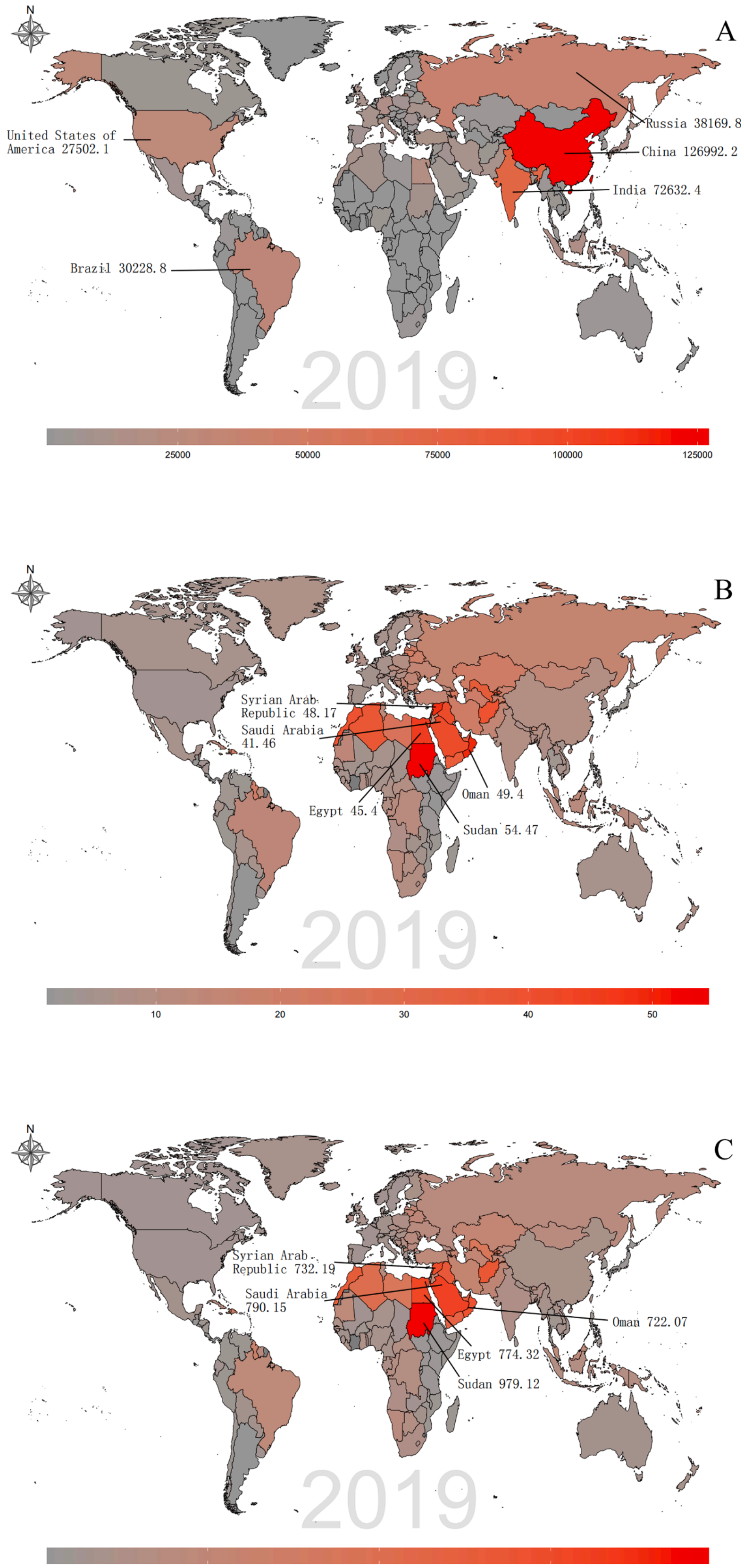


Fig. 2. Global distribution of cardiovascular diseases attributed to low physical activity burden in terms of deaths (A), ASMR (B) and ASDR (C) in 2019. ASMR = age-standardized mortality rate; ASDR = age-standardized DALYs rate; DALY= disability-adjusted life year.

physical activity was in North Africa and the Middle East, with 1984,195.15 [95 % UI: 923,056.11–3607,537.77], while the lowest was in Oceania, with 13,265.27 [95 % UI: 4133.25–32,997.73]. The ASDR was in North Africa and the Middle East, at 493.78 [95 % UI: 241.44–856.21], followed by Central Asia at 262.11 [95 % UI: 102.93–556.53] and Tropical Latin America at 229.6 [95 % UI: 116.1–370.11]. The two regions with the most significant EAPC decreases were Western Europe at −3.66 [95 % CI: −3.93 to −3.39] and Australasia at −3.65 [95 % CI: −3.83 to −3.47], while four regions showed an increase: Southern Sub-Saharan Africa at 0.44 [95 % CI: −0.17 to 1.05], Oceania at 0.4 [95 % CI: 0.29 to 0.52], Central Asia at 0.24 [95 % CI: −0.15 to 0.64], and Southeast Asia at 0.22 [95 % CI: 0.14 to 0.3] (Table 2).

