Neurological Sciences (2022) 43:255–264
https://doi.org/10.1007/s10072-021-05259-2

ORIGINAL ARTICLE

Secular trends of ischaemic heart disease, stroke, and dementia in high-income countries from 1990 to 2017: the Global Burden of Disease Study 2017

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Received: 16 November 2020 / Accepted: 12 April 2021 / Published online: 1 May 2021

Abstract

Background We assessed secular trends in the burden of ischaemic heart disease (IHD), stroke, and dementia in the Organization for Economic Co-operation and Development (OECD) countries.

Methods Using the Global Burden of Disease (GBD) Study 2017, we compared sex-specific and age-standardized rates of disability-adjusted life years (DALY); mortality, incidence, and prevalence of IHD and stroke; and dementia per 100,000 people, in the world, OECD countries, and Canada.

Results From 1990 to 2017, the crude incidence number of IHD, stroke, and dementia increased 52%, 76%, and 113%, respectively. Likewise, the prevalence of IHD (75%), stroke (95%), and dementia (119%) increased worldwide. In addition during the study period, the crude global number of deaths of IHD increased 52%, stroke by 41%, and dementia by 146% (9, 6, and 3 million deaths in 2017, respectively). Despite an increase in the crude number of these diseases, the global age-standardized incidence rate of IHD, stroke, and dementia decreased by −27%, − 11%, and − 5%, respectively. Moreover, there was a decline in their age-standardized DALY rates (− 1.17%, − 1.32%, and − 0.23% per year, respectively) and death rates (− 1.29%, − 1.46%, and − 0.17% per year, respectively), with sharper downward trends in Canada and OECD countries. Almost all trends flattened during the last decade.

Conclusions From 1990 to 2017, the age-standardized burden of IHD, stroke, and dementia decreased, more prominently in OECD countries than the world. However, their rising crude numbers mainly due to population growth and ageing require urgent identification of reversible risk and protective factors.

Keywords Public health · Stroke · Ischemic heart disease · Dementia · Alzheimer's disease · Incidence · Prevalence · Mortality · Disability

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Introduction

Non-communicable diseases are the leading healthcare priorities in the world. Among age-related non-communicable diseases, ischaemic heart disease (IHD), stroke, and dementia are the most important causes of death and disability worldwide [1–3]. Despite a significant decline over time in IHD mortality rate, IHD has remained the leading cause of death worldwide, with 17.9 million deaths in 2015 [1]. There is also an estimated 25% global lifetime risk of stroke from the age of 25 years onward [4], with 6.2 million deaths in 2017 [3]. In addition, a significant share of the global health burden is attributed to stroke and dementia [3–5].

Non-communicable diseases can be often seen as a cluster of diseases. One of the best examples is the combination of vascular diseases with dementia. IHD, stroke, and dementia have several common risk factors [6, 7] and thus pose risks for each other [8]. In the majority of cases, cognitive impairment is the most common clinical presentation of vascular disorders. According to the Rotterdam Study, for each clinical stroke, there are probably five so-called "silent" strokes in which—upon closer assessment—patients may have subtle cognitive impairment, including problems with processing speed and executive dysfunction. Vascular lesions may not only lead to vascular cognitive impairment but can also contribute to or accelerate neurodegenerative types of dementia, such as Alzheimer's disease [9]. Stroke doubles the likelihood of developing dementia [10], and 90% of strokes are preventable [11]. Stroke units, stroke prevention clinics [12], lifestyle changes, and medications have all contributed to the prevention of stroke and thus dementia. Therefore, a successful prevention strategy needs to consider vascular diseases and dementia simultaneously. This approach rests on a solid scientific basis [13] and is endorsed by the World Stroke Organization, Alzheimer's Disease International, the World Federation of Neurology, the World Heart Federation, and 18 other international, regional, and national organizations [14–16].

Despite mounting evidence regarding close associations between IHD, stroke, and dementia, there are only a few joint studies [17–19]. Moreover, due to the rapid growth of the aged population, particularly in high-income countries (HICs), it is important to be aware of the current status of these problems and their changing trends during recent years and foresee possible future trends.

