Cost-Effectiveness Analysis of a Large-Scale Crèche Intervention to Prevent Child Drowning in Rural Bangladesh

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Abstract

Drowning is the leading cause of death among children 12-59 months old in rural Bangladesh. This study evaluated the cost-effectiveness of a large-scale crèche intervention in preventing child drowning. Estimates of the effectiveness of the crèches was based on prior studies and the program cost was assessed using monthly program expenditures captured prospectively throughout the study period from two different implementing agencies. The study evaluated the cost-effectiveness from both a program and societal perspective. Results showed that from the program perspective the annual operating cost of a crèche was $416.35 (95%C.I.: $222 to $576), the annual cost per child was $16 (95%C.I.: $9 to $22) and the incremental-cost-effectiveness ratio (ICER) per life saved with the crèches was $17,803 (95%C.I.: $9,051 to $27,625). From the societal perspective (including parents time valued) the ICER per life saved was -$176,62 (95%C.I.: -$347,091 to -$67,684)—meaning crèches generated net economic benefits per child enrolled. Based on the ICER per disability-adjusted-life years averted from the societal perspective (excluding parents time), $2,020, the crèche intervention was cost-effective even when the societal economic benefits were ignored. Based on the evidence, the creche intervention has great potential for reducing child drowning at a cost that is reasonable.

Introduction

Drowning is one of the top five causes of death for children aged 1–14 in 48 out of 85 countries with data on drowning deaths\(^1\). The global burden of fatal drownings disproportionately affects low-and-middle-income countries (LMICs), with approximately 7 to 8 drowning deaths per 100,000 people in sub-Saharan Africa and South-east Asia compared to 2 to 3 in high-income countries\(^1\). Bangladesh, has one of the highest drowning rates among children aged 12–59 months (equivalent to 58% of deaths among children of this age)\(^2\). Despite its success in reducing under-five all-cause mortality by two thirds during the past decade\(^3\), drowning death rates have remained generally the same\(^4\).

In rural Bangladesh, children are at high risk of drowning because homes are generally located in areas surrounded by natural bodies of water\(^5\). In these settings, child caregivers are less able to mitigate the drowning risk posed by the large water bodies\(^5\). Most of these drownings occur in ponds and ditches between 9am – 1pm when caregivers are busiest with household chores\(^6\).

Interventions tailored to reduce drowning in LMICs focus on reducing children's unsupervised access to water bodies, including door barriers, playpens, swimming lessons and crèches (i.e., child care centers)\(^7\). In 2012, a study conducted in rural Bangladesh evaluated the effectiveness and cost-effectiveness of a drowning prevention package, including swimming lessons and crèches. The study found that the package of interventions reduced the relative risk of drowning in under-five age children by 89%\(^8\). However, the study did not disentangle the effects of the different interventions included in the study.

The high burden of drowning in Bangladesh and other LMIC countries requires urgent action from community leaders and policy makers to implement or scale up effective and efficient drowning
prevention strategies. More evidence on the cost-effectiveness of the strategies proposed and tailored to the specific needs of each setting are needed to identify and advocate for the interventions that can best mitigate the risk of drowning\textsuperscript{1,5,9,10}. This evidence would help guide policy makers on what interventions will save more lives efficiently and effectively.

Assessment of the costs and cost-effectiveness of community interventions requires availability of scientific evidence on program impact and comprehensive data on all the resources needed to implement and scale interventions. This study took advantage of the implementation of a large-scale crèche intervention in rural Bangladesh to incorporate prospectively a cost-effectiveness component into the evaluation of the intervention\textsuperscript{10,11}. The objective of this study was to evaluate the cost-effectiveness of the crèche intervention for reducing drowning deaths among children 9 to 47 months in rural Bangladesh. This paper answered the question on whether the crèche intervention is cost-effective compared to the status-quo from both a program and societal perspective.

**Methods**

**The intervention**

The crèche intervention was a community-based program designed to reduce child drowning in rural communities among children age 9 to 47 months old. The crèche program was a tuition-free daycare service run by two volunteer females (a crèche mother and an assistant). Each crèche supervised 24 to 30 children under 4 years old during peak drowning hours, 9am to 1pm, six days a week and provided learning activities on language, numbers, drawing, dancing, health, and injury prevention among other activities for development of cognitive and motor skills\textsuperscript{11,12}. Crèche mothers (i.e., caregivers referred to as “Ma”) were trained for five days and assistants were trained for one day. Each crèche was also supervised by a crèche supervisor 3–5 times each month. Local village and union injury prevention committee (VIPCs and UIPCs) members met at least once a month throughout the study period to plan sensitization of the community about injury prevention and engagement of parents in the crèches program. The committee members were elders known and respected by the local community and worked closely with the village parents to nominate potential crèche Mas, assistants, and sites. VIPCs also helped program staff monitor crèche operations and support crèche Mas’ and parents’ needs and feedback.

