Distribution of the compression and expansion of morbidity in 194 countries and territories, 1990–2016: The role of income inequality

He Chen

Renmin University of China

Jing Ning

University of International Business and Economics

Hongwei Hu (✉ hhwruc@126.com)

Renmin University of China <https://orcid.org/0000-0002-8635-7849>

Haochen Jiang

Renmin University of China

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Abstract

Background

Compression and expansion of morbidity are two critical hypotheses to analyze the relationship among morbidity, disability, and mortality. This study aims to analyze the global distribution of the compression and expansion of morbidity and to investigate its relationship with income inequality.

Methods

Data was from the Global Burden of Disease Study 2016 and Standardized World Income Inequality Database, version 8.2. Seven types of health changes were defined. Income inequality was measured with Gini coefficient index. Binary logistic regression was used to analyze the association of income inequality with the compression and expansion of morbidity.

Results

All the seven types of the compression and expansion of morbidity exist in the world, despite their uneven distribution. The relative expansion of morbidity with increased or constant life expectancy (Type 6) was the most popular type occurring to more than half of populations in the last quarter of century, which was followed by the relative compression of morbidity with increased or constant LE (Type 3, 30.71%). The income inequality was significantly associated with the health changes, which still held after controlling a variety of confounders and in robustness tests. Those societies with lower income inequality were more likely to incur Type 3.

Conclusions

It is necessary to distinguish the positive and negative changes in life expectancy when examining the compression and expansion of morbidity. The increasing popularity of Type 6 implies higher needs for health and social care. Measures to reduce income inequality or mitigate its negative influence on health changes might promote the occurrence of Type 3.

Introduction

Between 1990 and 2016, over 180 countries and territories enjoyed an increase in life expectancy (LE) (1). However, we are not sure whether the added years of life are spent in health (2, 3). Investigating the relationship between morbidity, disability, and mortality could help us understand the complicated process of health changes and its impact on the health and social care needs (4). Many studies have made effort to analyze the health changes by examining three alternative theoretical hypotheses: compression of morbidity, expansion of morbidity, and dynamic equilibrium hypothesis (2, 5–7). The

majority are conducted in developed countries and comparative studies are largely lacking (8). Meantime, our knowledge about the relationship between income inequality and health changes is very limited.

The compression of morbidity hypothesis argues that there is a natural limit to life span and, by adopting healthy lifestyle, the onset of chronic diseases can be delayed or even prevented, which results in a shorter life with morbidity (9). The expansion of morbidity hypothesis states that, medical interventions might increase years lived with morbidity by saving those with serious chronic conditions from dying and making more people survive to the oldest-old stage when the risks of morbidity are high (10, 11). Manton (1982) proposed an intermediate alternative, dynamic equilibrium hypothesis (12). When disability is regarded as severe morbidity, the life years with morbidity increase as mortality decreases and those with disability keep relatively constant as the medical interventions or life style changes reduce the progression rate of chronic diseases. Theoretically, this process will prolong the life years without disability.

The scenarios proposed by these hypotheses seem to coexist in the real world, although most evidences are from developed countries (2, 13). For example, in the United States, the disability-free LE at age 65 increased from 6.6 years in 1970 to 9.3 years in 2010, with its proportion in total LE rising from 50.8–52.5% (4). On the other hand, the expansion of morbidity appears in Germany and England (8, 14). Moreover, Jagger et al. (2016) reported mixed results for the same population: absolute compression of cognitive impairment, relative compression of self-perceived health, and dynamic equilibrium of disability (2).

The variation in health changes across populations is partly due to the different study designs, such as the data sources, health measurements, and estimation methods (2, 15). In other words, we cannot capture the global distribution of health changes by reviewing existing literatures, as their conclusions are not completely comparable. Thus, a comparative study covering a wide range of countries and territories is necessary. However, with some exceptions(16), existing studies mainly focus on single country or several countries, especially high-income countries (2, 4–6).

Is income inequality associated with health changes? The level of income affects the relationship between morbidity, disability, and mortality. People exposed to harsh economic conditions live a shorter disease-free and disability-free LE compared with their counterparts, especially for older women(17). Moreover, education attainment, a factor closely related to income, affects the health changes. In the United States between 1980 and 1990, people with higher education attainment enjoy compressed morbidity, while their counterparts experience the opposite (18). However, there is no direct evidence that the degree of income inequality matters for health changes.

Furthermore, although a large body of literature has examined the income inequality hypothesis that income distribution within a society influences population health with greater inequality associated with worse outcomes (19, 20), it is a different research question from the one raised in this study. The health outcomes in these literatures are commonly for single health domains, e.g., life expectancy and obesity

prevalence (20). By contrast, the health changes, e.g., the compression and expansion of morbidity, reflect the complex relationship between the changes in morbidity and mortality.

