BMJ Open  Change in global burden of unintentional drowning from 1990 to 2019 and its association with social determinants of health: findings from the Global Burden of Disease Study 2019

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ABSTRACT
Objective To systematically analyse global, regional and national burden change of unintentional drowning from 1990 to 2019, and to further quantify the contribution of social determinants of health (SDH) on the change.

Design Data from the Global Burden of Disease Study 2019 were used in this study.

Setting and participants Individuals of all ages and genders from 204 countries and territories.

Main outcome measures The main outcomes were the age-standardised rates (ASRs) of mortality and disability-adjusted life-years (DALYs) of unintentional drowning. The percentage change in the ASRs were used to estimate the joint effect of SDH on trends in global burden of drowning.

Results We observed that the global burden of unintentional drowning declined markedly from 1990 to 2019, with age-standardised mortality rate and DALYs rate decreasing by 61.5% and 68.2%, respectively. Women, children, middle Socio-Demographic Index (SDI) countries, South-East Asia and Western Pacific region had higher reduction. At national level, greater reductions were observed in Armenia and Republic of Korea, but significant increases in Cabo Verde and Vanuatu. We found that every one percentile increase in six SDHs (Gross Domestic Product (GDP) per person, SDI, educational attainment, health spending, health workers and urbanisation) was associated with a decrease of 0.15% and 0.16% in drowning age-standardised mortality rate and DALYs rate globally, respectively. Health spending and GDP per capita were the main contributors to the reduction of drowning globally.

Conclusions The global burden of unintentional drowning significantly declined in the past three decades, and the improvement of SDHs such as GDP per capita and health spending mainly contributed to the decrease. Our findings indicate that improvement of SDHs is critical for drowning prevention and control.

INTRODUCTION
Drowning has long been a serious public health issue in the world. Global report on drowning in 2014 released by the WHO found that drowning was among the 10 leading causes of death for children and young people globally, and half of drowning deaths occurred in people younger than 25 years. Moreover, more than 90% of drowning deaths occurred in low-income and middle-income countries (LMICs).1 WHO also estimated that about 225,000 population drowned in 2019 and drowning had killed more than 2.5 million people in the past decade. Drowning can also cause severe disability, for example, the Global Burden of Diseases (GBD) Study 2019 estimated that drowning ranked as the second leading cause according to disability-adjusted life years (DALYs) per 100,000 population after falls within unintentional injury in 2019.3

Fortunately, over the past decades, the global burden of unintentional drowning has gradually declined.4 5 The global burden of drowning estimated from GBD 2017 found that the number of drowning death decreased by 44.5% and age-standardised mortality rate

STRENGTHS AND LIMITATIONS OF THIS STUDY
⇒ We described the change of drowning burden in the past three decades at global, regional and national level, which provides important information for drowning prevention in the future.
⇒ We first estimated the joint effect of social determinants of health (SDH) on burden change of drowning, and further quantified the individual contribution of each SDH using a weighted quartile sum regression.
⇒ Our study only focused on unintentional drowning defined by International Classification of Diseases-10 codes W65–74, which limits our ability to assess drowning related to natural disaster and transport.
⇒ This study did not consider the potential impacts of climate change and drowning intervention programmes in different countries in the analysis.
decreased by 57.4% from 1990 to 2017. A recent analysis of unintentional drowning in Australia showed that the mortality rate of unintentional drowning dropped by 28% from 2008 to 2020. Canada has also made big strides in reducing drowning deaths, with mortality rate declining steadily over the past decade, from 1.42/100 000 in 2005 to 1.13/100 000 in 2014 with 28% reduction. The burden of drowning has also declined in many LMICs. For instance, a decrease of drowning mortality rate was observed in Vietnam, from 7.2/100 000 in 2009 to 6.9/100 000 in 2013.

This achievement was probably made by the intervention efforts initiated by international organisation and country’s governments. For example, the WHO’s guidance for drowning prevention has encouraged its member countries to take a range of intervention programmes of drowning. In Bangladesh, a project called ‘Anchal’, a community day-care centre, has been piloted to strengthen supervision of children and protect them from drowning. In Australia, fencing has been installed in dangerous waters to reduce the incidence of child drowning. In addition, the Blue Flag, established by the Foundation for Environmental Education, have played an important role in the prevention of drowning accidents in Europe.