Crèche Mas voluntarily offered space in their homes to run a crèche center. Program supervisors screened each site and only those that met criteria for safety, cleanliness, and child appropriateness were selected. The program provided initial investments for minor repairs (e.g., doors, fans, lighting improvements, floors etc.) to ensure strict safety requirements. Each crèche site space was one room with secured doors and windows, adequate light, and ventilation, and equipped with carpeted floors, age-appropriate toys, and educational supplies. Maintenance of space and supplies (e.g., soap, toys, food containers, recurrent repairs, etc.) were also provided on an annual basis. Details about the crèche program are provided elsewhere\textsuperscript{11,12}.
Study Population and Data

This study obtained program costs and drowning data from the Saving of Lives from Drowning (SoLiD) cohort study which implemented the crèche intervention and an injury surveillance system in two rural areas in Bangladesh with the collaboration of the Centre for Injury Prevention and Research, Bangladesh (CIPRB) and International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B). Area 1 included three sub-districts: Sherpur, Manohardi, and Raiganj. Area 2 included four sub-districts: Matlab North, Matlab South, Daudkandi and Chandpur. These sub-districts were purposely selected for their prior high drowning rates and the local partners’ experience working with communities in these areas. Crèche centers were established in every village creating capacity for all children ages one to four residing in the study areas. A total of 1,554 functional crèches were established in 451 villages with about 1.2 million people.

The primary outcome for the CEA was drowning deaths averted among children 09–47 months old. All parents in study sites were encouraged to enroll their children of this age group. Drowning and crèche program participation data were collected from a baseline and quarterly household surveys administered to all households in the study areas. Additional details about the study population, questionnaire design and data collection procedure are provided elsewhere. Enrollment started in June 2013 and continued through 2015. A one-year time horizon was used to evaluate program effects and a 3-year horizon was used to evaluate program costs. This time horizon captured changes in the annual cost overtime due to gains in efficiency as program staff became more experienced in running the program.

Effectiveness

The effectiveness of the crèche intervention in reducing the annual cumulative drowning death rate was based on a prior study. The effectiveness study was a pre-and-post intent-to-treat study design controlling for self-selection bias by adjusting for household fixed effects. The study compared the cumulative incidence of drowning between the eligible children during the treatment period (i.e. treated sample) and historical data on ineligible siblings and pre-treatment data on eligible children during the 12 months prior to the study baseline (i.e. untreated sample). This study produced estimates of the change in annual cumulative drowning death rate by age group. Furthermore, Alonge et al (2017) used historical drowning rates between the years 1998 to 2012 from the study areas to show that while all-cause child mortality declined over a 14 years period prior to the crèches study, drowning-specific mortality remained largely unchanged. Thus, supporting the claim that the observed effect in this study area was likely due to the crèche intervention and not a secular trend. The study found that risk ratios (RR) of drowning deaths in treatment vs. no treatment were 0.40 (95% CI: 0.28–0.57) overall. Age specific risk ratios were stronger for children over 3 and weaker for children between age 1 and 2. We applied age-specific risk ratios to a synthetic cohort of 100,000 children aged 1–4 to estimate deaths averted. We used the 95% confidence-range around the RR’s from the effectiveness study to produce an uncertainty range.
We converted deaths averted to years-of-life-lost (YLLs) to provide a conservative approximation of disability-adjusted-life-years (DALYs) averted. In the Bangladeshi context, emergency care is limited, and children pulled out of the water after being submersed either survive with no disability or die within 24 hours. As a first approximation, years lived with disability after a submersion in this setting are zero and so YLLs are nearly equivalent to DALYs. YLLs were estimated using the World Health Organization (WHO)’s DALY calculation template\textsuperscript{14,15}. Parameters in the calculation included the study population’s average age of drowning, 2.3 years old, life expectancy at birth, 72.2\textsuperscript{16} years, and a standard three percent discounted rate for future years of life lost.

**Costs**

The analysis of costs was conducted using an ingredients-based approach. With this methodology all program expenditures were recorded by category throughout the study period. Costs are evaluated from both a program and a societal perspective following the recommendations set by the Second Panel on Cost-Effectiveness in Health and Medicine\textsuperscript{17}.

Program expenditures were categorized into the following major groups or “program inputs”: start-up costs, equipment and trainings, rent, wages, community engagement, transportation, field overhead, and administration operations. Both program costs and the count of children enrolled (i.e., exposed to the program) were collected monthly in real time from program accountants and revised by program managers. For a detailed description of each program input see the appendix exhibit A. A total of 54-month observations of data were collected including 31 months from Area 1 (from June 2013 to December 2015) and 23 months from Area 2 (from February 2014 to December 2015).