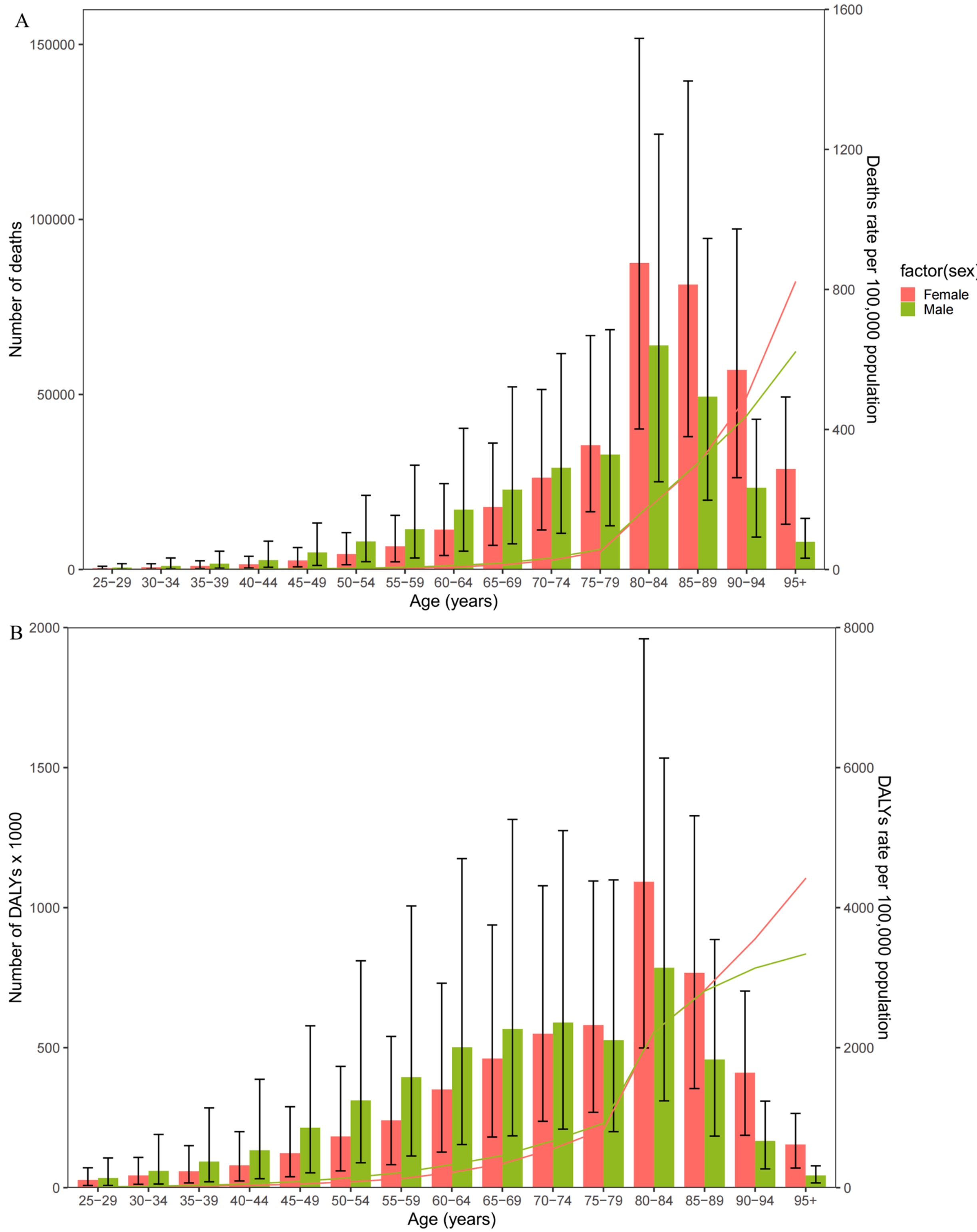


Fig. 3. Global number of deaths and death rate (A) and global number of DALYs and DALY rate per 100,000 population (B) of cardiovascular diseases attributed to low physical activity by age and sex in 2019. DALY, disability-adjusted life years.

3.4. Age and sex patterns

The number of deaths and DALYs attributed to low physical activity were higher in males compared to females before the age of 70–74 age group. However, it shifted to females having higher rates than males afterward. Death rates for both males and females gradually increased, reaching a peak in the 80–84 age group, and then began to decline. ASMR for both genders showed a slow increase until the age of 75–79 age group, followed by a steep rise. Between 85–89 age group, female mortality rates were notably higher than those of males. In terms of DALYs number, both male and female DALYs numbers increased gradually until the 80–84 age group, then gradually decreased, except for males in the 75–79 age group. ASDR showed that before the age of 75–79 age group, females had slightly higher rates than males, and there was little difference between the two before the age of 85–89 age group. However, beyond this age group, females exhibited significantly higher rates than males, and both male and female ASDR increased gradually with age, with a notable increase after the 75–79 age group (Fig. 3).

