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Global, regional, and national time trends in incidence for depressive disorders, from 1990 to 2019: an age-period-cohort analysis for the GBD 2019

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Abstract

Background Even with advances in primary health care, depressive disorders remain a major global public health problem. We conducted an in-depth analysis of global, regional and national trends in depressive disorders incidence over the past 30 years.

Methods Data on the incidence of depressive disorders were obtained by sex (female, male, and both), location (204 countries), age (5–84 years), year (1990–2019) from the Global Burden of Disease Study (GBD) 2019. Further, age-period-cohort modeling was used to estimate the net drift, local drift, age, period and cohort effects between 1990 and 2019.

Results In 2019, although the incidence of depressive disorders has increased by 59.3% to 290 million (95% UI: 256, 328), the age-standardized incidence rate has decreased by 2.35% to 3588.25 per 100,000 people (3152.71, 4060.42) compared to 1990. There was an emerging transition of incidences from the young and middle-aged population to the old population. From 1990 to 2019, the net drift of incidence rate ranged from −0.54% (−0.61%, −0.47%) in low-middle Socio-demographic Index (SDI) regions to 0.52% (0.25%, 0.79%) in high SDI regions. Globally, the incidence rate of depressive disorders increases with age, period effects showing a decreasing risk and cohort effects beginning to decline after the 1960s.

Conclusions Our current findings reflect substantial health disparities and potential priority-setting of depressive disorders incidence in the three dimensions of age, period and cohort across SDI regions, countries. The scope of healthcare to improve the progression of depressive disorders events can be expanded to include males, females of all ages.

Keywords Depressive disorders, Incidence, Age-period-cohort, Trend, Global burden of disease

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Introduction

Depression is a common chronic illness that negatively impacts the quality of life, interferes with daily activities, and induces depressive thoughts [1]. Estimated at 297.6 million cases in 2019, depressive disorders ranked as the 13th highest contributor to overall burden and the seventh among nonfatal burdens [2–4]. Beyond its widespread prevalence, depression manifests as a pivotal factor in cardiovascular disease morbidity and mortality, reduced survival rates among cancer patients, increased number of suicides, and exacerbation of cognitive impairment and disability in individuals with Alzheimer's disease [5–8]. Additionally, this condition places a substantial economic strain on patients and their families, with each case incurring average annual direct costs ranging from $1,000 to $2,500 [9].

Over the past three decades, the global burden of Disability-Adjusted Life Years (DALYs) attributed to depression has risen from 1.1 million in 1990 to 1.8 million in 2019 [3]. Consequently, conducting a comprehensive examination of temporal trends in depression's incidence rates across all countries becomes imperative to monitor present-day developments in the disorder and establish priority areas for investment. Analyzing incidence risks among individuals with depression involves the segregation of age, period, and birth cohort effects. Age effects pertain to variations in disease risk across different age groups, such as the exacerbation of depressive symptoms in older adults due to social disengagement [10]. Period effects, on the other hand, stem from advancements in mental health treatments and primary care for depression that affect individuals universally at a particular time, regardless of their age or birth cohort [11]. Cohort effects delineate the impact of distinct historical, social, and environmental conditions on individuals born in a specific calendar year. The socioeconomic adversities and traumatic events during World War II might have contributed to the development of depression as a notable example [12]. Thus, trends in depression can be attributed to cohort, age, and time effects, a particular focus on this problem may aid in identifying potential gaps in global health care. However, the vast majority of previous studies have conducted only country- or region-specific analyses. Additionally, earlier studies were retrospective in nature, lacking insight into the future depression burden and failing to distinguish between cohort, period and age effects on incidence.

To address this limitation, we used Global Burden of Disease Study (GBD) 2019 data and the age-period-cohort model to explore changes in depression incidence rate at the global, regional and national levels from 1990 to 2019. We hypothesized that the incidence of depression changed between 1990 and 2019 and was influenced by age, period and cohort. Findings from this study could illustrate changes in disease patterns, shed light on how resources should be allocated, as well as provide some guidance for developing prevention and control strategies to further lessen the burden of depression disease.

Method

Study data

In this study, the number of incidences, all-age incidence rate and age-standardized incidence rate of depressive disorders were obtained by sex (female, male, and both), location (204 countries), age (5–84 years old), year (from 1990 to 2019). The detailed information and original data can be explored through the website of Global Health Data Exchange query tool (http://ghdx.healthdata.org/gbd-results-tool). The relevant data were anonymous and publicly available, and a waiver of informed consent was reviewed and approved by the University of Washington Institutional Review Board. Depressive disorder cases were classified with The Tenth Revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10; codes: F32–F33.9 and F34.1).

GBD 2019 utilized the DisMod-MR 2.1 meta-regression tool based on a Bayesian model framework to model the epidemiology of depression disorders. The Bayesian approach provides an interpretation of statistical probability, incorporating existing data to inform the probability of a given hypothesis. A meta-regression can be regarded as an extension of a meta-analysis by pooling data from different sources into a weighted average adjusting for heterogeneities. The steps of modelling process in DisMod-MR 2.1 are as follows: (1) The tool aggregated heterogeneous raw data for each parameter and adjusted data for methodological differences. If the data were insufficient to indicate age-pattern variation, a common age pattern might be imposed based on the assessment of age-specific input data for the disease; (2) It checked data on incidence, prevalence, duration, remission and mortality risk for internal consistency; (3) It simultaneously integrated the input data from all parameters along with outputs from previous steps to derive internally consistent epidemiological estimates, carrying forward uncertainty from primary data sources; (4) The model could produce generating estimates for countries with limited or no primary data sources using available information, enabling the estimation of depression disorders burden on a global scale [3].

GBD 2019 also produced a sociodemographic index (SDI) for 204 countries and territories to measure the location's development status, which was categorized into five quintiles: high SDI (>0.81), high-middle SDI (0.70–0.81), middle SDI (0.61–0.69), low-middle SDI (0.46–0.60), and low SDI (<0.46). More details on the SDI

methodology can be found in the previous study [13]. All estimates were reported in 95% uncertainty intervals (UIs), which were obtained by repeatedly sampling the sample 1000 times, with upper and lower bounds based on the 2.5th and 97.5th percentiles of the uncertainty distribution [3].

Statistics analysis

Analysis of overall temporal trends in depressive disorders incidence

This study reported global depressive disorders incidence and its spatial and temporal trends from 1990 to 2019. We plotted incidence from 1990 to 2019 to compare depressive disorders across years. Temporal trends in incidence over the study period were assessed by all-age incidence (crude incidence) and age-standardized incidence, and the relative change of incidence in percentage between 1990 and 2019. We examined the age distribution of incidences by categorizing number of incidences into sixteen age strata (5–9, 10–14 … 80–84 years) and calculating the proportions of incidence cases in each age stratum.

