A CHILD HEALTH INTERVENTION IN POST-CONFLICT ANGOLA: A COST-EFFECTIVENESS ANALYSIS

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1 Introduction

This paper quantifies the health outcomes of a multi-intervention child health campaign in Angola in 2006. The outcomes of interest are the number of cases averted, the number of disability-adjusted life years (DALYs) averted and the number of deaths averted. The cost-effectiveness of the campaign is assessed as per the World Health Organization's (WHO) guidelines for assessing health programs and analyzed using methods from recent literature. Costs are expressed in 2006 USD, unless otherwise specified. The paper begins with the motivation behind this analysis, and then discusses the links between health and poverty and why child health in particular is so important, before introducing Angola and the campaign itself. The methodology section commences with an introduction to cost-effectiveness analysis and the use of DALYs and then analyzes each intervention in turn. Finally, the results are combined to determine the overall cost-effectiveness of the campaign and the discussion offers further analysis of expected educational returns, long-term health benefits and policy implications.

2 Motivation

Numerous cost-effectiveness and cost-benefit analyses have been performed and compared to assess the payoffs to investing in health care, and in particular in preventative care. The WHO lists over 200 cost-effectiveness estimates of child health interventions in the AFR D[1] sub-region, of which Angola is a member. However, there have been no known studies of such one-time intensive child health campaigns that combine five interventions, including both bed nets to prevent malaria and the poliovirus vaccine.

[1] The WHO classifies countries into regions based on geographical and epidemiological criteria.

Much of the literature on the cost-effectiveness of malaria prevention tactics has been used to identify the ideal preventative tactic for various at-risk groups in regions with varying levels of endemicity. Furthermore, the lack of vaccine or pill to guarantee immunity from the disease has caused researchers to focus on identifying the incentives needed to encourage the adoption of practices to minimize the risk of contracting malaria. As such, it is difficult to evaluate malaria prevention programs for young children whose behaviour depends that of their parents.

In this analysis, malaria cases and DALYs averted are calculated as a result of the distribution of bed nets in the campaign and the Vitamin A supplementation, which has been demonstrated to reduce both malaria morbidity and mortality. Additionally, the use of bed nets has been shown to reduce all-cause mortality, likely by reducing the incidence of malaria-induced anaemia thereby decreasing the burden on one's immune system. Furthermore, the 2006-2007 Malaria Indicator Survey (MIS) indicated that the distributed bed nets are often used by up to three additional household members, thus extending the benefits of the bed net distribution beyond the under-five age group.

Poliomyelitis is also rarely included in child health evaluations, and few studies have been done to evaluate the cost-effectiveness of vaccination campaigns. This is mainly due to the highly contagious nature of the virus and the difficulty in estimating the progression of the virus within a populace. Since the start of the polio eradication campaign in the 1980s, cost-benefit calculations have been continually updated as the struggle to eliminate the virus from the last four countries continues. As Angola has recently experienced the poliovirus both in an endemic state and as an outbreak due to the

virus being imported, the effects of this supplementary vaccination campaign can be easily extrapolated.

The distribution of Vitamin A supplements during national vaccination campaigns is increasingly common as the cost per pill is quite low and the additional overhead is minimal. The effects of Vitamin A supplementation on malaria morbidity and its reduction in all-cause child mortality rates in combined intervention analyses has been estimated in previous studies, but not to the extent considered here. In this paper, the combined effect of malaria bed net use and Vitamin A supplementation in decreasing all-cause child mortality and the effect of Vitamin A on decreasing endemic malaria morbidity are novel additions to the cost-effectiveness literature.

Furthermore, cost-effectiveness studies of child health campaigns are typically performed using a treatment and a control (or placebo) group, comparing the effect of a treatment to a do-nothing scenario. However, this is rarely a robust assumption, as all countries have some private or public health programs in place, minimal though they may be. Even Angola, with its civil conflict lasting almost three decades limiting access to health services and the destroying much of its infrastructure, demonstrated evidence of both prevention and treatment practices. This analysis attempts to quantify the marginal effect of a one-time child health intervention, controlling for the national health prevention practices already in place. The results of the cost-effectiveness of this type of supplementary campaign have policy implications for governments and public health organizations alike.

3 Background

3.1 Health and Poverty

The correlation between health and poverty is undisputed. The causation goes both ways; insufficient funds to cover the costs of medical treatment results in fewer days worked and hence there is less income to buy nutritious food or preventative vaccines thereby perpetuating the downward spiral of the poverty trap. Childhood illness can accelerate this cycle, as sick children require additional care, leaving caregivers with less time to spend on income-generating activities. The high rate of infant and child mortality further induces families to have more children than desired, spending additional time and energy in child rearing (Sachs & Malaney, 2002). Furthermore, children who are too ill to attend school have little hope of landing higher paying jobs than their parents.

It is this continuous cycle that justifies a one-time health intervention such as the Angolan campaign analyzed here, to give the poorest families an opportunity to break free of the health-induced poverty trap. Alleviating households of the financial burden of poor health enables them to reallocate their budget to other productivity- or utility-maximizing means. Sachs argues that with a sufficient health investment, this health trap can be eliminated within a single generation. Evidence of increased lifetime earnings exists from malaria eradication in the United States and countries in Latin American and South Asia (Banerjee & Duflo, 2011). The cost of smallpox eradication in the United States has been demonstrated to pay itself off every 26 days from vaccination and treatment costs savings (Seymour, 2011).

The question of interest is: to which diseases should funds be allocated, and in what capacity, in order to achieve the highest returns? The answer to this depends on

what type of returns are being monitored – life expectancy, morbidity or mortality rates, educational returns, lifetime earnings, or national healthcare expenditure. The logistics required for the eradication or control of a disease is often the most restricting factor. Infectious diseases require near-simultaneous global vaccination campaigns, water-borne illnesses require revamping of infrastructure and zoonotic diseases require pest or animal control while nutrient deficit-causing conditions require educational campaigns and supplemented foods.

3.2 Child Health

The payoffs to investing in child health are varied in both duration and effect. In addition to the obvious direct costs for doctors' visits, transportation to and from the clinic and medications, are a multitude of indirect costs and externalities. Indirect costs include lost income due to sick days taken (if the child himself is working) and/or the time taken off by a parent to care for a sick child. The freeing up of household and government budgets to reallocate funds to prevention or treatment of otherwise neglected or undertreated conditions further increases the health benefits to a society.

When compared to investing in preventative care for an adult, it is generally clear that the benefits to investments in child health will have a longer lasting impact as well as a more widespread effect. Affliction with any kind of illness during one's early years can have serious and lasting impacts on both the physical and cognitive development of a child. Furthermore, healthy children are more likely to attend school, and perform better.

More difficult to quantify are the effects on family planning and on the effectiveness of schooling. High infant and child mortality lead parents to have more children than desired, in order to ensure that at least some survive past the age of five,

usually to assist on the family farm. When the risk of childhood mortality decreases, parents can (theoretically) choose to have fewer children, thereby reducing the child-rearing workload and its associated expenses (Sachs, 2002). Furthermore, the loss of education due to children taking sick days is an inefficient use of educational resources, and can lead to gaps in knowledge that later translate into lower lifetime earnings.

For the poorest households especially, the increasing proportion of a household's budget spent on medical treatment may also cause substantial substitution effects that can affect the rest of the household. A cross-sectional study in rural Kenya estimated that malaria treatment costs amounted to 7.1% and 5.9% of the household budget in the wet and dry seasons, respectively (Chuma, Thiede & Molyneux, 2006), while the poorest households in Malawi were found to spend up to 28% of their household budget on treatment (Ettling et al, 1991). This suggests that a significant proportion of the budget typically spent on food has been shifted from food expenditure to medical expenditure, obviously causing nutritional losses to the entire household.

Investing in child health helps to disseminate the inequality that many developing countries face. National vaccination programs ensure that the poorest children will not be prevented from attending school by easily preventable diseases. Supplementation programs will further increase their attentiveness and productivity at school. This gives them an opportunity to break the health induced poverty cycle and allow the country to gain from the children's otherwise underutilised potential.

3.3 Returns to education

Psacharopoulos (1994) compiled economic returns to one additional year of primary education from 12 countries, finding return rates between 9.7% (for Brazil) to

35.0% (for Ethiopia), with the majority hovering between 10% and 20%. These returns can be interpreted as productivity improvements visible through increased wage rates. Van der Gaag and Tan (1996) found that the net present value of the Bolivian educational system increased by 20% (317,340-264,516/264,517) for a cohort of 1000 children, from decreasing the under-five child mortality rate from 20% to 1% assuming an enrolment rate of only 20%. This increased return to education was calculated solely from the increased productivity of the 20% of children saved. Including an increase in primary school enrolment to 95% and improved primary school performance, the value of the educational system jumped to $2,061,574. Of this increase, 87% was attributed to the maternal and child health program.

4 The Intervention

4.1 Angola

Angola is a country in south-central Africa, which after gaining independence in 1975 from Portuguese rule, struggled through more than two decades of civil war. A ceasefire was signed in 2002, initiating a period of economic growth driven by Angola's vast mineral resources and the high global demand for its oil. However, health and social infrastructure was almost completely nonexistent after 22 years of conflict, leaving Angola with some of the worst health ratings in the world. The WHO estimates the 2004 life expectancies to be 38.2 and 42 years for males and females, respectively, yielding an average life expectancy of 40 years. Infant mortality was among the worst in the world, at 107 deaths per 1000 live births in 2006, and an under-five mortality rate of 176 per 1000 live births according to the WHO. In 2004, there were 0.077 physicians and 1.19 nurses available per 1000 Angolans (WHO, 2006b). Given that rebuilding the health system will

take a long time, there is a definite need for a child health intervention in order to achieve immediate gains in the health of Angolans.

4.2 Viva a Vida com Saúde: Enjoy a Healthy Life

In the summer of 2006, the Government of Angola launched a child health campaign called Viva a Vida com Saúde (VaV): Enjoy a Healthy Life, partnering with UNICEF, the WHO, the Malaria Initiative, the Measles Initiative and the Global Fund to fight AIDS, Tuberculosis and Malaria with funding from an array of international donors. This project was initiated to combat the extraordinarily high infant and child mortality rates that have plagued Angola's post-conflict recovery. The $15.8 million campaign combined the administration of vaccinations for measles and polio with one-time doses of de-worming medicines and Vitamin A supplements and the provision of long lasting insecticide-treated bed nets (LLINs) in high-risk malaria areas. In total, 3.6 million children received at least some combination of these preventative measures, depending on their age at the time of the campaign, as seen in Table 1 below.