3.5. Proportion and relative distribution by cause

In the global context, as well as within specific SDI regions and 21 regions, IHD remains a major contributor to the burden of CVDs associated with low physical activity. In 2019, on a global scale, 76.2 % of deaths related to CVDs resulting from low physical activity were attributed to ischemic heart disease, while stroke accounted for 23.8 %. This proportion remained relatively stable compared to 1990. In terms of DALYs in 2019, IHD accounted for 75.9 %, showing a slight decrease from 1990. When comparing 2019 to 1990, it's noteworthy that, among the five SDI regions, only high-middle SDI regions saw a decrease in the proportion of stroke-related cases in 2019. Overall, the etiological patterns within the 21 regions did not exhibit significant changes from 1990 to 2019. Notably, in High-income North America, North Africa and the Middle East, and Oceania, the proportion of IHD cases was significantly higher compared to other regions (Fig. 4).

3.6. Association with the SDI

In 2019, the number of deaths attributed to CVDs due to low physical activity was highest in the High-middle SDI region at 199,973.9 [95 % UI: 85,794.59–365,651.12], and lowest in the Low SDI region at 27,249.71 [95 % UI: 11,570.83–55,671.2]. The corresponding ASMR was highest in the High-middle SDI region at 10.4 [95 % UI: 4.49–18.96], and lowest in the High SDI region at 5.04 [95 % UI: 1.93–9.75]. The EAPC for all five SDI regions showed a decrease, with the most significant decline in the High SDI region at −3.47 [95 % CI: −3.65 to −3.29] (Table 1). The DALYs number was highest in the Middle SDI region at 3294,768.32 [95 % UI: 1344,450.82–6944,407.97], with the highest ASDR at 150.93 [95 % UI: 62.57–310.6] In 2019. The EAPC for DALYs also showed a decrease across all regions, with the most substantial decline in the High SDI region at −3.06 [95 % CI: −3.26 to −2.87], and the lowest in the Low SDI region at −0.19 [95 % CI: −0.3 to −0.09] (Table 2).

We proceeded to investigate the connection between SDI and the corresponding ASDR of CVDs linked to low physical activity across 21 GBD regions from 1990 to 2019. Our findings revealed a distinctive 'n-shaped' relationship between the regional SDI and the associated ASDR of CVDs attributed to low physical activity over this period. When SDI was below 0.45, the ASDR of CVDs related to low physical activity showed a gradual increase with increasing SDI, followed by a significant decline. Notably, several regions, including North Africa and the Middle East, Tropical Latin America, Central Asia, the Caribbean, and Eastern Europe, experienced higher-than-expected burdens of ASDR for CVDs attributed to low physical activity from 1990 to 2019. Conversely, Southern Sub-Saharan Africa, Eastern Sub-Saharan Africa, Southeast Asia, Central Latin America, Andean Latin America, and Southern Latin America exhibited lower-than-expected ASDR for CVDs attributed to low physical activity. In the early years of the study period, Eastern Sub-Saharan Africa, Western Sub-Saharan Africa, Central Latin America, South Asia, Oceania, and Central Europe had a higher burden of ASDR than anticipated, but this burden decreased in the later years (Fig. 5).

4. Discussion

Using data from the GBD 2019, we assessed the burden of CVDs from 1990 to 2019 at the global, regional, national, and sex-age specific levels. We discovered that the burden of CVD deaths and DALYs varied greatly between areas and nations and was strongly related with poor physical activity. Males had a higher burden than females until later in life, when females experienced a greater burden. IHD continues to play a significant role in the overall burden of CVDs linked to low physical activity. We also observed a distinctive 'n-shape' relationship between the regional SDI and the ASDR of CVDs attributed to low physical activity over time.

According to the 2023 World Heart Report, modifiable risk factors for CVDs include behavioral factors (insufficient physical activity, excessive alcohol consumption, high sodium intake, and tobacco smoking) and metabolic factors (high blood pressure, increased body-mass index, high levels of low-density lipoprotein (LDL) cholesterol, elevated fasting plasma glucose, and diabetes). Environmental factors, such as ambient air pollution, also contribute to CVD risk. The World Heart Federation (WHF) Policy Brief on The Impact of Alcohol Consumption on Cardiovascular Health and the WHF Roadmap for Reducing Cardiovascular Mortality Through Tobacco Control provide comprehensive insights for effective policy implementation. Additionally, the Joint Position Paper on Obesity and Cardiovascular Disease by the WHF and World Obesity Federation emphasizes the direct and indirect links between obesity/being overweight and CVDs, offering recommendations for mitigating the risk of obesity-related CVDs and mortality. The WHO also outlines 20 policy actions aimed at enhancing physical activity [18,19].

