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abstract

BACKGROUND AND OBJECTIVES: We aimed to calculate the change in under-5 mortality rates (U5MRs) (1990–2016), to assess countries’ status regarding Sustainable Development Goal (SDG) 3.2.1 (reducing the U5MR to ≤25 deaths per 1000 live births by 2030), to list the most important causes of death (1990, 2016), and to examine the association between selected SDG indicators and U5MRs using a linear mixed-effects regression.

METHODS: Ecological study in which we used estimates from the Global Burden of Disease Study 2016 for Central American countries. Results were expressed as U5MRs (deaths per 1000 live births), cause-specific mortality rates (deaths per 100 000 population <5 years of age), and regression coefficients with 95% confidence intervals.

RESULTS: U5MRs decreased 65% (1990–2016), and in 2016, all countries but Guatemala had met SDG 3.2.1. The main causes of death were diarrheal diseases (1990; 311.1 per 100 000) and lower respiratory infections (LRIs) (2016; 78.1 per 100 000). When disaggregated by country (2016), congenital birth defects were the most important cause of death in all countries except for in Honduras (neonatal preterm birth) and Guatemala (LRIs). Nutritional status; availability of water, sanitation, and hygiene services; coverage of vaccines; and coverage of contraception were associated with a reduction in U5MRs.

CONCLUSIONS: Central America has achieved a large reduction in U5MRs. Countries must address both the high mortality caused by LRIs and the rising mortality caused by noncommunicable causes of death through an improvement of SDG indicators that guarantees equitable progress in child survival in the region.

WHAT’S KNOWN ON THIS SUBJECT: Changes in under-5 mortality rates have been reported in Central America, ranging from 39% (Panama) to 75% (El Salvador) (1990–2011 study). Vaccination coverage was related to a reduction in child mortality in a study including countries from the region.

WHAT THIS STUDY ADDS: This study highlights the need for addressing the high mortality resulting from communicable causes of death and the rising mortality resulting from noncommunicable causes in Central America by improving different components of the Sustainable Development Goals framework.


Drs Castro and Ortiz-Panozo conceptualized and designed the study, drafted the article, were responsible for the data collection, analyzed and interpreted data, and critically reviewed the manuscript for important intellectual content; Drs Benavides Lara, Garcés, and Moreno-Velásquez, Mr Odell, and Dr Pérez analyzed and interpreted data and critically reviewed the manuscript for important intellectual content; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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The Sustainable Development Goals (SDGs) framework emphasizes the need for countries to reduce under-5 mortality rates (USMRs) to ≤25 deaths per 1000 live births by 2030. When the SDG agenda was adopted in 2015, USMRs in all Central American countries were <25 per 1000, with the exception of Guatemala.

The Central American region stands out because of its high levels of income inequality. According to the World Bank, in 2016, countries from this region had Gini coefficients ranging from 0.4 in Honduras to 1.6 in El Salvador and Panama (Table 1). These socioeconomic differences could contribute to inequalities in rates for child mortality. As an example, despite large decreases in under-5 (US) mortality in the region over the decades, in 2011, USMRs in Guatemala were 3 times as high as those in Costa Rica.

With this study, we aim to fill the knowledge gap about the reduction in USMRs in Central America using a better understanding of the different paces at which this change is taking place among countries. We also aim to identify which SDG-related indicators are more strongly related to the observed USMRs. We calculated the change in USMRs in Central America from 1990 to 2016, listed the most important causes of death in 1990 and 2016, and explored the relationship between relevant SDG indicators and USMRs.

METHODS

Study Design and Population
We conducted a secondary analysis of data from the Global Burden of Disease Study (GBD) 2016, including Central American countries (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama) from 1990 to 2016. According to the classification used by the GBD, Belize is included in the Caribbean region.

Data Sources and Study Variables
In our study, we rely on 3 main estimates from the GBD 2016: all-cause mortality (for USMRs), causes of death, and SDG indicators. USMRs were expressed as the number of deaths per 1000 live births. To examine the most important causes of death, we used cause-specific mortality rates (CSMRs), expressed as the number of deaths per 100,000 population U5.

U5MR estimates were published by the GBD 2016 Mortality Collaborators and relied on information from vital registration systems, census data, surveys, and complete and summarized birth histories. Further information on how these data were obtained and adjusted can be found in the GBD publications.