We assessed the current status of IHD, stroke, and dementia and their corresponding epidemiological changes across time in the Organization for Economic Co-operation and Development (OECD) countries representatives of developed countries and HICs, and compared them with the values in Canada, a member of the OECD countries with universal health coverage. We also compared the changes with those in the whole world.

Methods

Population and data

We extracted data from the Global Burden of Disease (GBD), injuries, and risk factors study 2017 databank [20] on disability-adjusted life years (DALY; i.e. years of life lost from premature death and years of life lived in less than full health), mortality, incidence, and prevalence related to IHD, stroke, and Alzheimer's disease and other dementias between 1990 and 2017 in Canada, OECD countries, and the whole world. The GBD consortium originated from the 1990 World Bank study that was commissioned to measure disability and death from hundreds of diseases, injuries, and risk factors worldwide [21]. The goal is to improve health systems and eliminate disparities. The data comprises information from multiple regional, national, and global sources of 359 diseases and injuries in 195 countries and territories, by age and sex, from 1990 to the present, allowing comparisons over time, across age groups, and among populations. In the GBD study, dementia is defined as "Alzheimer's disease and other dementias", hereby referred to as dementia.

OECD countries aim to shape policies that foster prosperity, equality, opportunity, and well-being for all by finding evidence-based solutions to social, economic, and environmental challenges. We used this classification, rather than HICs, as it might better represent the overall socioeconomic status of a country with a desirable healthcare system. OECD countries in the present analysis included 35 countries: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Latvia, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland, Turkey, the UK, and the USA.

Data analysis

We reported the sex-specific and age-standardized rate of IHD, stroke, and dementia-related DALY, mortality, incidence, and prevalence per 100,000 people from 1990 to 2017. We used the joinpoint regression program (version 4.8.0.1) [22]. We performed joinpoint regression analysis to identify the average annual percent change (AAPC) and segmented annual percentage change (sAPC) in DALY, mortality, incidence, and prevalence related to IHD, stroke, and dementia.

AAPC is a summary measure of the trend over a prespecified fixed interval. AAPC is the weighted average of the sAPCs, with the weights equal to the length of the sAPC interval.

AAPC is derived by estimation of the underlying joinpoint model that best fits onto the data. The best model was selected using the permutation technique with 4499 permutation tests. We used two parameters to determine the number of join-points: (a) the minimum number of observations from a joinpoint to either end of data and (b) the minimum number of observations between two joinpoints. In our analysis, they were both set to 2. Using the grid search method [23], we determined where to locate the join-points on the time-scale. A grid is created for all possible join-point positions. The final position of the join-points depended upon where the sum of squared errors was minimal. We selected maximum number of five join points in the final join-point analysis [24]. A *P* value of less than 0.05 was considered statistically significant.

Results

Incidence and prevalence

From 1990 to 2017, the global crude number of incident cases with IHD, stroke, and dementia increased by 52%, 76%, and 113%, respectively. In 2017, their global incidence was estimated to be 11, 12, and 7 million, almost half of which were in OECD countries. From 1990 to 2017, their prevalence increased by 75%, 95%, and 119%, respectively (Table 1).

After adjusting for the effect of age and population, the global incidence rate of IHD, stroke, and dementia have shown a decrease of −27%, − 11%, and − 5% from 1990 to 2017 (Supplemental Figure 1; Table 1). Their age-standardized prevalence rate changed by −12%, 3%, and − 4%, respectively. The reductions were greater in OECD countries than in the world but lesser than in Canada. In 2017, IHD and stroke were more incident and prevalent in men than women, while dementia was more common in women (Table 2).

Trends in annual changes of incidence and prevalence

From 1990 to 2017, global age-standardized IHD, stroke, and dementia incidence rates declined by −1.18%, − 0.44%, and − 0.20% per year (Supplemental Table 1). Such decreasing trends were also seen in OECD countries and were steeper in Canada. During this period, a more prominent decrease in age-standardized dementia incidence rate per year was seen in Canada (− 0.72%), compared to OECD countries (− 0.21%), and the world (− 0.20%). From 1990 to 2017, overall, global age-standardized dementia prevalence rates declined (− 0.16% per year), with sharper downward trends in Canada (− 0.73% per year) and OECD countries (− 0.2% per year). However, these trends gradually became slower worldwide from 1990 to 2017 (Supplemental Figure 1). Despite an initial decline in the age-standardized stroke prevalence rate, it gradually increased worldwide: since 2005 in the world; since 2007 in OECD; and since 2013 in Canada. An increase in dementia incidence (since 2014) and prevalence (since 2013) was seen in Canada: 0.36% and 0.28% per year, respectively.