Therefore, this study aims (1) to analyze the global distribution of compression and expansion of morbidity and (2) to investigate the relationship between income inequality and the compression and expansions of morbidity. Due to data limitation, this study does not examine dynamic equilibrium hypothesis.

Methods

Data source

We obtained following data from Global Burden of Disease Study (GBD) 2016: sex specific life expectancy at birth (LE_0) and healthy life expectancy at birth ($HALE_0$); sex and cause specific age-standardized disability-adjusted life years (DALYs); socio-demographic index; and health access and quality index (HAQI) (1). GBD defines disability as any short term or long-term health loss, other than death. Life expectancy with disability at birth (LED_0) is equal to LE_0 minus $HALE_0$. With an effort to bring together all available epidemiological data, the GBD applies a coherent measurement framework and standardized estimation methods to produce comparable health assessment across countries and time points. More information on GBD data can be found in Annex 1.

We obtained Gini coefficients from Standardized World Income Inequality Database (SWIID) version 8.2 (21). The coverage and comparability of SWIID far exceeds those of the alternatives (21, 22). The source data for the SWIID 8.2 include 15,730 Gini coefficients from 2,984 country-years in 196 countries or territories, which are from, such as, OECD Income Distribution Database and World Bank's PovcalNet. To increase comparability, the SWIID standardizes the source data to the Luxembourg Income Study, which provides inequality statistics calculated using a uniform set of assumptions and definitions based on harmonized microdata.(22) We filled missing data with the values in the most recent year for the same country or territory.

Considering the differences in health changes across sex and period (4, 6), we generated four cases for each country and territory, i.e. male 1990–2006, female 1990–2006, male 2006–2016, and female 2006–2016. This process resulted in 776 cases. Mainly due to missing values in baseline Gini coefficients, the final sample size in multivariate analysis was 736. Binary logistic regression results showed that the presence of missing values had no significant relationship with the types of health changes, sex, period, baseline socio-demographic index, main driving cause group of the health changes, and average HAQI during the period.

Health changes

The changes in LE, LED, and HALE are usually used together to define the compression and expansion of morbidity, with increased LE as default situation (13, 23). This study further considered the situation of

decreased LE, making the classification framework able to cover all the scenarios of the compression and expansion of morbidity (Table 1). Specifically, based on the GBD 2016 data, we calculated the changes in LE_0 , $HALE_0$, LED_0 , and LED_0/LE_0 by sex and period and then classified the health changes into seven types according to the rules presented in Table 1.

Table 1
The definitions of the compression and expansion of morbidity

Types	LE	HALE	LED	LED/LE
Type 1. The absolute compression of morbidity with increased or constant LE	↑=	↑	↓	↓
Type 2. The absolute compression of morbidity with decreased LE	↓	↑↓=	↓	↓
Type 3. The relative compression of morbidity with increased or constant LE	↑=	↑	↑=	↓
Type 4. The absolute expansion of morbidity with increased or constant LE	↑=	↓	↑	↑
Type 5. The absolute expansion of morbidity with decreased LE	↓	↓	↑=	↑
Type 6. The relative expansion of morbidity with increased or constant LE	↑=	↑=	↑	↑
Type 7. The relative expansion of morbidity with decreased LE	↓	↓	↓	↑
↑ increase; ↓ decrease; = constant. LE, life expectancy; HALE, healthy life expectancy; LED, life expectancy with disability.				

Income inequality

Income inequality was measured with Gini coefficient, which refers to a ratio of the area between the diagonal and the Lorenz curve and the area of the whole triangle under the diagonal. Among a variety of Gini coefficients provided by SWIID 8.2 data, we chose the one estimated using the equivalized (square root scale) household disposable income, which reflects the income inequality after redistribution including taxes and transfers (21, 22). The coefficient's range is 0–1 with higher value indicating higher income inequality. We divided baseline Gini coefficients into five categories using their quintiles.

Control variables

In addition to sex and period (1990–2006; 2006–2016), we included three control variables.

First, baseline socio-demographic index measures the social development level at baseline. The GBD 2016 computed this index based on the geometric mean of income per capita, average years of schooling among people aged 15 years or older, and the total fertility rate. The index ranges between 0 and 1 with lower value indicating lower development level (24). We divided it into five categories using quintiles.

