Economic cost of dengue public prevention activities in Puerto Rico*

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Abstract

Dengue fever has become a major global public health problem in Puerto Rico. Approximately 5000 suspected cases were reported annually between 2002 and 2007. Vector control is currently the only approach to control the disease and includes prevention education, fumigation, inspections and clean-up campaigns. The annual cost to the public sector of dengue prevention, which includes surveillance and vector control activities, was estimated as part of a study of the economic burden of dengue in Puerto Rico. A telephonic survey was implemented to identify municipalities with vector control programmes and public agencies with dengue surveillance systems. Onsite interviews were conducted using a structured questionnaire. The economic cost of dengue was summarized by line item, function and year from 2002 through 2007. The Puerto Rico Department of Health (PRDH) and 12 municipalities out of 78 conducted vector control activities in different magnitudes during the study years. The cumulative cost of dengue vector control in the public sector was US$ 46.22 million for the years 2002–2007. PRDH spent an average of US$ 1.29 million ($0.33 per capita) per year, while the municipalities spent an average of US$ 6.41 million (US$ 1.64 per capita) per year. Clean-up campaigns had the highest share of average expenditure, followed by fumigation, surveillance and inspection. Puerto Rico’s per capita expenditure on dengue prevention activities is similar to that of other countries in the region. On average, Puerto Rico’s per capita spending on dengue illness is US$ 5.48 compared with US$ 1.97 spent on vector control.

Keywords: Dengue; economic cost; control activities; public exchequer; Puerto Rico.

Introduction

Dengue fever has become a major global public health problem.1–6 It has spread to more than 100 countries within its usual tropical boundaries with the occurrence of frequent and cyclical epidemics, and also beyond to new and hitherto uncharted...
Economic cost of dengue public prevention activities in Puerto Rico territories such as Africa and West Asia.\textsuperscript{[7–9]} Studies estimated an annual 50 to 100 million cases of human infection of dengue fever, of which 500 000 are of dengue haemorrhagic fever, and 22 000 deaths occur per year, mainly in paediatric patients.\textsuperscript{[7–10]}

Dengue is caused by four related, but antigenically distinct, viruses (DENV-1, DENV-2, DENV-3 and DENV-4) belonging to the genus \textit{Flavivirus}, family Flaviviridae.\textsuperscript{[7,11–14]} Dengue viruses are transmitted in an endemic/epidemic, human-mosquito-human, rural or urban cycle by the bite of infected mosquito vectors from the \textit{Aedes} family; mainly, \textit{Aedes aegypti} and \textit{Aedes albopictus}.\textsuperscript{[14–15]} \textit{Aedes aegypti} is a very effective vector of dengue viruses and adaptive to exploiting the domestic environment. Female \textit{Aedes aegypti} mosquitoes are very nervous feeders, they can often discontinue the feeding process and restart on the same or another individual soon after. Therefore, a single infected mosquito can transmit the dengue virus to multiple people over a short period of time.\textsuperscript{[14]} Additionally, the female \textit{Aedes aegypti} almost exclusively bites humans, most commonly feeds and rests indoors and is predisposed to lay eggs in man-made containers commonly found in and around homes such as flower vases, buckets, water storage containers, tyres and any trash items that collect water.\textsuperscript{[11,15]}

Infection with one dengue virus serotype results in lifelong homotypic immunity.\textsuperscript{[15]} Cross-protection heterotypic immunity may last up to a year.\textsuperscript{[14–16]} However, exposed individuals can theoretically be infected with all four serotypes with an increased risk of developing dengue haemorrhagic fever with subsequent infections.\textsuperscript{[15,16]} From the epidemiological perspective, dengue includes four diseases. However, from the clinical perspective it is only one with five different presentations: non-specific febrile illness, classic dengue fever, dengue hemorrhagic fever, dengue shock syndrome and other severe dengue syndromes.\textsuperscript{[14]}