Informant interviews were conducted with local program supervisors throughout the study period to capture the percent effort of staff and program inputs attributed to the crèche versus other interventions or research. The cost analysis excluded research and non-crèche program costs. Cost data was inflation-adjusted to 2015 BDT and currency converted to US dollars (USD) in 2015. Shared costs were apportioned to the crèche program based on the crèches’ shared percent effort. Fixed costs (i.e., start-up costs, trainings, and equipment) were discounted with a standard three percent rate and annualized using program experts’ advice on inputs’ lifetime. Program cost data from each month was compared against the number of children enrolled the same month to produce monthly total and average cost estimates and trends. The monthly cost trend was then used to assess how expenditures varied over the study period as the program reached maximum capacity and became more experienced, as well as to differentiate between the cost during a start-up year (i.e., when initial investments are spent) versus an annual operational cost. These estimates were used to model a 10-year projection of the program cost in which investments in fixed costs are annualized and investments in variable costs are the cost of a program running at mid-to-full capacity. Estimates from the 10-year expenditure model were then averaged over the ten years to estimate the annual total cost and average cost per child.

Societal costs added the opportunity cost of the crèche Ma’s and assistant’s time, VIPC and UIPC members’ time, and economic savings from a parent’s improved productivity. Regarding the economic
savings, currently the total fertility rate in Bangladesh is 2.06 and birth intervals are 47 months so most households with any children old enough to attend a crèche would be unlikely to have a remaining younger child ineligible for school or crèche\textsuperscript{18}. This implies that a crèche would free up four hours a day, 6 days a week. Guidance from the Second Panel on Cost-Effectiveness says that, “...economic theory implies clearly that the value people place on an hour of their leisure time can be inferred from their hourly wage...”. We recognize that rural Bangladeshi villages offer negligible opportunities for women to engage in wage-labor, however the activities that women will do with the extra 24 hours per week freed up from child-care responsibilities will have value to them and their households. Exactly how the mothers of enrolled children will spend their freed-up time is unknown. As a placeholder approach the value of freed-up mothers’ time was estimated as the equivalent fraction of the Bangladeshi minimum wage. Assuming a work week of 6 days, women with children in crèches are freed up 4 hours per day and it is assumed that the opportunity cost of time is 50% of the minimum wage of 8000 BDT ($78.5 in 2015)\textsuperscript{19}. Estimates with and without the inclusion of the opportunity cost of time are provided in a sensitivity analysis.

Parents’ improved productivity assumed one parent per child participant benefited producing economic benefits. Similarly, for the subset of women with children in a crèche who used the crèche less than 6 days per week, we valued their time by a fraction of the opportunity cost of time according to the utilization rates obtained from the study records\textsuperscript{12}.

The crèche worker’s honorarium of $27.38 per month is far lower than the minimum wage. Although crèche staff participate mostly out of a sense of voluntarism, guidelines mandate that the value of their time appeal to market rates\textsuperscript{20}. Because crèche workers work only half days and to avoid an underestimate of program costs from the societal perspective, we proxy opportunity cost of crèche Ma and assistant as half (for part-time) of the minimum wage instead of $27.38 per month and per crèche. VIPC and UIPC members’ time assumed a minimum of one 4-hour meeting per month with at least 7 members based on program records. Societal costs were estimated per crèche and child enrolled. For details about assumptions see the appendix.

### Cost-effectiveness analysis

The incremental-cost effectiveness ratio (ICER) was calculated by dividing the incremental cost between the crèche intervention and the status-quo by the incremental effect size (i.e., deaths averted with the intervention) for a hypothetical population of 100,000 children age 12 to 47 months old\textsuperscript{21}. ICERs were estimated from both the program and societal perspectives. A Monte Carlo simulation was used to produce confidence intervals around the ICER estimate\textsuperscript{22}. The simulation included 100,000 iterations of a costing model with 54-monthly observations of expenditures where each program input varied according to the distribution of monthly cost data for each input. The Monte Carlo simulation and identification of the distributional function of each input were obtained using the @Risk software version 8.0\textsuperscript{23}.

Univariate sensitivity analyses were done by varying program cost and effect parameters by one standard deviation to assess which parameter had the greatest impact on the ICER\textsuperscript{21}. Societal costs were also varied in sensitivity analysis assuming that these costs varied according to a normal distribution where...
the mean was the average value used in the costing analysis and the standard deviation was estimated assuming that the 95% C.I. was the maximum and minimum range, for details about assumptions for the sensitivity analysis see the appendix exhibit B. Program costs and lives saved were also changed linearly to assess how changes affected the ICER. All analyses and reporting of results were conducted in accordance with the guidelines provided by the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) checklist. Out of the 24 categories, we met all applicable standards, see the appendix for the checklist\textsuperscript{24}.

