PSI Family Planning Health Impact Estimation Model

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PSI shares its models with all interested individuals or organizations. Please note that the models are updated periodically based on the latest available epidemiological, demographic, intervention effectiveness, and utilization data. As a result, numbers used in this document should be considered illustrative only. They show how the model works, but they are likely to have changed since the time of writing.

For more information or the latest model updates, contact Amy Ratcliffe at aratcliffe@psi.org.

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Introduction

Development of the DALY Model for Estimating the Health Impact of PSI Products and Services

International public health nongovernmental organizations (NGOs) and other implementers and practitioners of health policy in developing countries find themselves at a crossroads. The issue of monitoring and evaluation has grown beyond its traditional role as an internal management tool and has become a tool for accountability for agencies charged with responsibility for funding and monitoring health interventions. This change occurred partly because new, large-scale funders such as the Global Fund and the Gates Foundation themselves need more effective measures to be accountable for the use of their resources. Additionally, many organizations were drawn together by their focus on the Millennium Development Goals (MDG).

Along with these changes, there has been movement toward a consensus regarding the method of measuring health impact across developing countries. The aim of this effort is to create a more objective component to use in prioritizing program activities and allocating resources. The disability-adjusted life year (DALY) is the result of this effort. The primary purpose of the DALY is to act as an umbrella measure to compare both the true burden of different diseases across different regions of the developing world, and to better estimate the cost-effectiveness of various interventions aimed at reducing that burden. The first phase of the DALY creation process was undertaken by the Disease Control Priorities Project (DCPP), which developed a series of documents designed to both estimate and explain the full burden of various diseases around the world (www.dcp2.org).

The second phase of the DALY creation process involved estimation of the cost-effectiveness of the interventions available to address the diseases. This phase has been more difficult to accomplish because of the conceptual distance between the people charged with evaluating health interventions and the people charged with implementing them. The number of studies estimating the relative cost-effectiveness of public health and clinical interventions in developing countries that incorporate measurement of health outputs using DALYS has increased substantially since the first DCPP report in 2000. However, publication of well-designed field trials is only half the story.

The belief that cost-effectiveness of public health interventions can be influenced by the methods and mechanisms employed, as well as scale, is a large part of the reasoning behind this work. The overall intent is to develop models that will better enable programmers to estimate the cost-effectiveness of public health interventions that are undertaken in practice on a large scale.
PSI DALY Calculator

PSI is developing a series of tools to evaluate the health impact of its interventions and services around the world. The model at the core of this toolkit will estimate: a) the burden of each disease or condition addressed in the countries in which PSI works, and b) the health impact and incremental costs associated with implementation of PSI’s interventions.

The first stage in this process is the development of a functioning (and evolving) mathematical model that estimates the burden of disease and the relative impact of PSI projects in specific countries, for six disease groups or health areas. They are: HIV, family planning, malaria, diarrheal disease, nutrition, and maternal health. The models are currently linear and deterministic, but future intention is to incorporate stochastic data inputs/outputs and non-deterministic relationships between variables. Shown below is a graphical representation of the working components of the model. Each disease area is treated slightly differently because of the nature of the infection or its symptoms, variations in the availability of data, and the complexity of outcomes.
Family Planning DALY Model: Measuring Direct and Indirect Benefits

Background

The benefits from family planning interventions are not limited to health benefits alone; there are also social and economic benefits that accrue to mothers and children. PSI has developed a methodology that incorporates both the direct health benefits associated with fewer pregnancies among women of reproductive age and the indirect health benefits of longer birth intervals on child mortality. The PSI family planning DALY model first analyzes the burden of morbidity and mortality associated with pregnancy. Then it uses a functional correlation model and multiple data sets from the Demographic and Health Surveys (DHS) to estimate population correlations between preceding birth interval (PBI) and child mortality. Lastly, the model incorporates the impact of contraceptive use (family planning) on birth intervals.

Section 1: Estimating the Country-Specific Disease Burden

Estimating the “disease burden” in relation to family planning is complex for two reasons: first, pregnancy and birth are not diseases, and second the benefits that accrue from family planning are not limited to improvements in health. The benefits from planning are multitude and complex, but for the sake of this model, we try to generate as best an estimate we can as to the added weight of disease burden that is generated from pregnancy and child birth both to the women themselves and their children who’s health is indirectly, but significantly affected.