Table 1: The five interventions offered in the VaV campaign and the number of children who received each treatment

Health Concern	Intervention	Target age	# Doses
Malaria	LLINs	All within high-risk area	800,000
Measles	Vaccine	9 months – 5 years	3,210,160# (97% coverage)
Polio	Vaccine	0 – 5 years	3,600,000
Worms	De-worming meds	1 – 5 years	2,880,000*
Immune boost	Vitamin A supplement	6 months – 5 years	3,240,000*

#Source: Measles Initiative

*Estimated by proportion of children in that age range (MIS) times 3.6 million.

5 Methodology

5.1 Cost-Effectiveness

Cost-effectiveness analysis is a form of economic evaluation, commonly used in health economics to compare the cost per case averted of different treatments, or between a treatment and a do-nothing scenario. It can be measured in cost per case averted, deaths averted or disability-adjusted life years (DALYs) averted. The WHO has established guidelines for measuring cost-effectiveness and developed a database to compare the cost-effectiveness of various health interventions. The WHO considers an intervention to be "very cost-effective" if the cost per DALY saved is less than the country's GDP/capita, "cost-effective" if it is within 1-3 times the GDP/capita and "not cost-effective" if it is greater than three times the GDP/capita.

5.2 Disability-Adjusted Life Years

Disability-Adjusted Life Years (DALYs) have become standard in health evaluation analyses as a measure of overall disease burden since their invention by researchers Murray and Lopez at Harvard University in 1990 for use by the World Bank. They combine the effect of morbidity and mortality by summing years of life lost (YLLs) and years lived with disability (YLDs). YLDs are calculated by standardized disability weights scaled between 0 (perfect health) and 1 (death) multiplied by the duration of the illness (WHO, 2008). The use of DALYs in cost-effectiveness analysis allows interventions with varying durations of effectiveness to be accurately compared.

The disability weights and durations of illness used in this paper are the figures established by the WHO for use in cost-effectiveness analysis. The most accurate estimate of life expectancy for Angola is most likely the one determined by the WHO in

their 2004 Global Burden of Disease (GBD) Report, and it is assumed that this figure did not change significantly by 2006. Life expectancy was found to be 38 years for males and 42 years for females, yielding an average life expectancy of 40 years and this will be the figure used to calculate YLDs and YLLs in the analysis to follow.

6 Analysis

6.1 Malaria

6.1.1 Malaria Introduction

Malaria is a life-threatening, mosquito-borne illness that primarily affects some of the most underdeveloped regions of the world. Since malaria is a vector-borne disease spread by infected mosquitos, eradication, or even just control of malaria has proven quite difficult, particularly in the warm, tropical environments in which mosquitos thrive. The attempted eradication campaign introduced by the UN in 1955 eliminated malaria from a few areas but failed in its global goal of eradication. Initiatives such as the Roll Back Malaria Partnership and Spread the Net campaign to minimize malaria prevalence have emerged in recent years in a humanitarian effort to reduce child mortality rates in the developing world. The WHO reported 247 million cases of malaria worldwide in 2008 with one million of those cases having resulted in death, and a majority of which were among African children (WHO, 2010a). In Angola in 2004, the death rate due to malaria was 137.4 per 100,000 and the DALY rate was 5,012 per 100,000, the second highest rate after diarrhea of all the infectious and parasitic diseases.

Economically, malaria has been estimated to cause losses in GDP of up to 1.3% in countries with the highest prevalence (WHO, 2010a). In a survey of 31 African countries, an average loss of 10% of 1995 income was attributed to malaria endemicity,

and 24 of the 31 countries averaged 1995 incomes losses of at least 17% (Sachs & Malaney, 2002).

Malaria in Angola is widespread and a serious concern due to its high death rate and the toll it takes on Angola's already weak healthcare system. Three regions with varying risks of transmission have been determined using climate data. The hyperendemic area, which spans the northern provinces of the country, has consistently high transmission rates of at least 0.9[2]. The middle band of provinces has been classified as stable mesoendemic, with an average transmission rate of roughly 0.5. The unstable mesoendemic region consists of the provinces edging Angola's southern border. This area has a lower rate of transmission most of the time, but because of this, malaria immunity is also lower, increasing the risk of a more serious outbreak (Ruebush et al, 2005).

Due to staff and equipment shortages, microscopic malaria diagnoses occur rarely, but prescription of antimalarials only requires a clinical diagnosis. The MIS confirmed that the suspected caseload of malaria hovers around 20% in children (6-59 months) nationwide, with a higher prevalence in rural areas (30.6% compared with 7.2% in urban areas). The survey also indicated higher antimalarial usage rates and a higher likelihood of drug treatment within two days of experiencing fever amongst urban children.

Prevention of malaria is particularly difficult because there is no vaccine - it requires vector control via insecticide spraying of residences or bed nets. Increased

[2] The transmission rates are based on a scale from 0 to 1, where 0 indicates an area unsuitable for transmission and 1 indicates an area highly suitable for transmission and is hence transmission stable.

resistance to insecticides further complicates this (WHO, 2010a). The WHO thus advocates for the use of LLINs over indoor residential spraying, especially in areas of high transmission, to target children under the age of five, as the cost of the nets is estimated to be 4-5 times cheaper than spraying (WHO, 2007b).

Treatment for malaria caused by the most prevalent species, *P. falciparum,* must be started within 24 hours of symptom presentation, otherwise, it will lead to severe illness and likely death. As Angola's health system is unable to ensure immediate treatment, prevention is even more imperative. To make matters worse, resistance to anti-malarial medications is also on the rise (Guthmann et al, 2005).

Drug efficacy testing in 2004 demonstrated that drug resistance was as high as 50% for chloroquine and 22% amodiaquine, leading the WHO to recommend artemisinin-based combination therapy (ACT) as the go-to antimalarial in Angola (Ruebush, 2005). However, chloroquine and amodiaquine continue to be the most commonly taken antimalarials (14% and 10.7%, respectively), regardless of wealth or place of residence, and quinine is the drug of choice for cases of severe malaria, with a recrudesence rate of 20% (Myint et al, 2004). This further emphasizes the need for preventative measures in order to mitigate the effects of malaria.

6.1.2 Malaria Methodology

The MIS was carried out after the VaV campaign and provided the necessary data on malaria risk in each region of Angola, malaria prevalence among children under-five and the number of household members using the VaV nets. This data is combined with the protective efficacy rates reported in the malaria literature to determine the cases and DALYs averted due to the distribution of bed nets during the VaV campaign. Total

averted DALYs are comprised of clinical cases of malaria, cases of neurological sequelae, malaria-induced anaemia and deaths. All the parameters used in the analysis can be found in Appendix I.i.

The MIS indicated that Angola's capital, Luanda, had a significantly different malaria prevalence rate than the region in which it climatically belongs to, and has thus been separated into a fourth region as shown below. Multiplying the prevalence rates by the population in each age-region cohort, the estimated number of cases in children under-five was found to be 707,739 in 2006. As this is fairly similar to the number reported in the WHO's 2010 report on malaria in Angola, 770,639, the total number of cases reported in the report (2,283,907) is used in the rest of the analysis to determine the caseload in the older cohorts. The survey also reported the total number of users of the 800,000 bed nets distributed during the VaV campaign was 1,277,966 due to multiple family members sharing the use of one bed net.

Malaria rates in children <5:

Hyperendemic = 34.81%
Mesoendemic stable = 30.36%
Mesoendemic unstable = 17.65%
Luanda = 7.34%

Malaria rates in persons ≥5:

Hyperendemic = 18.87%
Mesoendemic stable = 13.70%
Mesoendemic unstable = 5.81%
Luanda = 4.51%

Severe case rate and death rate in Angola:

In 2005, 13,768 deaths were attributed to malaria, of which 7354 of those were children, implying a death rate of about 1% in children and 0.4% in the rest of the population. Although pregnant women are the second highest at-risk group for

contracting malaria, the number of adult users of the VaV bed nets is not significant enough in this case to justify the additional analysis, and the cases and deaths averted for all persons over the age of four are thus combined. As quinine is the drug of choice for severe malaria cases, it is assumed that the proportion of severe cases of malaria in children in 2006 is equivalent to the proportion of children taking quinine of the total number of children taking antimalarials, as found in the MIS survey (2.8%/30.2% = 9.27%). The proportion of severe cases in adults is estimated by scaling this figure by the ratio of the death rates, yielding a rate of 4.10%.

Protective Efficacy (PE) of Bed Nets:

A 2004 review summarized studies of insecticide-treated nets (ITNs) and their protective efficacy in reducing mortality and morbidity in stable and unstable endemic regions. All-cause child mortality was reduced by 17%, 95% CI = (0.1 - 0.24), and severe malaria cases were reduced by 45%, 95% CI = (0.2 - 0.63). Clinical cases of malaria were reduced by 50% in stable endemic regions and 62% in unstable endemic regions (Lengler, 2004). (Confidence intervals were not given.) The number of clinical cases averted from the VaV nets is calculated from the number of users in each region multiplied by the malaria risk and the PE. The number of averted severe cases is the number of VaV net users at risk of malaria times the severe malarial rate and its PE. Averted deaths are 10.25% of the averted severe cases. These figures are given in Table 2 below.

Neurological Sequelae:

Severe malaria can result in irreversible neurological damage, particularly in young children who experience malaria-induced iron deficiency during their critical

growth period. A review of several studies analyzing the variety of outcomes following an episode of severe malaria found irreversible neurological damage occurring in 11% of the cases. Neurological sequelae was uncommon in adult cases (Newton, 1998). Averted cases are calculated from the averted severe malaria cases in children.