**Results**

**Effectiveness**

In the study area, 8\% of the population were children age 12 to 47 months old, the mortality rate from drowning ranged between 125 (95\% C.I. 87–181) to 101 (95\% C.I. 67–151) per 100,000 children depending on the child's age, 58\% of the children ever attended a crèche (of which 63\% attended five or more days per week, 27\% attended 2 to 4 days per week, and 10\% attended less than 2 days), and the crèche's intervention reduced the mortality incidence from drowning by 88\% (C.I. 95\%-71\%), see Table 1 for mortality rates by age group\textsuperscript{25}. Based on these estimates, in a hypothetical population of 100,000 children age 12 to 47 months old, 111.03 would fatally drown without the crèches intervention and 18.77 would fatally drown with the intervention implying an estimate of 92.26 deaths averted per 100,000 children with the intervention. The total number of DALYs per fatal under-five drowning is 29.23, for a total of 2,696.64 DALYs averted per every 100,000 children.

**Table 1** Population Parameters
### Bangladesh study population†

| Drowning Incidence | Mortality rate per 100,000 children in each age category | 95% C.I. | Deaths | 95% C.I. |
|--------------------|---------------------------------------------------------|---------|--------|---------|
| 12 to 23 months old| 125.45                                                  | 87.19   | 180.47 | 41.82   | 29.06   | 60.16   |
| 24 to 35 months old| 107.10                                                  | 72.93   | 157.26 | 35.70   | 24.31   | 52.42   |
| 36 to 47 months old| 100.55                                                  | 66.82   | 151.26 | 33.52   | 22.27   | 50.42   |

### Hypothetical population of 100,000 children aged 12 to 47 months old ‡

| Reducing drowning deaths with crèches | Reduction in drowning deaths | 95% C.I. | Child lives saved | 95% C.I. |
|--------------------------------------|------------------------------|---------|------------------|---------|
| 12 to 23 months old                  | -66.00%                      | -10.00% | -87.00%          | 27.60   | 4.18    | 36.38   |
| 24 to 35 months old                  | -91.00%                      | -64.00% | -98.00%          | 32.49   | 22.85   | 34.99   |
| 36 to 47 months old                  | -96.00%                      | -40.00% | -99.80%          | 32.18   | 13.41   | 33.45   |
| All (12 to 47 months old)            | -60.00%                      | -43.00% | -72.00%          | 92.26   | 40.44   | 104.82  |

†Data from Alonge et al (2020). ‡ Author’s calculations.

### Cost

Figure 1 shows the percent distribution of the crèche program costs by major input category. Non-administrative wages made the majority, 83%, of the total program cost. Based on the 10-year projection model, the crèche’s total annual cost for setting-up and running 1,554 crèche centers serving an average of 26 children per crèche was $647,074. See the appendix exhibit C and D for details about annual estimates used in the 10-year cost projection. The crèches intervention enrolled a total of 40,378 children. The annual average cost per crèche was $416.35 (95% C.I. $224-$576) and the average cost per child was $16.03 (95% C.I. $9-$22), respectively. The equivalent monthly average cost per crèche and child was $34.70 and $1.34, respectively. Table 2a provides a summary of program output and cost parameters. For details about cost estimates and time trend by program site see appendix exhibits E and F.

**Table 2a** Program Output and Cost Parameters
Note *See the appendix for details about the model of annualized costs. †Useful life of fixed costs for startup, equipment, trainings, and creche maintenance were assumed to be 10, 7.5, 5 and 3 years respectively.

Table 2b Societal Cost

| Parameters | Person-months | Annual Cost per Crèche | Annual Cost per child |
|------------|---------------|-------------------------|-----------------------|
| **Opportunity cost of time** (in 2015 US$) | | | |
| Crèche workers’ time (mother & assistant) † | 24.00 | $942.00 | $35.26 |
| VIPC and UIPC members’ time | 84.00 | $56.71 | $2.18 |
| Parents’ time ‡ | 27.62 | -$5,547.76 | -$213.54 |
| **Program cost** | - | $416.35 | $15.03 |
| **Total Cost (Savings)** | - | -$4,132.70 | -$159.07 |

Note: Negative values indicate savings. VIPC and UIPC are Village and Union Injury Prevention Committees. See the appendix for details about data assumptions and calculations. Assumptions are varied in sensitivity analysis. *The opportunity cost of time is the minimum wage, 8000 BDT per month (year 2018), see Butler (2019), equivalent to US$78.50 during the study years in 2015. †A crèche operates for 4 hours per day and 6 days per week, thus the wage for a crèche worker is 50% of the minimum wage. ‡ Assumes savings for only one parent per child and estimate is a weighted average of the cost based on the minimum wage and child crèches attendance, see appendix for details.