Age-period-cohort modelling analysis of incidence data

In this study, we used the Age-period-cohort (APC) model to decompose the incidence into three dimensions (age, period, and birth cohort), and analyze the corresponding effects on depressive disorders incidence [14]. In the APC model, age effects show the different risks of the outcome associated with different age brackets; the period effects show changes in the outcome over time that affect all age groups simultaneously; and the cohort effects show changes in the outcome across groups of people who share the same birth year [15].

GBD 2019 incidence estimates for depressive disorders and population data of each country/region were used as data inputs for the APC model with intrinsic estimator (IE) method. The utilization of the IE method within the framework of the APC model aimed to mitigate the inherent unpredictability associated with the model parameters encompassing age, period, and cohort effects. More methodological information is available in the previous literature [16]. In this model, it is required that the age and period intervals must all be equal, so we divided the population aged 5–84 years into 16 age groups (5–9, 10–14, …, 80–84) with successive 5-year age intervals. The groups under 5 years old and over 85 years old were not covered in this study due to the absence or rarity of depressive disorders events. The GBD data was incorporated into a single unit framework by selecting the incidence and population counts from the mid-year of six time point values (1992, 1997, …, 2017) rather than the 5-year averages to represent the specific period. The input data included 16 age groups and 21 consecutive cohorts, as referenced by the mid-year of birth, from 1906 to 1914 (median 1910) to 2006 – 2014 (median 2010). The lexis diagram of GBD data for the APC model was shown in Supplementary Table S1. In this study, we mainly focus on the following estimable functions. Net drift represents the overall annual percentage change for incidence rates over time. Local drifts reflect annual percentage changes by period and cohort for each age group; longitudinal age curve indicates the fitted longitudinal age-specific rates in the reference cohort adjusted for period deviations. The period (or cohort) rate ratio (RR) refers to the ratio of age-specific rates in each period (or cohort) relative to the reference one. The APC analysis for this study utilized the freely-available APC Web Tool (http://analysistools.nci.nih.gov/apc/) from the National Cancer Institute. The Wald chi-squared test was used to test the significance of the estimated parameters and functions. All statistical tests were two sided and $P < 0.05$ was considered statistically significant. All the graphics were produced with the R statistical program (version 4.2.0).

Results

Global, regional and countries trends in depressive disorders incidence, 1990–2019

In 2019, the number of depressive disorders incidence was 290 million (95% UI: 256, 328), an increase of 59.3% compared to 1990. The global age-standardized incidence rate (ASIR) of depressive disorders was 3588.25 per 100,000 population (95% UI: 3152.71, 4060.42), which was 2.53% lower than that in 1990. The number of incidences is significantly higher in females than in males (Table 1).

Regionally, the ASIR of depressive disorders was highest in the low SDI regions (4770.22 per 100,000 population, 95% UI: 4142.24, 5461.66) and lowest in the middle SDI regions (3139.00 per 100,000 population, 95% UI: 2765.35, 3540.43). Of note, the ASIR of depressive disorders showed a significant downward trend across SDI regions except high SDI regions, with EAPC ranging from −0.54% (95% CI −0.61%, −0.47%) to 0.52% (95% CI 0.25%, 0.79%) (Table 1).

At the national level, India (54.2 million, 95% UI: 47.5, 61.5) had the highest number of incidences, followed by China (41.0 million, 95% UI: 36.5, 46.2), United States of America (17.2 million, 95% UI: 15.3, 19.2), and Brazil (10.6 million, 95% UI: 9.5, 11.8), these four countries accounted for 42.4% of the global new cases. The highest ASIR was observed in Uganda (8062.8 per 100,000 population, 95% UI: 6946.5, 9437.0), and the lowest was found in Myanmar (1393.9 per 100,000 population, 95% UI: 1188.1, 1612.7). The incidence of depression is decreasing in 114 countries, increasing in 47 countries,

Table 1 Trends in depressive disorders incidence rate across Socio-demographic Index quintiles, 1990–2019

Characteristics	Incidences		All-age incidence rate[a]		Age-standardized incidence rate[b]		APC[c] model estimates
	Number in 2019, n (95% UI[d])	Percent change 1990–2019, % (95% UI)	Rate per 100,000 in 2019, n (95% UI)	Percent change 1990–2019, % (95% UI)	Rate per 100,000 in 2019, n (95% UI)	Percent change 1990–2019, % (95% UI)	Annual net drift[e] of incidence rate, % (95% CI[f])
Global	290185,741.60 (256024052.40, 328260552.70)	59.28 (54.88, 63.61)	3750.40 (3308.89, 4242.48)	10.13 (7.09, 13.12)	3588.25 (3152.71, 4060.42)	−2.53 (−3.70, −1.47)	−0.26 (−0.31, −0.21)
Sex							
Male	110123421.80 (96668365.29, 124305432.70)	63.98 (59.50, 68.20)	2837.52 (2490.83, 3202.94)	13.82 (10.71, 16.75)	2750.27 (2419.66, 3104.07)	0.52 (−0.50, 1.47)	−0.18 (−0.22, −0.14)
Female	180062319.80 (159076846.40, 204131417.20)	56.54 (51.84, 61.19)	4669.07 (4124.91, 5293.19)	7.82 (4.58, 11.02)	4416.34 (3886.90, 5015.49)	−4.28 (−5.77, −2.90)	−0.3 (−0.36, −0.24)
SDI region							
High SDI	44711792.44 (39796761.07, 50166003.31)	37.10 (33.34, 40.44)	4412.12 (3927.11, 4950.34)	11.21 (8.16, 13.92)	4013.63 (3545.48, 4550.43)	10.04 (7.29, 12.89)	0.52 (0.25, 0.79)
High-middle SDI	53642568.73 (47529705.87, 60307944.74)	31.91 (26.91, 36.78)	3750.17 (3322.82, 4216.15)	6.09 (2.07, 10.01)	3184.21 (2809.60, 3583.66)	−8.73 (−10.46, −6.98)	−0.53 (−0.67, −0.38)
Middle SDI	80760068.75 (71066731.89, 91500542.35)	61.17 (52.77, 68.98)	3369.82 (2965.36, 3817.99)	15.45 (9.44, 21.05)	3139.00 (2765.35, 3540.43)	−2.66 (−4.28, −1.09)	−0.36 (−0.80, 0.08)
Low-middle SDI	70155480.27 (61292236.79, 79973479.99)	70.27 (64.75, 75.66)	3977.11 (3474.65, 4533.69)	9.04 (5.51, 12.49)	4180.30 (3660.97, 4740.48)	−8.28 (−10.42, −6.43)	−0.54 (−0.61, −0.47)
Low SDI	40743981.19 (34959157.28, 47317677.84)	107.73 (104.92, 110.44)	3609.89 (3097.36, 4192.31)	−2.80 (−4.11, −1.53)	4770.22 (4142.24, 5461.66)	−8.59 (−9.74, −7.36)	−0.37 (−0.39, −0.34)

[a] All-age incidence rate = crude incidence rate

[b] Age-standardized incidence rate is computed by direct standardization with global standard population in GBD 2019

[c] *APC* age-period-cohort

[d] *UI* uncertainty interval

[e] Net drifts are estimates derived from the age-period-cohort model and denote overall annual percentage change in incidence rate, which captures the contribution of the effects from calendar time and successive birth cohorts

[f] *CI* confidential interval

and remaining stable in 43 countries out of 204 countries and territories. The fastest increase in ASIR was identified in the Spain (EAPCs = 1.06%; 95% CI 0.95%, 1.18%) and the fastest decrease in ASIR occurred in Singapore (EAPCs = −2.30%; 95% CI −2.41%, −2.19%) (Fig. 1).

