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Cost Effectiveness of Long-Lasting Insecticide Treated Bed Nets Distribution in Prevention of Malaria Deaths and Morbidity in Guyana

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Abstract

Malaria continues to pose a significant public health and economic threat in Guyana. In response, over 90,000 Long-Lasting Insecticide Nets (LLINs) were distributed in endemic regions in 2018 to curb malaria incidence. This study conducted a cost-effectiveness analysis from the provider's perspective, comparing the LLIN campaign to a no-intervention scenario. A model-based economic evaluation was used, incorporating cost per LLIN distributed, deaths averted, and disability-adjusted life years (DALYs) averted. The average cost of delivering one LLIN was US$3.29. The intervention averted an estimated 387.42 under-five deaths annually and 1,162.3 over three years. The annual cost per death averted was US$129.84, decreasing to US$32.51 over three years. DALYs averted totaled 12,784.86 annually and 38,354.58 across three years. The estimated cost per DALY averted was US$3.93, significantly lower than Guyana's 2017 GDP per capita of US$3,883, confirming the intervention's high cost-effectiveness based on the WHO threshold. Sensitivity analyses showed the findings were robust despite variations in LLIN cost, life span, discount rate, and mortality impact. The study concludes that the LLIN campaign was a highly cost-effective malaria intervention and recommends its continuation. It further suggests that similar economic evaluations should be conducted for other preventive measures such as indoor residual spraying and larviciding.

Keywords: *Cost-Effectiveness, Economic Evaluation, Malaria, Public Health.*

Introduction

According to the World Malaria Report, Malaria remains a life-threatening disease that can be prevented and treated. In 2024, the number of deaths due to Malaria accounted for 455,000 persons across the world [1], the majority of morbidity and mortality occurring in young children in sub-Saharan Africa [2]. However, when compared to year

2024 the estimate stood at 800,000 people globally [3], with the greatest impact in the tropical and sub-tropics regions. While Malaria related deaths have been reducing, the number of new cases has been increasing globally. Estimates stood at 216,000,000 new cases of malaria in 91 countries in 2016 [1], this was a 2% increase from 2015. Malaria remains a priority of the global health agenda where it has been identified as a targeted condition in the Sustainable Development Goal Three, where the commitment is to end epidemic of Malaria by 2030 [4, 5].

Malaria is a major Public Health problem in Guyana. As shown in Figure 1, out of ten administrative regions, Regions 1, 7, 8 & 9 (Hinterland Regions) are the known endemic Malaria regions which represents 40 % of all the regions in Guyana. However, cases are found in other regions mainly due to the population mobility related to cultural and economic factors [6, 7].

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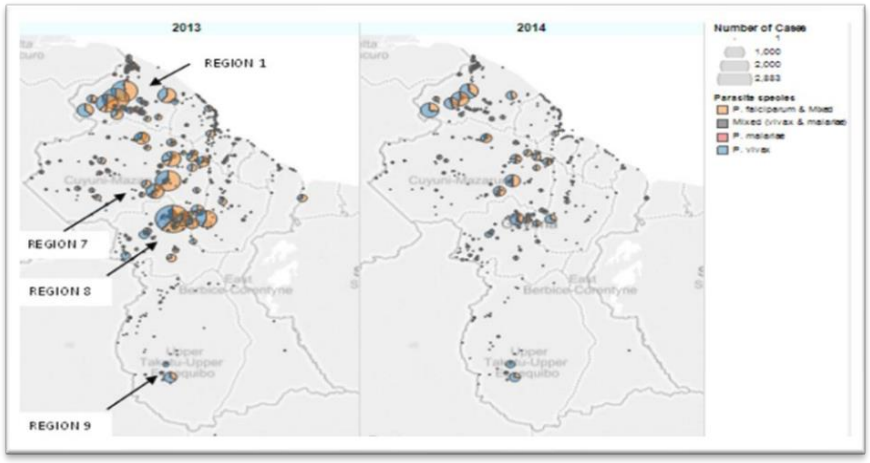

Figure 1. Map of Guyana Showing Malaria Incidence Per Region Source: Malaria Concept Note Ministry of Health

The national Malaria Programme began in the early 1950s with emphasis on the control of malaria in the sugar plantations located on the coastal regions which was eliminated in 1974. The number of malaria cases had decreased to just 72 cases in the entire country [8].