Potential approaches to reduce dengue infection include reduction of mosquito abundance, prevention of contact between the vector and humans, genetically manipulated vector mosquito and vaccine.\textsuperscript{[11,15]} Currently, the only available control strategies are reducing mosquito abundance, reducing adult mosquito lifespan and preventing mosquito-human contact. Despite tremendous efforts by public health organizations in dengue endemic countries to achieve effective and sustainable control of \textit{Aedes aegypti}, and thereby the outbreak of dengue cases, these efforts were very difficult to sustain due to uncontrolled urbanization, global spread of dengue viruses, lack of adequate resources for vector and dengue control programmes, the use of ineffective vector control methods, passive surveillance systems, the failure of governments to utilize data from active surveillance systems when available, and the need for substantial regional efforts to eliminate the vector in some regions.\textsuperscript{[2,3,4]}

Several approaches to eliminate the dengue vector have been implemented with various degrees of success. Findings on the effectiveness of these approaches are inconsistent. Many studies reported an effective reduction in the vector population using a community-based integrated approach tailored to local eco-epidemiological and sociocultural settings. This approach includes an educational component to increase knowledge and understanding of best practices.\textsuperscript{[17–19]} A recent evaluation of larviciding from Cambodia found the programme effective.
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Puerto Rico gives an excellent example to study vector control costs. It has a passive and active surveillance system with strong laboratory capabilities in both serology and virology, although it lacks the ability to predict an epidemic. Dengue is a major public health concern in Puerto Rico. According to the Dengue Branch of the Centers for Disease Control and Prevention (CDC) in Puerto Rico, 30,482 suspected dengue cases were reported between 2002 and 2007. Of these, 9,738 were confirmed dengue cases, with nearly 2.3% developing dengue haemorrhagic fever (DHF). In 2007, due to an island-wide dengue outbreak, 10,508 suspected dengue cases were reported, of which 3,294 were dengue confirmed cases and 2.6% of the cases were DHF. The general infection rate was 8.6 laboratory-positive cases per 10,000 population in 2007, and the severity of dengue has been increasing in Puerto Rico.  

Providing information on the cost of these activities is informative for policy-makers to allocate and/or reallocate scarce resources to projects which have the greatest benefit to society. Such data are also needed to balance existing and new potential strategies (e.g., vaccine and novel vector control technologies) against dengue, and to compare dengue with other diseases. Although studies from other localities, such as Panama and Thailand have emerged, no previous report of the costs of vector control in Puerto Rico had been prepared. Therefore, it is important to understand the current structure of dengue prevention activities, including vector control activities, and the services provided covering the cost of different vector control activities to mitigate the disease or estimate the associated costs of the same in Puerto Rico.

This paper presents a comprehensive analysis of dengue prevention activities, including vector control in Puerto Rico. It defines the main players involved in these activities and estimates the cost of these activities over a six-year period. This study is part of the economic burden of dengue in Puerto Rico, and seeks to inform future policy.
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Materials and methods

This retrospective descriptive study was conducted between April 2009 and June 2010 to estimate the annual cost of dengue prevention activities, including surveillance and vector control initiatives conducted in Puerto Rico during the years 2002 through 2007. Each of the 78 municipalities was contacted by telephone to determine which ones had carried out an active vector control programme during the study period.

Based on pilot studies in 2006 and 2008, a structured questionnaire was developed for collecting cost data from the PRDH and these jurisdictions. The questionnaire was divided into four parts. The first dealt with personnel cost, type of activities performed by each worker and the time and effort allocated to dengue prevention activities. The second dealt with recurrent costs, including cost of chemicals used; personal protection equipment; maintenance of the buildings, vehicles and fumigation equipment; insurance of the buildings, vehicles and equipment; utilities, education materials, the aggregate cost of clean-up campaigns allocated to dengue, office supplies, advertisements and fuel. The third part focused on the amortized capital cost of buildings, spraying and fogging equipment, vehicles, laboratory equipment, and office equipment including computers and software. The fourth and final part requested data on the type and number of activities undertaken during the study years. Inputs from other institutions, volunteer efforts and donations to activities designed to control dengue were also tallied.