Time trends in depressive disorders incidence rate across different age groups

Figure 2A shows the annual percentage change of incidence rate of depressive disorders in different age groups. Globally, the long-term trend of age-specific incidence can be roughly divided into 4 stages. In those aged 5–14 years old, the upward trend of depressive disorders incidence rate diminished with age, while there was a downward trend among 15- 64 years, with the greatest reduction occurring in 30–34 years. In those aged 65 ~ 79 years, there was an upward trend in depressive disorders incidence rate, and again decreases in the age of 80–84 years. Interestingly, depressive disorders incidence rates in the population aged 65–84 years were shown to be decreasing in high SDI regions and increasing in middle SDI regions, respectively. Also, among the population over 15 years, high-middle SDI regions exhibited a decreasing tendency in the incidence rate of depressive disorders, while in low SDI regions, the decrease occurs 5 years earlier. The local drift of incidence rate for each country is shown in Additional Fig. 1–5.

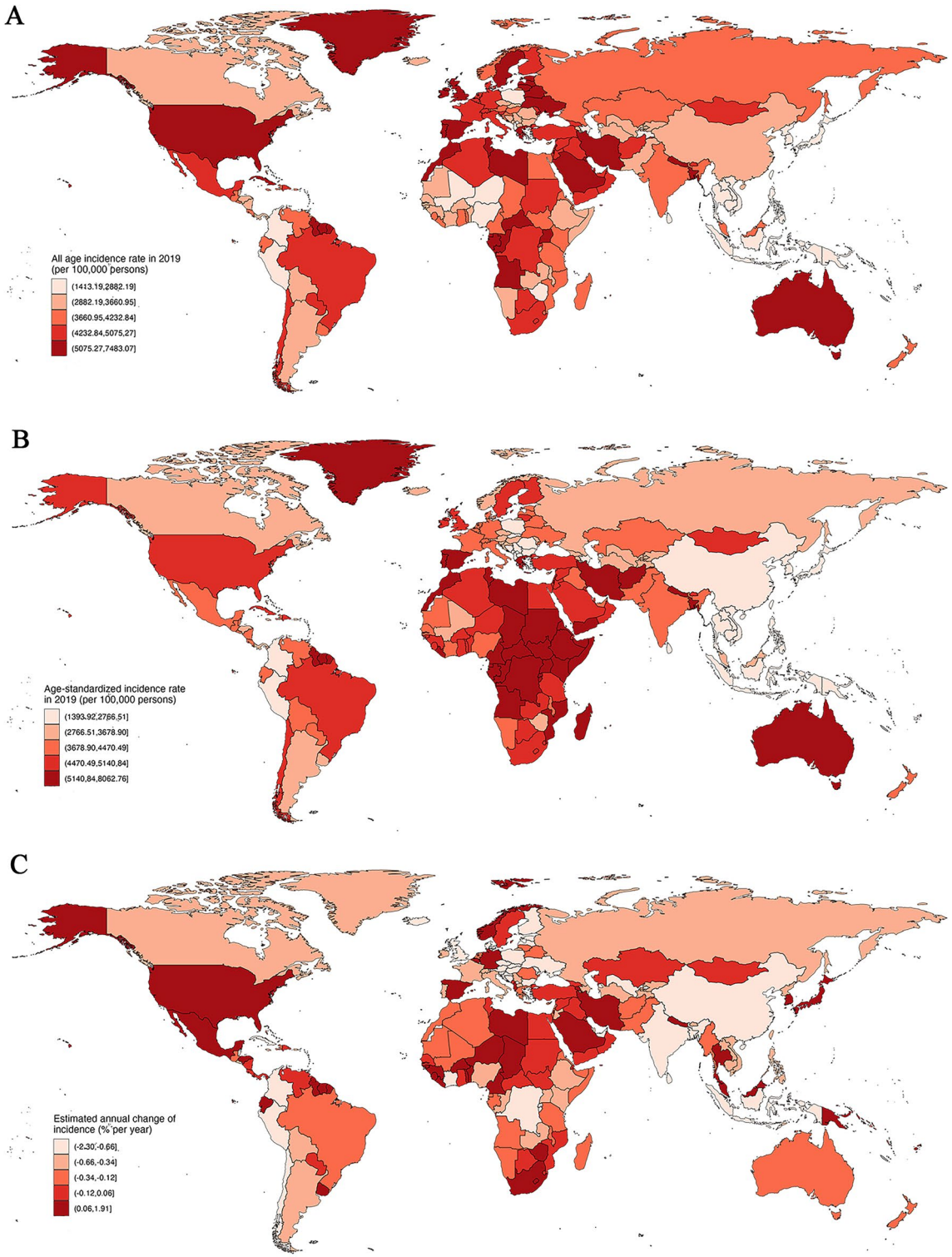

Fig. 1 The all-age incidence rate in 2019 (**A**), age-standardized incidence rate in 2019 (**B**), and net drift of incidence rate during 1990–2019 (**C**) for depressive disorders in 204 countries and territories