Table 2b provides a summary of the societal cost estimates and assumptions. The annual cost of the crèche Ma and assistant was $36.26 per child enrolled and of the VIPC and UIPC members was $2.18 per child enrolled. The opportunity cost of caregivers freed up time is valued at $213.54 per child enrolled. With the value of parents freed up time included the crèche program generates a total of $159.07 in economic value per child enrolled from the societal perspective. If one takes the view that parents freed up time is of no value to society then the program’s societal cost is $16.03+ $36.26 + $2.18= $54.47 per child per year.

**Cost-effectiveness**
Scaled up to a hypothetical population of 100,000 children age 12–47 months, at $16.03 per child exposed the total program cost was $1,602,556 and it would save 92.26 lives per year. Comparing the crèches program to the status-quo, the incremental cost per life saved (ICER) was $17,370 (95% C.I. $9,051 - $27,625) from the program perspective. In the societal perspective results depend on whether the economic value of freed up time is included. With the value of time included the program generates $172,410 (95% C.I. $347,091 - $67,684) in economic benefit, as well as saving 92.26 lives which averts 2,743.95 DALYs. However, if parents freed up time is not valued, the ICER is $59,035 per life saved. Expressed in $ per DALY averted, the ICER was $594 from a program perspective, or -$5,899 (i.e., generated savings) from a societal perspective if parents’ time is valued. If parents’ time is not valued the ICER from a societal perspective is $2,020 per DALY averted.

Table 3 Incremental Cost-Effectiveness Ratio

| Cost-effectiveness Analysis (in 2015 US$) | Incremental Cost (Annual)* | Incremental Effect Size (Annual)* | Incremental Cost-Effectiveness Ratio (ICER), (95% C.I.) |
|------------------------------------------|-----------------------------|-----------------------------------|--------------------------------------------------------|
| **Comparison between the intervention and status-quo by program perspective** |                             |                                   |                                                        |
| **ICER per Live Saved**                  |                             |                                   |                                                        |
| **Program Perspective**                  |                             |                                   |                                                        |
| Crèche Intervention                      | $1,602,556                  | 92.26                             | $17,370 ($9,051 to $27,625)                            |
| **Societal Perspective**                 |                             |                                   |                                                        |
| Crèche Intervention (Parents' time valued) | -$15,906,920              | 92.26                             | -$172,410 (-$347,091 to -$67,684)                     |
| Crèche Intervention (Parents' time not valued) | $5,446,650                 | 92.26                             | $59,035 ($41,188 to $88,016)                          |
| **ICER per DALY Averted**                |                             |                                   |                                                        |
| **Program Perspective**                  |                             |                                   |                                                        |
| Crèche Intervention                      | $1,602,556                  | 2,696.64                          | $594 ($0,311 to $0,808)                               |
| **Societal Perspective**                 |                             |                                   |                                                        |
| Crèche Intervention (Parents' time valued) | -$15,906,920              | 2,696.64                          | -$5,899 (-$11,003 to -$2,327)                         |
| Crèche Intervention (Parents' time not valued) | $5,446,650                 | 2,696.64                          | $2,020 ($1,494 to $2,628)                             |

Note: Negative values indicate savings. *Estimates for a hypothetical population of 100,000 children age 12 to 47 months old.
Sensitivity analysis

In order to determine if a project is cost-effective one needs a country specific acceptability threshold that had been determined in a way to reflect local values. Whereas other countries have developed official thresholds, no such threshold exists for Bangladesh. Basing a threshold on Gross domestic product (GDP) per capita is no substitute for using a country’s stated acceptability threshold. However, if one were to refer to Bangladesh’s GDP per capita of $1,248.48 per year (in 2015 USD) and a value of 3 x GDP of $3,745.44 one could conduct sensitivity analysis to see what would be required for the program to cross the 3 X GDP threshold. We find that from the societal perspective (parents time not valued) the societal cost per child enrolled would have to increase by more than 90%, from $54 to $103.5. Similarly, the program effect size would have to decrease by 54%, from 92 to 42 lives saved, for the program to fall from the category of very cost-effective to just cost-effective. See appendix exhibit G2 for figures showing the linear relationship between the ICER (per DALY averted) and changes to the program unit cost and lives saved.

Figure 2 shows program inputs ranked by effect on the ICER mean. Each input is varied by 1 SD (the value shown on each bar) and the x-axis shows the percent change in the ICER (per live saved). From a societal perspective, among the cost inputs, both parent productivity and minimum wage (the first and third top bars) were the most important factors affecting the ICER. For example, when the monthly minimum wage rate increased by $30 (1 standard deviation), the ICER cost savings increased approximately by $8,333 or 5%, or vice versa. Likewise, when the number of lives saved increased by 16.42 lives (1 standard deviation), the ICER savings decreased approximately by $10,000 or 6%, and vice versa.