The first step the model undertakes is to allocate each country into one of five geographical regions within which PSI actively distributes products or interventions aimed at the increasing the utilization of family planning methods. Both frameworks then use the incidence of maternal conditions and maternal mortality rates from these regions to estimate part of the burden, and the birth interval relative-risk framework to estimate the burden from infant and child mortality that can be indirectly attributed to birth intervals below those associated with zero risk.

In addition each population was then broken down into rural and urban populations and demographic subgroups, as follows:

- women age 15-19
- women age 20-29
- women age 30 and over

The model then combines the demographic subgroups in absolute numbers with the rates from the regional datasets to estimate the absolute burden in terms of mortality and morbidity by demographic sub group for each country. A graphical representation is shown below.
Estimates of the burden from pregnancy-related complications and conditions are summarized in three groups; morbidity from maternal conditions, mortality from maternal conditions, and the incremental burden on children due to reduced interval between consecutive births in the form of relative risk of mortality. The final stage of the modeling process is the translation of the diverse measures of health impact into a total figure for burden measured in DALYs. For this process the methodology is followed from the original DCPP report published in 2000, incorporating any updates from the more recent DCPP version 2 published in 2005.

**Section 2: Estimating the Impact of the PSI Family Planning Program**

The second component of the model involves estimating the impact of each of the interventions on the burden of the disease in that specific population. In this instance, it is estimating the reduction in risk of health events associated with pregnancy and child birth. The first stage of the process is the translation of the individual products and services into proxies of effective coverage—in this instance, a full year of protection from pregnancy, or couple-year of protection (CYP). CYP is a common proxy indicator for family planning interventions. The translation of individual products and services into CYPs is done by estimating utilization levels of all products, incorporating estimated wastage levels and protective efficacy, to get an index of units utilized per product equivalent to one full CYP, i.e., 100% protection from pregnancy for one full year. The CYPs are then combined with population level morbidity and mortality rates from maternal conditions and complications to estimate the burden averted which, in turn, is translated into DALYs.
CYPs are also used to estimate a proportion shift in the average birth interval by subgroup. The distribution of birth intervals by subgroup is interpolated using DHS data from multiple surveys across a specific region. The resulting distribution functions as a proxy for all countries in that region. Once the shift in the birth interval is estimated, the data can be combined with country-specific population data, and the function between the birth interval and the odds-ratio of the under-five mortality rate (U5MR), to estimate the reduction in the absolute number of deaths in that age group due to changes in the length of the average birth interval.

**Example of estimating the impact of the preceding birth interval (PBI) on the under-five mortality rate (U5MR)**

The process of estimating the impact of the sale of 50 million male condoms in Tanzania is shown below:

For a family planning intervention, additional birth spacing (i.e., an increase in the PBI) is calculated as: $A/B$

Where, $A = 12 \times \text{CYP} \times (\text{female population age 15-44 in urban or rural area})/(\text{total 15-44 female population})$

And $B = (\text{female population age 15-44 in urban or rural area})$

This simplifies to,

Change in birth spacing = $12 \times \text{CYP}/(\text{total 15-44 female population})$, for either urban or rural area

**Tanzania Example:** For 50,000,000 male condoms in Tanzania, CYP = 336,458 and total 15-44 maternal population is 8,586,007, giving an increase in birth spacing of $12 \times 336,458/8,586,007 = 0.47$ months.
**Calculation of deaths averted:**

The number of women with a birth occurring less than three years (≤ 35 months) after a previous birth is evaluated for each month, for urban or rural areas, from the relevant DHS data. Figure 2.1 shows the distribution of birth intervals less than three years in length (≤ 35 months) among rural women in Tanzania (2005 Tanzania DHS survey).

**Figure 2.1** Distribution of birth intervals of less than three years (≤ 35 months), rural women in Tanzania (18,936 births), 2005 Tanzania DHS survey

Note: The red lines in the figure separate the birth intervals into four birth spacing groups: <18 months, 18-23 months, 24-29 months, and 30-35 months.