Anaemia:

Anaemia is a common symptom of malaria and an additional cause of the loss of DALYs. Ronald et al (2005) determined the population-attributable risk of anaemia due to malaria to be 16.5% in a study of children in Ghana. Murphy & Breman (2001) found the rate of severe malarial anaemia to be 15-60 cases per 1000 children under-five in sub-Saharan Africa per year. The MIS, however, indicated that 8% of the children who tested positive for malaria were severely anaemic, with haemoglobin levels < 8g/dL, compared with 4% in all children. Thus the rate of severe malarial anaemia is assumed to be 4% in children with malaria, and this rate is assumed for all age groups. The number of averted cases of severe malarial anaemia is thus 4% of the averted malaria cases.

Table 2: Cases of mild and severe malaria and malaria-caused deaths averted

Case Type	Children <5	Persons ≥5	Total
Malaria cases averted	63,497	65,361	128,858
Severe malaria cases averted	17,110 (7605 – 23,954)	16,010 (7116 – 22,416)	33,121 (14,720 – 46,369)
Cases of neurological sequelae averted	1882 (836 – 2635)	N/A	1882 (836 – 2635)
Cases of anaemia averted	2540	2614	5154
Malaria deaths averted	1754 (779 - 2455)	1641 (729 – 2298)	3395 (1509 – 4753)

Table 3: YLDs, YLLs and DALYs averted from the distribution of 800,000 bed nets during the VaV campaign

Case type	Cases averted	YLDs averted	YLLs averted	DALYs averted
Episode	128,858	492		492
Neurological Sequelae	1882 (836 – 2635)	33,241 (14,766 – 46,541)		33,241 (14,766 – 46,541)
Anaemia	5154	1.24		1.24
Deaths				
<5	1754 (779 - 2455)		65,767 (29,230 – 92,074)	65,767 (29,230 – 92,074)
5-14	442 (197 – 619)		13,270 (5898 – 18,578)	13,270 (5898 – 18,578)
>14	1199 (532 - 1678)		14,984 (6660 – 20,979)	14,984 (6660 – 20,979)
Total	3395 (1508 – 4752)	33,734 (15,259 – 47,034)	94,022 (41,788 – 131,631)	127,756 (57,047 – 178,665)

Table 2 and 3 above list the cases, deaths and DALYs averted from distribution of the LLINs to children. Due to family members sharing the use the nets, the number of DALYs averted increased by more than 20%.

6.2 Measles

6.2.1 Measles Introduction

A highly contagious and viral disease, measles has caused high rates of infant and child mortality across the developing world because of inadequate vaccination campaigns. The virus has an incubation period of one to two weeks, after which a mild fever presents for a few days, followed by the onset of a full body rash accompanied by a much more acute illness (WHO, 2009a). Complications, including diarrhea, pneumonia, and encephalitis (swelling of the brain) are especially common in the developing world due malnourishment and a lack of health services (Strebel, 2004). Death occurs in 5-15%

of the cases in the developing world (WHO, 2009b). The communicable period lasts for up to eight days, four of which occur before the presentation of symptoms. Transmission occurs via sneezing, coughing and close personal contact, emphasizing the need for vaccine prevention as measles outbreaks can spread quickly.

The measles vaccine has been in use for over forty years and has been shown to be safe and cost-effective. The WHO claims that the vaccine saves more lives per unit cost than any other health intervention and vaccination coverage is a key indicator used in monitoring the reduction of child mortality rates of the fourth Millennium Development Goal (MDG). However, due its high communicability, eradication is currently a lofty goal, as it requires simultaneous global vaccination coverage of at least 95%. Since the cohort vaccinated during the campaign is the age group with the highest transmission rates, the campaign will have yielded significant positive externalities in terms of decreasing infection rates across all age groups, particularly because vaccination rates of 1 year olds fluctuated between 41% and 74% in the 8 years prior to the campaign. However, the herd immunity effect captured from the 97% coverage rate of the VaV campaign will drop off quickly as the following cohorts of children will require further vaccination.

The vaccine is generally administered at 9 months, when the seroconversion (vaccine effectiveness) is around 80-85%. Although this can increase up to 98% if vaccination is delayed an additional 6 months, there is a trade-off in the risk of contacting measles in the meantime (Strebel, Papania & Halsey, 2004).

Since measles is caused by a virus, there is no treatment to cure the disease itself, however, the WHO does recommend Vitamin A supplementation for its immune

boosting properties. The recommended dosage is 200,000 IU of Vitamin A for two days as D'Souza & D'Souza (2002) reported a risk reduction of mortality of 0.36 (95% CI: (0.14 - 0.82)) and a 50% reduction in measles morbidity. However, insufficient evidence of a reduction in measles morbidity and mortality rates following a single dose (D'Souza) implies that there was no additional reduction in the burden of measles due to Vitamin A supplementation at the time of the VaV campaign.

A 2003 summary of the state of measles in Angola stated that on average, 9,000 - 12,000 cases were reported per year and 1,000 – 2,000 deaths were reported each year. However, as these were only the officially reported numbers, it is hypothesized that these numbers underestimate the true values. Regardless, these numbers do indicate a death rate of roughly 10%, and this will be the estimated rate in this analysis. The WHO's GBD report stated measles was the cause of 900 deaths in Angola in 2004 and caused the loss of 33,000 DALYs nationwide.

Although the WHO promotes widespread measles vaccination as a simple and inexpensive life-saving intervention, recent in-depth cost-benefit analyses of the intervention are few. A study of a vaccination campaign in two South African provinces in 1996-1997 found the campaign to be cost-effective in both provinces, but cost saving in only one province. The analysis accounted for the costs of the vaccination campaign and potential adverse effects and the benefits accounted for included measles cases, hospitalizations and deaths averted (Uzicanin et al, 2004). A 1985 evaluation of the savings from measles vaccination between 1963 and 1982 in the United States accounted for benefits from cases averted, lives saved, cases of mental retardation averted, additional productive working years gained and healthcare costs averted yielding a net

benefit of $5.1 billion (1985 USD). The estimated benefit-cost ratio for 1981 was 14.6:1 (Bloch et al, 1985). A study of a measles vaccination campaign compared costs and benefits in terms of time, and the cost of the epidemic in terms of health services and community costs but excluding lost earnings, was found to be higher than the cost of the campaign (Anderson & May, 1991). The WHO reports that the cost per DALY averted from 95% coverage of measles vaccination is $39 (2005 USD), averting 5,298 DALYs per one million people in the WHO defined AFR D region.

6.2.2 Measles Methodology

In the VaV campaign, 97% of children between 9 months and 5 years were given the measles vaccination. As is consistent with previous literature, a seroconversion rate of 85% is assumed for children under a year and 95% for children at least twelve months old (Uzicanin et al, 2004). Adverse effects to the vaccine are rare; 1 in 20 may experience a 24-48 hour fever and there is a similar chance of experiencing a rash for the same time period, but neither is severe enough to affect DALY calculations. Furthermore, the risks of seizures, anaphylactic seizures or decreases in platelet counts from vaccination are too rare to be considered in this analysis.

Measles cases have been heavily underreported in Angola, both during the civil conflict and after, as the process of rebuilding the health system has been slow moving. In 2003, a national catch-up vaccination campaign organized by UNICEF and the Angolan government, immunized 7,226,105 children aged 9 months and up, reaching a coverage rate of 95%. This was stimulated by UNICEF estimates that over 10,000 Angolan children (of whom 95% are less than 15 years old) die each year from measles. As the death rate from measles is approximately 10%, this implies a measles caseload of

approximately 100,000 per annum in the years prior to 2003. Comparing this to the number of reported cases in 2001 and 2002 at 9,046 and 11,945, respectively, the underreporting ratio is estimated to be 10%. Due to a lack of significant investments into Angola's health infrastructure in the mid-2000s it is assumed this underreporting ratio holds. (Parameters are listed in Appendix II.i.)

Vaccination reports in Angola are assumed to be accurate since only a medical professional can administer a vaccination. Using these vaccination records of one-year olds in the five years prior to 2006, the proportion of immunized children both with and without the intervention were determined (see Appendix II.ii). The relationship between the under-five per annum case rate and the previous year's immunization rate was found to be a negative log relationship averaging 0.09978 (with a minimum of 0.09027 and a maximum of 0.11184). The averted measles case rate was then determined using this ratio and the immunization rates with and without the intervention (see Appendix II.iii).

Table 4: Cases, deaths, YLDs, YLLs and DALYs averted from measles vaccination

Age	Measles cases averted	Measles deaths averted	YLDs averted	YLLs averted	DALYs averted
Children <5	13,230 (6,878 - 22,068)	1323 (688 – 2,207)	156.9 (82 – 262)	49,613 (25,800 – 82,763)	49,770 (25,882 – 83,025)
Children 5-14	3987 (2072 – 6651)	399 (207 – 665)	47.3 (25 – 79)	11,970 (6210 – 19,950)	12,017 (6235 – 20,029)
Adults >15	906 (471 – 1512)	91 (47 – 151)	10.7 (6 – 18)	1138 (588 – 1888)	1,149 (594 – 1906)
Total	18,123 (9,421 – 30,231)	1813 (942 – 3023)	214.9 (113 – 359)	62,721 (32,598 – 104,601)	62,936 (32,711 – 104,960)

Controlling for non-intervention measles vaccination rates, Table 4 demonstrates that by WHO standards, the VaV campaign is very cost-effective from the measles

vaccination alone, with the cost per DALY averted equal to $251.05 ($15,800,000/62,936), which is a tenth of the average Angolan GDP/capita. Furthermore, it is also interesting to note that the herd immunity effect from vaccinating only children under-five, protected Angolans five years of age or older and this accounted for 20% of the total DALYs averted.

6.3 Vitamin A Deficiency

6.3.1 Vitamin A Deficiency Introduction

Vitamin A deficiency (VAD) is a common occurrence in the developing world; the WHO estimates that a quarter of a billion children under the age of five are deficient and up to half a million of those children will become blind as a result. Vitamin A is also crucial in immune system functioning and supplementation is thus advocated for to reduce morbidity and mortality rates, especially among children. Adamson (2004) has reported that VAD compromises the immune systems in up to 40% of children in the developing world. Vitamin A supplementation has contributed to minimizing measles and diarrheal-related deaths (Imdad et al, 2010). A review of eight studies found a mortality rate reduction of approximately 23% among children between 6 months and 5 years, attributed to Vitamin A supplementation either by high-potency dosages or food fortification (Beaton et al, 2003) and Adamson (2004) reported that VAD is responsible for 16% of the global burden of disease caused by malaria.