Second, the main driving cause group of health changes refers to the cause group bringing the biggest changes to age standardized DALYs during the period. We employed the three broad cause groups developed by the GBD, i.e., communicable, maternal, neonatal, and nutritional diseases; non-communicable diseases; and, injuries.

Third, HAQI is developed by the GBD to measure health-care access and quality. It ranges between 0 and 100, with higher values indicating better health-care access and quality. We computed the average of HAQI in the starting and ending year of the period and then divided it into five categories using quintiles. More information on estimating HAQI can be found in Annex 1.

Statistical analysis

We used frequencies and proportions to describe sample distribution. In the bivariate and multivariate analysis, we examined the influencing factors of the relative compression and expansion of morbidity with increased or constant LE (Type 3 & 6). These two types accounted for 85.19% of the total sample (Table 2). The remaining five types only occurred to 1–50 cases and thus were excluded from the more complicated analysis to avoid unstable results. We performed two binary logistic regressions to investigate the relationship between baseline Gini coefficient categories and the presence of Type 3 & 6, respectively. The model specifications were the same, except their dependent variables. The control variables included sex, period, baseline socio-demographic index categories, main cause driver of health changes, and average HAQI categories.

Table 2
The sample characteristics (N = 736)

	N	%
Types of health changes		
Type 1. The absolute compression of morbidity with increased or constant LE	47	6.39
Type 2. The absolute compression of morbidity with decreased LE	50	6.79
Type 3. The relative compression of morbidity with increased or constant LE	226	30.71
Type 4. The absolute expansion of morbidity with increased or constant LE	1	0.14
Type 5. The absolute expansion of morbidity with decreased LE	4	0.54
Type 6. The relative expansion of morbidity with increased or constant LE	401	54.48
Type 7. The relative expansion of morbidity with decreased LE	7	0.95
Baseline Gini coefficient		
Low	146	19.84
Low middle	146	19.84
Middle	148	20.11
High middle	146	19.84
High	150	20.38
Sex		
Male	368	50
Female	368	50
Period		
1990–2006	368	50
2006–2016	368	50
Baseline socio-demographic index		
Low	150	20.38
Low middle	148	20.11
Middle	150	20.38

* $p < 0.05$, # $p < 0.01$, † $p < 0.001$. LE refers to life expectancy, communicable diseases refer to communicable, maternal, neonatal, and nutritional diseases, and HAQI refers to health access and quality index.

	N	%
High middle	144	19.57
High	144	19.57
Average HAQI during the period		
Low	148	20.11
Low middle	152	20.65
Middle	146	19.84
High middle	136	18.48
High	154	20.92
Main driver of health changes		
Communicable diseases	359	48.78
Non-communicable diseases	353	47.96
Injuries	24	3.26
* $p < 0.05$, # $p < 0.01$, † $p < 0.001$. LE refers to life expectancy, communicable diseases refer to communicable, maternal, neonatal, and nutritional diseases, and HAQI refers to health access and quality index.		

As the sample size is small (736), we did not include country-level dummy variables in the regressions. To deal with potential omitted variable bias, we made the following efforts. First, most control variables are composite indicators representing rich information. Second, we adjusted the standard errors for the intragroup correlation within the same country or territory to reduce the potential effect on the standard errors of the coefficients. Third, we examined the impact of omitted variable bias on estimations by performing residual analyses. Two linear regressions of the standardized Pearson residuals were ran on the independent variables. Only the coefficients of period were significant and the R-squared were below 0.06, which indicate a very small influence of the omitted variable bias on the consistency in estimations.

All analyses were conducted using Stata version 15 software (StataCorp, College Station, Texas).

Results

Sample characteristics

Both of the communicable, maternal, neonatal, and nutritional diseases and non-communicable diseases were the main drivers of health changes for around 48% of the populations; injuries were for the remaining 3.26% of populations. All the other variables were equally distributed (Table 2).

The distribution of compression and expansion of morbidity

As shown in Table 2, the relative expansion of morbidity with increased or constant LE (Type 6) was the most popular type of health changes occurring to more than half of populations, followed by the relative compression of morbidity with increased or constant LE (Type 3, 30.71%). Both of the absolute compression of morbidity with increased or constant LE (Type 1) and with decreased LE (Type 2) occurred to around 6.5% of populations. The other types rarely happened.

From 1990–2006 to 2006–2016, the proportions of Type 6 increased by 18.56% in male populations and 26.80% in female populations (Fig. 1). Despite the proportion of Type 3 quite stable in male populations, it decreased by nearly 10% in female populations. Both Type 1 & 2 occurred to less populations over time.