Childhood mortality rates are calculated for the following birth intervals: <18 months, 18-23 months, 24-29 months, 30-35 months, 36-41 months, 42-47 months, 48-53 months, 54-59 months, and 60+ months. These intervals are used in calculating mortality rates for both infants (IMR) and children under five years (U5MR).

Figure 2.2 (below) shows under-five mortality rates by length of the preceding birth interval for the following birth spacing groups: <18 months, 18-23 months, 24-29 months, and 30-35 months, with the over 35 month group (>35) calculated as the median of groups 36-41, 42-47, 48-53, 54-59, and 60+ months.
Figure 2.2  Under-five mortality rates (U5MR) by length of preceding birth interval, rural areas, Tanzania DHS survey

![Graph showing U5MR by birth spacing]

Note: In Figure 2.2, the category greater than 35 months (>35) is the median of groups 36-41, 42-47, 48-53, 54-59, and 60+ months.

Given an increase in the birth interval of ΔB months, the number of births that change birth spacing group in Figure 2.1 can be calculated. For example selling 50,000,000 male condoms in Tanzania gives ΔB=0.47 months. Assuming that birth spacing is evenly distributed, 0.47 * number of births in the most recent birth spacing groups: <18 months, 18-23 months, 24-29 months, and 30-35 months, will move to a new group with a longer interval, and as seen in Figure 2.2, have a lower mortality rate. Table 2.1 (below) shows the number of births affected in this example.
### Table 2.1  Number of births changing group

<table>
<thead>
<tr>
<th>Spacing group</th>
<th>Number of births in most recent birth spacing group</th>
<th>Number of births changing group</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;18</td>
<td>262</td>
<td>123.14</td>
</tr>
<tr>
<td>18 to 23</td>
<td>650</td>
<td>305.50</td>
</tr>
<tr>
<td>24 to 29</td>
<td>687</td>
<td>322.89</td>
</tr>
<tr>
<td>30 to 35</td>
<td>487</td>
<td>228.89</td>
</tr>
</tbody>
</table>

Note: Deaths averted can be calculated by multiplying the number of births that change group by the difference in the U5MR from Table 2.2.

### Table 2.2  Calculating the number of deaths averted

<table>
<thead>
<tr>
<th>Spacing group</th>
<th>Number changing group</th>
<th>U5MR difference</th>
<th>Deaths averted</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;18</td>
<td>123.14</td>
<td>0.231-0.186</td>
<td>5.55</td>
</tr>
<tr>
<td>18 to 23</td>
<td>305.50</td>
<td>0.186-0.134</td>
<td>15.69</td>
</tr>
<tr>
<td>24 to 29</td>
<td>322.89</td>
<td>0.134-0.115</td>
<td>6.40</td>
</tr>
<tr>
<td>30 to 35</td>
<td>228.89</td>
<td>0.115-0.093</td>
<td>4.88</td>
</tr>
</tbody>
</table>

Note: Table 2.2 shows a total of 32.5 deaths averted. This is a survey-based total and is changed to a rate by dividing by the total number of births in the rural survey population, which is 24970, giving a percentage of deaths averted as 1.3*10^-3. Country-specific deaths averted in this example are calculated as follows: Country CBR * total country population * (rural proportion)* 1.3*10^-3.
Section 3: Parameters and Data Sources

Testing of the model, and results

Estimates of maternal morbidity and mortality can be compared with regional estimates from DCPP and other sources.

Table 3.1  Estimates of maternal deaths and DALYs for selected countries in sub-Saharan Africa and Asia, PSI model and DCPP

<table>
<thead>
<tr>
<th>Country/region</th>
<th>Model estimates: Number of maternal deaths</th>
<th>Number of maternal DALYs</th>
<th>DCPP estimates: Number of maternal deaths</th>
<th>Total DALYs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burundi</td>
<td>2,472</td>
<td>98,208</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nigeria</td>
<td>50,014</td>
<td>1,987,493</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kenya</td>
<td>13,129</td>
<td>521,511</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tanzania</td>
<td>14,267</td>
<td>566,784</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>251,868</td>
<td>9,994,339</td>
<td>237,000</td>
<td>9,743,000</td>
</tr>
<tr>
<td>India</td>
<td>171,760</td>
<td>8,375,311</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nepal</td>
<td>4,236</td>
<td>206,588</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Asia</td>
<td>216,729</td>
<td>10,568,120</td>
<td>199,000</td>
<td>10,069,000</td>
</tr>
</tbody>
</table>