In the GBD 2016, 37 of 50 health-related SDG indicators were measured. On the basis of a priori knowledge, we selected 8 indicators that could explain the variation in USMRs in Central America over time: prevalence of stunting, prevalence of wasting, risk-weighted prevalence of populations using unsafe water sources, risk-weighted prevalence of populations using unsafe sanitation, risk-weighted prevalence of populations without access to a hand-washing facility, coverage of 8 vaccines in target populations, proportion of women of reproductive age who have their need for family planning met with modern contraceptive methods, and proportion of births attended by skilled health personnel. Risk-weighted prevalence is a measure of a population’s exposure to a risk factor that reflects the extent of exposure by risk level and the severity of that risk’s contribution to disease burden, ranging from 0% when there is no excess risk for a population and 100% when the population is at the highest risk level. Definitions and data sources for all indicators are shown in Supplemental Table 3.

Prevalence of stunting and prevalence of wasting both measured nutritional status; to address multicollinearity, we averaged these indicators’ geometric means and created the composite indicator measure of performance in the reduction of

| TABLE 1 Central American Countries’ Socioeconomic and Health Profiles |
|-------------------|-----------------|-----------------|----------------|-----------------|------------------|-----------------|
| GDP per Capita,   | Gini Index      | Health Expenditure, % of GDP | Physicians, No. per 1000 Population | UHC Service Coverage Index |
| USD               | Expenditure     | % of GDP         | Population | Coverage Index |
| Costa Rica       | 1831.00         | 11 668.56        | 45.3       | 48.7           | 6.6              | 7.6             | 1.3             | 1.2           | 76               |
| El Salvador      | 914.13          | 3800.10          | 54.6       | 40             | 8.1              | 7.7             | 0.8             | 1.6           | 75               |
| Guatemala        | 825.81          | 4140.59          | 54.2      | 48.3           | 5.7              | 5.8             | 0.8             | 0.9           | 57               |
| Honduras         | 993.48          | 2342.59          | 57.4       | 50             | 6.4              | 8.4             | 0.7             | 0.6           | 66               |
| Nicaragua        | 241.88          | 2107.59          | 57.4      | 46.2           | 5.2              | 8.7             | 0.7             | 0.9           | 71               |
| Panama           | 2603.85         | 14 356.52        | 58.2      | 50.4           | 7.3              | 7.3             | 1.1             | 1.6           | 76               |

Data are based on 1990 and 2016 unless stated otherwise and are from ref 4. UHC, universal health coverage; USD, US dollar:
- 2013
- 1991
- 2014
- 1990
- 2000
- 1993
- 1991
undernourishment in children U5. We did the same to create a second composite indicator (availability of adequate and equitable water, sanitation, and hygiene [WASH] services) by averaging the risk-weighted prevalence of populations using unsafe water sources, risk-weighted prevalence of populations using unsafe or unimproved sanitation, and risk-weighted prevalence of populations without access to a hand-washing facility.

For these 5 SDG indicators that were merged into 2 composite indicators, we used rescaled indices (1–100, computed by the GBD SDG collaborators) instead of prevalence (percentages) because we wanted to measure progress. Data were only available quinquennially (1990, 1995, 2000, 2005, 2010, 2016), and we assumed similar annual values over the subsequent 5-year periods. For the remaining SDG indicators (vaccine coverage, proportion of women of reproductive age who have their need for family planning met with modern contraception methods, and skilled birth attendance), we used annual data points as percentages. From the initial 8 SDG indicators, we ended up with a total of 5 indicators (for each country), and we used these as covariates in a regression model. Annual and quinquennial data points are shown in Supplemental Table 4.

**Data Analysis**

*Change in U5MRs, Magnitude of the Change, and Current Status Toward Achievement of SDG 3.2.1*

We calculated the proportion of U5 deaths out of the total number of deaths in all age groups in 1990 and 2016. We plotted U5MRs for the region and each country to identify those with the lowest and highest rates. We calculated the U5MR ratio between the countries with the lowest and highest rates in 1990 and 2016 to gain understanding of how the gap in U5MRs between countries has changed over time. We also assessed countries’ current status (2016) regarding achievement of SDG 3.2.1 on U5 mortality (=25 deaths per 1000 live births by 2030) and examined which countries have already met the target. The magnitude of the change in U5MRs (1990–2016) was quantified by annualized rates of change (ARC) and total percentage change (TPC), and comparisons were drawn across countries.

**Causes of Death**

For every country and for the region, we ranked the 10 most important causes of death in 1990 and 2016 on the basis of CSMRs. We also calculated percentage changes to identify the causes with the largest declines during the study period.