Figure 3 shows how proportional changes in increments of 20% to each program parameter changed the ICER (per live saved). Decreasing the number of lives saved by 20% would increase the ICER from the baseline value from $17,370 to $21,710 (an increase of almost 25%). Similarly, from a societal perspective, the Bangladeshi minimum wage rate ($78.50 per month) would have to decrease by 50% for the ICER (per live saved) to decrease to zero savings, see the appendix exhibit H.

Discussion

This study compared the crèche intervention to the status-quo in cost-effectiveness analysis from both a program and societal perspective. Results showed that for a typical Bangladeshi population of 100,000 children age 12 to 47 months who enrolled in crèches in rural areas the intervention would cost $1.6 million annually ($16 per child) from the program perspective and saved 92.26 children from fatal drownings (equivalent to 2,696.64 YLLs or DALYs averted). From the societal perspective, the intervention could generate approximately $15.9 million in cost savings to the community if parents freed up time is valued at the Bangladeshi minimum wage. This is equivalent to $172 thousand cost savings per live saved. From the program perspective alone, the creches’ ICER per DALY averted, $584, is very cost-
effective, relative to a reference point of GDP per capita, which was $1,248 in Bangladesh. Similarly, from the societal perspective excluding savings from parents freed up time, the creches’ ICER per DALY averted, $2,020, is cost-effective.

These results are in line with a prior CEA in Bangladesh which compared a package of drowning prevention interventions, including the crèches, with the status-quo. Both studies found a similar effect size for reducing fatal drownings (88% vs. 89%) but the prior study’s effect was attributed to the creche and swimming lesson interventions implemented together, making the comparison of impact between both creche interventions inadequate. Further, while both studies showed that about 80% of the program cost were wages, the cost per child estimate for that study was slightly higher than in this study ($51 in 2010 International USD, or $20–24 in 2015 USD, vs. $16). While both unit cost estimates produce cost-effective ICERs, the cost differences may be attributed to the costing methodology.

The creche’s intervention success in reducing child drowning can be explained by several child protective effects, including provision of a safe environment away from water and supervision with capable child care, particularly during peak drowning hours, and community education about drowning risk expanded by active community engagement strategies. Specifically, the UIPCs and VIPCs played a major role in the sensitization of the community about both drowning prevention practices and dissemination of information about the creches and their safety. The UIPCs also focus on building local support among community leaders and the VIPCs provided a standard and regular platform available to parents and community members to provide feedback about the creche operations.

These CEA results are important to the fields of global health and injury prevention especially for countries like Bangladesh with high incidence of drowning. We make broad comparisons between our results and other cost-effectiveness analysis, but caution should be used in comparing our results to individual studies due to the variety of methodological approaches, costing perspectives and cost inputs used by each study. Overall, our results indicate that from a societal perspective the crèche’s cost-effectiveness ratio per DALY averted (including economic savings from parents free up time), $-5,899, is significantly more cost effective compared to other injury prevention interventions for which cost-effectiveness ratios per DALY averted range between $5 to $556 (or $7 to $744 in 2015 $US). Excluding economic savings from parents free up time the crèche cost per DALY averted, $2,020 is higher but cost-effective. These other interventions include speed bumps, use of helmets, and enforcement of traffic codes for road tariff injury prevention and childproof containers for poisoning prevention. Compared to other child health interventions (e.g., treatment of febrile conditions, diarrheal disease, vaccines, severe acute malnutrition, platforms for delivery of interventions, etc.) with cost per DALY averted estimates ranging between $8 for treatment of severe malaria up to $50,000 for sanitation improvement interventions, our CEA shows the crèches to be an cost-effective alternative to improve child health.

This CEA was limited using fatal drowning reduction estimates derived from a pre- and post-experimental design which may be biased by self-selected enrollment of children into creches. There also could have
been secular trends (e.g., smaller family size or improved income) or other unobserved factors associated with higher or lower drowning rates (e.g., local interventions or policies, etc.). However, recent studies from Bangladesh show that while all-cause under-five mortality decreased over the last 10 years that drowning trends remained generally the same\textsuperscript{4,25}, suggesting secular trends did not impact drowning rates. Similarly, the estimation attempted reducing self-selection bias by controlling for the drowning rate of the creche participant’s older sibling the year before the intervention. This control reduced the bias under the assumption that the reasons that parents chose to participate or not remained constant over time\textsuperscript{12}. Our sensitivity analysis showed that the intervention would remain cost-effective even if the number of drowning deaths averted fell by 54%, from 92 to 42 deaths. Further, the positive results are conservative given that the ICER excludes both improvement in YLDs and long-term socio-economic benefits. For example, creches can offer protection against other child injuries\textsuperscript{9} and long-term economic benefits from improved childhood cognitive development and productivity in livelihood activities\textsuperscript{32,33}.