A number of studies (Koenig et al 1990; Rutstein 2005; Rao et al 2006; Makepeace & Pal 2006) have estimated the impact of insufficient (too-short) preceding birth interval to be between 13% and 24% of the total burden of infant and child mortality in developing countries. Table 3.2 (below) gives estimates of the mortality burden due to insufficient PBI for children under five in selected countries and regions.
Table 3.2  Estimates of child deaths attributable to insufficient PBI, and DALYs, for selected countries in sub-Saharan Africa and Asia, PSI model and DCPP

<table>
<thead>
<tr>
<th>Country/region</th>
<th>Model estimates: Number of under-five deaths attributable to insufficient PBI</th>
<th>Number of PBI DALYs</th>
<th>DCPP estimates: Number of under-five deaths</th>
<th>PBI estimate as % of total under-five deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burundi</td>
<td>6,412</td>
<td>196,530</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nigeria</td>
<td>129,616</td>
<td>3,972,554</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kenya</td>
<td>34,051</td>
<td>1,043,627</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tanzania</td>
<td>37,007</td>
<td>1,134,224</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>652,174</td>
<td>19,988,316</td>
<td>4,298,000</td>
<td>15.17%</td>
</tr>
<tr>
<td>India</td>
<td>630,184</td>
<td>19,314,340</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nepal</td>
<td>15,544</td>
<td>476,415</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Asia</td>
<td>795,177</td>
<td>24,371,185</td>
<td>3,564,000</td>
<td>22.13%</td>
</tr>
</tbody>
</table>

Section 4: Case Study from Nepal

Nepal provides a case study for the use of the DALY model in a family planning intervention. In 2006, sales of male condoms were 7,370,396, with 127,447 units of three-month injectable contraceptives and 484,538 units of oral contraceptives. Using model calculations, this equates to a total of 97,403 CYPs in 2006. Additionally, there were 60 maternal deaths averted, for a total of 2,945 maternal DALYs. When summed with the impact of birth spacing, the result is an estimated 11,919 DALYs averted in 2006, which is 1.75% of the total burden in Nepal.

Section 5: Incorporating Stochastic Data into the Model

The model relies on point estimates, but realistically these estimates lie within an interval representing the precision with which they were measured. The accuracy of parameter estimates (such as mortality rate) used in the model can be reflected by assuming a probability distribution for the estimate. This allows random data drawn from this distribution to be propagated through the model, giving a corresponding distribution of DALYs averted. This in turn allows:

Quantification of the central tendency of the estimated DALYs averted;

Construction of suitable ranges that define the accuracy of the estimated DALYs averted; and

Performance of a full sensitivity analysis using the same Monte-Carlo approach to identify the most important parameters in terms of model accuracy.
Generating stochastic data from probability distributions

Generally rate data have a non-symmetrical distribution, which may be skewed to the right or the left. For skewed continuous measures, the Weibull distribution offers a variety of shapes. (The generalized extreme value distribution is also useful.) Figures 5.1 and 5.2 show typical probability density functions (pdf) for a Weibull distribution, where the x-axis could represent a proportion-based parameter.

Figure 5.1  Weibull probability density function (pdf) focused on a narrow range
The deterministic proportions in the model can now be replaced by random samples from these distributions, which—if typically repeated with 10,000 iterations (on a medium specification machine)—occurs almost instantaneously. The advantages of this approach are as follows:

Any appropriate summary statistics for the calculator outcome can be calculated; they are not limited in the same manner as the range data;

Any range width can be chosen 99% confidence intervals or IQRs, for example;

Many stochastic variables can be implemented simultaneously without having to propagate limits through all the equations, as in the previous section.

Both of the aforementioned methods (narrow range and skewed range have their strengths: the first is more empirical, while the second gives the model greater flexibility in terms of outputs and allows for more consistent computation within the model. It is likely that the models will use a combination of both methods, based on the wide variance in the availability of empirical data on uncertainty around the rates and proportions being addressed through the incorporation of stochastic modeling.
References


Demographic and Health Surveys (DHS). Selected DHS surveys. Available at: www.measuredhs.com