**Statistical Analysis**

We explored the relationship between relevant SDG indicators and U5MRs by fitting a linear mixed-effects regression model, in which we included the year as a covariate and added random effects at a country level. We calculated regression coefficients and their respective 95% confidence intervals (CIs), setting the statistical significance level at $P = .05$. A supplementary analysis was conducted by using quinquennial instead of annual data points for all indicators. All statistical analyses were conducted with Stata 14.2 (Stata Corp, College Station, TX), and figures were plotted by using R Studio 1.2.1335.

**Uncertainty Estimation**

For U5MRs, 95% uncertainty intervals (UIs) were estimated by the GBD 2016 Mortality Collaborators by generating 1000 draws with Markov Chain Monte Carlo simulations. Ethical Considerations

Our study is a secondary analysis of data gathered and analyzed in the GBD 2016, following the Guidelines for Accurate and Transparent Health Estimates Reporting.14

**Role of the Funding Source**

The GBD 2016 database development, methods improvement, and global analysis are primarily funded by the Bill & Melinda Gates Foundation, which has no role in the design, data collection, data analysis, data interpretation, or writing of this article.

**RESULTS**

*Change in U5MRs, Magnitude of the Change, and Current Status Toward Achievement of SDG 3.2.1*

U5 deaths accounted for 32.6% of all deaths in 1990 and 8.6% in 2016 in the Central American region. In 2016, all countries but Guatemala had attained SDG 3.2.1 on reducing U5 mortality to ≤25 deaths per 1000 live births. Guatemala remained the country with the highest U5MRs in the region over the years, with 80.4 deaths per 1000 live births (95% UI: 76.2–84.8) in 1990 and 26.7 per 1000 (95% UI: 22.9–31.2) in 2016. On the other hand, the lowest U5MRs were observed in Costa Rica, with 20 per 1000 (95% UI: 17.3–22.8) in 1990 and 10.6 per 1000 (95% UI: 8.1–13.7) in 2016. The gap in U5MRs between these 2 countries decreased during the study period. In 1990, Guatemala had U5MRs 4 times as high as those reported in Costa Rica, whereas in 2016, the U5MR ratio was 2.5 (Fig 1). U5MRs in Central America went down from 59.7 per 1000 in 1990 to 20.9 per 1000 in 2016 for a TPC of −65% and an ARC of −3.8% (Fig 1). Panama exhibited the lowest reduction (TPC: −40.5%; ARC: −1.9%) in the region and El Salvador the largest (TPC: −77.7%; ARC: −5.4%). Overall, U5MRs in Costa Rica and Panama remained low, and the decline was steady during the study period, whereas other countries exhibited higher rates and larger declines.
Causes of Death

The 10 main causes of death in 1990 and 2016 ranked by CSMRs in population U5 in Central America are shown in Fig 2. Diarrheal diseases were the most important cause of death in 1990 (311.1 per 100 000), followed by lower respiratory infections (LRIs) (234.5 per 100 000), neonatal preterm birth (188.1 per 100 000), congenital birth defects (83.4 per 100 000), and neonatal encephalopathy due to birth asphyxia and trauma (73.2 per 100 000). The most important causes of death in 2016 were LRIs (78.1 per 100 000), neonatal preterm birth (68.1 per 100 000), congenital birth defects (60.7 per 100 000), neonatal encephalopathy due to birth asphyxia and trauma (35.6 per 100 000), and diarrheal diseases (32.3 per 100 000). CSMRs decreased from 1990 to 2016 for all causes of death. For causes of death that remained within the 10 most important in 2016, the highest changes in CSMRs were observed for diarrheal diseases (-89.6%), protein-energy malnutrition (-74%), and LRIs (-66.7%).

When examining causes of death disaggregated by country in 2016, congenital birth defects were the most important cause of death in all countries except for Honduras, where neonatal preterm birth was the most important cause of death, and Guatemala, where LRI was the most important cause of death (Fig 3).

Factors Related to U5MRs

After adjusting for all other covariates, a linear mixed-effects regression model revealed there was a statistically significant association between the following covariates and U5MRs: measure of performance in the reduction of undernourishment (coefficient: −0.1; 95% CI: −0.19 to −0.02; P = .02), availability of WASH services (coefficient: −0.23; 95% CI: −0.41 to −0.04; P = .02), coverage of vaccines (coefficient: −0.44; 95% CI: −0.58 to −0.31; P < .001), and coverage of modern contraception methods (coefficient: −0.57; 95% CI: −0.75 to −0.39; P < .001). The association between skilled birth attendance (coefficient: −0.07; 95% CI: −0.17 to 0.04; P = .21) and U5MRs was not statistically significant (Table 2). Supplemental Table 5 reveals a similar analysis using quinquennial instead of annual data points, yielding similar results.