Mortality and burden

From 1990 to 2017, the crude global burden of IHD, stroke, and dementia, measured by DALY, increased by 43%, 34%, and 115%, respectively. During this 28-year period, the crude number of deaths related to these diseases increased globally; IHD by 52% (9 million deaths in 2017), stroke by 41% (6 million deaths in 2017), and dementia by 146% (3 million deaths in 2017). In 2017, a substantial proportion of non-communicable diseases was related to IHD (170 million DALY equal to 11.0% of total non-communicable diseases DALY), stroke (132 million DALY equal to 8.5% of non-communicable diseases DALY), and dementia (31 million DALY equal to 2.0% of non-communicable diseases DALY) (Table 1). After adjustment for age and population, from 1990 to 2017, the age-standardized rate of DALY and deaths per 100,000 population related to IHD, stroke, and dementia reduced more in OECD countries than in the world. Canada had an even higher decrease in almost all of these rates than OECD countries (Supplemental Figure 1; Table 1). In 2017, IHD and stroke had higher burden and mortality rates among men than women, while dementia had higher burden and mortality rate among women than men (Table 2).

Trends in annual changes of mortality and burden

Globally, from 1990 to 2017, the age-standardized rates of IHD, stroke, and dementia DALY declined by −1.17%, − 1.32%, and − 0.23% per year, with sharper downward trends in Canada and OECD countries (Supplemental Figure 1; Supplemental Table 1). Despite a decline in the burden of stroke and IHD between 1990 and 2017, these declines gradually became slower worldwide. Globally, from 1990 to 2017, the age-standardized rates of IHD, stroke, and dementia death declined by −1.29%, − 1.46%, and − 0.17% per year, with sharper downward trends in Canada and OECD countries. Although there was an initial decline in the age-standardized stroke death rate worldwide, it remained almost stable in recent years: since 2014 in the world (− 0.67% per year) and OECD (− 0.46% per year) and since 2012 in Canada (− 0.02% per year).

Discussion

Our study has major public health implications. From 1990 to 2017, the declining trend in age-standardized rates of DALY, mortality, and incidence of IHD, stroke, and dementia has

Table 1 Incidence, prevalence, mortality, and burden related to ischaemic heart disease, stroke, and dementia from 1990 to 2017