Guyana's Malaria programme mirrored other eradication programme in Africa and other parts on the world [9]. In 2018, Malaria still remains a major public health threat in Guyana with major movements in the incidence rate between the years of 2006 to 2017 as shown in Figure 2. It has been noted that when the economic pull factors such as gold and diamond mining are high in the endemic regions, there is an indirect correlation with the levels of Malaria.

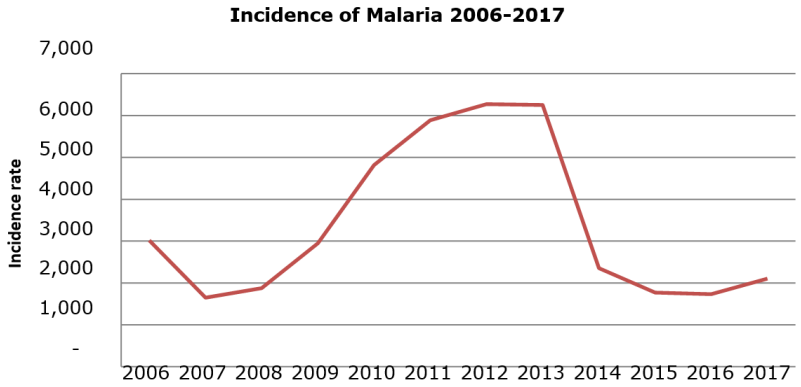

Figure 2. Trend of Malaria in Guyana (2006-2017)

Figure 2 above shows the annual incidence of Malaria in Guyana over 11 years. The incidence rate started to increase from 2007 and peaked in 2013. The high number of incidences are from the malaria endemic regions. One explanation was the pull factor of the rise in gold prices in the world market because of the global economic crisis in 2008, which led to an increase of gold in the world market [10]. The reduction of incidence in 2014 can be attributed to the public health approach of stakeholders and partners engagement between the Guyana Geology and Mines Commission, the Guyana Forestry Commission, miners and loggers' associations, who saw the improved control of malaria through education campaign by handing out educational materials on the disease; such as pamphlets and brochures about treatment and prevention behavior and the importance of Long Lasting Insecticide Nets (LLINs) use, among other methods [11].

LLINS are among the most efficacious methods against the prevention of malaria mortality and morbidity [13]. According to the last Multiple Indicator Cluster Survey [14], it was shown that there was a 31% usage of LLINs in the Malaria endemic regions of Guyana. Therefore, almost 70% of the target population is not using this core preventative tool against Malaria transmission. In fact, the World Health Organization (WHO) reports that LLINs have contributed significantly to the reduction of the global malaria burden during the past decade [1, 3, 15]. WHO recommends full coverage of LLINs which means that each household should have at least one LLINS for every two occupants [16, 17].

There is an important need to increase coverage and use of preventative measures, particularly LLINs in the country. Universal coverage which includes access and usage of LLINs is a priority goal for the population at risk for Malaria. The terminology 'Universal' implies a target of 100% of people sleeping under a LLINS every night [14]. However, it is generally accepted that coverage of 80% to 85% of the population sleeping under LLINs is enough to protect a specific population against Malaria transmission and is considered as the minimum coverage needed to have an impact on Malaria transmission [18].

From 2012 to 2016 Regions 1, 7, 8 and 9 have accounted for more than 95% of all Malaria cases among the ten administrative regions in Guyana. In response to combat the spread of Malaria in 2018 the MOPH embarked on a mass campaign to distribute over 90,000 LLINs free of cost to the effected population within the second and third quarters of 2018, targeting communities within regions 1,7,8 and 9. The LLINs were procured by the MOPH and then distributed to the effected population as a part of the stand-alone distribution campaign.