DISCUSSION

We found that the Central American region exhibited a total change in U5MRs of −65% from 1990 to 2016. The main causes of death in children U5 were diarrheal diseases in 1990 and LRIs in 2016. Nutritional status, availability of WASH services, coverage of vaccines, and coverage of modern contraception methods were associated to a reduction in U5MRs.

The total reduction in U5MRs observed in the region (−65%) surpasses the figures reported at a global level and in the Eastern Mediterranean region (−50% to −54%).3,15,16 This finding was consistent with a previous study using data from Central America which reported reductions ranging from −39% in Panama to −75% in El Salvador.6 Our results underscore disparities in the burden of U5 mortality among Central American countries, which may reflect the differences between these in terms of socioeconomic indicators.4 In previous studies, authors have pointed out inequalities in infant mortality in the region, where rates in countries from the lowest gross domestic product (GDP) quintile were 4 times as high as those reported in countries from the highest quintile.17 However, it is promising to see how the gap in U5MRs has diminished over time. With remarkable
decreases, El Salvador and Nicaragua went from having some of the highest U5MRs in the region in 1990 to having some of the lowest in 2016. Costa Rica stands out as the country with the lowest U5MRs. This might be somewhat because of a more effective health system with emphasis on universal health coverage, allowing increased access to public health services in the most deprived sectors of the population. Guatemala, the country with the lowest GDP per capita, remained the country with the highest U5MRs in our study. Even if considerable declines were reported in this country, low levels of insurance coverage, decreasing public health expenditure, and reduced geographic availability of health care services in rural communities might have contributed to smaller reductions in U5 mortality compared with neighboring countries.

Even if the proportion of deaths due to communicable diseases decreased during the study period, in 2016, this group still accounted for two-thirds of U5 deaths in the region. This reduction has led to noncommunicable diseases (mainly congenital defects) playing an increasingly important role in U5 mortality. Despite that decline, the main cause of death in 2016 in the region remained a communicable disease (LRIs), similar to 1990 (diarrheal diseases). This could be related to the fact that even if almost all countries have moved toward congenital birth defects or neonatal disorders as the most important cause of death, the excessively high mortality rate due to LRIs in Guatemala makes this cause rank first in the region when producing regional estimates. This underscores how the epidemiological transition is taking place at a different pace in Central American countries.

Diarrheal diseases, protein-energy malnutrition, and LRIs exhibited the largest declines in CSMRs from 1990 to 2016. This parallel decrease might have been facilitated by advances in a common framework of interventions to reduce mortality for some of these causes: environmental, nutritional, vaccines, and treatment. Even if it is likely that by 2030 all countries in the region will meet the reduction in U5MRs proposed by the SDG framework, the disparities in U5MRs and the high mortality due to LRIs are a reminder that guaranteeing access to life-saving interventions to reduce U5 mortality must still be regarded as a predominant challenge in the region.

An improvement in children’s nutritional status, hygiene and sanitation, vaccination coverage, and coverage of modern contraception might have contributed to a decline in U5MRs in Central America over time. Our results are consistent with a previous study that included data on 154 countries from 2000 to 2010, revealing an association between access to water and sanitation systems, measles vaccination coverage, and skilled birth attendance and U5MRs. A study from Mexico (1980–2005) suggested that children’s nutritional status and measles vaccination were associated to U5 mortality. In another study, vaccination coverage also revealed an association with child mortality. The associations observed could be partially explained by the fact that nutritional status and availability of WASH services are 2 of the main risk factors for diarrheal diseases and LRIs, which are causes of death that accounted for the majority of the

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**FIGURE 2**

CSMRs (ranking, cause, rate, and TPC) for the 10 main causes of death in population U5 in Central America (1990 and 2016). Congenital birth defects refer to structural anomalies. Neonatal encephalopathy is limited to birth asphyxia and trauma. Neonatal sepsis does not include sepsis caused by respiratory infections. The list of diseases included in other neonatal disorders and endocrine, metabolic, blood, and immune disorders are shown in Supplemental Table 6.
However, in our study, the strongest associations with U5MRs were observed for coverage of vaccines and modern contraception methods ($P < .01$). Vaccination coverage might have contributed to a decrease in U5MRs by preventing deaths mainly due to pneumonia, whooping cough, and meningitis. Coverage of modern contraception could be a proxy of access to maternal health services, which have shown to play an important role in U5 mortality.\(^9\)\(^{–}\)\(^{27}\) Our results are a reminder of the importance of family planning and reproductive health services not only aiming at improving women’s health but also as an approach to reduce USMRs. Skilled birth attendance is an indicator of the quality of neonatal care services. Given the importance of neonatal deaths in U5 mortality, a decrease in USMRs could partially be explained by this covariate. This association was not statistically significant, which is expected because some countries reported skilled birth attendance coverages >97.5% from 1990 on (Supplemental Table 4). Unmeasured confounding might also account for this finding.