However, most of previous evidence focused on fatal drowning, and research on non-fatal drowning was scarce and it was also unknown on the contribution of social determinants to the reduction of global drowning burden. WHO and several studies reported that this reduction might be related to rapid improvement in social determinants of health (SDH) such as income, educational attainment and living environment. For instance, Nguyen et al. found that low socioeconomic status or low-income households were associated with increased drowning mortality, but this study only investigated the impact of a single SDH on the burden of drowning at family level. However, humans are always simultaneously exposed to multiple SDHs, and there is currently no clear evidence on how much mixture SDHs drive the decline in the burden of drowning globally. Therefore, it is necessary to explore joint effects of multiple SDHs and understand the contribution of each SDH.

In the present study, we comprehensively described the global, regional and national burden change of unintentional drowning from 1990 to 2019 based on GBD 2019 and then further explored the joint effects of SDHs on the reduction. Our findings will help understand the global, regional and national heterogeneity of the change of drowning burden and its potential SDHs, which will help guide drowning prevention policymaking to further reduce global burden of drowning.

METHODS

Study data

We collected the GBD 2019 data on global, regional and national burden attributable to unintentional drowning in the GBD Results Tool (http://ghdx.healthdata.org/ gbd-results-tool), which includes all up-to-date data on GBD. The GBD 2019 conducted comprehensive assessment of the global burden for 369 diseases and injuries and 87 risk factors in 204 countries and territories from 1990 to 2019, and the estimation methods have been published elsewhere. The Institute for Health Metrics and Evaluation (IHME) is an independent global health research centre at the University of Washington, and it created the Global Health Data Exchange (GHDx) website (https://ghdx.healthdata. org/ihme_data). We also collected data on six SDHs in each country including Gross Domestic Product (GDP) per person, Socio-Demographic Index (SDI), population weighted educational attainment per person for people over 25 years old (educational attainment), total health spending per person and the number of health workers per 10 000 population from the GHDx website.

In addition, we obtained the urbanisation rate of each country from data catalogue of the World Bank (https://datacatalog.worldbank.org/home). More detailed information on SDH is presented in online supplemental table S1. As educational attainment and health spending were missing in some years in several countries, we used regression imputation to interpolate missing data: linear regression models were established between educational attainment and year, health spending and year, respectively; thereafter the missing data of educational attainment and health spending were predicted by the model. Since only 200 countries had data on urbanisation rate and 188 countries had data on educational attainment with 3 duplicate countries with missing data, we ultimately selected 187 countries to analyse the association between percentage change in unintentional drowning age-standardised mortality rate or DALYs rate and percentage change in SDHs.

Patient and public involvement
The patients and the public were not involved in the design, conduct, reporting or dissemination of our study. The data used in this study are freely available from the IHME’s GBD database.

Percentage change of drowning burden and SDH from 1990 to 2019

GBD Results Tool (http://ghdx.healthdata.org/gbd-results-tool) provides the percentage change in age-standardised mortality and DALYs rate of unintentional drowning from 1990 to 2019. The percentage change in SDH from 1990 to 2019 is calculated in the same way as the unintentional drowning burden. We described the trend of unintentional drowning age-standardised mortality and DALYs rate by region, nation, sex, age and SDI groups. Statistical significance test of the intragroup difference uses the following formula:

\[ Z = \frac{(b_1 - b_2)}{\sqrt{SE_1^2 + SE_2^2}} \]
Where $b_1$ and $b_2$ are estimated values for two levels within a group, and $SE_1$ and $SE_2$ are the SEs of the estimated values.

**The association of SDHs with the change of drowning burden**

To explore whether SDHs are the drivers of global burden changes of unintentional drowning, we used a weighted quartile sum (WQS) regression, which can reduce collinearity in model fitting caused by highly correlated SDHs (online supplemental table S2). WQS regression is designed to explore the joint effects of correlated components on health outcomes and assess the relative contributions of each component. WQS regression constructs a single index that was combined by all components after the contributions of each component. WQS regression helps to estimate its association with health outcomes. The results of WQS regression are mainly composed of two parts: a regression model between WQS index and health outcome, and WQS weights that were described as the contribution of each component to the WQS index.