Income inequality and the compression and expansion of morbidity

The first and third columns in Table 3 show the bivariate analysis results. A reverse U-shape relationship existed between the baseline Gini coefficient categories and Type 3. Those populations with lower baseline Gini coefficients were more likely to incur Type 6. Except sex, nearly all the control variables had a significant bivariate relationship with both Type 3 & 6.

Table 3

Bivariate and multivariate analyses results on the correlates of the relative compression with increased or constant life expectancy (Type 3) and the relative expansion with increased or constant life expectancy (Type 6)

	Type 3		Type 6	
	% of Type 3	OR (95% CI)	% of Type 6	OR (95% CI)
Baseline Gini coefficient				
Low	16.44% [†]	1.00	69.86% [†]	1.00
Low middle	30.14%	0.49 (0.16, 1.50)	58.22%	2.54 (0.97, 6.68) [§]
Middle	37.84%	0.54 (0.16, 1.86)	48.65%	2.29 (0.75, 7.00)
High middle	43.84%	0.48 (0.14, 1.66)	45.21%	2.93 (0.96, 8.96) [§]
High	25.33%	0.19 (0.05, 0.75) [*]	50.67%	3.48 (1.04, 11.60) [*]
Sex				
Male	30.98%	1.00	53.26%	1.00
Female	30.43%	0.92 (0.69, 1.22)	55.71%	1.09 (0.86, 1.39)
Period				
1990–2006	33.42%	1.00	42.66% [†]	1.00
2006–2016	27.99%	1.16 (0.76, 1.76)	66.30%	2.21 (1.42, 3.43) [†]
Baseline socio-demographic index				
Low	66.67% [†]	1.00	18.00% [†]	1.00
Low middle	41.22%	0.17 (0.07, 0.38) [†]	37.16%	3.91 (1.75, 8.71) [†]
Middle	21.33%	0.06 (0.02, 0.18) [†]	63.33%	10.68 (3.91, 29.16) [†]
High middle	12.50%	0.03 (0.01, 0.11) [†]	72.92%	12.24 (3.43, 43.68) [†]

[§] $p < 0.10$, ^{*} $p < 0.05$, [#] $p < 0.01$, [†] $p < 0.001$. Communicable diseases refer to communicable, maternal, neonatal, and nutritional diseases, and HAQI refers to Health access and quality index. The standard errors are adjusted for the intragroup correlation within the same country or territory. Chi-square test is used in the bivariate analysis; binary logistic regression is used in the multivariate analysis.

	Type 3		Type 6	
High	10.42%	0.04 (0.00, 0.28) [#]	82.64%	6.57 (1.25, 34.72) [*]
Average HAQI during the period				
Low	56.08% [†]	1.00	24.32% [†]	1.00
Low middle	43.42%	2.90 (1.12, 7.52) [*]	40.79%	0.51 (0.22, 1.14) [§]
Middle	30.14%	5.76 (1.77, 18.76) [#]	50.68%	0.35 (0.13, 0.95) [*]
High middle	13.97%	4.66 (1.22, 17.81) [*]	68.38%	0.50 (0.13, 1.82)
High	9.09%	2.67 (0.36, 19.74)	88.31%	3.01 (0.53, 17.11)
Main driver of health changes				
Communicable diseases	50.14% [†]	1.00	33.70% [†]	1.00
Non-communicable diseases	12.18%	0.26 (0.15, 0.47) [†]	77.05%	3.11 (1.74, 5.58) [†]
Injuries	12.50%	0.18 (0.05, 0.64) [#]	33.33%	0.59 (0.23, 1.47)
Model				
N		736		736
Pseudo R ²		0.2381		0.2602
§ $p < 0.10$, * $p < 0.05$, # $p < 0.01$, † $p < 0.001$. Communicable diseases refer to communicable, maternal, neonatal, and nutritional diseases, and HAQI refers to Health access and quality index. The standard errors are adjusted for the intragroup correlation within the same country or territory. Chi-square test is used in the bivariate analysis; binary logistic regression is used in the multivariate analysis.				

The second and fourth columns in Table 3 present results from the binary logistic regressions. There was a positive gradient relationship between baseline Gini coefficient categories and Type 6. Compared to those with low baseline Gini coefficient, populations with low middle (OR = 2.54, $p < 0.10$), middle (OR = 2.29, $p = 0.14$), high middle (OR = 2.93, $p < 0.10$), and high (OR = 3.47, $p < 0.05$) baseline Gini coefficient were more likely to incur Type 6. The relationship's direction for Type 3 was on the opposite, although only the coefficient of high baseline Gini coefficient was significant (OR = 0.19, $p < 0.05$). The multivariate results differed dramatically from those of bivariate analyses, mainly because most control variables

significantly associated with both dependent variables and baseline Gini coefficient categories. The differences indicated an effective control of confounding factors in the multivariate analyses. Considering the potential lag effect of income inequality on health changes, we further examined the association of Gini coefficient categories in each of the last nine years before baseline year and the mean Gini coefficients during the ten consecutive years with Type 3 & 6. The model specifications were the same with the binary logistic regressions presented in Table 3, except that the Gini coefficients were for different years. A total of 20 regressions were performed and their odds ratios of Gini coefficient categories were consistent with those in Table 3.