The questionnaire was validated by review of officials from Carolina, the municipality with the largest programme, and sent to each jurisdiction by e-mail, mail and fax prior to an onsite personal interview. The onsite interviews were conducted between May 2009 and May 2010 with vector control personnel from the PRDH and the active municipalities. For each jurisdiction, an average of four visits were needed to interview executive directors and other key personnel to determine the level of effort given to dengue prevention and collect the cost data. Breakdowns of all resources were also estimated according to the following functions: inspections, fumigation, education, clean-up campaigns, surveillance and general management.

Inspections denote visits to premises where a dengue case or a mosquito-larval habitat had been identified through a resident complaint or a vector control inspector. Whenever possible, the larval habitat (e.g. location of standing water) was removed or destroyed. When destruction is not possible, a larvicide is applied.

Fumigation refers to outdoor spraying of insecticides (malathion, permethrin, aqueleur, etc.) with ultra-low volume (ULV) foggers or thermal fogging machine mounted on pick-up trucks. Fumigations take place according to the daily schedule in some municipalities or during a local or national outbreak when authorized by a municipal mayor or the PRDH, or in response to residents’ complaints about increased mosquito populations.

Educational efforts include the preparation of leaflets, brochures, posters, videos, documentaries, newspaper articles, public service announcements on television and radio spots with the purpose of informing and educating the population about dengue, disease outbreaks and its prevention.

Clean-up campaigns are conducted by the Waste Management Program of the municipalities to collect potential larval habitats for Aedes aegypti, in addition to its main
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Purpose of maintaining a clean environment in the cities. During a dengue outbreak, clean-up campaigns are organized by the municipal health officials and vector control programme personnel within the collaboration with other municipal employees.

Surveillance denotes collecting, analysing and reporting the results from blood sample tests received from private and public clinics and hospitals island-wide, usually run by CDC/PRDH Passive Dengue Surveillance System.

General management refers to the facilitation of specific dengue prevention activities such as receiving complaints, scheduling inspection visits and larviciding of premises, educational activities, and fumigation. Purchase of vector control equipment and supplies as well as printing of educational materials, management and transportation of blood samples and reporting are also part of general management activities.

Results

All 78 municipalities responded to the telephonic interviews. The results of these interviews highlighted that in addition to PRDH, 12 municipalities have vector control programmes, and all have at least three activities to control and prevent dengue, namely outdoor fumigation, educational activities and clean-up campaigns. The history and magnitude of dengue vector control activities varies across jurisdiction; the programmes were well established in Guaynabo and Carolina while Ponce and Bayamon initiated their programmes in 2003. While all jurisdictions were active in clean-up campaigns, the Bayamon programme started in 2004, Lajas in 2005, Toa Baja in 2006 and Juana Diaz in 2007. Manati started their fumigation programme in 2006. Table 1 lists municipalities with dengue vector control programmes and the PRDH, their vector control activities, and the average population they served between 2002 and 2007.

The funding and implementation of vector control is decentralized in Puerto Rico. The state pays, through the PRDH, for 16.8% of the total public expenditure of dengue prevention activities, while the 12 municipalities pay the overwhelming share of 83.2%. The PRDH spent an average US$ 1.29 million per year (US$ 0.33 per capita) while the 12 municipalities spent on average US$ 6.41 million per year (US$ 1.64 per capita).

The results illustrate that only Carolina and Guaynabo have comprehensive vector control programmes, including fumigation, clean-up campaigns, inspection and surveillance, while the other ten municipalities have more limited programmes in terms of their scope and continuity of services, and the degree of focus on fumigation, education and clean-up campaigns.

As illustrated in Table 2, the cumulative six-year cost of dengue vector control in the public sector was US$ 46.22 million for the years 2002 to 2007. The annual expense increased gradually from US$ 6.49 million (US$ 1.68 per capita) in 2002 to US$ 9.41 million (US$ 2.39 per capita) in 2007 due to the introduction of new vector control programmes in some municipalities and the expansion of existing vector control activities in others in response to an island-wide epidemic in 2007. The average annual cost of dengue vector control for 2002–2007 was US$ 7.70 million per year (US$ 1.97 per capita).
As shown in Figure 1, among the municipalities, Carolina had the highest average expenditure (US$ 4.197 million per year or US$ 22.41 per capita), while Juana Díaz had the lowest average expenditure (US$ 21 266 per year, or US$ 0.41 per capita). The range in per capita spending is enormous; with figures for the highest municipality (Carolina) being fifty times that of the lowest (Juana Díaz). As clean-up campaigns are often a particularly effective strategy, Carolina is noteworthy for spending 92% of its annual expenditure on this function. In contrast, the other 11 municipalities had an average annual budget of US$ 104 553 of which 52% was spent on clean-up campaigns. Supplementary tables illustrating the breakdown of vector control activities by the municipalities classified by line item, function and year are available on request.