For continuous $Y$ measured in individual $i$, the WQS regression equation can be expressed as:

$$Y_i = \beta_0 + \beta_1 \text{WQS}_i + \varepsilon_i$$

Where $\beta_0$ is equation intercept, WQS here is WQS index representing mixed exposure index, $\beta_1$ is the regression coefficient representing the change in $Y$ for per unit increase in the WQS index and $\varepsilon_i$ is an error term. The WQS index can be defined as follow:

$$\text{WQS} = \sum_{i=1}^{c} \omega_i q_i$$

where $\omega_i$ are the weights for each component and $q_i$ is the score of each component. To improve the reliability of the results, we randomly split the data into two data sets (training set and validation set). The weights are determined as the average weights in different training sets of the bootstrap samples (here, size of samples=1000), with all weights are constrained to sum to 1 and be between 0 and 1 ($0 \leq \omega_i \leq 1$, $\sum_{i=1}^{c} \omega_i = 1$). For this analysis, the $c=6$ SDHs were scored into percentiles based on the original data and denoted by $q_i$, where $q_i$ equal from 0 to 99 for $i=1$ to $c$, corresponding to the component $q_i$ will fall into one of the percentile (from 0 to 1st, 1st to 2nd and so on, until 99th to 100th) of that component.

It is worth noting that in the WQS model, in order to make the coefficient $\beta_1$ to reflect the effect of WQS index on the outcome of $Y$ without bias, we assume that all components have associations with outcome in the same direction, which can be achieved by pre-encoding the positive and negative of $\beta_1$. When we used generalised linear models to analyse the association between a single SDH and unintentional drowning burden, we found that all the associations except educational attainment, which had a very limited positive effect, satisfied the assumptions of directional homogeneity and linearity (online supplemental figure S1 and S2).

All analyses were performed using the R V4.1.2 in the ‘gWQS’ package of R software. A two-sided $p$ value<0.05 is considered to be statistically significant.

**RESULTS**

**The burden change of unintentional drowning from 1990 to 2019**

From table 1, we observed that the global age-standardised mortality rate and DALYs rate of unintentional drowning declined markedly from 1990 to 2019. Specifically, the mortality rate is 3.1/100 000 in 2019, representing a 61.5% decrease compared with 8.1/100 000 in 1990 and DALYs rate decreased by 68.2% from 553/100 000 in 1990 to 175.9/100 000 in 2019.

The stratified analysis found that the burden of drowning had slightly higher reduction for women (−66.6% for mortality rate and −73.5% for DALYs rate) than for men (−58.8% for mortality rate and −65.3% for DALYs rate). In terms of age, we found that the change in burden decreased with age, with the greatest reduction in children under 5 years old (−81.1% for both mortality rate and DALYs rate).

Globally, the region with the largest decrease of mortality rate was Western Pacific region (−65.0%), followed by South-East Asia (−61.3%), Eastern Mediterranean (−57.8%), Europe (−55.5%), America (−52.0%) and Africa (−49.6%). Similar pattern was shown in the DALYs rate, in which Western Pacific region (−72.1%) and South-East Asia (−67.7%) had the largest reduction. For the countries with different SDI, there is a decrease trend with SDI rise (table 1).

Further analysis simultaneously stratified by SDI, age group and gender, we found similar results to the total population for most groups, while the old adults with 70+ years old in high-SDI countries showed an increasing trend of drowning burden in both men and women (online supplemental table S3).