This study also excluded healthcare costs associated with the medical treatment of drowning cases because likely there are few to no drowning survivors in rural Bangladesh. However, literature from high income countries where many more children survive near drowning, but suffer brain injury, suggests that the higher cost associated with drowning and other unintentional injuries are health care services and the lost productivity of survivors\textsuperscript{34}. Other indirect costs that cannot be monetized in our study may include reduced quality of life from pain, suffering, and social isolation.

In conclusion, this paper shows the cost and cost-effectiveness of the large-scale implementation of the crèche intervention showing that crèches are cost-effective, even under scenarios of higher costs or lower effect sizes. Furthermore, the creches have the potential to improve parental economic status by freeing up their childcare time. More research is necessary to determine the extent to which parents use this freed-up time in ways that benefit the household and the economy. Our present findings provide strong empirical support for investing in the scale up of creches in communities burdened by high risk of child drowning.

**Abbreviations**

BDT: Bangladesh Taka; USD: United States dollars; LMICs: Low- and middle-income countries; SoLiD: Saving of Lives from childhood Drowning; UIPC: Union Injury Prevention Committees; VIPC: Village Injury Prevention Committees; GDP: Gross Domestic Product; Risk Ratio (RR); WHO: World Health Organization.

**Declarations**

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Authors’ contributions

YNA led the design of the study and data collection, conducted the analysis, and wrote the first draft of the manuscript. DB oversaw the study design and analysis and edited the manuscript for intellectual content. OA contributed to the study design, data acquisition and edited the manuscript. SSS, KB, AR, EH, MII, FR, SE, AH contributed to the study implementation and data acquisition. AH was the principal investigator for the research project. All authors reviewed and contributed to the manuscript and approved the final manuscript.

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Availability of data and materials

The data used/or analyzed during the current study are available from the corresponding author on reasonable request and upon the approval of local implementation partners.

Ethics approval and consent to participate

Ethical approval for this study was obtained from the Institutional Review Boards of the Johns Hopkins Bloomberg School of Public Health (reference number - 00004746), the Center for Injury Prevention and Research, Bangladesh and International Center for Diarrheal Disease Research, Bangladesh. Written informed consent was obtained for all participants in this study.

Conflict of interest

All authors report no conflict of interest.

References

1. World Health Organization. *Global report on drowning: preventing a leading killer*. World Health Organization; 2014.
2. National Institute of Population Research and Training (NIPORT) and ICF. *Bangladesh Demographic and Health Survey 2017-18*. Dhaka, Bangladesh, and Rockville, Maryland, USA: NIPORT and ICF;2020.
3. Chowdhury AMR, Bhuiya A, Chowdhury ME, Rasheed S, Hussain Z, Chen LC. The Bangladesh paradox: exceptional health achievement despite economic poverty. *The Lancet*. 2013;382(9906):1734-1745.
4. Rahman A, Jagnoor J, ul Baset K, et al. Vulnerability to fatal drowning among the population in Southern Bangladesh: findings from a cross-sectional household survey. *BMJ open*. 2019;9(9):e027896.

5. Hyder AA, Borse NN, Blum L, Khan R, El Arifeen S, Baqui AH. Childhood drowning in low- and middle-income countries: Urgent need for intervention trials. *Journal of Paediatrics and Child Health*. 2008;44(4):221-227.

6. Rahman A, Mashreky SR, Chowdhury SM, et al. Analysis of the childhood fatal drowning situation in Bangladesh: exploring prevention measures for low-income countries. *Injury Prevention*. 2009;15(2):75-79.

7. Hyder AA, Alonge O, He S, et al. A Framework for Addressing Implementation Gap in Global Drowning Prevention Interventions: Experiences from Bangladesh. *Journal of Health, Population & Nutrition*. 2014;32(4):564-576.

8. Rahman F, Bose S, Linnan M, et al. Cost-Effectiveness of an Injury and Drowning Prevention Program in Bangladesh. *Pediatrics*. 2012;130(6):e1621-e1628.

9. Callaghan JA, Hyder AA, Khan R, Blum LS, Arifeen S, Baqui AH. Child supervision practices for drowning prevention in rural Bangladesh: a pilot study of supervision tools. *Journal of Epidemiology and Community Health (1979-)*. 2010;64(7):645-647.

10. Royal Life Saving, Alliance for Safe Children. Building a global platform to reduce drowning. Paper presented at: World Conference on Drowning Prevention 2011; Danang, Vietnam.

11. Hyder AA, Alonge O, He S, et al. Saving of Children's Lives from Drowning Project in Bangladesh. *American Journal of Preventive Medicine*. 2014;47(6):842-845.