Analysing costs according to the line item reveals that recurrent costs were the highest, with an average of US$ 5.57 million per year.
### Table 2: Expenditure on dengue control by year and jurisdiction, 2002–2007 (in US$)

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>Total</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PRDH</strong>*</td>
<td>1 329 191</td>
<td>1 404 541</td>
<td>1 412 076</td>
<td>977 661</td>
<td>1 034 167</td>
<td>1 621 606</td>
<td>7 779 243</td>
<td>1 296 540</td>
</tr>
<tr>
<td><strong>Municipality</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bayamon</td>
<td>0</td>
<td>124 765</td>
<td>190 834</td>
<td>235 214</td>
<td>253 089</td>
<td>265 466</td>
<td>1 069 369</td>
<td>178 228</td>
</tr>
<tr>
<td>Cabo Rojo</td>
<td>128 796</td>
<td>129 293</td>
<td>129 769</td>
<td>136 589</td>
<td>142 763</td>
<td>148 659</td>
<td>815 870</td>
<td>135 978</td>
</tr>
<tr>
<td>Carolina</td>
<td>3 599 397</td>
<td>3 787 785</td>
<td>4 006 174</td>
<td>4 389 204</td>
<td>4 544 182</td>
<td>4 859 969</td>
<td>25 186 711</td>
<td>4 197 785</td>
</tr>
<tr>
<td>Dorado</td>
<td>121 970</td>
<td>157 966</td>
<td>142 980</td>
<td>149 840</td>
<td>163 335</td>
<td>188 123</td>
<td>924 215</td>
<td>154 036</td>
</tr>
<tr>
<td>Guayanilla</td>
<td>56 038</td>
<td>62 906</td>
<td>62 248</td>
<td>66 475</td>
<td>66 733</td>
<td>68 172</td>
<td>382 571</td>
<td>63 762</td>
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<tr>
<td>Guaynabo</td>
<td>328 357</td>
<td>310 252</td>
<td>315 294</td>
<td>318 474</td>
<td>313 105</td>
<td>370 786</td>
<td>1 956 269</td>
<td>326 045</td>
</tr>
<tr>
<td>Juana Diaz</td>
<td>18 715</td>
<td>19 573</td>
<td>19 532</td>
<td>22 433</td>
<td>22 618</td>
<td>24 724</td>
<td>127 594</td>
<td>21 266</td>
</tr>
<tr>
<td>Lajas</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>162 749</td>
<td>164 980</td>
<td>174 172</td>
<td>501 900</td>
<td>83 650</td>
</tr>
<tr>
<td>Manati</td>
<td>683 106</td>
<td>622 507</td>
<td>603 926</td>
<td>671 557</td>
<td>720 659</td>
<td>856 871</td>
<td>4 158 626</td>
<td>693 104</td>
</tr>
<tr>
<td>Ponce</td>
<td>0</td>
<td>97 018</td>
<td>286 999</td>
<td>295 704</td>
<td>309 234</td>
<td>394 216</td>
<td>1 383 171</td>
<td>230 528</td>
</tr>
<tr>
<td>Salinas</td>
<td>151 820</td>
<td>169 911</td>
<td>199 841</td>
<td>212 709</td>
<td>234 993</td>
<td>236 981</td>
<td>1 206 255</td>
<td>201 043</td>
</tr>
<tr>
<td>Toa Baja</td>
<td>73 227</td>
<td>86 935</td>
<td>81 380</td>
<td>91 082</td>
<td>191 965</td>
<td>203 852</td>
<td>728 440</td>
<td>121 407</td>
</tr>
<tr>
<td>Total</td>
<td>6 490 618</td>
<td>6 973 452</td>
<td>7 451 053</td>
<td>7 729 690</td>
<td>8 161 824</td>
<td>9 413 598</td>
<td>46 220 234</td>
<td>7 703 372</td>
</tr>
</tbody>
</table>

*PRDH denotes Puerto Rico Department of Health.