**Mapping global, regional and national distribution of burden change of drowning**

Figure 1 depicts the spatial distribution of changes in drowning mortality rate (Panel A) and DALYs rate (Panel B) for 204 countries from 1990 to 2019. Over the past 30 years, drowning burden declined in most countries and the greatest reductions were observed in Armenia (ARM) (−84.4% for mortality rate and −84.2% for DALYs rate), Republic of Korea (KOR) (−81.9% for mortality rate and −85.3% for DALYs rate) and Eritrea (−80.6% for mortality rate and −85.3% for DALYs rate). However, a significant increase in the burden of drowning was observed in some countries, such as Cabo Verde (57.2% for mortality rate and 44.3% for DALYs rate), Vanuatu (10.5% for mortality rate and 11.1% for DALYs rate) and Liberia (12.0% for mortality rate and 9.4% for DALYs rate). Online supplemental figure S3 and S4 further show the percentage change of drowning age-standardised mortality rate and DALY rate by gender. Overall, women were higher than
## Table 1  
Age-standardised mortality and DALYs rate (per 100 000) of unintentional drowning in 1990 and 2019, and percentage change from 1990 to 2019 by SDI, sex and age

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Age-standardised mortality rate per 100 000 (95% uncertainty interval (UI))</th>
<th>Percentage change, 1990–2019</th>
<th>Age-standardised DALYs rate per 100 000 (95% UI)</th>
<th>Percentage change, 1990–2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>8.1 (7.1 to 8.8)</td>
<td>3.1 (2.8 to 3.5)</td>
<td>−61.5 (−65.6 to −56.3)</td>
<td>553.0 (476.1 to 607.0)</td>
</tr>
<tr>
<td>SDI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High SDI*</td>
<td>2.4 (2.3 to 2.4)</td>
<td>1.3 (1.2 to 1.3)</td>
<td>−46.0 (−49.1 to −43.2)</td>
<td>138.7 (133.1 to 144.5)</td>
</tr>
<tr>
<td>High-middle SDI</td>
<td>7.1 (6.6 to 7.6)</td>
<td>2.7 (2.5 to 2.9)</td>
<td>−62.0 (−65.5 to −58.1)†</td>
<td>451.3 (416.4 to 490.0)</td>
</tr>
<tr>
<td>Middle SDI</td>
<td>9.5 (8.1 to 10.4)</td>
<td>3.4 (3.0 to 3.8)</td>
<td>−64.0 (−67.9 to −59.6)†</td>
<td>644.7 (534.8 to 706.9)</td>
</tr>
<tr>
<td>Low-middle SDI</td>
<td>10.8 (9.2 to 12.3)</td>
<td>4.0 (3.5 to 4.7)</td>
<td>−62.7 (−67.9 to −55.5)†</td>
<td>732.5 (615.8 to 835.0)</td>
</tr>
<tr>
<td>Low SDI</td>
<td>6.6 (5.4 to 7.8)</td>
<td>3.0 (2.6 to 3.7)</td>
<td>−54.3 (−61.9 to −39.2)</td>
<td>439.9 (343.7 to 528.3)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male*</td>
<td>10.7 (9.0 to 11.7)</td>
<td>4.3 (3.8 to 4.8)</td>
<td>−58.8 (−63.4 to −52.7)</td>
<td>706.6 (576.5 to 782.2)</td>
</tr>
<tr>
<td>Female</td>
<td>5.5 (4.9 to 6.1)</td>
<td>1.8 (1.6 to 2.0)</td>
<td>−66.6 (−70.8 to −61.0)</td>
<td>394.5 (340.6 to 440.6)</td>
</tr>
<tr>
<td>Age (year)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under 5*</td>
<td>29.1 (23.0 to 33.9)</td>
<td>5.5 (4.5 to 6.8)</td>
<td>−81.1 (−84.7 to −73.4)</td>
<td>2512.6 (1989.1 to 2925.9)</td>
</tr>
<tr>
<td>5–14</td>
<td>9.4 (8.2 to 10.5)</td>
<td>2.8 (2.5 to 3.3)</td>
<td>−70.1 (−73.5 to −65.6)†</td>
<td>756.3 (657.5 to 841.2)</td>
</tr>
<tr>
<td>15–49</td>
<td>4.5 (4.0 to 5.0)</td>
<td>2.2 (2.0 to 2.5)</td>
<td>−50.1 (−55.9 to −43.6)†</td>
<td>272.3 (245.9 to 303.9)</td>
</tr>
<tr>
<td>50–69</td>
<td>4.9 (4.5 to 5.4)</td>
<td>3.0 (2.7 to 3.3)</td>
<td>−38.5 (−46.4 to −30.4)†</td>
<td>155.6 (143.5 to 171.9)</td>
</tr>
<tr>
<td>70+</td>
<td>8.1 (7.3 to 9.0)</td>
<td>7.6 (6.6 to 8.3)</td>
<td>−6.2 (−19.4 to 6.6)†</td>
<td>126.1 (115.3 to 140.6)</td>
</tr>
<tr>
<td>WHO region</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western Pacific*</td>
<td>12.1 (10.4 to 13.2)</td>
<td>4.2 (3.6 to 4.6)</td>
<td>−65.0 (−69.4 to −59.8)</td>
<td>836.6 (712.1 to 927.3)</td>
</tr>
<tr>
<td>Africa</td>
<td>4.3 (3.6 to 5.0)</td>
<td>2.2 (1.8 to 2.7)</td>
<td>−49.6 (−58.8 to −34.6)</td>
<td>279.5 (222.2 to 335)</td>
</tr>
<tr>
<td>America</td>
<td>4.2 (4.1 to 4.4)</td>
<td>2.0 (1.8 to 2.3)</td>
<td>−52.0 (−56.5 to −46.8)†</td>
<td>276.1 (263.4 to 290.3)</td>
</tr>
<tr>
<td>Eastern Mediterranean</td>
<td>4.1 (2.9 to 5.3)</td>
<td>1.7 (1.5 to 2.2)</td>
<td>−57.8 (−67.0 to −41.3)</td>
<td>292.5 (199.8 to 383.5)</td>
</tr>
<tr>
<td>South-East Asia</td>
<td>5.1 (4.9 to 5.3)</td>
<td>2.3 (2.1 to 2.4)</td>
<td>−55.5 (−58.7 to −52.0)†</td>
<td>312.7 (301.9 to 325)</td>
</tr>
</tbody>
</table>