As Vitamin A is abundant in animal-based protein, VAD is highly prevalent in areas that already have high rates of protein-energy malnutrition. Furthermore, Vitamin A uptake is constrained by simultaneous iron deficiencies. Since the immune system requires high quantities of Vitamin A, VAD can quickly lead to a poverty-related disease

trap, in which poorly nourished children are more prone to infection, depleting their Vitamin A supplies, leading to weaker immune systems and so on. As such, Vitamin A supplementation has been strongly endorsed as a child health intervention by the WHO. The World Bank has estimated that Angola loses at least 2.1% of their GDP per year from vitamin and mineral deficiencies, a problem that could be solved through additional supplementation campaigns which would cost less than 6% of their estimated loss in GDP (Adamson, 2004).

Since Vitamin A supplements do not require cold storage or dispensation by a healthcare practitioner and cost a mere $0.02 each, it is an easily administrable intervention. Furthermore, there have been no adverse effects reported from taking Vitamin A. Unfortunately, the high-potency dose usually administered lasts only 4-6 months, thus repeated supplementation is required, generally twice a year. Adamson (2004) reports that numerous countries with at least 80% coverage of Vitamin A supplementation per year still have VAD prevalence rates of over 50% in children under the age of six.

The WHO claims the cost per DALY averted from Vitamin A supplementation with 95% coverage is $121 (2005 USD). However, when in combination with other interventions, the cost-effectiveness increases dramatically. Zinc and Vitamin A supplementation with measles vaccination at 95% coverage costs only $66 (2005 USD) per DALY averted.

6.3.2 Vitamin A Deficiency Methodology

1999 survey data of VAD prevalence and recent literature estimates of the prevalence of xeropthalmia and corneal scarring were used to determine averted cases as

seen below in Table 5. UNICEF reports deaths due to VAD of Angolan children under the age of six to be 34,000 per annum, even with 75% of preschoolers receiving at least one dose of Vitamin A per year (Adamson, 2004). This gives the death rate already controlling for the baseline Vitamin A supplementation program in Angola, and the marginal benefits of the intervention are thus determined using this rate. Since the VaV campaign only administered a one-time dose of Vitamin A to the children, the long-term immune-boosting properties are limited. It is assumed that with the 4-6 month duration of effectiveness of the supplement, both DALYs and mortality rates are reduced by one third to one half of the per annum rates. A full list of the parameters used in these calculations can be found in Appendix III.i.

Table 5: Cases of VAD, xeropthalmia, corneal scars and deaths averted from one-time supplementation

Age	Cases VAD Averted	Cases Xeropthalmia Averted	Cases Corneal Scar Averted	Deaths Averted
<5	868,050 (694,440 – 1,041,660)	18,900 (15,120 – 22,680)	2079 (1663 – 2495)	21,371 (17,096 – 25,645)

Table 6: YLDs, YLLs and DALYs averted from Vitamin A supplementation

Age	YLDs averted	YLLs averted	DALYs averted
<5	21,596 (8638 – 55,532)	801,394 (641,115 – 961,673)	822,989 (649,753 – 1,017,204)

Tables 5 and 6 demonstrate that Vitamin A supplements yield some of the highest returns of child health interventions. However, it is important to note that the averted cases and deaths from VAD are only for the six-month period following the campaign, and risk of VAD and its various complications will increase again to pre-intervention levels after this period.

6.4 Poliomyelitis

6.4.1 Poliomyelitis Introduction

Poliomyelitis (polio) is similar to measles in that is an untreatable, viral infection that primarily affects children under the age of five. It is highly contagious, spreading either orally or fecal-orally in the 7-10 days before and after the onset of symptoms. Although most cases of polio present with symptoms including fever, vomiting, stiffness and pain, up to 0.5% of the cases result in irreversible paralysis (Atkinson, Hamborsky, McIntyre & Wolfe, 2009). The Global Polio Eradication Initiative (GPEI) was initiated in 1988 by the WHO in cooperation with governments and NGOs worldwide, and has resulted in a 99% decrease in infections with 5 million cases of paralysis averted since its inception. However, the disease currently remains endemic in four countries: India, Nepal, Pakistan and Nigeria (GPEI, 2011a).

Angola's civil war posed huge problems to the vaccination campaign during the 1990s. Polio immunization coverage (of all three doses) of one year olds averaged 28.1% in the 1990s due to the difficulty in reaching much of the population during the civil war. Coverage increased in the early 2000s to around 46%, with a high of 83% in 2007 among one year olds. The VaV campaign administered only one dose of the recommended three to 3.6 million children under the age of five, and was likely the catalyst in achieving the high coverage rate in 2007.

Between 1992 and 1998, polio remained endemic in Angola, with the number of reported cases between 15 and 149, and a mean caseload of 58 per annum. However, a serious outbreak of the virus occurred in 1999, the largest ever recorded in Africa, with 1093 cases across three provinces and 108 deaths. The outbreak affected those between

two months and 22 years, of which 91% were under-five, 9% were under-fifteen and <1% were over fifteen. The Ministry of Health in Angola, assisted by the WHO, responded to the epidemic with an emergency vaccination campaign in Luanda and three additional national immunization days several months later (Valente et al, 2000). The Angolan outbreak caused ripples worldwide, due to some polio cases being exported to the DRC while other countries reviewed their polio control strategies to ensure the virus would not be imported (EPI News, 1999).

The potential for an outbreak of this size occurring again was mitigated by the 2006 vaccination campaign, which ensured three years of a polio-free populace. Cross-border transmission continues to threaten national elimination campaigns, forcing continual vaccination in countries that have not seen outbreaks in twenty years. The Congo experienced an outbreak in 2010, with at least 476 reported cases and 176 deaths despite a coverage rate of 91% of the third dose of the polio vaccine in 2009 (GPEI, 2010a). The virus was then imported to Angola, which reported 33 cases in 2010 and an additional four cases thus far in 2011 (GPEI, 2011a). The cost of the emergency response which included mop-up vaccination campaigns and increased surveillance in Angola and the DRC totalled almost $22 million (2010 USD), roughly one and half times the cost of the entire VaV campaign, demonstrating the necessity of coordinated global eradication.

The oral polio vaccine used in Angola is quite inexpensive at $0.08/dose (1999 USD), can easily be administered by a volunteer and provides immunity to all three types of the poliovirus. One dose provides immunity to 50% of recipients, while the recommended three doses yields immunity in 95% of recipients (GPEI, 2010b). Furthermore, as the vaccine is live, the recipient can pass on antibodies via fecal contact

indirectly immunizing those in close contact. Adverse effects of the vaccine are rare, paralysis has been reported in 1 in 750,000 – 2,700,000 vaccinations (WHO, 2010b).

A cost-benefit analysis of polio elimination in the United States estimated total savings to be $180 billion (1995 USD) from vaccinations between 1955 and 2015. A total of 1.7 billion vaccinations were estimated to have prevented 1.1 million cases of paralytic polio and at least 160,000 deaths (Thompson & Tebbens, 2006). A 2002 analysis of the eradication initiative estimated that between 1970 and 2050, 41.73 million cases and 855,000 deaths would be averted globally with a total savings of $57.417 billion (2000 USD), if vaccination had been discontinued after 2010. Africa, however, was estimated to have a net cost of $1.942 billion (2000 USD), costing $14,938 per death averted and $442 per DALY saved (Khan & Ehreth, 2003).

6.4.2 Polio Methodology

Outbreaks in previously polio-free regions occur with a high degree of unpredictability due to the random chance that a case of polio is imported. Since the global eradication campaign began in 1988, polio vaccination coverage among one-year olds has fluctuated from year to year due to the insecurity stemming from the constant civil conflict, however it was sufficient to keep the high pre-1988 prevalence rates at bay. As such, the average number of polio cases from the 1990s is used to estimate the minimum averted caseload in this analysis. However, the risk of an epidemic during this period was still high, evident from the outbreak in 1999, and the VaV campaign was successful at preventing this from recurring in the three years following the campaign. Furthermore, since Angola's poor health infrastructure had seen little improvement in the decade following the last outbreak, it is assumed that Angola's capacity to control polio

outbreaks is roughly similar. The number of cases reported during the 1999 outbreak is thus used to estimate the maximum averted caseload. Mean prevalence rates are averaged from these best-case and worst-case scenario estimates.

Although population growth resulting in a higher population density should imply a higher risk of an outbreak, the increased risk is minimal and is ignored. Furthermore, it is assumed that there is no underreporting of clinical cases of polio, as the chance of an unreported case not causing further undetected infections is too high.

The cases reported between 1992 and 1998 were either cases of clinical polio or flaccid paralysis, which account for only 5% of total polio infections; the remaining 95% cases are asymptomatic. Paralysis typically occurs in 0.5% of total infections, and death in 5% of these paralytic cases (WHO, 2010b & Atkinson, Hamborsky, McIntyre & Wolfe, 2009), however, deaths reported from the 1999 outbreak imply a much higher mortality rate, and this is used as the upper bound for deaths averted (Atkinson et al). A full list of the parameters is found in Appendix IV.i.

Table 7: Cases and deaths averted in children and adults from polio vaccination

Age	Infections Averted	Clinical cases averted	Paralytic Cases Averted	Deaths Averted
<5	10,474 (1055.6 - 19,892.6)	523.7 (52.78 - 994.63)	52.4 (5.278 - 99.463)	49.27 (0.264 - 98.28)
≥5	1036 (104.4 - 1967.4)	51.8 (5.22 - 98.37)	5.2 (0.522 - 9.837)	4.87 (0.0261 - 9.72)
Total	11,510 (1160 - 21,860)	575.5 (58 - 1093)	57.6 (5.8 - 109.3)	54.15 (0.29 - 108)

Table 8: YLDs, YLLs and DALYs averted from polio vaccination

Age	YLDs averted	YLLs averted	DALYs averted
<5	724.6 (73.0 - 1376.3)	1847.7 (9.9 – 3685.5)	2572.4 (82.9 – 5061.8)
≥5	57.4 (5.8 – 108.9)	146.2 (0.8 – 291.6)	203.6 (6.6 – 400.5)
Total	782 (78.8 – 1485.2)	1993.9 (10.7 – 3977.1)	2775.9 (89.5 – 5462.3)

Tables 5 and 7 demonstrate that the inclusion of the poliovirus vaccine in the VaV campaign has not had as significant an impact in reducing the caseload or mortality rate of children as Vitamin A supplementation had because of the earlier efforts of the GPEI in immunizing approximately half of Angola's infants each year. The non-intervention vaccinations had increased herd immunity sufficiently, thereby decreasing the risk of infection for the unvaccinated population. However, the Congolese outbreak in 2010 demonstrated the financial costs of not preventing further outbreaks and for a risk-averse government this could be incentive enough.