12. Alonge O, Bishai D, Wadhwaniya S, et al. Large-scale evaluation of interventions designed to reduce childhood Drownings in rural Bangladesh: a before and after cohort study. *Injury epidemiology*. 2020;7:1-12.

13. Alonge O, He S, Hoque DE, et al. Shifting disease burden in low and middle-income countries: a 14-year survival analysis of childhood mortality in Bangladesh. *J Epidemiol Community Health*. 2017;71(9):882-888.

14. World Health Organization. Health statistics and information systems: National Burden of Disease Supplementary Files (DALY calculation template). 2020; https://www.who.int/healthinfo/global_burden_disease/tools_national/en/. Accessed July, 2020.

15. World Health Organization. Chapter 3: The Global Burden of Disease concept. *Introduction and methods: Assessing the environmental burden of disease at national and local levels*. Geneva2003.

16. United Nations Population Division. Life expectancy at birth for both sexes combined (years): 2015-2020 Bangladesh. *World Population Prospects: The 2019 Revision* 2019; https://population.un.org/wpp/, 2020.

17. Sanders GD, Neumann PJ, Basu A, et al. Recommendations for conduct, methodological practices, and reporting of cost-effectiveness analyses: second panel on cost-effectiveness in health and medicine. *Jama*. 2016;316(10):1093.
18. Khan JR, Bari W, Latif AHMM. Trend of determinants of birth interval dynamics in Bangladesh. *BMC Public Health*. 2016;16(1):934.

19. Butler S. Why are wages so low for garment workers in Bangladesh? 2019; https://www.theguardian.com/business/2019/jan/21/low-wages-garment-workers-bangladesh-analysis, 2020.

20. Neumann PJ, Sanders GD, Russell LB, Siegel JE, Ganiats TG. *Cost-effectiveness in health and medicine*. Oxford University Press; 2016.

21. Drummond MF, Sculpher MJ, Claxton K, Stoddart GL, Torrance GW. *Methods for the economic evaluation of health care programmes*. Oxford university press; 2015.

22. Buckland ST. Monte Carlo Confidence Intervals. *Biometrics*. 1984;40(3):811-817.

23. @Risk: *Risk Analysis with Monte Carlo Simulation* [computer program]. Version 8.0.0.: Palisade; 2019.

24. Husereau D, Drummond M, Petrou S, et al. Consolidated Health Economic Evaluation Reporting Standards (CHEERS) statement. *Cost Effectiveness & Resource Allocation*. 2013;11(1):6-11.

25. Alonge O, Agrawal P, Talab A, et al. Fatal and non-fatal injury outcomes: results from a purposively sampled census of seven rural subdistricts in Bangladesh. *The Lancet Global Health*. 2017;5(8):e818-e827.

26. World Health Organization. Cost effectiveness and strategic planning (WHO-CHOICE). *Table: Threshold values for intervention cost-effectiveness by Region* 2015; http://www.who.int/choice/costs/CER_levels/en/, 2015.

27. Organization WH. *Preventing drowning: an implementation guide*. World Health Organization; 2017.

28. Saluja G, Brenner R, Morrongiello BA, Haynie D, Rivera M, Cheng TL. The role of supervision in child injury risk: definition, conceptual and measurement issues. *Injury control and safety promotion*. 2004;11(1):17-22.

29. Bishai DM, Hyder AA. Modeling the cost effectiveness of injury interventions in lower and middle income countries: opportunities and challenges. *Cost Effectiveness & Resource Allocation*. 2006;4:2-11.

30. Peden M, Oyegbite K, Ozanne-Smith J, et al. *World report on child injury prevention*. Vol 2008: World Health Organization Geneva; 2009.

31. Zeng W, Li G, Ahn H, Nguyen HTH, Shepard DS, Nair D. Cost-effectiveness of health systems strengthening interventions in improving maternal and child health in low-and middle-income countries: a systematic review. *Health policy and planning*. 2018;33(2):283-297.

32. Nair D, Alonge O, Derakhshani Hamadani J, Sharmin Salam S, Islam I, Hyder AA. Developmental assessments during injury research: is enrollment of very young children in crèches associated with better scores? *International journal of environmental research and public health*. 2017;14(10):1130.

33. Richter LM, Daelmans B, Lombardi J, et al. Investing in the foundation of sustainable development: pathways to scale up for early childhood development. *The lancet*. 2017;389(10064):103-118.
34. Miller TR, Romano EO, Spicer RS. The Cost of Childhood Unintentional Injuries and the Value of Prevention. *The Future of Children*. 2000;10(1):137-163.

**Figures**

**Figure 1**

Proportional Distribution of Creche Program Costs
Figure 2
Sensitivity Analysis of the Effect of Changes to Program Parameters on the ICER
Figure 3

Effect of Proportional Changes to the Program Parameters on the ICER

Supplementary Files

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