*The reference in significance test of the intragroup comparison.  
†The difference between a certain level and the reference was statistically significant (p<0.05).  
DALYs, disability-adjusted life years ; SDI, Socio-Demographic Index .
men in the percentage change of drowning burden in developing countries. In addition, online supplemental figures S5 and S6 show the percentage change in drowning burden by age. We found that globally, the change in drowning decreased with the increase of age, but DALYs among adolescents aged 5–14 years old increased in some countries, such as Kazakhstan (606.2%), Lesotho (537.9%) and China (70.1%).

Figure 2 further shows the percentage change of drowning burden for the top 15 countries and territories by age and gender from 1990 to 2019. Overall, there were a total of 64 countries and territories that ranked in the top 15 in various age-specific and gender-specific groups, which are mainly distributed in Asia (22), followed by Europe (18), Americas (10) and Africa (10). The countries with the greatest reduction in the burden of drowning varied by gender and age group, but mainly concentrated in Asia. For the whole population, the KOR saw the largest decline in the 5–14 years age group (−92.0% for mortality rate and −91.8% for DALYs rate) and 15–49 years age group (−84.1% for mortality rate and −84.9% for DALYs rate), but ARM had the largest decline in the 50–69 years age group (−83.9% for mortality rate and −82.4% for DALYs rate) and the old adults with 70+ years age group (−80.6% for mortality rate and −76.8% for DALYs rate) and Equatorial Guinea had the greatest decline in the age group under 5 years old (−93.7% for mortality rate and DALYs rate). For women, ARM had the highest reduction in drowning burden among all countries across all age groups, with the largest reduction for children under 5 years old (−96.6% for mortality rate and −96.4% for DALYs rate). In terms of men, we observed a similar pattern as for the whole population, but Serbia experienced the greatest decline in the age
group under 5 years old (~94.3% for mortality rate and DALYs rate).

**The association of SDHs with the burden change of drowning**

The WQS index was negatively associated with the percentage change of drowning burden. Specifically, 1% increment in the WQS index resulted in 0.15% ($\beta=-0.15$) and 0.16% ($\beta=-0.16$) decrease in drowning mortality rate and DALYs rate, respectively, (table 2).