Numerous advantages of physical exercise for cardiovascular health include decreasing blood pressure, raising insulin sensitivity, improving lipid profiles, reducing inflammation, and avoiding obesity [20]. Through processes such as lowered sympathetic tone, enhanced vascular endothelial function, and decreased arterial stiffness, exercise lowers blood pressure [21]. While reducing LDL and triglycerides, exercise can increase HDL cholesterol [22]. Exercise lowers inflammatory cytokines like IL-6 and CRP, which decreases systemic inflammation [23]. Additionally, being active aids weight control by increasing energy expenditure and favorably altering appetite regulators [24,25]. Through enhanced GLUT4 transporter translocation, it also improves glucose uptake [26]. By influencing these physiological processes, physical exercise protects against atherosclerosis, hypertension, diabetes, and obesity-all major risk factors for heart disease and stroke [26].

According to our findings, between 1990 and 2019, the number of global CVD-related fatalities and DALYs grew by 72.3 % and 59.0 %, respectively. This is in line with other research that found an upward trend in CVD mortality and morbidity linked to physical inactivity [9]. Population expansion, age, and the epidemiological switch from communicable to non-communicable illnesses might all contribute to the rise in the absolute number of deaths and DALYs. The related ASMR and ASDR, however, fell by 31.5 % and 29.8 %, respectively, showing a relative advancement in the treatment and prevention of CVDs over time. The country's and the health system's effort on lowering risk factors including high blood pressure, diabetes, and obesity may also be reflected in the declining age standardization rate [18]. ()Patients with heart failure who receive better IHD care tend to have lower rates of heart failure overall [9].

The nations with the highest national rates of CVD mortality associated with inactivity were China, India, and Russia. This may be because to these countries' sizable populations, fast economic

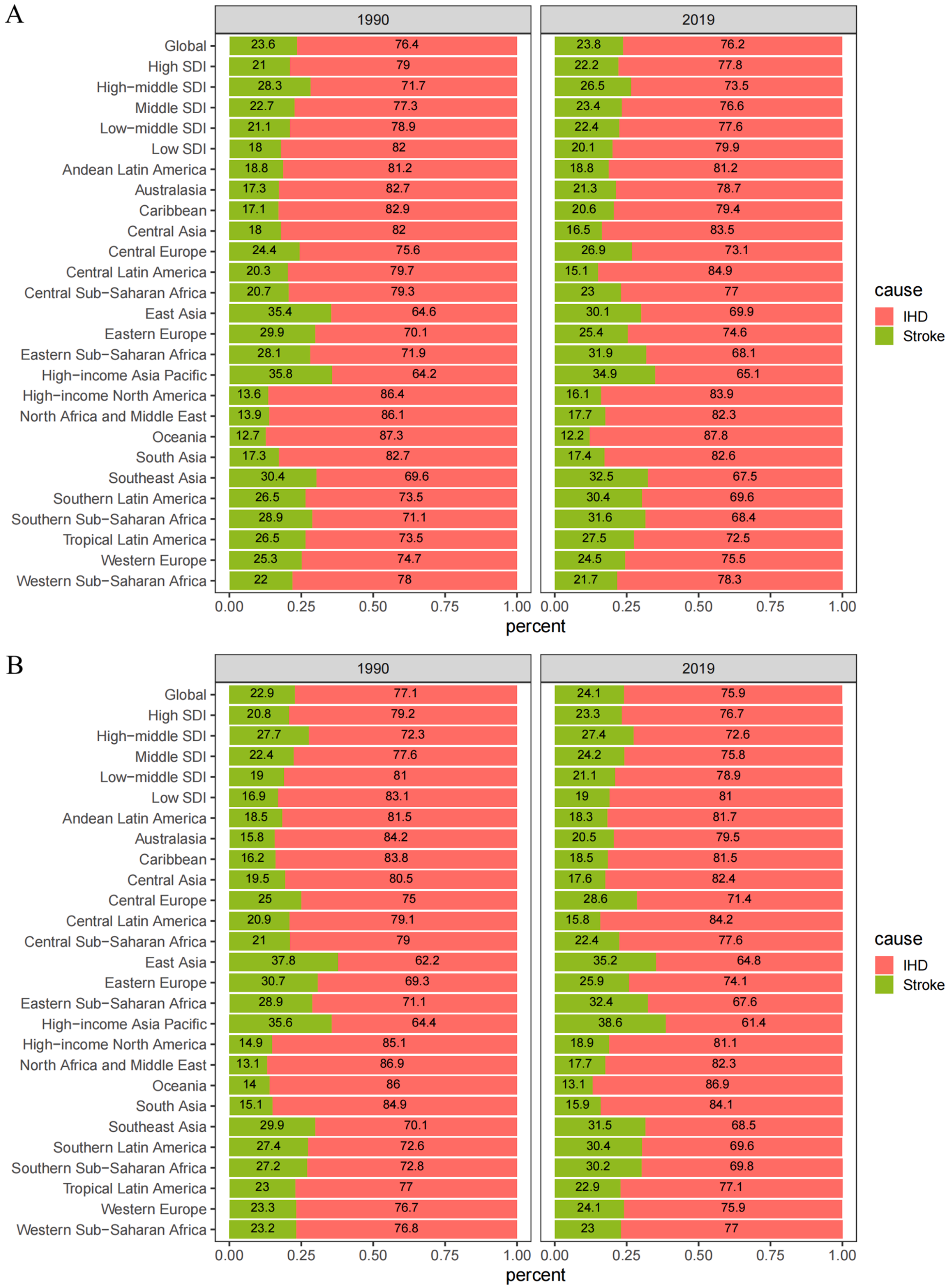


Fig. 4. Deaths (A) and DALYs (B) from ischemic heart disease, stroke, and all-age population attributable fractions of cardiovascular illnesses related to inadequate physical activity in 1990 and 2019 by global burden of disease area. DALYs = Disability-Adjusted Life Years.