According to the Guyana National Malaria Strategic Plan (2016 to 2021) the epidemiological profile of Malaria in Guyana has changed considerably to reflect a significant reduction in the total number of cases, but recent data has shown a gradual increase of new cases [5].

Purpose and Objectives

The purpose of the study is to undertake a cost-effective analysis of LLINs distribution for prevention of malaria deaths and morbidity in Guyana.

Specific Objectives

1. To estimate the costs of the LLINS distribution campaign.
2. To estimate the Disability Adjusted Life Years (DALYS) averted and deaths averted from the LLINS distribution.
3. To estimate the cost effectiveness ratio for the LLINS distribution based on the costs of LLINS distribution and outcomes gained.

Literature Review

WHO recommends that Cost-Effectiveness Analysis (CEA) is considered before the introduction of any intervention such as vaccines and other treatment and preventive measures [19]. The literature has shown that many high-income countries started such assessments before introducing any interventions, however, in Low-Income and Middle- Income Countries (LMICs), such assessments are less common, but are equally, if not more, important because of insufficient funding for public health interventions and the need to establish the financial case [20].

The primary reason to conduct an economic evaluation on health intervention is to make informed health care resource allocation decisions and to achieve the best possible returns on investment. Economic evaluation has been defined as ''the comparative analysis of alternative courses of action in terms of both their costs and their consequences' [21]. Economic evaluations assess costs but approaches to measuring and valuing the outcome of health interventions may differ from study to study.

An internet search was done in databases hosted on Google scholar, Pub Med, Health Economic Evaluations Database, the National Health Service Economic Evaluation Database, and WHO compendium of literature. The search was done by looking for key words such as CEA, LLINs, cost of illness study, cost of distribution of LLINs, DALYs and life years gained. However, the researcher found that not many studies were done on either the cost or the cost-effectiveness of mass distribution of LLINs [15, 22, 23].

Determinants of the cost effectiveness on LLINs distribution were identified from the literature review of similar study carried out in other parts of the world. Eritrea did a similar study but collected cost data and cost-effectiveness estimates from a large programme providing LLINs at the community level and ante-natal care facilities in Eritrea [24].

Few studies look at the cost of distribution only rather than look at an outcome variable; A a study in coastal and western parts of Kenya in which the cost of the employers distributing LLINs to employees was calculated [25]. However, a similar study using the same setting as but looked at the information gaps, the distribution cost and the effectiveness of the different LLINs distribution model with the aim to compare the cost effectiveness ratios [26]. A similar study in Tanzanian where they evaluated the cost of distributing LLINs through a social marketing campaign [27]. A similar study in South Africa but chose residual house-spraying as a comparator rather than not having LLINS distribution [28].

In Ghana a study on the cost and cost-effectiveness of the LLINS Campaign using a before-after design in three regions of Ghana, estimated using reported variation in the implementation of hang-up activities and LLINS use [15]. In Togo a CEA was done on LLINS distribution as a part of the integrated child health campaign (vaccination campaign) [22].

The intervention under examination is the cost of distribution of LLINs in the malaria endemic regions of Guyana. A study was done in Eritrea in which they disaggregated the cost into capital cost and recurrent cost, where the capital cost was the cost of procurement of the LLINs, acquisition of building and vehicles from a provider perspective [17, 29]. Togo used the recurrent cost; cost of personnel, health education and administrative cost from a provider perspective. The recurrent cost was the cost of personnel, health education/promotion and administrative cost [24]. In Ghana the CEA used economic costs which was estimated from a societal perspective which meant that the indirect and direct cost was used in the analysis [15].

One of the uses of a CEA is to provide information on the most efficient way to allocate scarce resources from the perspective of the sector. This is done by comparing the costs and outcomes of all the different types of health interventions that would be possible [29]. The literature surveyed from three countries; Eretria, Ghana and Togo in which the outcome variable was cost per DALYs averted, cost per child death averted and the number of child deaths averted [15, 22, 24].