After stratified analysis by economic development level, we found that for every one percentile increase in WQS index, the decline in drowning mortality rate ($\beta=-0.39$) and DALYs rate ($\beta=-0.41$) in low-income and lower-middle-income countries was greater than that in high-income and upper-middle-income countries ($\beta=-0.10$ for drowning mortality rate and $\beta=-0.08$ for DALYs rate), but the difference was not statistically significant.

The weights of SDHs in the WQS index are shown in figure 3. Globally, top three SDH contributing to drowning burden change were health spending (53% for mortality rate and 55% for DALY rate), GDP per capita (24% for mortality rate and 21% for DALY rate) and health workers (20% for mortality rate and 18% for DALY rate). After stratification analysis by economic development level,
we observed that, for high-income and upper-middle-income countries, GDP per capita (61% for mortality rate and 56% for DALY rate) and health spending (34% for mortality rate and 38% for DALY rate) were much more important. For low-income and lower-middle-income countries, the contributions of health spending (31% for mortality rate and 30% for DALY rate) and SDI (30% for mortality rate and 34% for DALY rate) make the largest and roughly equal contribution, followed by educational attainment (17% for mortality rate and 16% for DALY rate). The specific weight values of each SDH are shown in online supplemental table S4.

**DISCUSSION**

Based on GBD 2019, our study described the global, regional and national burden change of unintentional drowning from 1990 to 2019 and found a significantly downward trend over the past three decades with higher reduction in middle-SDI countries, which is consistent with the GBD 2017 study. More importantly, we observed that SDHs might be important drivers of the reduction of drowning burden, and GDP per person and health spending could be major contributors to the reduction globally. To our best knowledge, this is the first study to examine the joint effect of multiple SDHs on the burden change of drowning.

Generally, great progress has been made in drowning prevention in most countries from 1990 to 2019, and this finding was consistent with previous studies. For instance, the burden of drowning from GBD 2017 found that the global number of drowning death decreased by 44.5% from 1990 to 2017. This achievement was probably made by the combined effects of socioeconomic development, environmental change and intervention efforts initiated by international organisations and country’s governments.

We observed the global reductions of drowning burden were spatial heterogeneity, and the countries in South-East Asia and Western Pacific region had higher reduction than others. This is consistent with WHO’s estimates. WHO reported that the reduction in drowning mortality rate from 2000 to 2019 in South-East Asia and Western Pacific region were 53.9% and 45.4%.

In the subgroup analysis, we further found that women had a higher reduction of drowning burden than men.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>The change of unintentional drowning burden for a percentile increment in weighted quartile sum index by economic development level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
<td>β (95% CI)</td>
</tr>
<tr>
<td>The change of age-standardised mortality rate</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>−0.15 (−0.28 to 0.01)</td>
</tr>
<tr>
<td>High-income and upper-middle-income countries</td>
<td>−0.10 (−0.28 to 0.08)</td>
</tr>
<tr>
<td>Low-income and lower-middle-income countries</td>
<td>−0.39 (−0.77 to 0.01)</td>
</tr>
<tr>
<td>P value</td>
<td>0.178</td>
</tr>
<tr>
<td>The change of age-standardised DALYs rate</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>−0.16 (−0.29 to 0.02)</td>
</tr>
<tr>
<td>High-income and upper-middle-income countries</td>
<td>−0.08 (−0.26 to 0.10)</td>
</tr>
<tr>
<td>Low-income and lower-middle-income countries</td>
<td>−0.41 (−0.78 to 0.04)</td>
</tr>
<tr>
<td>P value</td>
<td>0.116</td>
</tr>
<tr>
<td>DALY, disability-adjusted life years.</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 3** WQS index weights estimated for each SDH by countries with different economic development level. DALYs, disability-adjusted life years; GDP, Gross Domestic Product; SDH, social determinants of health; SDI, Socio-Demographic Index; WQS, weighted quartile sum.
which confirms the findings of the GBD 2017. The possible reasons may be that men are more involved in open water than women, and more likely to swim alone and consume alcohol during recreational water activities. We also found that children younger than 5 years of age had greater burden of drowning. This is consistent with the results of previous studies. For example, WHO’s Global Health reported that in 2019 the highest DALYs and mortality rate attributed to drowning were observed in children who are under 5 years of age. The higher drowning burden for children may be due to children with mobile and curious characteristics, but without the perception of danger and they always slip away from their supervising adults and fall or climb into nearby water. In addition, we found an upward trend for adolescence aged 5–14 years old in some countries. This is consistent with previous findings that drowning causes the second highest number of DALYs among adolescence in 2019 (3.27 million) among unintentional injuries, which suggests that drowning in adolescents is still a serious public health problem.