Even if we only examined disparities at a country level, it is likely that within-country disparities might partially explain some of our findings. In previous studies in the region, authors have highlighted a disproportionate mortality for some causes of death in the most underserved sectors of the population and indigenous communities.\(^{28}\)\(^{–}\)\(^{30}\) Our results are based on robust estimations from the GBD and include data from a 27-year period. Regarding limitations, some covariates were reported at 5-year intervals, unmeasured confounding might have had an impact on the observed estimates, and our findings are only applicable to the region. With such limitations, we stress the importance of family planning and reproductive health services not only aiming at improving women’s health but also as an approach to reduce USMRs.
importance of conducting similar studies to better understand U5 mortality in other regions of the world.

CONCLUSIONS

Despite disparities in U5MR and its decline in Central America, it is promising to observe how some countries (eg, El Salvador) have reduced U5 mortality at a faster pace in comparison with others (eg, Panama) despite lower socioeconomic indicators.4 Even if SDG 3.2.1 has been attained by almost all countries, achieving greater reductions in U5 mortality should continue to be prioritized in the Central American development agenda. Although special attention should be paid to communicable and nutritional causes of death, countries should simultaneously address challenges posed by neonatal and congenital causes of death. Our results highlight the synergistic nature between health-related SDG indicators. Even if lowering U5MRs is a goal in and of itself within the SDG framework, the reduction in U5MRs should not be envisioned as a target alone but rather as a multisectoral process in which all pillars of development are addressed altogether. Furthermore, continuing the improvement of these indicators could potentially lead to additional gains in the reduction of U5MRs in the upcoming years. In one of the most unequal regions of the world, it is important to implement strategies to ensure a greater, sustainable, and equitable reduction in U5MR.

TABLE 2 Factors Related to U5MR in Central America

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<tr>
<th>Variable</th>
<th>Coef</th>
<th>95% CI</th>
<th>P</th>
<th>Coef</th>
<th>95% CI</th>
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<td>Measure of performance in the reduction of undernourishment in U5 (composite indicator), %a</td>
<td>-0.77</td>
<td>-0.86 to -0.69</td>
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<td>-0.10</td>
<td>-0.19 to -0.02</td>
<td>.02</td>
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<td>Availability of adequate and equitable WASH services (composite indicator), %b</td>
<td>-1.45</td>
<td>-1.57 to -1.33</td>
<td>&lt;.0001</td>
<td>-0.23</td>
<td>-0.41 to -0.04</td>
<td>.02</td>
</tr>
<tr>
<td>Coverage of vaccines in target populations</td>
<td>-1.65</td>
<td>-1.87 to -1.43</td>
<td>&lt;.0001</td>
<td>-0.44</td>
<td>-0.58 to -0.31</td>
<td>&lt;.001</td>
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<td>Coverage of modern contraception methods</td>
<td>-1.5</td>
<td>-1.60 to -1.41</td>
<td>&lt;.0001</td>
<td>-0.57</td>
<td>-0.75 to -0.39</td>
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<td>Proportion of births attended by skilled health personnel</td>
<td>-0.94</td>
<td>-1.05 to -0.82</td>
<td>&lt;.0001</td>
<td>-0.07</td>
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<td>Year</td>
<td>-1.25</td>
<td>-1.37 to -1.14</td>
<td>&lt;.0001</td>
<td>-0.33</td>
<td>-0.48 to -0.19</td>
<td>&lt;.001</td>
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a Constructed by averaging SDG indices (GBD, 2016) on 2 separate indicators: wasting and stunting.
b Constructed by averaging SDG indices (GBD, 2016) on 3 separate indicators: access to unsafe water sources, hand-washing facilities, and sanitation services.

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REFERENCES


ABBREVIATIONS

ARC: annualized rate of change CI: confidence interval
CSMR: cause-specific mortality rate
GBD: Global Burden of Disease Study
gdp: gross domestic product
LRI: lower respiratory infection
SDG: Sustainable Development Goal
TPC: total percentage change
UI: uncertainty interval
U5: under-5
U5MR: under-5 mortality rate
WASH: water, sanitation, and hygiene


**Under-5 Mortality in Central America: 1990–2016**
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