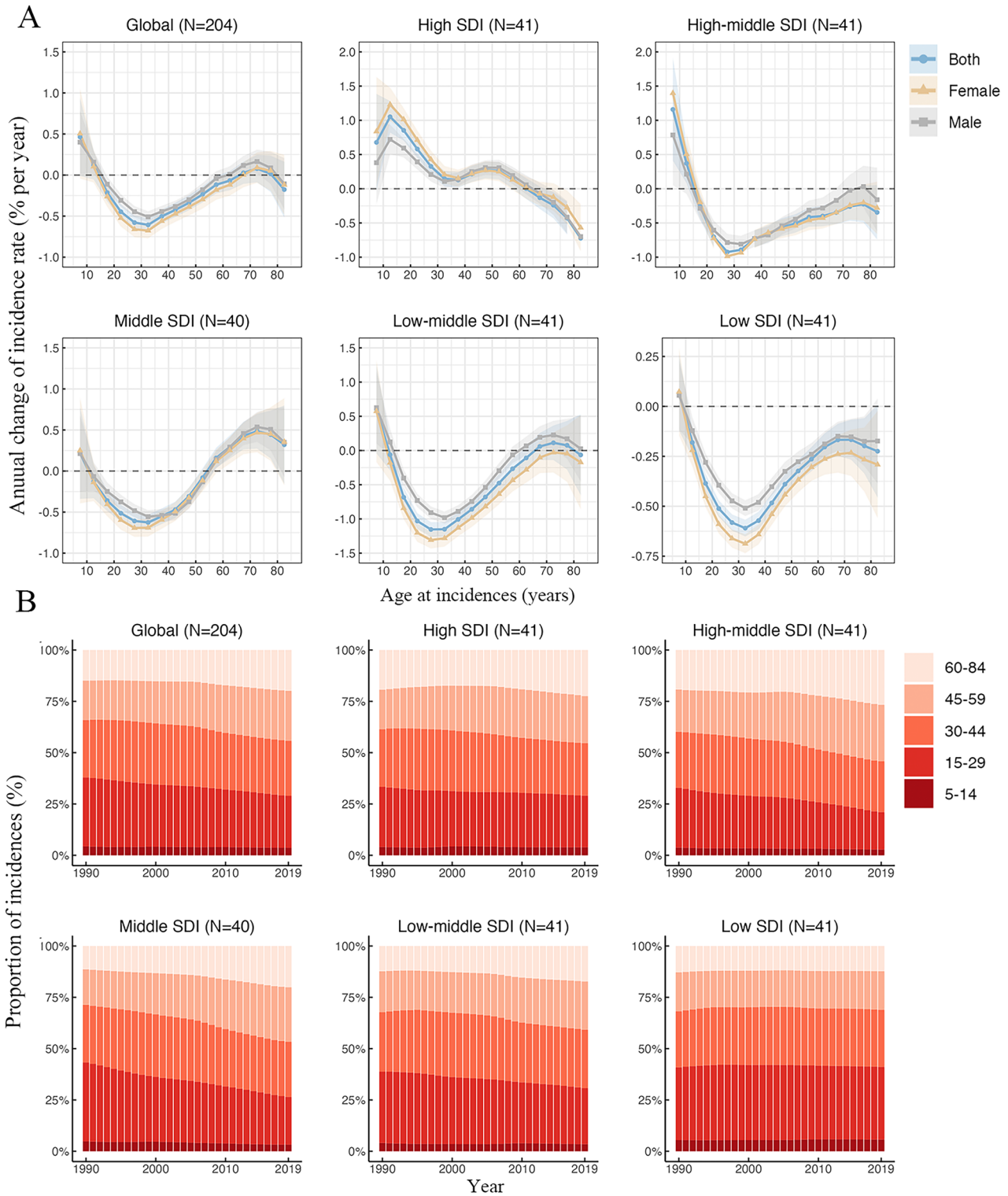

Fig. 2 Local drifts of incidence rate and age distribution of incidences by SDI quintiles, 1990–2019. **A** Local drifts of depressive disorders incidence rate (estimates from age-period-cohort models) for 16 age groups (5–9 to 80–84 years), 1990–2019. The dots and shaded areas indicate the annual percentage change of incidence rate (% per year) and the corresponding 95% CIs. **B** Temporal change in the relative proportion of depressive disorders incidences across age groups (5–14, 15–29, 30–44, 45–59, 60–84 years), 1990–2019. *SDI* Socio-demographic Index

Figure 2B shows the long-term trend of the age distribution of depressive disorders. Overall, the highest number of incidents occurred in the 15–29 years. Of note, the age distribution of depressive disorders did not change much in 5–14 years old, but there was an emerging transition of incidences from the young and middle-aged population (15–59 years) to the old population (60–84 years). The same pattern was observed in the SDI regions except for the low SDI regions, where the proportion remained stable across age groups. The age distribution of incidences for each country is shown in Additional Fig. 6–10.

Age, period, and cohort effects on depressive disorders incidence rate

Figure 3 illustrates the estimates for age, period, and cohort effects by SDI quintile. Globally, the incidence rate of depressive disorders increases rapidly before age 20 years and then increases smoothly with age. Same pattern can be found in high-middle, middle, and low SDI regions. For high SDI regions, the incidence rate declines slowly after age 40 years, while the incidence rate begins to decline after age 60 years in low-middle SDI regions. It is noteworthy that the female incidence rate was higher than males in all age groups.

Globally, period effects generally showed a decreasing risk of incidence rate. Over the past three decades, period risk decreased significantly in high SDI regions, while remaining nearly constant in middle SDI regions, indicating little improvement in incidence rates. For high-middle SDI, low-middle SDI, and low SDI countries had more favorable reduction of period risks only in the past 10 years.

Globally, cohort effects remained relatively stable until the 1960s, after which they began to decline. Same as global scale, the overall risk for younger birth cohorts declined in high-middle SDI, middle SDI, low-middle SDI, and low SDI regions after the 1960s; however, it was observed that the risk increased in high SDI regions. The age, period, and cohort effects on depression incidence rate in each country are shown in Additional Fig. 11–25.

Age-period-cohort effects in exemplary countries

We presented a number of representative countries across SDI quintiles in order to more accurately illustrate the trends in the incidence rate of depressive disorders. Figure 4A shows countries with favorable age-period-cohort effects. The United Kingdom exhibited trends typical of high-SDI countries, displaying a reduction in incidence rates among adults aged over 20 years. This reduction was associated with diminished period risks after 2005 and declining cohort risk in individuals born after 1980. Conversely, Italy demonstrated a decline in incidence rates (local drifts < 0) across all age groups, with a progressive decrease in relative risk of incidence rates observed over successive periods and birth cohorts. Cuba stood out for achieving a significant net drift, marking the third most substantial reduction in depression incidence rates among 204 countries and territories, with a net drift of -1.25% (95% CI $-1.42, -1.31$). Additionally, Cuba displayed an emerging shift in the age distribution of incidences, signifying an increasing trend in incidence among the elderly population. India, classified within low-middle SDI regions, exhibited the highest incidences of depression. A reduction in incidence rates was observed in the 15–64 age groups throughout the entire study period. Pakistan showcased the highest incidence rate in the 60–64 age group, demonstrating a gradual decrease in the relative risk of incidence rates across successive periods and birth cohorts. In contrast to other countries with similar SDI levels, Pakistan's incidence of depressive disorders exhibited a distinctive age distribution, manifesting a rising incidence among the middle-aged population.

Figure 4B shows countries with unfavorable age-period-cohort effects. Republic of Korea showed a transition in the age distribution of incidences like other high-SDI countries. What's more, there was an accelerated upward trend in the incidence rate among people aged 60–84 years, with notable increases in risks were found in the whole period and born after 1990. Spain had the worst trends in the incidence rate of depressive disorders among the 204 countries and territories, with a net drift of 1.06 (95% CI 0.94, 1.18). Furthermore, the risk of depressive disorders incidence rate increased gradually with the change of period and birth cohort. Iran was a middle SDI country with significant increase in incidence rate for all age groups, with notable increasing risk over the periods and in successive birth cohorts. Lesotho and Guinea are countries belonging to Africa, which demonstrated a progressive increase in incidence with increasing age. The two countries were relatively similar in terms of period and cohort effects, that is, period and cohort risks increased during the entire study, indicating no improvements for the entire population incidence across the study.