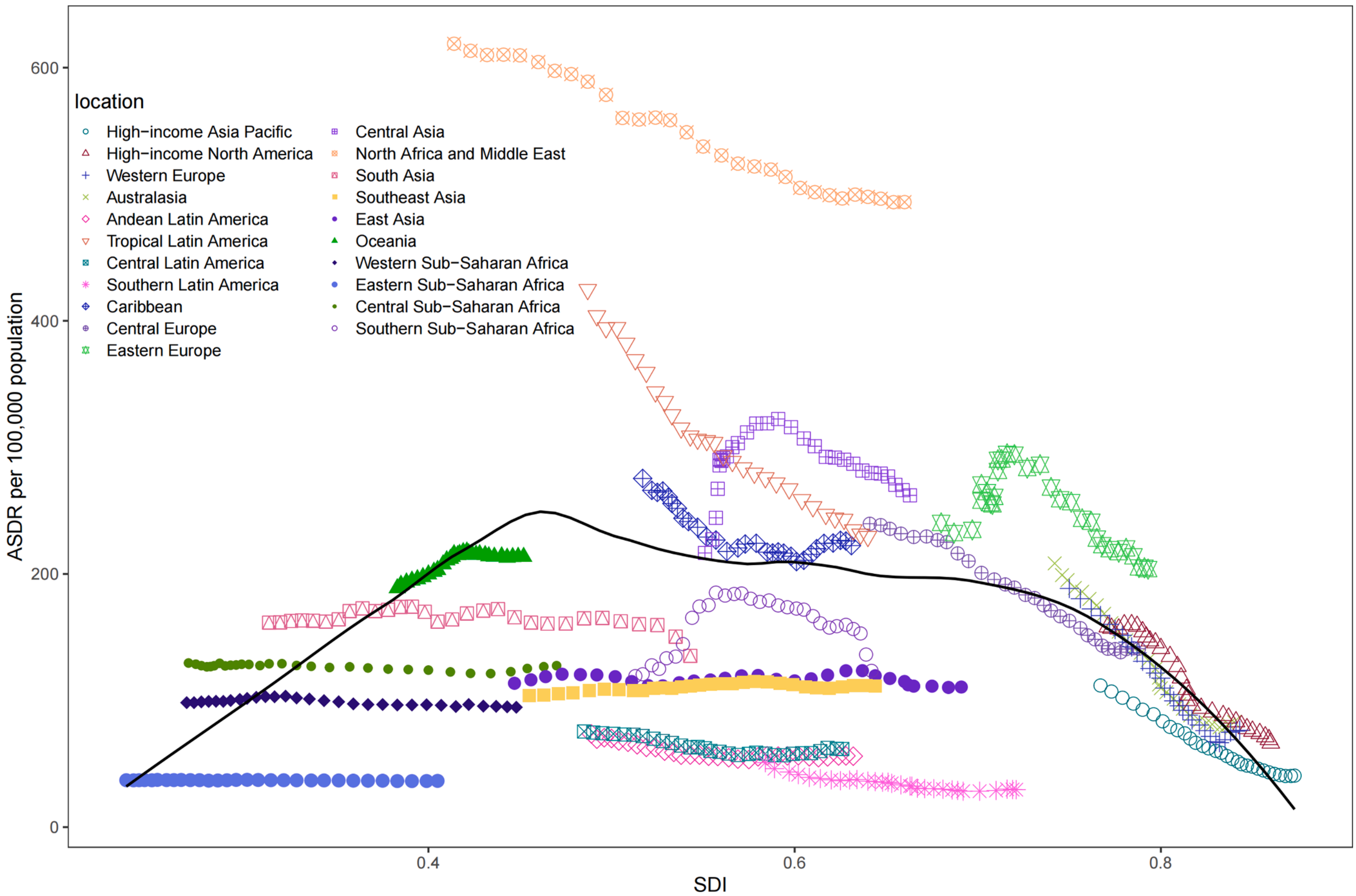


Fig. 5. Age-standardised DALY rates (ASDR) of cardiovascular diseases attributed to low physical activity for 21 GBD regions by Socio-demographic Index, 1990–2019. Expected values based on Socio-demographic Index and disease rates in all locations are shown as the black line. DALY=disability-adjusted life-year; GBD=Global Burden of Diseases.

development, and urbanization processes, which have exposed them to more CVD risk factors such inactivity and low levels of physical activity. The greatest ASMR and ASDR were found in Sudan, Oman, and the Syrian Arab Republic, which may be associated to their low socioeconomic position, political turbulence, and weak health systems, which limit access to high-quality healthcare and preventative interventions [27,28]. The lowest ASMR and ASDR were found in Japan, Singapore, and France, which may be connected to their high socioeconomic status, cultural norms, and effective health programs that encourage regular exercise, a healthy diet, and regular checkups [29].