6.5 Helminth Infections

6.5.1 Helminth Infections Introduction

Helminths are miniscule parasitic worms that live in the small intestines of humans and feed off their blood, disrupting nutrient absorption and causing anaemia in their hosts. The intensity of the infection is based directly on the worm count and can thus result in a wide array of symptoms from general weakness and fatigue to intestinal obstruction and cognitive delays. There are three soil-transmitted helminths (STHs) that are of particular concern to humans: roundworm (*Ascaris lumbricoides*), whipworm (*Trichuris triciura*) and hookworms (*Ancylostoma duodenale* and *Necator americanus)* which affect 1 billion, 795 million and 740 million people, respectively, primarily in the developing world (WHO, 2011).

Helminths thrive in warm, moist environments, hence the high infections rates in the developing tropics. Furthermore, because the infection is transmitted by contact with fecal matter, areas without latrines or where fecal matter is used as fertilizer have the highest infection rates. Children are also especially prone to infection due to their lack of

knowledge of basic hygienic practices and since they are less likely to use latrines or wear shoes.

The treatment for a helminth infection is de-worming medicine which is cheap, easy to take and highly effective. However, high re-infection rates are very common, often occurring within a few months, if the unsanitary conditions that caused the initial infection have not changed. Thus the recommended treatment alongside the de-worming medications is prevention of re-infection by improving personal hygiene practices and/or developing the infrastructure of the area. As this is not cost-effective in the developing world, the WHO recommends the periodic distribution of de-worming medicines either in combination with child immunization campaigns or at schools.

Because of the higher infection rates among children, researchers have been especially interested in the potential effects of helminth infection on cognitive development, and several studies have attempted to measure this. Jukes et al (2002) evaluated a Tanzanian study of moderate hookworm infection and achievement in cognitive tests, which yielded inconclusive results. However, an Indonesian study found that hookworm infection explained significantly lower results in 6 out of 14 cognitive or motor tests. These tests implied that children infected with hookworm have lower working memory, which could cause adverse effects on reasoning ability and reading comprehension (Sakti et al, 1999). A review of 30 randomized trials of hookworm de-worming interventions by Dickson et al (2000), showed evidence of weight gain among children but inconclusive evidence of changes in cognitive performance after de-worming treatments. However, most of these studies were likely limited in their results due to the lack of prevention of re-infection that would guarantee sustained improvements in the

long term. Miguel and Kremer (2004) dispute Dickson's results on the basis that the randomization within schools prevented the generation of positive external benefits through improved herd health, which would aid in yielding stronger, more definitive results. They also argue that improvements in school attendance and participation alone, without improvements in cognitive functioning are sufficient to justify an intervention.

Bleakley (2007) found in a 50 year follow up study of hookworm eradication in several southern American states where previous prevalence rates for children averaged 40%, that school attendance, enrolment and literacy rates all increased. He controlled for crop-specific shocks, demographic shifts, parental socio-economic status, the simultaneous health intervention in malaria and other factors. Furthermore, Bleakley found that hookworm infection explained 22% of the income divide and 50% of the literacy gap between the American South and the American North.

Despite these mixed results of improvements in cognitive functioning, the World Bank (2011) endorses the mass distribution of de-worming medicines in developing countries because of the improvements in school attendance and the fact that the pills are inexpensive, easily transportable and safe to take even if one is not infected. Compared to the cost of prevention, which, in most cases, requires the construction of entire sanitation systems to eliminate the breeding ground of the helminths, de-worming treatments alone are highly cost-effective. It can also be hypothesized that continual de-worming treatment can be likened to a prevention strategy to curtail the incidence of the most severe infections.

An additional benefit of the inclusion of de-worming medicines in an integrated health campaign is that the impact of the medication can be immediately seen through the

excretion of the dead worms in a child's fecal matter. Seeing the immediate effectiveness of the treatment has enticed parents to bring their older children to health centres for treatment as well and resulted in participation rates to increase the following year (WHO, 2006).

Numerous organizations including the WHO and the Jameel Poverty Action Lab at MIT have touted de-worming as one of the most cost-effective treatments to combat child morbidity in the developing world. Assuming treatment 1.1 times per year, the cost per DALY averted in school children in low- and middle-income countries has been estimated to be $3.41 (2006 USD), (Jamison, Breman & Measham, 2006).

Despite the push for de-worming, there has been minimal surveying to determine the intensity of helminth infections in most countries. As warm, tropical climates foster the continued propagation of helminths, health experts often use climate data to estimate the likelihood of infection (Brooker et al, 2000). However, the World Food Programme (WFP) conducted a nation-wide survey of helminth infection prevalence in Angola in 2005, finding 40% prevalence rates. A 2006 survey of school-aged children in the province of Bié confirmed these findings, with prevalence rates of up to 66% in some schools (Tomlinson et al, 2006). On average, roundworm prevalence was found to be 39%, whipworm to be 30% and hookworm to be 7%. Intestinal worm infections have not been reported to be severe enough to cause deaths in Angola (WHO, 2004).

6.5.2 Helminth Infections Methodology

Due to the high likelihood of STH reinfection, one dose of de-worming medication will only last six months, mitigating the short-term symptoms but with only a minimal impact on the potential long-term developmental disabilities resulting from

continual high intensity infections. As helminth infection prevalence is strongly correlated with particular climates, it is assumed that the prevalence rates found in the province of Bié can be extrapolated to the entire country since Bié's central location ensures that its climate is representative of the country. Furthermore, the study's findings were very similar to the WFP's national survey results a year earlier.

A much-referenced analysis by Bundy et al (2004) of the burden of intestinal infections among different age groups and different regions is used to extrapolate the survey data to preschoolers and to estimate the prevalence of high intensity infections causing contemporaneous and permanent disabilities. As the risk of a disabling intensity of infection is not linearly proportional to the prevalence rate, Bundy et al approximated the relationship by the negative binomial distribution and verified it empirically. The risk of the varying levels of worm burden by age group and region determined from Bundy's methodology are used in this paper. The lower estimate corresponds to a higher minimum worm burden required to cause more serious developmental symptoms while the higher estimate corresponds to the lower worm burden threshold estimate of the proportion of children affected with serious clinical symptoms of helminth infections. Brooker (2010) linked these threshold estimates to the various disabling symptoms related to each worm infection as outlined in the WHO's GBD report. A table of the calculations determining the number of children at risk of disability can be found in Appendix V.ii.

Average prevalence rates calculated from the minimum and maximum rates are shown below in Table 9. It is also assumed that STH infections in children go untreated in Angola and as such, prevalence rates represent the proportion of children with permanent infections, thus there is no need for incidence scaling.

Table 9: Cases averted (for a 6 month period) and YLDs and DALYs saved from one-time de-worming

Disease	Symptom	Number of cases averted	YLDs averted	DALYs averted
Round-worm	High intensity infection	385 (27 – 743)	0	0
	Contemporaneous cognitive deficit	9936	29.8	29.8
	Cognitive impairment	270	4687.9	4687.9
	Intestinal obstruction	270	3.24	3.24
Whip-worm	High intensity infection	346 (13 – 678)	0	0
	Contemporaneous cognitive deficit	0	0	0
	Massive dysentry syndrome	0	0	0
	Cognitive impairment	225.2	202.7	202.7
Hook-worms	High intensity infection	2654.2	8.0	8.0
	Anaemia	17.3 (5.8 – 28.8)	0.104 (0.07 - 0.35)	0.104 (0.07 – 0.35)
	Cognitive impairment	0	0	0
Total			4931.74 (4,931.7 – 4,932)	4931.74 (4,931.7 – 4,932)

Although STHs don't cause as severe effects such as permanent disabilities or deaths due to the relatively low intensity of infections in Angola, the high prevalence rates of STHs, averaging 40% nationwide, indicate that there may be widespread underperformance in schools, significantly impeding economic development as suggested by Bleakley's 2007 findings.

6.6 Indirect Effects

6.6.1 Reduction of malaria cases and deaths due to Vitamin A supplementation

Vitamin A supplementation has contributed to a 16% reduction in the global burden of disease caused by malaria (Adamson, 2004). It is assumed in this analysis that the 16% reduction equivalently reduces malaria-specific morbidity and mortality rates in

the children aged 6-59 months who had received the Vitamin A supplement and had not already been protected by the VaV bed nets. The number of cases averted is further scaled down by 5/12 (4/12 – 6/12) as the effect of Vitamin A lasts only 4-6 months. The calculations for this analysis as well as the GBD disability weights and durations can be found in Appendix VI.i.

Table 10: Averted YLDs, YLLs and DALYs from malaria due to Vitamin A supplementation in children 6-59 months

Case type	Cases averted	YLDs averted	YLLs averted	DALYs averted
Episode	38,130 (30,314 – 45,756)	146 (116 – 175)		146 (116 – 175)
Neurological Sequelae	389 (309 – 467)	6871 (5458 – 8248)		6871 (5458 – 8248)
Anaemia	1525 (1213 – 1830)	0.37 (0.3 – 0.4)		0.37 (0.3 – 0.4)
Deaths	362 (288 – 435)		13,575 (10,800 – 16,313)	13,575 (10,800 – 16,313)
Total		7017 (5574 – 8423)	13,575 (10,800 – 16,313)	20,592 (16,374 – 24,736)

Table 10 details the additional malaria-specific cases and DALYs averted from Vitamin A supplementation, controlling for the effect of the bed nets also distributed during the VaV campaign. Vitamin A supplementation increased the malaria-specific reduction in DALYs by an additional 13%.