Discussion

Between 1990 and 2019, the total number of depressive disorders incidences worldwide increased by nearly 60% over the study period, driven by rapid population growth. Meanwhile, the incidence rate shown a slight downward trend after considering the inconsistency in age composition. Events related to depressive disorders are primarily concentrated among individuals in the productive, value-creating age group (15–59 years), and there is a trend for

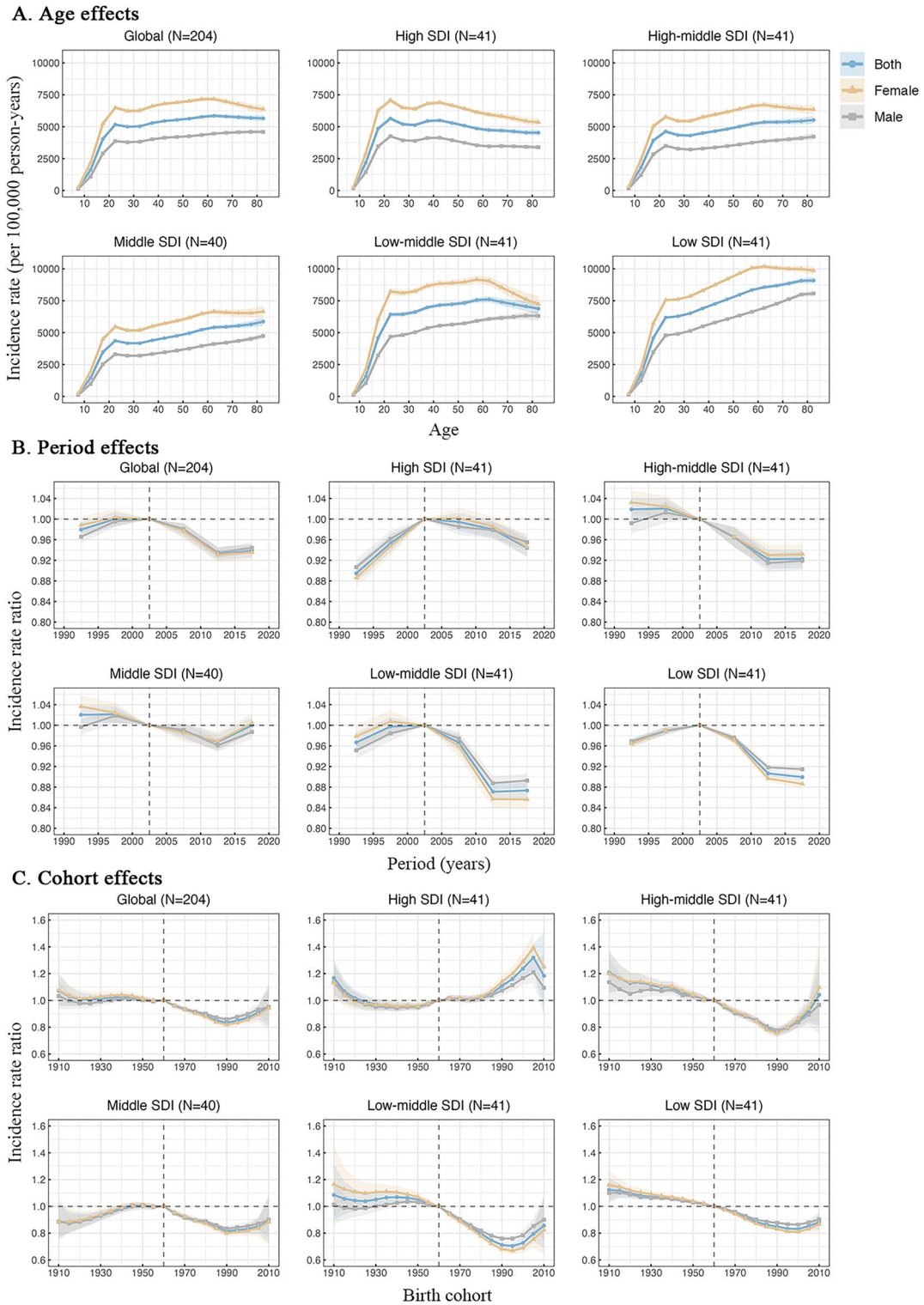

Fig. 3 Age, period and cohort effects on depressive disorders incidence rate by SDI quintiles. **A** Age effects are shown by the fitted longitudinal age curves of incidence rate (per 100,000 person-years) adjusted for period deviations. **B** Period effects are shown by the relative risk of incidence rate (incidence rate ratio) and computed as the ratio of age-specific rates from 1990–1994 to 2015–2019, with the referent cohort set at 2000–2004. **C** Cohort effects are shown by the relative risk of incidence rate and computed as the ratio of age-specific rates from the 1910 cohort to the 2010 cohort, with the referent cohort set at 1960. The dots and shaded areas denote incidence rates or rate ratios and their corresponding 95% CIs. *SDI* Socio-demographic Index