East Asia, North Africa, and the Middle East were the regions with the greatest number of CVD fatalities linked to insufficient physical activity. The high population density, increasing urbanization, and lifestyle changes in these areas that have increased exposure to inactivity and other CVD risk factors may be to blame for this [30]. North Africa and the Middle East have the greatest ASMR and ASDR, followed by Central Asia and Tropical Latin America. This can be a result of these areas' poor socioeconomic position, environmental difficulties, and underdeveloped health systems, which have restricted access to high-quality healthcare and preventative treatments [31].

There were some discrepancies between the age and sex distributions of CVDs linked to inadequate physical activity. Males had more fatalities and DALYs than females before the age of 70–74, which is in line with earlier research that discovered that men are more prone to be physically inactive than women [32]. The longer life expectancy of women and the higher prevalence of CVD risk factors, such as hypertension and diabetes, in older women, may account for the larger numbers and rates of females than males beyond this age group [33]. For both sexes, the ASMR and ASDR gradually increased with aging, peaked in the 80–84 age group, and then began to decline. The competing causes of death for the elderly, such as cancer, respiratory disorders, and dementia [34], may be to blame for this. Females showed considerably higher rates than men beyond the ages of 85 to 89, which might be explained by the greater burden of CVDs among females in this age range [33].

IHD continues to play a significant role in the burden of CVDs linked to insufficient physical activity on a worldwide scale. IHD accounted for 76.2 % of the CVD-related fatalities associated with insufficient physical activity in 2019; stroke accounted for the remaining 23.8 %. Notably, the percentage of IHD patients dropped somewhat from 1990, although the overall CVD pattern linked to inactivity remained consistent. In 2019, only regions with high-middle SDI levels exhibited a decrease in stroke-related cases. High-income The regions with noticeably larger proportions of IHD cases were North America, North Africa and the Middle East, and Oceania. These results highlight the need for focused interventions in these areas to address the link between inactivity and CVDs.

In our study, we discovered that the Middle SDI region had the second-highest number of deaths and DALYs, followed by the High-middle SDI region. This could be due to the rapid industrialization, urbanization, and lifestyle changes that have occurred in these areas, which have increased the exposure to other CVD risk factors and low levels of physical activity [35–37]. The EAPC for all SDI areas did, however, show a decline over time, indicating that there has been some improvement in lowering the effect of insufficient physical activity on CVDs. The most significant decline was observed in the High SDI region, which could be attributed to the higher awareness, prevention, and treatment of CVDs in this region [38]. The relationship between SDI and ASDR had an 'n-shape,' showing that when SDI was below 0.45, the ASDR increased with increasing SDI, which could be due to the lack of physical activity opportunities and facilities in low-income settings . However, when SDI was above 0.45, the ASDR decreased with increasing SDI, which could be due to the adoption of more active lifestyles and policies in high-income settings.

Overall, the study highlights significant burdens globally from CVDs attributed to physical inactivity, with variations by country, regions and development levels. Context-specific strategies and policies are warranted to promote physical activity and reduce CVD risks at the population level. Further research can elucidate specific barriers in high-risk groups and settings to inform targeted interventions.

However, there are certain limitations to this study. The assessment of poor physical activity was firstly relied on self-reported data, which is susceptible to measurement error and recall bias. Second, relative risks obtained from observational research, which might not represent causal linkages or take into account relevant confounders, were used to attribute CVDs to poor physical activity. Third, the quality and accessibility of the data differed among nations and regions, which can have an impact on the comparability and accuracy of the estimates. Fourth, the SDI index could not include all socioeconomic development factors that could affect CVDs and physical activity.

5. Conclusion

Our study utilizes data from the GBD 2019 to offer a comprehensive assessment of the CVDs burden stemming from low physical activity spanning the years 1990 to 2019. While there has been a decline in death rates and DALYs since 1990, it's important to note that the actual number of deaths attributable to CVDs due to low physical activity is on the rise, highlighting an ongoing public health concern. High to moderate SDI regions carry the most substantial burden of CVDs resulting from low physical activity. The elderly population, particularly women, continue to bear a significant portion of this burden. These findings hold significant implications for the development of targeted interventions and policies to prevent and manage CVDs stemming from low physical activity across diverse countries and regions, aligning with the broader goal of reducing the global CVD burden.

Availability of data and materials

The datasets featured in this study are accessible through an online database. You can locate them in the following database: https://vizhub.healthdata.org/gbd-results/.

Funding

No funding.

CRediT authorship contribution statement

Yanfang Luo: Data curation, Writing – original draft, Validation. **Jinguang Liu:** Writing – original draft, Validation. **Jinshan Zeng:** Writing – review & editing. **Hailin Pan:** Conceptualization, Supervision, Validation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ajpc.2024.100633.