**Figure 1:** Annual per capita spending on dengue prevention activities by jurisdiction, 2002–2007 (in US$)
(72%); followed by personnel, with an average of US$ 1.91 million per year (25%); and amortized capital costs averaging US$ 0.22 million per year (3%). The breakdown of cost across line items is illustrated in Figure 2.

Figure 2: Average annual spending on dengue prevention activities by line item, 2002–2007

Figure 3 shows the breakdown of annual expenditure on dengue control by function. Clean-up campaigns had the highest annual average expenditure of US$ 4.99 million per year (65%), followed by fumigation with an average of US$ 1.01 million per year (13%), surveillance with an average of US$ 0.73 million per year (9%), and inspection with an average of US$ 0.43 million per year (6%), while education had the lowest expenditure with US$ 0.18 million per year (2%). Table 3 shows the average annual expenditure jointly by function and jurisdiction. It indicates that clean-up campaigns are the most variable component of costs.

Discussion

The overall results suggest that the public expenditure on dengue prevention activities in Puerto Rico, which is US$ 7.73 million (US$ 1.97 per capita), is broadly comparable to that of other countries in the region. For example, Panama spent US$ 5 million (US$ 1.56 per capita)....

Figure 3: Average annual spending on dengue prevention activities by function, 2002–2007
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The additional cost of dengue prevention was studied in a few other countries including Cambodia where the annual vector control campaigns, focusing on larvicide and communication in Phnom Penh and Kandal (PP&K), cost US$ 0.6 million (US$ 0.2 per person living in PP&K).[19]

To help sustain and improve dengue prevention activities, policy-makers need to understand the economic cost of dengue illness as well as the cost structure of the current vector control and surveillance programmes in the country. Recent literature provides a few examples of costs of dengue in endemic countries in the Americas. The total impact of dengue illness in the Americas is estimated at US$ 2.1 billion per year.[25] The economic impact of dengue illness for officially reported dengue cases in five countries in the Americas was estimated to range from US$ 135.2 million in Brazil to US$ 0.9 million in Panama. In three other countries, the costs were US$ 10.2 million in Venezuela, US$ 1.7 million in El Salvador, and US$ 1.2 million in Guatemala.[26]

The variability among municipalities in per capita costs deserves further investigation. The per capita cost of vector control in Carolina is 11 times the average cost of US$ 1.97, followed by Manati which spent seven times the national average. DHPR spent only one sixth of the average national expenditure on dengue vector control followed by Juana Diaz which spent one fifth of the national average on vector control.

The high level of spending in some municipalities of Puerto Rico on dengue vector control currently indicates the economic importance of the disease. The results underscore the value estimated through studying alternative technologies, including vaccines, personal protection methods against mosquito bites, and new vector control approaches, which collectively can help reduce the transmission and severity of this disease. This variability between municipalities illustrates their perspective on the importance of dengue compared with other public health problems and constraints that they face in prioritizing available resources. This natural variability provides an opportunity for further research to inform policy-makers about the effectiveness of various vector control strategies implemented in these jurisdictions.

One limitation in this analysis is that the municipalities reported costs of clean-up campaigns only as lump-sum amounts. The reporting did not distinguish components within these aggregates, such as personnel, materials, transportation, etc. If more detailed data were available, the recurrent costs would have been smaller and the personnel costs larger. This limitation affects the breakdown by line item, but not the overall cost of dengue control. As part of the national effort to control dengue, CDC Dengue Branch helps support dengue surveillance. This cost was not included in this analysis. Therefore, the total cost of dengue prevention may be underestimated.

Acknowledgements

The authors are grateful to Drs Kay Tomashek and D. Fermin Arguello of the Centers for Disease Control for their advice and support, to Dr Jose Suaya of Brandeis University for assistance in study design, and to officials of the municipalities and the PRDH for their contribution towards supplying the requested data.
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