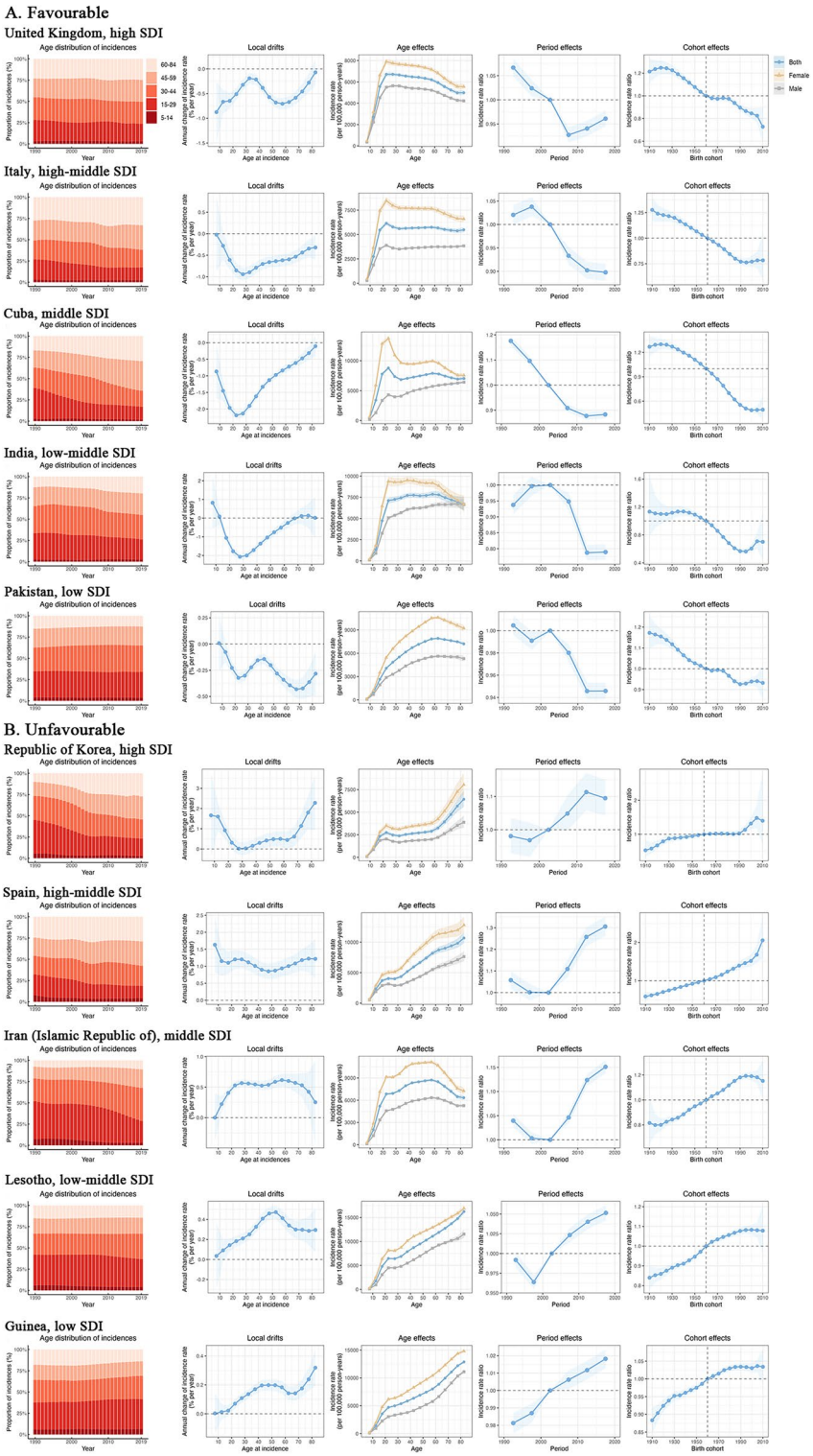

Fig. 4 Favorable (**A**) and unfavorable (**B**) age-period-cohort effects on exemplar countries across SDI quintiles. Local drifts indicate the annual percentage change of incidence rate (% per year) across five-year age groups (from 5–9 to 80–84 years). Age effects are represented by the fitted longitudinal age curves of incidence rate (per 100,000 person-years) adjusted for period deviations. Period effects are represented by the relative risk of incidence rate (incidence rate ratio) and computed as the ratio of age-specific rates in each period compared to the referent 2000–2004 period. Cohort effects are represented by the relative risk of incidence rate (incidence rate ratio) and computed as the ratio of age-specific rates in each cohort compared to the referent 1960 cohort. The shaded areas indicate the corresponding 95% CIs of each point estimate. *SDI* Socio-demographic Index

the age distribution of depressive disorder cases to shift towards an older population. Additionally, the current findings reflect substantial health disparities and potential priority-setting of depressive disorders incidence in the three dimensions of age, period and birth cohort in countries around the world, which support deeper advancement of the Sustainable Development Goals (SDGs) in the field of mental health.

We have witnessed the vigorous development of the mental health construction program and the encouraging progress in the political, economic and cultural fields over the past thirty decades [17, 18]. However, different frameworks of ASIR and age-period-cohort effects for depressive disorders can be observed to vary across SDI regions, and our results may not support the validity of differentiating priority areas with socioeconomic development. SDGs explicitly address the unique impact of social determinants on depression (Fig. 5) [19]. Individual-level interaction between diverse determinants throughout the life course, from conception to death, may indirectly weaken the ability to control the disease burden with continuous economic growth and social development.

Considerable disparities in the incidence rates of depressive disorders are evident among different countries. National policymakers may evaluate their country-specific attributes concerning this issue to formulate informed decisions, taking into account their positioning relative to other nations. However, some potential triggers for depression are often questioned, with age, period, and cohort effects warranting further investigation. In light of these considerations, we have focused on the analysis of depressive disorders incidence patterns in representative countries from different SDI regions utilizing the APC framework. In a well-established National Health Service (NHS) environment, the management of depression in primary care had been reviewed in considerable detail in the UK. The Department of Health and professional organizations in the UK embarked on a joint "Defeat Depression" program as early as 1992 to develop guidelines for the diagnosis and treatment of depression [20, 21]. These guidelines promoted the involvement of a wide range of health service organizations, professionals, voluntary groups and consumers to make a good response to the prevalence of depression [22]. Furthermore, the UK government issued a national service framework, allocating £700 million toward enhancing mental healthcare services [23]. As the only country to have closed its psychiatric hospitals, the Italian mental health care system aroused much interest in the world. In Italy, primary health care was provided to the entire population by the NHS for free [24]. Italian policy supported the shift of mental health care from large isolated institutions into the community [25]. This reform had facilitated the linkage between mental health services and the primary care system in Italy (in particular general medicine community services), which had led to the creation of an extensive network of facilities [26]. The implementation of the community-oriented models of mental health care had increased public access to specialized mental health services with better social inclusion.

The incidence of depressive disorders across all age groups in Cuba had seen a nearly 30% reduction, with successive period effects showing even more significant improvements over the study period. Cuba, with a population of 11 million, had contributed to the reorientation of its mental health system with both the Caracas