References

[1] World Health Organization. Cardiovascular diseases (CVDs). https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds). Accessed: Sep 22, 2023.
[2] Ma LY, Chen WW, Gao RL, Liu LS, Zhu ML, Wang YJ, Wu ZS, Li HJ, Gu DF, Yang YJ, Zheng Z, Hu SS. China cardiovascular diseases report 2018: an updated summary. J Geriatr Cardiol 2020;17(1):1–8. Jan.
[3] World Health Organization. Global recommendations on physical activity for health. https://www.who.int/publications/i/item/9789241599979. Accessed: Sep 22, 2023.
[4] Li J, Siegrist J. Physical activity and risk of cardiovascular disease–a meta-analysis of prospective cohort studies. Int J Environ Res Public Health 2012;9(2):391–407. Feb.
[5] Guthold R, Stevens GA, Riley LM, Bull FC. Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1·9 million participants. Lancet Glob Health 2018;6(10):e1077–86. Oct.
[6] Xu YY, Xie J, Yin H, Yang FF, Ma CM, Yang BY, Wan R, Guo B, Chen LD, Li SL. The global burden of disease attributable to low physical activity and its trends from 1990 to 2019: an analysis of the global burden of disease study. Front Public Health 2022;10:1018866. Dec 15.
[7] Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT. Lancet physical activity series working group. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. Lancet 2012;380(9838):219–29. Jul 21.
[8] Liu Z, Li Z, Xie J, Xia R, Li Y, Zhang F, Ouyang W, Wang S, Pan X. The cardiovascular disease burden attributable to low physical activity in the western pacific region, 1990-2019: an age-period-cohort analysis of the global burden of disease study. Eur Heart J Qual Care Clin Outcomes 2023:qcad063. Oct 18.
[9] Roth GA, Mensah GA, CO Johnson, Addolorato G, Ammirati E, Baddour LM, et al. Global burden of cardiovascular diseases writing group. Global burden of cardiovascular diseases and risk factors, 1990-2019: update from the GBD 2019 study. J Am Coll Cardiol 2020;76(25):2982–3021. Dec 22.
[10] Kazemi A, Sasani N, Mokhtari Z, Keshtkar A, Babajafari S, Poustchi H, Hashemian M, Malekzadeh R. Comparing the risk of cardiovascular diseases and all-cause mortality in four lifestyles with a combination of high/low physical activity and healthy/unhealthy diet: a prospective cohort study. Int J Behav Nutr Phys Act 2022;19(1):138. Nov 16.
[11] Wang K, Jin Y, Wang M, Liu J, Bu X, Mu J, Lu J. Global cardiovascular diseases burden attributable to high sodium intake from 1990 to 2019. J Clin Hypertens (Greenwich) 2023;25(9):868–79. Sep.
[12] Li Y, Cao GY, Jing WZ, Liu J, Liu M. Global trends and regional differences in incidence and mortality of cardiovascular disease, 1990-2019: findings from 2019 global burden of disease study. Eur J Prev Cardiol 2023;30(3):276–86. Feb 14.
[13] Lindstrom M, DeCleene N, Dorsey H, Fuster V, Johnson CO, LeGrand KE, Mensah GA, Razo C, Stark B, Varieur Turco J, Roth GA. Global burden of cardiovascular diseases and risks collaboration, 1990-2021. J Am Coll Cardiol 2022;80(25):2372–425. Dec 20.
[14] Shi D, Tao Y, Wei L, Yan D, Liang H, Zhang J, Wang Z. The burden of cardiovascular diseases attributed to diet high in sugar-sweetened beverages in 204 countries and territories from 1990 to 2019. Curr Probl Cardiol 2023;49(1): 102043. Aug 17Pt A.
[15] World health organization. Disability-adjusted life years (DALYs). https://www.who.int/data/gho/indicator-metadata-registry/imr-details/158. Accessed 14 December 2023.
[16] GBD 2019 Risk Factors Collaborators. Global burden of 87 risk factors in 204 countries and territories, 1990-2019: a systematic analysis for the Global burden of disease study 2019. Lancet 2020;396(10258):1223–49. Oct 17.
[17] Ammar A, Trabelsi K, Hermassi S, Kolahi AA, Mansournia MA, Jahrami H, Boukhris O, Boujelbane MA, Glenn JM, Clark CCT, Nejadghaderi A, Puce L, Safiri S, Chtourou H, Schöllhorn WI, Zmijewski P, Bragazzi NL. Global disease burden attributed to low physical activity in 204 countries and territories from 1990 to 2019: insights from the Global Burden of Disease 2019 Study. Biol Sport. 2023;40 (3):835–55. Jul.
[18] World Heart Report. Confronting the world's number one killer. Geneva, Switzerland. World Heart Federation; 2023. 2023.
[19] Vaduganathan M, Mensah GA, Turco JV, Fuster V, Roth GA. The Global Burden of Cardiovascular Diseases and Risk: a Compass for Future Health. J Am Coll Cardiol 2022;80(25):2361–71. Dec 20.
[20] Pedersen BK, Saltin B. Exercise as medicine - evidence for prescribing exercise as therapy in 26 different chronic diseases. Scand J Med Sci Sports 2015;25(3):1–72. DecSuppl.
[21] Zhou H, Wang S, Zhao C, He H. Effect of exercise on vascular function in hypertension patients: a meta-analysis of randomized controlled trials. Front Cardiovasc Med 2022;9:1013490. https://doi.org/10.3389/fcvm.2022.1013490. Dec 21.
[22] Mann S, Beedie C, Jimenez A. Differential effects of aerobic exercise, resistance training and combined exercise modalities on cholesterol and the lipid profile: review, synthesis and recommendations. Sports Med 2014;44(2):211–21. Feb.
[23] Beavers KM, Brinkley TE, Nicklas BJ. Effect of exercise training on chronic inflammation. Clin Chim Acta 2010;411(11–12):785–93. https://doi.org/10.1016/j.cca.2010.02.069. Jun 3Epub 2010 Feb 25.