The role of a sensitivity analysis is examining the effects on the key assumptions of the cost per output and on the cost of the effectiveness ratio of the study. The study in Eritrea, Ghana and Togo examine the life span of the LLINS, the cost of LLINs and the discount rate. In the Eretria and the Togo study it showed that the mentioned variables were not sensitive to the analysis, however, the life span and the cost of the LLINs were sensitive in the Ghana and Eretria study [15, 22, 24].

Protective efficiency was examined based on the parameter from the Cochrane study where the base is 5.5 deaths averted per 1000, the lower limit of 3.4 per 1000 deaths averted and the upper limit of 7.7 deaths averted per 1000. In areas with stable malaria, with LLIN it is expected that the incidence of uncomplicated

malarial episodes to reduce malaria by 50% compared to no nets, and in areas of unstable malaria by 62% for compared to no nets [22]. The results showed that protective efficiency was very sensitive to the changes with the limits, especially the lower limit. The study done in Ghana also noted for the changes in the discount rate from 0 to 10 % was also very sensitive [15].

The criteria to measure cost effectiveness are based on willingness-to-pay thresholds related to Gross Domestic Product (GDP), in accordance with the WHO's Commission on Macroeconomics. The World Health Organization's (WHO) Commission on Macroeconomics and Health classifies interventions as a function of their range of cost-effectiveness in the following manner [30].

Methods

This research examined the cost effectiveness of the mass distribution of LLINs in Guyana. The study looked at the cost of procurement and distribution of LLINS in the Malaria endemic Regions of 1,7,8 and 9 of Guyana. At the time of the study the campaign had been completed which took place February to August of 2018.

The study examines the data from the general population but to measure effectiveness the under 5 population in the malaria endemic regions and the non-endemic regions was used.

Study Design

This study was a cost effectiveness study LLINS in Guyana using a model-based economic evaluation approach. The study perspective was from a provider or health system perspective where travel cost, salaries, procurement of commodities, health promotion among others was accounted. All cost reflected in the study was converted to United States Dollars using the bank of Guyana average exchange rate.

The primary outcome measure was the cost per LLINS delivered, the cost per DALY averted per child death and the number of deaths averted.

The comparator that was use with regards to the outcome variable was that an incremental cost effectiveness ratio (ICER) was calculated i.e. the additional effect (person using an LLINS or death averted) for additional cost of the LLINS Campaign compared to no campaign [15].

The analysis covered a time horizon of three-year period, to allow capturing cost from of procurement, which took a while since the LLINs had to me imported into Guyana and planning.

Data Gathering

The researchers used quantitative methods by collecting secondary data such as reports which captured expenditure (payment vouchers, reports and receipts) from authorized sources within the MOH, Regional Democratic Councils (RDCs), Health Sector Development Unit-MOPH which is the execution agency of the Global Fund - AIDS, Tuberculosis and Malaria (GFATM) and the local organs of the financial system. If the cost was not documented the activity was approximated by the researcher using the ingredients approach where the unit activities were first determined and then the unit cost assigned to each activity for the total cost calculations.

Sensitivity Analysis

Sensitivity analysis was performed to examine the robustness of the key assumptions within the model. The parameter examine includes cost of the LLINs, life span of the LLINs, discount rate and the mortality impact which was the number of under 5 deaths averted because of the LLINs.

The parameters have been varied to the extreme to their potential range based on surveys of the literature and expert opinion. The lifespan of the LLINS was varied to 2-5 years

along with the cost of procurement. The outcome measure was varied to reflect the upper and lower limit i.e. that deaths averted (95% CI 3.39 to 7.67). Finally, the discount rate was varied with the using the same upper a lower methodology of 0% and 10 %.

Therefore, the formula used to calculate the outcome measure is as follows:

$$DE = \frac{5.5}{1000} * epop$$

Where

DE is the Deaths averted

epop was the estimated population that was given a LLINS in this study the researcher will be using the under 5 population.