Measure	Cause	Metric	Age	Location	Mean value in 2017 (95% UI)	Percent change from 1990 to 2017 (95% UI)
Incidence	Ischaemic heart disease	Number (thousand)	All ages	Global	10,637 (9573–11,794)	52 (49–55)
				Canada	91 (79–104)	25 (15–36)
				OECD countries	3707 (3367–4083)	22 (19–24)
		Rate per 100,000	Age-standardized	Global	135.6 (122.2–150.4)	− 27 (− 29 to −26)
				Canada	134 (115.9–152.7)	− 40 (− 45 to −35)
				OECD countries	157.9 (142.8–174.3)	− 30 (− 32 to −29)
			All ages	Global	139.2 (125.3–154.4)	7 (5–9)
				Canada	253.1 (220.8–289.3)	− 6 (− 13–3)
				OECD countries	286.1 (259.9–315.2)	2 (− 1 to 4)
	Stroke	Number (thousand)	All ages	Global	11,931 (11118–12,826)	76 (71–80)
				Canada	65 (60–71)	63 (55–71)
				OECD countries	2548 (2378–2728)	35 (32–39)
		Rate per 100,000	Age-standardized	Global	150.5 (140.3–161.8)	− 11 (− 13 to −9)
				Canada	100.5 (92.5–110.2)	− 19 (− 23 to −15)
				OECD countries	113.9 (106.4–122.1)	− 21 (− 23 to −19)
			All ages	Global	156.2 (145.5–167.9)	24 (21–27)
				Canada	180.7 (165.5–198.2)	23 (17–30)
				OECD countries	196.7 (183.5–210.6)	13 (10–16)
	Alzheimer's disease and other dementias	Number (thousand)	All ages	Global	7301 (6516–8133)	113 (109–118)
				Canada	62 (57–69)	86 (75–97)
				OECD countries	2706 (2431–3006)	87 (81–94)
		Rate per 100,000	Age-standardized	Global	97.5 (86.8–108.9)	− 5 (− 6 to −5)
				Canada	82.5 (74.7–91.7)	− 18 (− 23 to −14)
				OECD countries	98.5 (88.6–109.1)	− 6 (− 7–4)
			All ages	Global	95.6 (85.3–106.5)	50 (47–54)
				Canada	173.6 (158–193.1)	41 (32–49)
				OECD countries	208.9 (187.6–232)	56 (51–62)
Prevalence	Ischaemic heart disease	Number (thousand)	All ages	Global	126,452 (118587–134,706)	75 (72–79)
				Canada	840 (752–937)	59 (48–72)
				OECD countries	36,274 (33615–39,140)	42 (36–47)
		Rate per 100,000	Age-standardized	Global	1583.7 (1484.5–1691.1)	−12 (−14– −10)
				Canada	1274.2 (1146.5–1415.1)	−20 (−25– −14)
				OECD countries	1597.1 (1488.4–1718.1)	−16 (−19– −13)
			All ages	Global	1655 (1552.1–1763.1)	24 (21–26)
				Canada	2335.5 (2089.4–2603.1)	21 (12–30)
				OECD countries	2800.2 (2595–3021.5)	18 (14–23)
	Stroke	Number (thousand)	All ages	Global	104,179 (98454–110,125)	95 (91–100)
				Canada	709 (660–765)	74 (64–85)
				OECD countries	24,647 (23357–25,919)	52 (47–56)
		Rate per 100,000	Age-standardized	Global	1300.6 (1229–1374.7)	3 (1–5)
				Canada	1165.7 (1086–1253.5)	−9 (−14 to −4)
				OECD countries	1140.7 (1087–1197.6)	−8 (−11 to −6)
			All ages	Global	1363.5 (1288.6–1441.3)	38 (35–41)
				Canada	1971.5 (1833.5–2126.9)	32 (24–40)

Table 1 (continued)