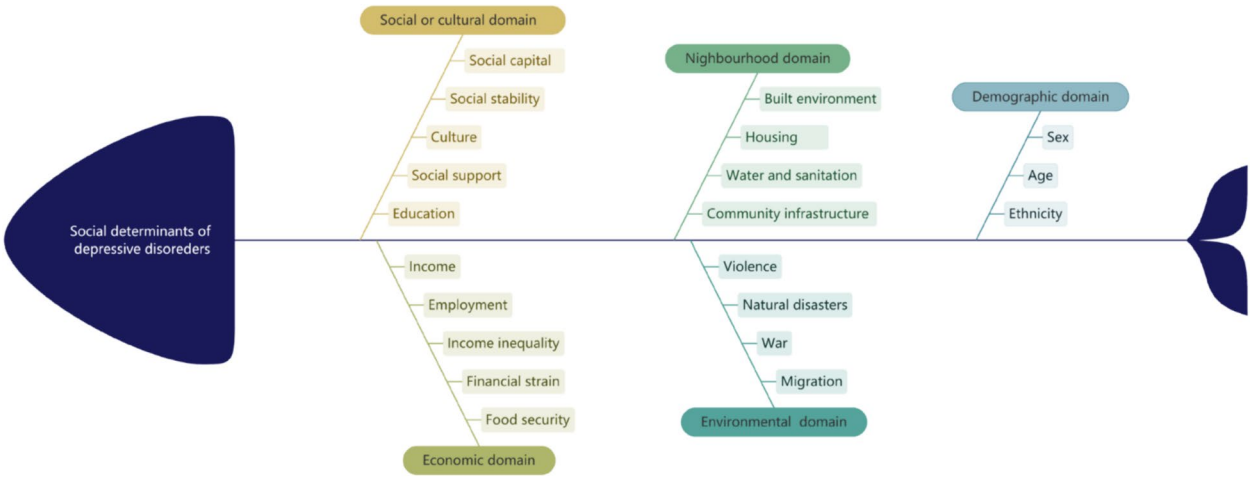

Fig. 5 Key domains of social determinants of depressive disorders

Declaration and the Havana Charter in 1995 [27]. The system had three levels of management: primary services consisting of community mental health centers, mental health teams in polyclinics and family doctors; psychiatric services in polyclinics with crisis intervention teams; and psychiatric hospitals, which were sufficient to meet the varying degrees of mental health needs of citizens. India, as the world's second-most populous country, faces the highest incidence of depressive disorders. It is crucial to acknowledge India's pioneering role in health services planning, particularly emphasizing primary health care, in combatting depression. This includes substantial increases in budgetary allocations for the National Mental Health Program, the integration of mental health into public health initiatives, advocacy against stigmatization and human rights violations related to mental illnesses, and the initiation of campaigns by non-governmental organizations advocating for mental health [28–31]. However, mental health resources in India were relatively inadequate and severely misallocated. The limited trained manpower was mostly in urban areas while nearly 75% of the Indian population still lived in rural areas [30]. Meanwhile, the program in Pakistan emphasized the role of early interventions in promoting mental health and preventing mental illness, and called for the phased implementation of two evidence-based interventions for at-risk mothers and students aimed at the early recognition and management of depression [32, 33]. In addition, the recently launched President's Program to Promote Mental Health of Pakistanis supported technologies such as online training programs, technology-assisted delivery tools, and self-help apps to improve access to mental health, thereby bypassing the barrier of lack of mental health resources [34].

Republic of Korea, Spain, Iran (Islamic Republic of), Lesotho and Guinea represent the impact of unfavorable age-period-cohort effects on incidence rate in countries with different socioeconomic development. Republic of Korea is a high-SDI country, with a low level of all-age incidence rate in the world but worsening trends over time and cohort. It was not until mid-1980s that the Korean government began to give its attention to mental health care problems [35]. Korea had a large number of mental health hospitals, accounting for almost 70% of all mental health institutions and facilities. This fact indicated that the current mental health system was still framed by the hospitalization model rather than adopting a community-centered primary health care system. Although the Korean government has striven to break the mental health system from hospitalized treatment and expand the coverage of community services to the general population, no concrete plans including an increase in resources have been put forward to achieve these goals. Spain and Iran (Islamic Republic of) had been plagued by unfavorable age and period effects, as well as an increase in cohort risks. Spain is an example of a country that has undergone substantial economic and democratic transition in a short time frame, experiencing mass immigration and an economic crisis that took a toll on its mental health [36]. What's worse, public and non-profit funding for mental health research remained notably insufficient in Spain [37]. Iran had successfully integrated mental health services into primary health care settings. However, only one mental health worker per 30,000–40,000 inhabitants can be employed to provide them with health counseling and treatment in urban catchment areas in Iran [38]. Similar challenges, including the scarcity of specialized human resources and limited access to sustainable financial support, were observed in various developing countries such as Lesotho and Guinea in Africa [39, 40]. Social services were virtually non-existent in these countries, with families, traditional healers and religious leaders playing a dominant role in dealing with depressive disorders [39]. Guinea's highly centralized health-care system, which was mainly located in the major cities with only 39% of the population, leading to inequalities in health care between urban and rural communities [40].

The prominent position of depressive disorders in special populations should receive more attention in the global mental health debate. Depressive disorders events can be observed across nearly all age groups but are mainly concentrated among those of productive value-creating ages (15–59 years). Globally, neglect, violence, abuse, poverty, overburdened school schedules and undesirable behaviors such as drug and alcohol abuse have been substantial risk factors for the prevalence of depression in the child and adolescent population [18, 41]. Adding insult to injury, the lack of power over life decisions deprives them of equal access to psychological assistance [42]. During the sensitive period of childhood and adolescence, neurological changes provide opportunities to positively affect the developing brain [18]. Taking action early in the life course is therefore key to preventing mental health problems later in life. Depressive disorders in young and middle-aged populations are often precipitated by stressful life experiences such as interpersonal conflicts, financial hardships [18]. The age distribution of depressive disorders cases has a tendency to shift toward older people. Adversity in later life in the form of declining health, increasing functional limitations, loss of lifelong partners and friends, and social isolation is unavoidable [43]. Females have many special life stages. Our findings may support the gonadal theory that cyclically fluctuating estrogen interferes with the ability of estrogens to neutralize glucocorticoids released in

response to stress, rendering women more susceptible to stress and thus at risk for depression [44, 45]. Males and females exhibit different environmental risk factors and ability to cope with stress across the life course [44]. In addition, social structure theory provides a framework for understanding the relationship between gender differences in depression and gender inequality [46].

The present research findings present a thought-provoking question in the field of mental health: how to cope with and manage depression? Typically, a lengthy prodromal period occurs before the diagnosis of depression is made. In the early stages of depressive disorders, symptoms are usually transient, mixed, and responsive to the environment [18]. Intervention during these prodromal periods can have a better preventive effect on the onset of depressive disorders [47]. Early intervention before severe disability due to depression is therefore of particular importance. Despite noteworthy progress in comprehending many aspects of neurobiology and metabolic pathways of depression, there is still some critical information that needs to be confirmed, such as the true triggering factors, established mechanisms, and personal characteristics [18, 19, 48]. Further research is warranted to continue knowledge creation, since the integration of knowledge from multiple disciplines may lead to enhanced clinically significant phenotypes, facilitate early detection of disorders, and provide opportunities to uncover novel environmental and biological mechanisms that serve as targets for intervention. Equally important, there is a clear need to further build a better blueprint for mental health globally. We identified some pioneering aspects of depression health care and potential management priorities from countries with favorable age-period-cohort effects. The reconfiguration of mental health care away from hospitals into community settings can improve access to psychosocial interventions, which have been shown to be effective across a range of goals, from prevention to treatment and to recovery [18, 49]. The scale-up of quality mental health services has not occurred in the majority of countries, and our study underscores the imperative need to enhance mental health care provision with increased urgency. Moreover, investments in mental health should be increased, and efforts to strengthen public awareness and engagement with individuals with depressive disorders should be enhanced. Pharmacological and psychological interventions and their combination can be provided in response to the needs of specific individuals, while minimizing social discrimination and stigmatization [50, 51]. Embracing digital technology to extend the capacity and reach of the limited number of mental health specialists. Rapid growth in digital technologies provides new opportunities to reduce the incidence of depression and contribute to bridging the mental health gaps (Fig. 6) [52], but the accompanying significant harms and challenges (such as cyberbullying and information security) need to be noted. There is also a need to recognize the great inequalities that exist within all countries as well as between countries. The balanced depression care model emphasizes the importance of adjusting to the context of resources (low-income, medium-income, and high-income country settings) [53]. In low-resource settings, improving the mental health capacity of primary and community health-care workers and related service providers is a priority. In medium-resource settings, a range of community and hospital-based secondary and tertiary prevention strategies can be urged in conjunction with the provision of adequate primary mental health services. In high-resource settings, it