Cost Per Child Death Averted

$$C_{DE} = \frac{Cint}{DE}$$

Where

C_DE is the Cost per child death averted.

C_Int is the cost of the intervention, i.e., that LLINS distribution campaign.

Cost Per Daly Averted

$$C_{DALYsAvt} = \frac{C_{DE}}{DALY}$$

Where

C_DALYS Avt is the cost per DALYS averted as a result of the intervention C_DE is the Cost per child death averted DALYs Averted is the DALYs averted based on the estimates on the global disease burden which is 33 DALYS averted for the under 5 population [13, 32].

$$Total\ DALYSAvt = DE * DALYavt$$

Where

Total DALYs avt is the total number of DALYS saved because of the intervention. The deaths averted were done using three years which was the useful life of the LLINs against the malaria vector.

Results

As shown in Table 1 a total of 91,166 LLINs were distributed to the Regions 1,7,8 and 9.

Costing for LLINs Distribution

Table 1. Costing for LLINs Distribution

Regions	Bed Nets	Hammock Nets	Total LLINS	Total population	% of LLINs distributed to the population
Region 1	15,550	13,133	28,683	27,643	104%
Region 7	9,300	20,750	30,050	18,375	164%
Region 8	4,882	15,332	20,214	11,077	182%
Region 9	10,119	2,050	12,169	24,238	50%
Total	39,851	51,265	91,116	81,333	112%

Region 9 fell short of at least 50 % coverage when compared with the total population. This can be explained in the selection method which was to give LLINs only to persons that live in or frequently visit the vector's habitat (and not all villages in the Malaria endemic regions). The other three regions distributed more LLINs than initially planned. At the National Level 12 % more or 9,783 were distributed to the at-risk population.

Table 2. Campaign Delivery Cost

Activity	Description	Amount	Unit Cost ($)	Total Cost ($)
LIINS-Procurement	Bed and Hammock nets-cost, insurance and freight.	91,116	2.27	206,833.32

Per-diem	Meals and accommodation for staff duration of the LLINS campaign.	35		31,366.19
Cargo	Cost to transport LLINs to the Regions and the community via air, water and roads.			40,174.55
Health promotion	An NGO was contracted to assist with the mass sensation of the LLINs.			5,880.00
Personnel cost	Health worker delivers 5-minute LLINS care session per person.	20	309.5	6,190.48
Monitoring and Evaluation	M&E activities by campaign supervisors.	20	100	8,000.00
Overheads	Stationery, utilities charges, and supporting services.			1,000.00
Total cost				299,444.53

After using the data collected in Table 2, the average cost of delivering one LLINS was $3.29 per LLINs with the total campaign having a financial cost of $299,444.53.

The total cost to deliver LLINs to the under 5 population was $ 37,782 (under 5 population in the endemic regions multiple by the unit cost per LLIN delivered).

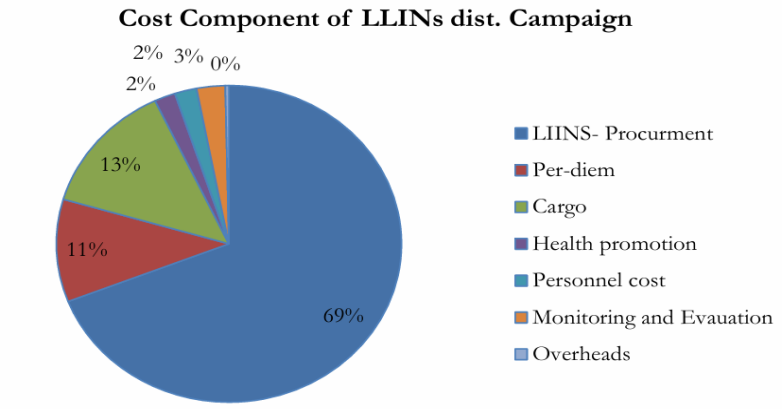

Figure 3. Cost Drivers

Figure 3 shows the disaggregation of the cost component of the LLINs campaign where 69 % of the cost was for the cost of procurement of the LLINs; the other 31 % was for the offsetting of payments for the delivery of the LLINs to the endemic communities. DALYS averted and deaths averted from the LLINS distribution. The estimation of the DALYs gain has to start by estimating the deaths averted because of the intervention using the under 5 population taken for the 2012 census [33].