				OECD countries	1902.7 (1803.1–2000.8)	27 (23–30)
	Alzheimer's disease and other dementias	Number (thousand)	All ages	Global	44,989 (39716–50,378)	119 (115–123)
				Canada	378 (342–418)	90 (79–101)
				OECD countries	16,466 (14669–18,282)	93 (87–99)
		Rate per 100,000	Age-standardized	Global	604.9 (533.1–675.9)	− 4 (− 5 to −4)
				Canada	493.8 (447–546)	− 18 (− 23 to −14)
				OECD countries	588.9 (523.9–653.9)	− 5 (− 7 to −4)
			All ages	Global	588.8 (519.8–659.4)	55 (52–58)
				Canada	1051.5 (951.6–1162.2)	44 (36–52)
				OECD countries	1271.1 (1132.4–1411.3)	61 (56–66)
DALY (disability-adjusted life years)	Ischaemic heart disease	Number (thousand)	All ages	Global	170,275 (167140–174,047)	43 (39–46)
				Canada	661 (626–701)	− 21 (− 25 to −17)
				OECD countries	26,045 (25456–26,789)	− 28 (− 30 to −27)
		Rate per 100,000	Age-standardized	Global	2132.1 (2093.7–2179.8)	− 28 (− 29 to −26)
				Canada	992.4 (938.3–1053.3)	− 61 (− 63 to −58)
				OECD countries	1144.2 (1119–1175.5)	− 58 (− 58 to −57)
			All ages	Global	2228.6 (2187.6–2278)	1 (− 2 to −3)
				Canada	1837.3 (1739.3–1947.8)	− 40 (− 44 to −37)
				OECD countries	2010.6 (1965.1–2068)	− 40 (− 41 to −39)
	Stroke	Number (thousand)	All ages	Global	132,051 (126499–137,350)	34 (29–37)
				Canada	320 (287–356)	23 (16–30)
				OECD countries	14,819 (13705–15,889)	− 13 (− 17 to −10)
		Rate per 100,000	Age-standardized	Global	1657.2 (1587.4–1723.8)	− 31 (− 33 to −29)
				Canada	492.2 (438.4–546.5)	− 38 (− 42 to −35)
				OECD countries	652.7 (602.5–701.9)	− 49 (− 51 to −47)
			All ages	Global	1728.3 (1655.6–1797.7)	− 6 (− 9 to −3)
				Canada	890.7 (798.2–988)	− 7 (− 12 to −1)
				OECD countries	1144 (1058–1226.6)	− 27 (− 30 to −25)
	Alzheimer's disease and other dementias	Number (thousand)	All ages	Global	30,521 (28530–32,558)	115 (109–120)
				Canada	254 (235–274)	94 (86–102)
				OECD countries	11,327 (10586–12,079)	90 (86–94)
		Rate per 100,000	Age-standardized	Global	412.6 (385.7–440.3)	− 6 (− 8 to −4)
				Canada	328 (302.9–354.1)	− 18 (− 21 to −14)
				OECD countries	402.4 (376.1–429.2)	− 7 (− 9 to −6)
			All ages	Global	399.5 (373.4–426.1)	52 (48–55)
				Canada	706.4 (652–761.6)	47 (41–53)
				OECD countries	874.4 (817.2–932.5)	59 (56–62)
Deaths	Ischaemic heart disease	Number (thousand)	All Ages	Global	8930 (8791–9139)	52 (49–55)
				Canada	48 (46–51)	− 5 (− 10 to 0)
				OECD countries	1845 (1809–1909)	− 15 (− 17 to −13)
		Rate per 100,000	Age-standardized	Global	116.9 (115.1–119.7)	− 30 (− 31 to −29)
				Canada	63.3 (60.2–66.6)	− 59 (− 61 to −57)
				OECD countries	68.8 (67.5–71.1)	− 57 (− 58 to 56)
			All ages	Global	116.9 (115.1–119.6)	8 (5–9)
				Canada	134.5 (128.2–141.2)	− 28 (− 32 to −25)
				OECD countries	142.4 (139.7–147.4)	− 29 (− 30 to −27)

Table 1 (continued)

	Stroke	Number (thousand)	All ages	Global	6167 (6044–6328)	41 (38–45)
				Canada	18 (17–19)	32 (23–41)
				OECD countries	864 (846–899)	− 8 (− 11 to −5)
		Rate per 100,000	Age-standardized	Global	80.5 (78.9–82.6)	− 33 (− 35 to −32)
				Canada	23 (21.6–24.5)	− 45 (− 48 to −41)
				OECD countries	31.6 (31–32.8)	− 55 (− 56 to −53)
			All ages	Global	80.7 (79.1–82.8)	0 (− 3 to 2)
				Canada	50.2 (47.2–53.2)	0 (− 7 to 7)
				OECD countries	66.7 (65.3–69.4)	− 23 (− 25 to −21)
	Alzheimer's disease and other dementias	Number (thousand)	All ages	Global	2515 (2471–2550)	146 (140–151)
				Canada	25 (24–26)	125 (114–137)
				OECD countries	1092 (1073–1108)	126 (122–130)
		Rate per 100,000	Age-standardized	Global	35.4 (34.8–35.9)	− 4 (− 6 to −2)
				Canada	29.3 (27.9–30.7)	− 17 (− 21 to −12)
				OECD countries	35.5 (34.8–36)	− 4 (− 6 to −3)
			All ages	Global	32.9 (32.3–33.4)	74 (69–78)
				Canada	70.1 (66.9–73.4)	70 (62–79)
				OECD countries	84.3 (82.9–85.6)	89 (86–92)

slowed and almost flattened or increased in recent years. Thus, health authorities should foresee an [18] increase in these outcomes, necessitating joint surveillance and preventative measures [25]. While some studies have suggested that the age/sex-standardized rate of dementia may remain constant [26], the novelty of the current study is that the age-standardized dementia incidence rate has gradually declined in OECD countries, more prominently in Canada. This could reflect a favourable outcome of preventive measures against vascular risk factors [14–19, 27, 28], particularly for IHD and stroke.