What are the driving factors of the downward trends of drowning burden globally? While drowning intervention programmes may partially explain the reduction, our results found that SDHs may play an important role. Although, several previous studies examined the individual effect of each SDH, to date, few studies have explored the mixture effects of multiple SDHs on drowning. Here we used the WQS regression to estimate the joint effect of six SDHs on drowning burden, and found the improvement of SDHs resulted in significant decrease of drowning burden, and the mixture effect of these SDHs was greater in low-income and lower-middle-income countries. This may be due to the fact that over the past three decades, the less developed countries had experienced more rapid and complex social changes, and it was well known that SDHs were usually the causes of diseases and injuries.

We found that economy-related SDHs, such as GDP per capita and health spending, were relatively important driving factors which caused reduction of drowning burden. Similar to our findings, Ozanne-Smith and Li found that the dramatic decline of fatal drowning rates in China since 1987 could largely be attributed to the development of socioeconomic structures. Rahman and colleagues found that the risk of drowning decreased with the socio-economic status index rise. Low economic status may result in lack of adult supervision for children because parents have to work long hours, thus increasing the risk of drowning for children.

We also found that educational attainment was an important factor of drowning, especially in lower-middle-income and low-income countries, which is in line with previous studies. A study conducted in Bangladesh showed that individuals without education had 3.7 times and about 2.9 times higher risk of fatal and non-fatal drowning, respectively. Possible explanation for that was children who lack education leave school at an early age to start work, which means they are unable to take part in swimming lessons and more likely to exposed to drowning risks. Moreover, illiterate parents do not have access to drowning prevention knowledge and have poor water safety awareness, which make their children more prone to drowning.

In term of urbanisation, existing studies found that urbanisation was an important factor leading to the dramatical decline of drowning burden. For example, a study in Australia found that urbanisation was associated with the decline in drowning mortality in the 19th century when few drowning prevention programmes were implemented. Our finding is inconsistent with this study. The possible reason for this may be that the association between urbanisation and burden change of drowning could largely be explained by other SDHs such as GDP per capita. Therefore, we could not observe the effect of urbanisation on drowning reduction in the present study.

There were several strengths in this study. First, we described the change of drowning burden in the past three decades at global, regional and national level, which provides important information for drowning prevention in the future. Second, we first estimated the joint effect of SDHs on burden change of drowning, and further quantified the individual contribution of each SDH using a WQS regression, which will help guide the development of drowning prevention policies.

Several limitations should also be acknowledged. First, this study only focused on unintentional drowning defined by International Classification of Diseases-10 codes W65–74, which limits our ability to assess drowning related to natural disaster and transport. Previous studies have found that defining drowning with code W65–74 captures only 61% of drowning deaths in Australia and may adversely affect the design of prevention policies in some disaster and water transport impacted countries. Second, since data were not available, we were unable to assess the impact of education on those under 25 years old, and only 187 countries were included in the analysis on the association of SDHs with burden change of drowning. Third, we did not consider the potential impacts of climate change and drowning intervention programmes in different countries in the analysis. Sindall et al believes that climate change is a contributor to the global burden of drowning. For example, higher temperatures would cause people to spend more time in water, and droughts would lead to increased exposure to more dangerous water sources. Further research is needed to consider the impact of climate change on drowning risk.

CONCLUSION

The global burden of unintentional drowning has been continuing to decline, with a higher decrease for woman, children, low-middle SDI countries, South-East Asia and Western Pacific region, and the rapid improvement of
SDHs may mainly contribute to the dramatic reduction of global burden of unintentional drowning.

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Supplemental material This content has been supplied by the author(s).

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