6.6.2 Reduction in all-cause mortality

Both Vitamin A supplements and insecticide-treated bed nets have been demonstrated to reduce all-cause child mortality. Beaton (2003) reported that Vitamin A supplements lead to a 23% in the all-cause mortality rate in children aged 6-59 months

and the protective efficacy of insecticide-treated bed nets in reducing all-cause child mortality was reported by Lengler (2004) to be 17% (95% CI: 0.1 – 0.24).

The reduction in all-cause mortality due to Vitamin A supplementation is first scaled by 5/12 (4/12 – 6/12) as was done previously and then the VAD-specific averted deaths are subtracted to find the net all-cause deaths averted from Vitamin A supplementation. The all-cause deaths averted from LLIN use are calculated by multiplying the 17% protective efficacy rate by the number of children using the VaV bed nets times the child mortality rate and then subtracting the malaria-specific deaths determined earlier from this number. The total minimum number of all-cause deaths averted is the difference between the maximum of these averted all-cause death estimates and the total number of disease-specific deaths averted. The maximum number of all-cause deaths averted is the sum of the two averted all-cause death estimates, provided this number is less than the expected number of under-five child deaths in Angola. These calculations can be found in Appendix VI.ii.

Table 11: Reduction in all-cause mortality from Vitamin A Supplementation and IITNs

Age	Deaths averted	YLLs averted	DALYs averted
<5	26,383 (0 – 65,028)	989,363 (0 – 2,438,550)	989,363 (0 – 2,438,550)

Thus the indirect effects of Vitamin A supplementation in reducing both malaria morbidity and all-cause mortality and the effect of malaria bed net use in reducing all-cause mortality as well, is seen above in Table 11. This contribution in averting a further 200,000 DALYS represents approximately 20% of the total averted DALYs in children under-five attributed to the VaV campaign.

7 Results

7.1 Health Outcomes

The combined outcomes in terms of cases, deaths and DALYS averted are seen below in Tables 12 and 13. Due to families sharing bed nets and the herd immunity effects from the polio and measles vaccines, 41,874 additional DALYS were averted from the VaV campaign.

Table 12: Health outcomes from campaign (children <5 only)

Disease	Cases Averted	Deaths Averted	YLDs averted	YLLs averted	DALYs averted
Malaria (Averted from bed net usage)	63,497	1754 (779 - 2455)	33,485 (15,010 – 46,785)	65,767 (29,230 – 92,074)	99,252 (44,240 – 138,859)
Malaria (Averted from Vit A)	38,130 (30,314 – 45,756)	362 (288 – 435)	7017 (5574 – 8423)	13,575 (10,800 – 16,313)	20,592 (16,374 – 24,736)
Measles	13,230 (6,878 - 22,068)	1323 (688 – 2,207)	156.9 (82 – 262)	49,613 (25,800 – 82,763)	49,770 (25,882 – 83,025)
VAD	868,050 (694,440 – 1,041,660)	16,490 (15,233 – 17,078)	21,596 (8638 – 55,532)	801,394 (641,115 – 961,673)	822,989 (649,753 – 1,017,204)
Polio	10,474 (1055.6 - 19,892.6)	49.27 (0.264 - 98.28)	724.6 (73.0 - 1376.3)	1847.7 (9.9 – 3685.5)	2572.4 (82.9 – 5061.8)
STHs	1,299,600	0	4931.74 (4,931.7 – 4,932)	0	4931.74 (4,931.7 – 4,932)
All-cause	/	26,383 (0 – 65,028)	/	989,363 (0 – 2,438,550)	989,363 (0 – 2,438,550)
Total		46,361 (16,988 – 87,301)	67,911 (34,309 – 117,310)	1,921,560 (706,955 – 3,595,059)	1,989,471 (741,264 – 3,712,369)

Table 13: Health outcomes from campaign (all persons)

Disease	Cases Averted	Deaths Averted	YLDs averted	YLLs averted	DALYs averted
Malaria	128,858	3395 (1508 – 4752)	33,734 (15,259 – 47,034)	94,022 (41,788 – 131,631)	127,756 (57,047 – 178,665)
Malaria (Averted from Vit A)	38,130 (30,314 – 45,756)	362 (288 – 435)	7017 (5574 – 8423)	13,575 (10,800 – 16,313)	20,592 (16,374 – 24,736)
Measles	18,123 (9,421 – 30,231)	1813 (942 – 3023)	214.9 (113 – 359)	62,721 (32,598 – 104,601)	62,936 (32,711 – 104,960)
VAD	868,050 (694,440 – 1,041,660)	16,490 (15, 233 – 17,078)	21,596 (8638 – 55,532)	801,394 (641,115 – 961,673)	822,989 (649,753 – 1,017,204)
Polio	11,510 (1160 - 21,860)	54.15 (0.29, 108)	782 (78.8 – 1485.2)	1993.9 (10.7 – 3977.1)	2775.9 (89.5 – 5462.3)
STHs	1,299,600	0	4931.74 (4,931.7 – 4,932)	0	4931.74 (4,931.7 – 4,932)
All-cause	/	26,383 (0 – 65,028)	/	989,363 (0 – 2,438,550)	989,363 (0 – 2,438,550)
Total		48,497 (17,971 – 90,424)	68,276 (34,595 – 117,765)	1,963,069 (726,312 – 3,656,745)	2,031,345 (760,906 – 3,774,510)

7.2 Cost-effectiveness

The cost-effectiveness of the campaign is determined by dividing the total cost of the campaign ($15.8 million) by the total number of DALYs averted. The cost-effectiveness in terms of DALYs and deaths averted for both children under-five alone and for all ages can be seen in Appendix VII.i. Based on the WHO's guidelines for cost-effective health programs, the VaV campaign can easily be classified as very cost-effective as the 2006 Angolan GDP/capita at $2643 is more than 300 times that of the cost per DALY averted in children. Furthermore, the VaV campaign proved to be more cost-effective than all 246 interventions reported for the AFR D region, and half the cost

per DALY averted of the most cost-effective WHO intervention (Vitamin A fortification at 95% coverage).

7.3 Ranking the interventions

Combining health interventions to minimize overheard costs has undoubtedly made the VaV campaign as a whole cost-effective. However, the relative cost of each intervention varies widely, and the cost-effectiveness of each intervention is thus compared below by its relative cost and the number of DALYs and deaths averted. The costs per unit of each intervention as reported by the Measles Initiative are listed in Table 14 below, assuming the various transportation and cold storage requirements of each intervention are negligible. Only the child data is used here to rank the interventions, as promoting child health was the primary goal of this campaign. Averted all-cause deaths have been used to estimate the total number of lives saved from LLIN use and Vitamin A supplementation. To estimate the DALYs averted, the all-cause estimates were added to the previously calculated averted YLDs for LLINs and Vitamin A. It should be noted that the cost-effectiveness results reported below in Tables 14 and 15 are only intended to rank the interventions and cannot be compared to those reported in the literature as the overhead costs have been omitted.

The rationale for the WHO's recommendation of supplementing children in the developing world with Vitamin A can clearly be seen in Tables 14 and 15 below. It is by far the most cost-effective intervention at $1.73 per death averted and $0.04 per DALY averted (only twice the unit cost). Also, despite only targeting the second fewest number of children of the five interventions, it is responsible for averting the most deaths and DALYs. However, if a governing body was to prioritize reducing the maximum number

of cases of a certain illness, it can be seen in Table 12, that de-worming medicines would be the optimal choice.

Table 14: Ranking the cost-effectiveness of each intervention by the number of deaths averted

Intervention	Cost per unit ($)	Total units	Total cost	Deaths averted	Cost per death averted ($)	Ranking
LLINs	5.50	800,000	4,400,000	10,518 (4764 – 16,546)	418.33 (265.93 – 923.59)	2
Measles vaccine	0.30	3,210,160	963,048	1323 (688 – 2207)	727.93 (436.36 – 1399.78)	3
Polio vaccine	0.13	3,600,000	468,000	49 (0 – 98)	9551.02 (4775.51 – undefined)	4
Vitamin A supplement	0.02	2,880,000	57,600	33,372 (18,263 – 48,482)	1.73 (1.19 – 3.15)	1
De-worming medicines	0.02	3,240,000	64,800	0	undefined	5

Table 15: Ranking the cost-effectiveness of each intervention by the number of DALYs averted

Intervention	Cost per unit ($)	Total units	Total cost	DALYs averted	Cost per DALY averted ($)	Ranking
LLINs	5.50	800,000	44,000,00	427,910 (193,660 – 667,260)	10.28 (6.59 – 22.72)	2
Measles vaccine	0.30	3,210,160	963,048	62,936 (32,711 – 104,960)	15.30 (9.18 – 29.44)	4
Polio vaccine	0.13	3,600,000	468,000	2776 (90 – 5462)	168.59 (85.68 – 5200.00)	5
Vitamin A supplement	0.02	2,880,000	57,600	1,280,063 (699,075 – 1,882,030)	0.04 (0.03 – 0.08)	1
De-worming medicines	0.02	3,240,000	64,800	4932 (4932 – 4932)	13.14 (13.14 – 13.14)	3

7.4 Child mortality

The role of the VaV campaign in reducing Angola's child mortality rate is particularly important as child mortality is a common gauge of child health and development and one of the three indicators of the fourth MDG. Using the 2006 child mortality rate of 176 deaths per 1000 live births and the estimated deaths averted from Table 12, a 7.1% reduction in the child mortality rate in the year following the VaV campaign was determined (calculations in Appendix VII.ii). Unfortunately, this is only a temporary reduction in the under-five mortality rate, as almost half of the averted deaths were due to the Vitamin A supplementation.

7.5 Returns to education

Van der Gaag and Tan (1996) determined the returns to the educational system in Bolivia following the implementation of a maternal and child nutrition program. Using their results, the returns to the Angolan educational system following the VaV campaign are estimated here. As they assumed a 20% enrolment rate with a 35% dropout rate and 10% repetition rate, the estimated returns in Angola will likely be much higher as the World Bank reports a 40% enrolment rate in Angola in 2008 (no data available for 2006). The reduction in the Bolivian child mortality rate from 162/1000 to 105/1000 (35% reduction) yielded an increase in the net present value of the education system from $966,212 to $1,031,933 (6.8%). Thus, for an 11% reduction in the child mortality rate, a 1.38% increase in the net present value of the Angolan educational system is estimated. This increase is from the additional 20% of survived children alone, ignoring the additional benefits of healthier children who are able to perform better in the classroom.