Encouraging and alarming trends

Similar to previous findings [29], we observed a significant gap between global IHD and stroke mortality rates in the whole world, vs. OECD countries and Canada. Canada had a better status in almost all age-standardized measures (i.e. incidence, prevalence, DALY, and mortality rate of IHD, stroke, and dementia) compared to the world and overall OECD countries, except for the age-standardized stroke prevalence rate that slightly increased. While this increase was justified by the increasing rates in middle-income countries [3], the rocketing trend of stroke prevalence in Canada should call for urgent action. Despite an age-adjusted decreasing trend, the absolute trends of vascular diseases and dementia burden are increasing in OECD countries including Canada. The epidemiological shift toward higher burden of IHD, stroke, and dementia may be explained by population growth and ageing. More importantly, non-communicable diseases can be frequently seen as a cluster of chronic diseases. For example, according to the Canadian Study of Health and Ageing, 64% of patients with stroke aged ≥65 years had some cognitive impairment. In addition, 25% of patients with some cognitive impairment had a history of prior stroke [30]. To decrease the burden of these diseases, it is necessary to have a more comprehensive approach to public health. We need not only to intensify, but to diversify our prevention efforts. Current clinical high-risk individual level approaches need to be complemented by a population level approach, where small changes make a big difference.

Impact of healthcare service on outcome

All-age incidence and prevalence rates of IHD, stroke, and dementia are increasing worldwide, probably due to ageing. However, the DALY and mortality rates of IHD and stroke did not surge, which could be explained by improved healthcare delivery and general awareness. According to the World Health Organization report [31], half of the world's population do not have full coverage of essential health services. In the current study, we selected Canada as a high-income country with universal health coverage in the highest decile [32]. With its fair health delivery system,

Table 2 Sex difference in incidence, prevalence, mortality and burden related to ischaemic heart disease, stroke, and dementia in 2017

Region	Condition	Measure	Female to male ratio	Age-standardized rate in females (95UI)
Ischaemic heart disease	Global	Incidence	0.62	105.4 (94.3–117.4)
		Prevalence	0.74	1361.3 (1274.8–1453.4)
		DALY	0.55	1534.3 (1487.3–1580.5)
		Deaths	0.65	93.3 (91.2–96.1)
	Canada	Incidence	0.28	60.6 (50.8–71.7)
		Prevalence	0.37	700 (602.2–805.8)
		DALY	0.43	603.9 (554.9–655.8)
		Deaths	0.55	46.1 (42.7–49.9)
	OECD countries	Incidence	0.5	107.6 (97–119.5)
		Prevalence	0.56	1177.9 (1097.6–1265.2)
		DALY	0.43	709.5 (686.4–737)
		Deaths	0.54	49.7 (48.3–52.1)
Stroke	Global	Incidence	0.84	137.7 (128.1–148.1)
		Prevalence	0.96	1272.7 (1205.7–1343)
		DALY	0.73	1412.1 (1336.8–1485.8)
		Deaths	0.75	69.6 (67.7–71.9)
	Canada	Incidence	0.94	97.6 (90–106.9)
		Prevalence	1	1169.8 (1088.4–1258.5)
		DALY	0.92	471.6 (412–532.7)
		Deaths	0.87	21.5 (19.7–23.5)
	OECD Countries	Incidence	0.87	106.2 (99.6–113.8)
		Prevalence	0.96	1119.9 (1070.3–1174.2)
		DALY	0.77	574.4 (522.5–624.7)
		Deaths	0.77	27.8 (26.9–29.2)
Alzheimer's disease and other dementias	Global	Incidence	1.17	103.6 (92.4–115.6)
		Prevalence	1.16	641.3 (565.5–716.8)
		DALY	1.16	436.2 (407.7–466.2)
		Deaths	1.19	37.6 (36.9–38.2)
	Canada	Incidence	1.17	87.4 (78.3–97.9)
		Prevalence	1.12	514.1 (459.4–573.5)
		DALY	1.16	347.2 (318.2–380)
		Deaths	1.22	31.3 (29.4–33.4)
	OECD Countries	Incidence	1.15	103.8 (93.3–115)
		Prevalence	1.13	615.2 (546.7–681.8)
		DALY	1.08	413.4 (385.1–443)
		Deaths	1.12	36.7 (35.9–37.5)