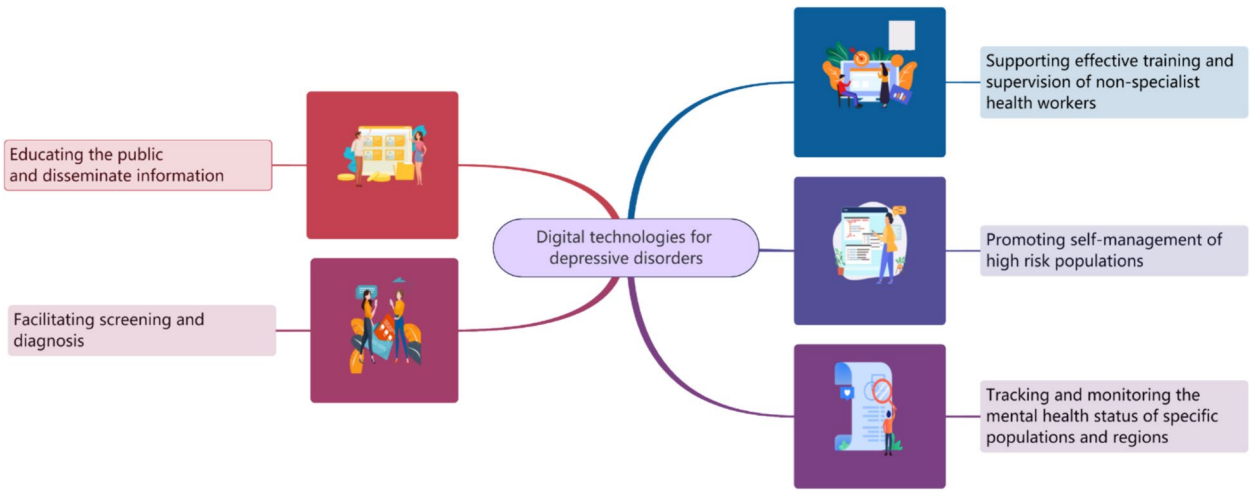

Fig. 6 The role of digital technology for depressive disorders

is recommended that the coverage and specialization of different levels of prevention strategies be strengthened to provide more integrated and comprehensive evidence-based management. Although additional resources are indeed essential, there are immediate opportunities to enhance the efficiency and effectiveness of the current resource utilization. Another key focus of this study is to pay attention to vulnerable and high-risk populations for depressive disorders. Empowering children and young people, and recognizing their right to self-determination; achieving gender equality and empowering all women and girls can challenge this status quo [18].

Our findings support horizontal comparisons between different regions and countries. Compared to traditional epidemiologic analyses [2, 54], this study analyzes and captures in detail the independent effects of age, period, and cohort effects on depressive disorders incidence trends at the global, regional, and national levels, highlighting success points and potential key areas in a timely manner. Meanwhile, this paper comprehensively shares the limitations from multiple perspectives. First, some limitations of the GBD models still exist: (I) in certain models, the presence of collinearity among covariates may potentially introduce instability in the estimated fixed effects across cycles; (II) the existing statistical modeling framework is constructed to encapsulate uncertainty stemming from stochastic fluctuations in the input data, the stratification of data by age and sex, adjustments for diverse case definitions, as well as rectifications for uninformative cause-of-death coding. Despite these efforts, there persists a significant challenge in accurately delineating the UIs surrounding the estimates, especially in geographical areas characterized by limited or completely absent data. Second, this study is not free of the general limitations shared by APC model: (I) the parameter estimates generated using this method are not intuitive, and their actual meaning could not be explained; (II) age–period–cohort analysis might result in ecological fallacies, so we have proposed some reasonable scientific hypotheses about the causal relationship of temporal trends of depressive disorders incidence supported by the available information and existing evidences; (III) some minor variations in age, period and cohort effects might be smoothed out influenced by the most commonly used age-interval data format (five years) in APC model. Third, the original data for this study is limited by resource settings: (I) many countries with little or no access to treatment do not have proper data on depressive disorders, and the results for these countries are susceptible to being driven by estimates of severity distributions from high-income countries and needs to be reconsidered; (II) this study lacks a more detailed analysis to capture subnational differences, because there are still differences in health issues and access to health care providers and services at the subnational level, and evidence-based health decision making at the subnational level is crucial for every country; (III) variations in the incidence may partially represent information bias linked with the definition, screening and diagnostic protocol's modifications of depressive disorders; (IV) period and cohort effects were investigated using cross-sectional data from the GBD 2019 estimates, which span from 1990 to 2019, and subsequent international cohort studies are essential to evaluate location- and time-specific relative risks and to assess varying risks in susceptible populations.

Conclusion

Depressive disorders are important contributors of the global burden from mental disorders worldwide. Age-period-cohort effect of depressive disorders incidence is not fully commensurate with socioeconomic development between 1990 and 2019. We fully recognize the diversity of environments across SDI regions, countries as well as within countries and recommend an incremental approach to advancing depression prevention matters based on the starting point in a particular setting and the possible policy-driven human and financial resources. The scope of healthcare to improve the progression of depressive disorders attacks can be expanded to include males and females of all ages, with a particular focus on vulnerable populations.

Supplementary Information

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Supplementary material 1.

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Author contributions

YW and LF prepared the first draft. YW, FL, FX, YZ and ZL accessed and acquired the raw data, performed the primary analysis, and prepared tables and figures. YW, FL, JH, LF and SX contributed to the interpretation of the data. WX, ZX, JH, DL and SH critically reviewed results and provided important comments on the manuscript. LC and TW substantially edited and critically reviewed the manuscript. YW, JD and YX managed all of the incidence modelling data. LC and TW were responsible for general supervision and had final responsibility for the decision to submit for publication. All authors reviewed and approved the final manuscript and are accountable for all aspects of the work, including accuracy and integrity.

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Availability of data and materials
The datasets generated during and/or analyzed during the current study are available in the GBD Data Tool repository (http://ghdx.healthdata.org/gbd-results-tool). This public link to the database of GBD study is open, and the use of data does not require additional consent from IHME.

Declarations

Ethics approval and consent to participate
Data were all analyzed anonymously, so ethical approval was not needed. All methods in this paper were performed following the relevant guidelines and regulations.

Consent for publication
Not applicable.

Competing interests
The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential competing interests.

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