7.6 Long-term benefits

In this analysis, only the immediate benefits of the interventions within a one-year time span of the campaign have been calculated. This, however, does not accurately represent the long-term benefits of the campaign, as both the polio and measles vaccines provide immunity for life and the bed nets will provide protection for at least three years with proper use before requiring retreatment with insecticide.

Retrospectively, it can be seen that the VaV campaign held off polio infections for three years, as prior to the campaign the virus remained endemic in Angola when vaccination rates were less than 50%. The outbreak in neighbouring Congo in 2010 demonstrated how critical continuous, high coverage vaccination is, and the global cost to society in having to contain such an outbreak. The inconsistency in the reporting of measles cases makes it difficult to extrapolate the exact number of cases averted, especially in the long run. However, following the 2003 vaccination campaign, with 95% coverage in children under-fifteen years, there was a 98% drop in reported cases in 2004 compared to 2003 and a 99.8% drop compared to 2002 rates. Thus it is clear that vaccination is highly effective. The 2005 caseload is nine times that of 2004, and the 2006 caseload in 26 times that of 2004, which demonstrates the need for annual high-coverage vaccination. Extrapolating from the 2003 campaign, it can therefore be estimated that the 2006 VaV campaign with 97% coverage, staved off a further 78% and 36% of cases in the second and third year following the campaign.

8 Limitations

The children saved by the polio vaccine are most likely also the ones with the highest susceptibility to any one of these additional illnesses. Thus there may be double counting in that one death averted from the measles vaccine may be the same life saved from the Vitamin A supplement, for example. However, as it is also the children from the poorest families who tend to have the highest morbidity and mortality rates, the combined campaign offers these children the greatest chance to break the health-inflicted cycle of poverty and will yield the highest returns to education due to higher enrolment, attendance and participation rates.

9 Discussion

The decision as to which diseases should receive top priority in terms of funding is not an easy one. The use of DALYs in cost-effectiveness analysis has attempted to remedy the cases versus deaths debate, but there is still a fair amount of discussion as to whether or not they accurately capture potential cognitive delays or decreased school attendance and participation. Table 15 does demonstrate however, that in terms of cost-effectiveness per DALY saved, LLINs, Vitamin A supplements, measles vaccines and de-worming medicines are all roughly comparable interventions, with all costs per DALY averted being less than $20. This, however, does not account for the costs of treatment, to either the individual or the healthcare system.

A country looking to maximize returns to investments in health might rank health programs by expected returns to education from healthier children. If this is the case, then de-worming school children, which has been demonstrated to improve school enrolment, attendance and participation rates and increase income in the long term (Bleakley, 2007),

might be opted for over measles vaccination programs despite the potential global implications of failing to prevent a viral epidemic.

Another concern that must be accounted for is the potential costs of failing to control communicable diseases. It was noted earlier that the cost of the emergency clean-up campaign from the 2010 poliovirus outbreak in the Congo was $22 million (2010 USD). This indicates that the cost of the VaV campaign has easily paid for itself by the polio vaccines alone, from staving off a similar outbreak. However, the unpredictability in the spread of the virus could also mean that the non-intervention polio immunization program in Angola might be sufficient to keep the virus at bay by itself and these unseen savings may dissuade a government from investing in such a campaign. Furthermore, as the poliovirus has been shown to easily traverse international borders, Angola has a further disincentive to invest in preventive measures, knowing the international community has enough incentive themselves to step in and organize an emergency vaccination campaign, if the need should arise.

The choice of which interventions to include in such a combined, child health campaign thus depends on a variety of financial, ethical, logistical and political issues. The WHO's 2004 GBD report identified diarrheal diseases as causing a loss of 6658 DALYs per 100,000 – one third of all DALYS caused by infectious and parasitic diseases – yet oral rehydration salts (ORSs) are rarely distributed during child health campaigns. At only a few cents per treatment, the salts are highly accessible. Unfortunately, case management of diarrheal diseases through the use of ORSs has been declining globally despite diarrheal diseases being the second leading cause of child mortality (Ram, 2008). Thus further research might include the distribution of ORSs during such child health

campaigns. The WHO also heavily advocates for the addition of zinc supplementation to child vaccination programs and this can also be further studied.

Of the childhood cluster diseases analyzed in the GBD, pertussis was the cause of the most DALYs lost, followed by tetanus, measles and diphtheria. The combined burden of diphtheria, pertussis and tetanus (DPT) was six times that of measles and the cost of the DPT vaccine is less than that of the measles vaccine. Few cost-effectiveness studies of the DPT vaccine have been carried out and it is unclear why these three childhood illnesses have been understudied. Further research is required as to whether DPT vaccinations, with some combination of the other interventions will yield the same results as found here.

Poor sanitation is often blamed for the continued endemicity of STHs, measles and polio, as well as a number of other diseases afflicting Angola, including diarrheal diseases, cholera and DPT. Thus the cost-effectiveness of constructing infrastructure to mitigate the spread of such infections is another area requiring further research.

Lastly, as Angola is still in the process of rebuilding much of their infrastructure while attempting to reboot their economy, allocating funds between ministries, let alone within the health sector, is a crucial decision. Comparing the returns to investing in health, education, transportation or industry would provide a post-conflict country a clearer idea of the optimal allocation of its budget.

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11 Appendices

I Malaria

I.i Parameters

Severe case rate (children <5) = 9.27%
Severe case rate (persons ≥5) = 4.10%
Death rate (children <5) = 0.95%
Death rate (adults ≥5) = 0.42%
Death rate of severe cases (children <5) = 10.25%
Death rate of severe cases (adults ≥5) = 10.25%

PE of clinical cases (stable endemic) = 50%
PE of clinical cases (unstable endemic) = 62%
PE of severe cases = 45% (0.2 – 0.63)

Case rate of neurological sequelae (children) = 11%
Case rate of neurological sequelae (adults) = 0%

Case rate of severe malarial anaemia (all ages) = 4%

Table 16: GBD disability weights and durations for malaria episodes, symptoms and deaths

Case type	Disability weight	Duration
Episode	0.191	0.02
Neurological Sequelae	0.471	37.5
Anaemia	0.012	0.02
Deaths		
<5		37.5
5-14		30
>14		12.5

II Measles

II.i Parameters

Number of children vaccinated = 3,210,160
Total number of children in 9-59 month age group = 3,282,707

Seroconversion rate (9-11 months) = 85%
Seroconversion rate (12-59 months) = 95%

The 2006 WHO Measles Surveillance bulletin reported that measles outbreaks in 2005 mainly affected children under the age of five (73%) and unvaccinated persons (81%):
Measles caseload in children <5 = 73%
Measles caseload in children 5-14 = 95%-73% = 22%
Measles caseload in persons ≥5 = 5%

Underreporting ratio = 10%

Duration (years) = 0.078
Disability weight = 0.152

II.ii The 2006 proportion of immunized children between the age of 9 and 59 months, with and without the intervention

Measles immunization rates of one year olds were 64%, 45% and 48% in the three years following the 2003 vaccination campaign. Since the 2006 campaign reached 97% of children 9-59 months, the number of children between 9 and 59 months is estimated to be 3,309,443. Assuming equal proportions in each year range, the immunized population without the intervention in 2006 is estimated in Table 17, and with the intervention, in Table 18.

Table 17: Determining the 2006 proportion of immunized children between the age of 9 and 59 months, based on non-intervention vaccination rates

Age (months)	Population	Vaccination coverage	Seroconversion	Immunized	Susceptibles
9-11	194,673	.523*	.85	86,542	108,131
12-23	778,693	.48	.85	317,707	460,986
24-35	778,693	.45	.85	297,850	480,843
36-47	778,693	.64	.85	423,609	355,084
48-59	778,693	.95	.925	684,276	94,417
Total:	3,309,445			1,809,984	1,499,461

*Averaged from previous 3 years coverage rates.

In 2006, without the intervention:
Immunized population = 55%
Susceptible population = 45%

Table 18: Determining the proportion of immunized children between the age of 9 and 59 months, based on the 97% vaccination coverage rate from the 2006 intervention

Age (months)	Population	Vaccination coverage	Seroconversion	Immunized	Susceptibles
9-11	194,673	.97	.85	160,509	34,164
12-59	3,114,772	.97	.95	2,870,262	244,510
Total:	3,309,445			3,030,771	278,674

In 2006, with the intervention:

Immunized population = 91.6%

Susceptible population = 8.4%

II.iii Determining the averted caseload of measles

Table 19: Estimating the ratio of measles cases to the number of immunized children under-five

	2002	2003	2004	2005	2006	2007
Cases reported	11,945	1,196	29	258	765	1,014
Estimated total cases	119,450	11,960	290	2,580	7650	10,014
Population	15,164,026	15,646,832	16,135,465	16,617,589	17,089,111	17,554,585
Population <5 (18.7%: MIS)	2,835,673	2,925,958	3,017,332	3,107,489	3,195,664	3,282,707
Number of cases <5 (73%: PI)	87,199	8,731	212	1,883	5,585	7,310
Measles rate <5 (%)	3.08	0.298	0.007	0.061	0.175	0.223
-log (Measles rate <5)	3.48024	5.81583	9.567	7.402	6.348	6.1057
Reported vaccination rate of one year olds (%)	62	45	64	45	48	88
Vaccination rate of <5 (%)*	56	95	87	75	97	95
Immunized rate <5**	52	90	82	70	92	89
Ratio***		0.11184	0.1063	0.09027	0.09069	0.06637

*Estimated from previous 4 years (as vaccination occurs after 9 months) or from campaign data. Assumed no underreporting, as vaccination can only take place in a health centre.

** Average seroconversion rate = 93% (85% for 9-11 and 95% for 12-23 months) for routine vaccination; or 94.4 % (85% for 9-11 months and 95% for 12-59 months) from campaigns.