*In both sexes; DALY, disability-adjusted life years; UI, uncertainty interval

universal health coverage presents an important research opportunity to assess the efficacy of health policies and track the associations between the clusters of diseases at a population level. From 1990 to 2017 in Canada, the age-standardized DALY, mortality, and incidence rates of IHD, stroke, and dementia declined significantly more than those of the global and OECD measures. Previously and in the province of Ontario (population: ~ 13.6 million), Canada, our group showed a similar finding with a concomitant decline in the age-adjusted incidence of stroke (32%) and dementia (7%) between 2002 and 2013 [17]. It is possible that this might be related to the implementation of coordinated stroke strategies in Canada, including implementation of secondary stroke prevention clinics at designated stroke hospitals [33], better control of vascular risk factors (e.g. hypertension, which is better controlled in North America than in Europe, and better controlled in Canada than in the US) [34, 35], treatment of B12 deficiency [36], supplementation with B vitamins [37], and lipid lowering agents [38], all of which reduce the risk of stroke [37] and thus dementia [39]. A significant reduction of age-adjusted incidence of dementia in Canada may represent a public

health opportunity for other high-income countries to implement joint prevention of vascular diseases and dementia.

Limitations

We were unable to analyse global data excluding OECD, but if we had, the differences would have been even greater. Although the GBD consortium offers the most comprehensive and integrated global results available, it is limited by the differential availability of data and a greater uncertainty among older age groups, locations with scarce data, and under-reported diseases. However, we attempted to address this uncertainty by providing the uncertainty ranges of all estimates. National averages may mask significant differences within countries and regions. We now recognize that environmental, socioeconomic factors, healthcare systems, and individual risk and protective factors contribute to the likelihood of disease and their outcomes. Data are not available in proportion to their importance nor in relationship to each other, except in the limited way that the multiple databases, algorithms, and analytics allow. Algorithms are based on assumptions that are not always fulfilled when dealing with diverse or incomplete data. We probably underestimated the burden of disease because we did not consider the interactions between co-existing diseases. Finally, although this novel approach brings new insights into the patterns and trends of IHD, stroke, and dementia, we acknowledge that this is one of many ways one can define and measure population risk of these diseases.

Conclusions

We analysed epidemiological changes in the incidence, prevalence, mortality, and burden of IHD, stroke, and dementia in Canada, OECD countries, and the world, from 1990 to 2017. Despite overall declining trends in the age-adjusted incidence, prevalence, mortality, and burden of these three diseases, we found subtle increasing trends of these diseases during recent years with the ageing of the population. This absolute trend is relevant for policymakers, even if it is a secondary phenomenon. In order to implement national strategies to decrease the burden of these diseases worldwide, new epidemiological studies should focus on multiple interacting conditions and not one specific entity. The decreasing trend in the age-standardized burden of the diseases worldwide indicates an improvement of population health and awareness over time. In particular, the age-standardized dementia incidence rate has gradually declined in OECD countries, which indicate the efficacy of preventive measures against vascular risk factors, particularly for IHD and stroke. However, globally the general focus and interest have often been placed on improvements in child and maternal health instead of the ageing population. Clearly, IHD, stroke, and dementia care requires far more than only acute care; it needs timely recognition of illness (by improving public and physicians' knowledge about signs and symptoms of vascular disorders), fair access and delivery of care with a targeted plan for less privileged areas [40], comprehensive rehabilitation plans, and an intensive approach for the secondary prevention of vascular disorders [41]. The findings emphasize the need for better surveillance systems and national and international campaigns to tackle IHD, stroke, and dementia, and public health plans for the ageing population.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10072-021-05259-2.

Availability of data and material The datasets generated and/or analysed during the current study are available in the Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2017 (GBD 2017) Results. Seattle, United States: Institute for Health Metrics and Evaluation (IHME). 2019. http://ghdx.healthdata.org/gbd-results-tool. Accessed 22 April 2019.

Declarations

Conflict of interest The authors declare no conflicts of interests.

Ethical approval None.

Informed consent None.

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