Discussion

The present study extends existing literatures by analyzing the distribution of compression and expansion of morbidity in a very wide range of countries and territories. The analyses used the GBD 2016 data which has recognized comparability across populations and time (1) and employed consistent measurements and definitions for health changes. Compared with those focused on a single country or some countries (5, 6), this study provides a clearer picture of the global distribution of health changes. The relative expansion with increased or constant LE (Type 6) is the most popular type of health changes in both sexes and periods and its popularity increases over time. In other words, while more and more populations live a longer life without disability, their extended life years lived with disability require more health and long-term care (8, 10).

Moreover, this paper reveals the existence of three types of health changes with LE reduction (Type 2, 5, and 7), which have not been reported before. Previous studies on health changes assume an increase in LE (3, 7). However, LE could decline due to causes such as HIV/AIDS and the recent pandemic “COVID-19” (25, 26). Our results showed that 8.28% of populations had decreased LE during the periods examined, indicating the necessity to distinguish the positive and negative changes in LE in future studies.

Another main finding of this study is that the societies with lower income inequality tend to enjoy the prolonged life years with a reduced proportion spent with disability (Type 3). While no studies have ever analyzed the relationship between income equality and health changes, our results are partly supported by the literatures on income inequality hypothesis: population health is better in societies where income is more equally distributed (19, 20). At least two theories could help us understand the mechanism between income inequality and health changes (27). First, according to the political capture theory, higher income inequality may increase the political influence of the rich people, which probably restricts the provision of public goods (e.g., education and sanitation) and limit the ability of poor people to access health resources and live a healthy life (20, 27). Second, according to the theory of relative deprivation, the perceived income inequality may cause more stress behaviors and less positive emotions among the poor people, which results in a heavier burden of morbidity (28, 29). Higher income inequality, therefore, exacerbates the expansion of morbidity among the socioeconomic disadvantaged groups (18), which then affects the health changes of whole population.

This study has some limitations. First, we did not examine the dynamic equilibrium hypothesis due to data unavailability. Second, despite the effort of collecting all available health data by the GBD 2016, some unpublished data sources are still not included. The low data quality in some middle- and low-income countries probably influences the data accuracy and comparability. Third, the large-scale literature review serves as the basis for Gini coefficients in SWIID. The study designs may differ across literatures, which may reduce data comparability. Finally, the analyses are performed at population level, which is subject to ecological biases and reduces our ability to conclude a causal relationship.

In conclusion, it is necessary to distinguish the positive and negative LE changes when defining and analyzing the compression and expansion of morbidity. In the last quarter of century, the relative expansion with increased or constant LE (Type 6) was the most popular type of health changes and its popularity significantly increased over time. This implies higher needs for health and long-term care. Those societies with lower income inequality are more likely to enjoy the more favorable scenario, the relative compression of morbidity with increased or constant LE (Type 3). Measures to reduce income inequality or mitigate its negative influence on health changes might promote the occurrence of this scenario.

Declarations

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Competing interests

The author(s) declare(s) that they have no competing interests

Ethics approval and consent to participate The study is based on the aggregated data on population health and income distribution, which are obtained from open database. The data do not include any individual identification information. Ethics approval is, thus, not required.

Consent for publication

Declarations of interest: none.

Availability of data and materials

The datasets generated and/or analysed during the current study are available in the [Global Burden of Disease Study] repository, [<http://ghdx.healthdata.org/gbd-2016>].

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Figures

Figure 1

Distribution of the compression and expansion of morbidity, by sex and period (N=776). Type 1 refers to the absolute compression of morbidity with increased or constant life expectancy. Type 2 refers to the absolute compression of morbidity with decreased life expectancy. Type 3 refers to the relative compression of morbidity with increased or constant life expectancy. Type 4 refers to the absolute expansion of morbidity with increased or constant life expectancy. Type 5 refers to the absolute expansion of morbidity with decreased life expectancy. Type 6 refers to the relative expansion of morbidity with increased or constant life expectancy. Type 7 refers to the relative expansion of morbidity with decreased life expectancy.

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