***Ratio of –log(measles rate <5) to the previous year's immunization rate.

Table 19 lists the case rates and immunization rates for the five years prior to the VaV campaign in order to estimate the relationship between the two variables. As the number of reported cases in 2007 is unusually high, particularly following a vaccination campaign with a 97% coverage rate, it is assumed that the underreporting ratio did not hold and the 2007 ratio is thus ignored in further calculations. The mean ratio of the log of the measles case rate in children <5 to the previous years' <5 immunization rate is 0.09978, (min = 0.09027, max = 0.11184). Using the immunized proportions as determined above, the measles case rates are estimated to be:
Non-intervention: $\log^{-1}$ (-0.09978)(55) = 0.0041377 (0.0021309 - 0.0069790)
With intervention: $\log^{-1}$ (-0.09978)(91.6) = 0.000107352 (0.00003555 - 0.00025641)
Averted measles case rate = 0.0041377 - 0.000107352 = 0.00403035

Thus,
Averted cases in children <5 = 0.00403035 * 3,282,707 = 13,230 (6,878 - 22,068)
Averted cases in children [5-14] = (.22/.73) * 13,230 = 3987 (2072 – 6651)
Averted cases in adults = (.05/.73) * 13,230 = 906 (471 – 1512)

III Vitamin A Deficiency

III.i Parameters

A 1999 survey found VAD (serum retinol <0.70micromol/L) among 64.3% (95% CI = (59.4 - 68.9)) of children under the age of five and night blindness (the first symptom of xeropthalmia) prevalence to be 1.4% (95% CI = (0.7, 3.0)) (WHO, 2007a). Eleven percent of xeropthalmia cases in Africa in 1990 resulted in corneal scarring (Rastogi & Mathers, 2002), thus the prevalence of corneal scarring in Vitamin A deficient children is estimated to be 0.154% (95% CI = (0.077 - 0.33)). However, since these rates are prevalence rates and not incidence rates, supplementation only decreases the occurrence of VAD and its related conditions by four to six months. Assuming children under-five are at highest risk of long-term complications to VAD, the estimated decrease in the incidence of VAD in children aged 6-59 months is 4/54 – 6/54.

Prevalence of VAD = 64.3% (59.4, 68.9)
Prevalence of Xeropthalmia = 1.4% (0.70 - 3.00)
Prevalence of Corneal Scars = 0.154% (0.08 - 0.33)

Deaths per annum due to VAD = 34,000
Incidence rate scaling factor (VAD, Xeropthalmia, Corneal scar, Deaths) = 5/12 (4/12 - 6/12)
Number of children who received supplement = 3,240,000
Total number of children in eligible age group = 3,340,296 (Assume 97% coverage as with measles)
VAD death rate per case = 34,000/(0.643*3,340,296) = 1.5830%

Disability weight of xeropthalmia = 0
Disability weight of corneal scar = 0.277

IV Poliomyelitis

IV.i Parameters

Clinical caseload (endemic case) = 58
Clinical caseload (epidemic case) = 1093
Clinical caseload (mean) = 575.5
Percentage of caseload affecting children <5 = 91%
Percentage of caseload affected persons ≥5 = 9%
Percentage of clinical cases of total infections = 5%
Percentage of paralysis cases of total infections = 0.5%
Death rate of paralysis cases (endemic case) = 5%
Death rate of paralysis cases (epidemic case) = 9.88%

Disability weight of paralytic cases = 0.369
Duration of paralysis (<5) = 37.5
Duration of paralysis (≥5) = 30

V Helminth Infections

V.i Parameters

Number of children who received de-worming medicines = 2,880,000
Intestinal obstruction = lower estimate of disability*
Hookworm-caused anaemia = 0.1 – 0.5/1000 cases per year*
Contemporaneous cognitive deficit = lower estimate of disability*
Cognitive impairment = 3% of upper estimate of disability*
Massive dysentry syndrome = 5% above lower estimate of disability*
Proportions of infected children <5 at risk of disability** (min, max)
    Roundworm = 0.05, 1.84 / 130 = 0.0003846, 0.014154
    Whipworm = 0, 0.04 / 96 = 0, 0.000417
    Hookworm = 0, 0 / 41 = 0, 0
Proportions of high intensity infections***
    Roundworm = 58,100,000/1,470,000,000 = 0.03952
    Whipworm = 26,600,000/1,050,000,000 = 0.02533
    Hookworm = 59,900,000/1,300,000,000 = 0.04608
*Brooker (2010)
**Bundy et al (2004)
***WHO Global Burden of Disease: Estimates for 2001, reported in Brooker (2010)

Table 20: GBD disability weights and durations for episodes and complications of roundworm, whipworm and the hookworms

Disease	Symptom	Disability weight	Duration (years)
Roundworm	High intensity infection	0	0.5
	Contemporaneous cognitive deficit	0.006	0.5
	Cognitive impairment	0.463	37.5
	Intestinal obstruction	0.024	0.5
Whipworm	High intensity infection	0	0.5
	Contemporaneous cognitive deficit	0.006	0.5
	Massive dysentry syndrome	0.116	0.5
	Cognitive impairment	0.024	37.5
Hookworms	High intensity infection	0.006	0.5
	Anaemia	0.024	0.5

V.ii Estimation of number of children <5 at risk of disability from STHs

Table 21: Prevalence of high intensity, disability causing helminth infections among children under-five

Species	Preva-lence (5-14)	Age-ratio (Preschool:School aged)	Preva-lence (<5)	Number of cases averted (for 6 months)(<5)	Proportion of infected population at risk of disability, scaled by age	Number at risk of disability
Roundworm	.39	0.75:1.2	.24375	702,000	(0.0003846 - 0.014154)	(270 - 9,936)
Whipworm	.30	0.75:1.2	0.1875	540,000	(0 - 0.000417)	(0 - 225)
Hookworms	.07	0.2:0.7	0.02	57,600	(0, 0)	(0, 0)
Total				1,299,600		(270 – 10,161

VI Indirect Effects

VI.i Effect of Vitamin A on reducing malaria morbidity and mortality

Per annum reduction of malaria cases and deaths due to Vitamin A = 16%
Duration of VAS effectiveness scaling factor = 5/12 (4/12 – 6/12)
Actual reduction from Vitamin A post-VaV = 6.7% (5.3% - 8%)

Total potential malaria cases (children <5) in 2006 = 707,738.7357
Total averted malaria cases (children <5) in 2006 = 63,497

Total non-averted cases (children <5) in 2006 = 644,242
Total malaria cases (children 6-59 months) in 2006 = (54/59)*644,242 = 589,645
Children with malaria who also received Vitamin A (assuming 97% coverage) = 571,956
Averted malaria cases due to Vitamin A = 38,130 (30,314 – 45,756)
Averted severe malaria cases (9.27% of cases) = 3,535 (2810 – 4242)
Averted malaria deaths (0.95% of cases) = 362 (288 – 435)
Averted cases of neurological sequelae (11% of severe cases) = 389 (309 – 467)
Averted cases of severe malaria-induced anaemia (4% of cases) = 1525 (1213 – 1830)

VI.ii Reduction in all-cause mortality

Reduction from VAS:
Per annum reduction of all-cause child mortality = 23%
Duration of VAS effectiveness scaling factor = 5/12 (4/12 – 6/12)
Actual reduction from Vitamin A post-VaV = 9.6% (7.7% - 11.5%)
Number of children receiving Vitamin A supplement = 3,240,000
Child mortality rate (2006) = 0.176
All-cause deaths in children receiving Vitamin A supplement = 570,240
Averted all-cause deaths from Vitamin A supplementation = 54,743 (43,908 – 65,578)
VAD deaths averted = 21,371 (17,096 – 25,645)
Net all-cause deaths averted (All-cause deaths – VAD deaths) = 33,372 (18,263 – 48,482)

Reduction from LLINs:
PE of bed nets in all-cause child mortality = 17% (0.1 – 0.24)
Number of children using VaV nets = 410,169
Child mortality rate = 0.176
All-cause deaths in children <5 using VaV nets = 72,190
Averted all-cause deaths from bed net usage (children <5) = 12,272 (7219 – 17,325)
Malaria deaths averted = 1754 (779 - 2455)
Net all-cause deaths averted (All-cause deaths - malaria deaths) = 10,518 (4764 – 16,546)

VAD deaths averted = 21,371 (17,096 – 25,645)
Measles deaths averted in children = 1323 (688 – 2,207)
Malaria deaths averted in children (due to bed nets alone) = 1754 (779 - 2455)
Polio deaths averted in children = 49.27 (0.264 - 98.28)
Total deaths averted in children = 24,497 (18,563 - 30,405)
Total expected deaths in children <5 = 0.176*(3,600,000/.97) = 653,199

Minimum additional all-cause deaths = (Max number of all-cause deaths averted (Vitamin A supplementation, bed nets)) – Total deaths averted = 33,372 (18,263 – 48,482) - 24,497 (18,563 - 30,405) = 8875 (0 – 29,919)

Maximum additional all-cause deaths (no overlap assumed between VAS and LLINs) = Sum of all-cause deaths averted from Vitamin A supplementation and bed net usage = 33,372 (18,263 – 48,482) + 10,518 (4764 – 16,546) = 43,890 (23,027 – 65,028)

Total additional all-cause deaths averted (averaged from min and max) = 26,383 (0 – 65,028)

VII Results

VII.i Cost-effectiveness

Cost of the campaign = $15,800,000 (2006 USD)

Children alone:
Cost per death averted = 15,800,000 /46,361 (16,988 – 87,301) = $340.80 (180.98 – 930.07)
Cost per DALY averted = 15,800,000/1,989,471 (741,264 – 3,712,369)= $7.94 (4.26 – 21.31)

All ages:
Cost per death averted = 15,800,000/48,497 (17,971 – 90,424) = $325.79 (174.73 – 879.19)
Cost per DALY averted = 15,800,000/2,031,345 (760,906 – 3,774,510)= $7.78 (4.19 – 20.76)

VII.ii Child Mortality

Calculate total decrease in child mortality:
Deaths averted (children <5) = 46,361 (16,988 – 87,301)
Total number of children (3,600,000/.97) = 3,711,340
Deaths without campaign = .176*3,711,340 = 653,196
Actual number of deaths following VaV = 653,196 - 46,361 (16,988 – 87,301)= 606,835 (565,895 - 636,208)
Child mortality rate following VaV = 0.1635 (0.1525 – 0.1714)