Table 3. Deaths Averted

Region	**Under 5 Population**	**Annual Deaths Averted**	**LLINs Life Span (3 years) Deaths Averted**
Region 1	3,896	21.43	64.3
Region 2	4,457	24.51	73.5

Region 3	9,208	50.64	151.9
Region 4	27,510	151.31	453.9
Region 5	4,445	24.45	73.3
Region 6	9,090	50.00	150.0
Region 7	2,315	12.73	38.2
Region 8	1,613	8.87	26.6
Region 9	3,663	20.15	60.4
Region 10	4,243	23.34	70.0
Total	70,440	387.42	1,162.3

The annual deaths averted as shown in table 3 the under 5 population were 387 deaths averted per year and 1,162 deaths averted over a three-year period which is the useful life of the LLINS.) In examinations of the endemic regions of 1,7,8 and 9 the deaths averted per year were 63.18 and 189.54 over the three-year useful life of the LLINs.

Cost Per Child Deaths AVERTED

Table 4 shows the cost per child deaths was estimated at the population level and level of the endemic regions.

Table 4. Cost Per Child Deaths Averted

Target Group	Cost of Intervention	Annual Deaths Averted	Three-Year Deaths Averted	Annual Cost per Death Averted	Three-Year Average Cost per Death Averted
Population	37,782	387.42	1,162.26	129.84	32.51
Endemic Region	37,782	63.18	189.54	598.02	199.34

The calculation showed that the annual cost per child death was 129.84 in the general population and 598,02 in the endemic regions. Using the three averages it was estimated 32.51 cost per child death in the general population and 199.34 in the endemic regions. The number of deaths averted was estimated in table 8 and the cost of the intervention was estimated.

Total DALYs Averted

The total DALYs averted were calculated form the results presented in table 5. The general population and the endemic population both annually and the life of accumulated useful life on the LLINs, i.e, three years.

Table 5. Total Deaths Averted

Region	Annual Deaths Averted	LLINs Life Span Deaths Averted	DALYs Averted (Annual)	DALYs Averted (3 years)
Region 1	21.43	64.3	707.12	2,121.37
Region 2	24.51	73.5	808.95	2,426.84
Region 3	50.64	151.9	1,671.25	5,013.76
Region 4	151.31	453.9	4,993.07	14,979.20
Region 5	24.45	73.3	806.77	2,420.30
Region 6	50.00	150.0	1,649.84	4,949.51
Region 7	12.73	38.2	420.17	1,260.52

Region 8	8.87	26.6	292.76	878.28
Region 9	20.15	60.4	664.83	1,994.50
Region 10	23.34	70.0	770.10	2,310.31
Total	387.42	1,162.3	12,784.86	38,354.58

The total DALYs averted for the under 5 population was 12,784.86 annually and 38,354.58 across the three years use life of the LLINs. With regards to the endemic regions the total DALYs averted annually was 2,084.89 and a total of 6,254.67 over the useful life.

Cost Per DALYs Averted

The cost per DALYs calculated used the results from table 6, i.e., the cost per death averted this was then divided by 33 DALYs based on the recommendation from the literature [13, 32].

Table 6. Cost Per Child Deaths Averted

Target Group	Annual Cost per Death Averted	Three-Year Avg Cost per Death Averted	DALYs Averted	Cost per DALY Averted (Annual)	Cost per DALY Averted (3 Years)
Population	129.84	32.51	33	3.93	0.99
Endemic Region	598.02	199.34	33	18.12	6.04

The estimated cost per DALY averted for the under 5 population was $3.93 for the general population annually and $0.99 for the three years. With regard to the endemic regions the cost per DALY was $18.12 annually and $6.04 when looking at the three years.