[24] Martins C, Morgan L, Truby H. A review of the effects of exercise on appetite regulation: an obesity perspective. Int J Obes 2008;32(9):1337–47.
[25] Chaput JP, Klingenberg L, Rosenkilde M, Gilbert JA, Tremblay A, Sjödin A. Physical activity plays an important role in body weight regulation. J Obes 2011; 2011:360257.
[26] Tian D, Meng J. Exercise for prevention and relief of cardiovascular disease: prognoses, mechanisms, and approaches. Oxid Med Cell Longev 2019:3756750. 2019 Apr 9.
[27] GBD 2015 Eastern Mediterranean Region Cancer Collaborators. Burden of cancer in the Eastern Mediterranean Region, 2005-2015: findings from the global burden of disease 2015 study. Int J Public Health 2018;63(Suppl 1):151–64. May.
[28] Nansseu JR, Bigna JJ. Antiretroviral therapy related adverse effects: can sub-Saharan Africa cope with the new "test and treat" policy of the world health organization? Infect Dis Poverty 2017 Feb 15;6(1):24.
[29] Foo LL, Vijaya K, Sloan RA, Ling A. Obesity prevention and management: singapore's experience. Obes Rev 2013;14(2):106–13. https://doi.org/10.1111/obr.12092. NovSupplPMID: 24102951.
[30] Essien OE, Andy J, Ansa V, Otu AA, Udoh A. Coronary artery disease and the profile of cardiovascular risk factors in South South Nigeria: a clinical and autopsy study. Cardiol Res Pract 2014;2014:804751.
[31] Mate K, Bryan C, Deen N, McCall J. Review of health systems of the middle east and north africa region. International Encyclopedia of Public Health; 2017. p. 347–56.
[32] Azevedo MR, Araújo CL, Reichert FF, Siqueira FV, da Silva MC, Hallal PC. Gender differences in leisure-time physical activity. Int J Public Health 2007;52(1):8–15. https://doi.org/10.1007/s00038-006-5062-1.
[33] Rodgers JL, Jones J, Bolleddu SI, Vanthenapalli S, Rodgers LE, Shah K, Karia K, Panguluri SK. Cardiovascular risks associated with gender and aging. J Cardiovasc Dev Dis 2019;6(2):19. Apr 27.
[34] Mackenbach JP, Kunst AE, Lautenbach H, Oei YB, Bijlsma F. Competing causes of death: a death certificate study. J Clin Epidemiol 1997;50(10):1069–77. Oct.
[35] Zhao D, Liu J, Wang M, Zhang X, Zhou M. Epidemiology of cardiovascular disease in China: current features and implications. Nat Rev Cardiol 2019;16(4):203–12. Apr.
[36] Wang W, Hu M, Liu H, Zhang X, Li H, Zhou F, Liu YM, Lei F, Qin JJ, Zhao YC, Chen Z, Liu W, Song X, Huang X, Zhu L, Ji YX, Zhang P, Zhang XJ, She ZG, Yang J, Yang H, Cai J, Li H. Global burden of disease study 2019 suggests that metabolic risk factors are the leading drivers of the burden of ischemic heart disease. Cell Metab 2021;33(10):1943–56. Oct 5e2.
[37] Tian Y, Jiang C, Wang M, Cai R, Zhang Y, He Z, Wang H, Wu D, Wang F, Liu X, He Z, An P, Wang M, Tang Q, Yang Y, Zhao J, Lv S, Zhou W, Yu B, Lan J, Yang X, Zhang L, Tian H, Gu Z, Song Y, Huang T, McNaughton LR. BMI, leisure-time physical activity, and physical fitness in adults in China: results from a series of national surveys, 2000-14. Lancet Diabetes Endocrinol 2016;4(6):487–97. Jun.
[38] Yusuf S, Islam S, Chow CK, Rangarajan S, Dagenais G, Diaz R, et al. Use of secondary prevention drugs for cardiovascular disease in the community in high-income, middle-income, and low-income countries (the PURE Study): a prospective epidemiological survey. Lancet 2011;378(9798):1231–43.