Sensitivity Analysis

Univariate sensitivity was done on the following variables LLINs life span of the LLINs, discount rate and the mortality impact which was the number of under 5 deaths averted because of the LLINs.

The parameters have been varied to the extreme to their potential range based on surveys of the literature and expert opinion. The lifespan of LLIN varied to 2-5 years along with the cost of procurement. The outcome measure, that is, the productive efficiency was varied to reflect the upper and lower limit i.e. that deaths averted (95% CI 3.39 to 7.67) [13, 32]. Finally, the discount rate was varied with the using the same upper a lower methodology of 0% and 10%.

Table 7. Results of the Sensitivity Analysis

Variable	Base Value	Assumed Value	Deaths Averted	Cost per Death Averted	Cost per DALY Averted
Life Span on the LLINs*	3 years	2 years at $1.13	nil	291	8.82
Life Span on the LLINs	nil	5 years at $3.4	nil	134	4.06
Protective efficiency	5.5 deaths per 1,000	3.39 deaths per 1,000	238	158	4.79

Protective efficiency	nil	7.67 deaths per 1,000	540	69	2.90
Discount Rate	nil	0-10%	348	62	1.88

* The base value per unit of LLIN was $ 2.27; the cost decreased by 50 % corresponding to 2 years which was $1.13 of useful life per LLIN. The cost per LLIN increased to 50% corresponding to 5 years useful life per LLIN.

The sensitivity analysis was done using the annual cost figures for the under-five population that is $ 37,782 as seen in table 7.

Discussion

Malaria imposes a significant economic impact on the individual, the family and the economy [33]. This paper estimated the cost of delivery per LLIN at $3.29 as a part of the distribution campaign in which total of 91,116 LLIN was distributed. The average cost per LLIN distributed was lower than the similar campaign done in Eretria, Ghana and Togo. Other studies estimated the average annual cost of LLINs delivery was USD $3.98, all cost was done from the provider perspective [24] compare Togo which had an average cost of $ 4.41 form also provider perspective. In Ghana the CEA used economic costs which was estimated from a societal perspective which meant that the indirect and direct cost was used in the analysis, the cost to deliver one LLINS was $2.90. [15].

The total number of deaths averted in looking at the under 5 population level was 387.42 and 1,162.3. The total DALYs averted was 12,784.86 annually and 38,354.58 across the three years. The cost per death was estimated to be $129.84 annually and $32.51 across the three years. The cost per DALYs averted was $3.93 annually and $ 0.99 over the three years

The cost per DALY was $13 in Eretria, $ 4.1 in Ghana and $16.39 in Togo. The cost per child death averted was $438 in Eritrea, $6.619 in Ghana and $635 in Togo. Because of the LLINS campaign 2,553 deaths were averted in Eretria, 1,608 deaths averted in Ghana and 6,285 deaths were averted in Togo [9, 17, 18].

The Incremental Cost Effectiveness Ratio (ICER) when calculate showed that the intervention was very cost effective when examining the cost per DALYS averted against Guyana's GDP per capita which according to Guyana Bureau of Statistics stood at US$3,883 in 2017. The estimated cost per DALYs averted was $3.93 annually which meant that it fulfilled the indicator/criteria of begin cost effective. The results of the univariate sensitivity showed that the impact of uncertainty on variables such as the lifespan of the LLIN, productive efficiency and the discount rates demonstrated that the results were robust to moderate changes with causing the change of not begin a cost-effective intervention.

With any model there is a limitation, with regards to this model some limitation was that mop-up and evaluation of the campaign was not estimated because it is currently on going. Another limitation was that the study perspective was from a provider or health system perspective where travel cost, salaries, procurement of commodities, health promotion among others was accounted not from a societal perspective.

Conclusion

On the basis of the cost effectiveness ratio the researcher concluded that the intervention was cost effective and similar studies be done using other preventative methods such as indoor residual spraying.

Conflict of Interest

The author declares that there is no conflict of interest in this manuscript.

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