Cost Benefit Analysis of Vitamin D supplementation to prevent rickets in Ethiopia

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Table of Contents

Acronym

UNICEF	United Nations International Children's Emergency Fund
WHO	World Health Organization
Et al	And others
DALY	Disability Adjusted Life Years
YLD-	Years Lived with Disability
YLL	Years Life Lost
P	Prevalence
DW	Disability Weight
ICER	Incremental Cost- Effectiveness ratio
GNI	Gross national income

Abstract

Background

In Ethiopia where diseases related to nutritional deficiency is common due to under nutrition, vitamin D deficiency is one of the shareholders. The alarming side of vitamin D deficiency is its strong association with clinical complications pausing higher mortality and morbidity. More specifically, the consequence of vitamin D deficiency is prominent on growing children. "The global prevalence of vitamin D deficiency (defined as 25(OH)D levels <30 nmol/L) was 15.7% between 2000 and 2022."(Cui et al., 2023). “The pooled prevalence of vitamin D deficiency among healthy children was 50.06%. The pooled prevalence among the sick children was 39.36 %”.(Shaka et al., 2022). Speaking of epidemiologic statistics in regards to vitamin D deficiency in Ethiopia, it has been reported that it is quite prevalent (41%) among children in Ethiopia and is commonly associated with protein energy malnutrition, infectious diseases of various cause including respiratory tract, anemia, congestive heart failure and gastrointestinal tract risk recurrent diarrhea and mal absorption. (Assessment of Knowledge, Attitude, and Practice of Sunlight Exposure of Infants among Mothers Attending in Governmental Health Facilities in Farta District, South Gondar Zone, North West Ethiopia, 2018 - Gedamu - 2019 - International Journal of Reproductive Medicine - Wiley Online Library, n.d., p. 2). As per our paper, the DALY of vitamin D supplementation and the DALY averted would be 0.033 per 100 children and 2.0667 per 100 children respectively. An ICER of 148 was calculated meaning that for each DALY averted by giving vitamin D supplementation, we save $148 dollars compared to the status quo.

Methodology

This study measures the cost-effectiveness of preventive Vitamin D supplement based on the cost of the intervention and the DALY averted. After the prevalence of Rickets, burden of its complications and DALY with the status quo were calculated and subsequently the cost of Vitamin D supplementation and other indirectly and directly related costs were assessed. DALYs are more

commonly used in cost-effectiveness analyses for developing countries, where rickets is often a more significant problem. (Neumann et al., 2018) In addition Cost-per-DALY studies are commonly used in low and lower-middle income countries. DALYs are used in the Global Burden of Disease studies, which provide comprehensive data on disease prevalence and impact across countries. This makes it easier to contextualize rickets within the broader health landscape of a country or region.

Conclusion Overview

Vitamin D deficiency is a worldwide problem despite its accentuated effect on the underdeveloped nations like Ethiopia. It leads to Rickets which is more specific to children who face vitamin D deficiency. This paper focuses on the affected pediatric subgroup of the society. The socioeconomic and health burden of Rickets to children and their families is significant when compared to the expense of the intervention proposed in this paper. Therefore, the cost of intervention is effective and efficient in preventing Rickets and avoiding morbidity and mortality associated with it. As a result, it is to be suggested to all responsible bodies that this model would not only be economically effective, but also efficient and therefore for sufficient budget to be allocated.

Introduction

Vitamin D deficiency, which commonly manifests itself in infants as a growing bone disease known as Rickets, has been a hazardous clinical condition in Ethiopia. The human body depends on nutritional components to suffice its Vitamin D requirements. Newly born neonates and infants require adequate amount of vitamin D due to their relatively higher bone mineralization rate. Therefore, deficiency of Vitamin D in this period of pediatric life causes delayed and weak bone formation. The paradox of vitamin D's imperativeness to a new born and its deficiency in breast milk has made things worse, especially for underdeveloped countries. Mothers with poor

nutritional state have a higher propensity of having even lower Vitamin D content in their breast milk. The circumstances in Ethiopia are no more different than what has been described in regards to all other underdeveloped countries. Moreover, the fact that delayed presentation to health centers and the poor medical attention seeking culture are deep rooted in Ethiopia and countries like Ethiopia worsens things. This is because the earlier the diagnosis and intervention of Rickets the better. If Rickets is not diagnosed and treated early the rate and intensity of its complications are more consequential. Therefore, it is imperative that policies and responsible bodies should be aggressive in adequately addressing the prevention of Rickets in a wider scale.

Multiple studies from the past have concluded that humans can be able to synthesize adequate amount of functional vitamin D level within their skin by the conversion of sunlight exposure (*The journal of clinical investigation, 2006, resurrection of vitamin D deficiency and rickets*). Thus, mothers and care givers have been thought to expose their children to sunlight on daily bases as it is the most practical and effective way to suffice the vitamin D requirements of infants. This has been the mainstay mechanism of providing the necessary amount of vitamin D to infants especially in tropical regions of the world like Ethiopia. To the defense of this notion, morning sunlight prevails almost in all seasons of the year especially in tropical regions of the world making sunlight exposure the most plausible method of fulfilling the demand. However, many kinds of blunders and misconceptions, poor adherence to disciplined daily sunlight exposure, and child neglect have contributed to the higher incidence of rickets and its subsequent complications. These challenges are worth noting and are of considerable magnitude when we see the problem set in light of the lifestyle of the Ethiopian population. One can easily notice that the social intimacy of the Ethiopian society is strong enough that misconception and malpractices are contagious leading mass destruction. The conviction that sunlight exposure is a layman activity and should not be attended by any health professional contributes to the propagation of the failures in executing sunlight exposure to children effectively and efficiently.

Providing Vitamin D supplement to infants in different forms has been proposed and implemented in different parts of the world to prevent rickets and its complications. Fortifying formula milks

with adequate amount of vitamin D, and providing daily oral vitamin D drops are the basic methods of vitamin D supplementation. These mechanisms of supplying vitamin D are more objective, measurable, reliable, and easy to adhere to. In addition, the above mentioned mechanisms of supplementing vitamin D are convenient irrespective to the geographical area. Therefore, analyzing the cost effectiveness of treating rickets, and its short and long term complications—which is high likely to happen if we solely rely on mere sunlight exposure as explained earlier—in contrast to the cost effectiveness of vitamin D supplementation is the main objective of this paper. The cost effectiveness model that will be investigated on this paper will specifically be based on supplemental vitamin D drops. Even though fortified formula milk has been mentioned in this introduction it was only for a brief overview as it is legitimately one possible way of supplementing children with vitamin D.

Objective

The objective of this paper is to undergo cost-effective analysis of undergoing preventive vitamin D supplement to newly born neonates and infants until their first year of life. This age ceiling was chosen considering the fact that children are highly probable of developing rickets in this age group if they are not provided with adequate vitamin D supplement. On top of this, the average time for a child to stand on foot unsupported is approximately eleven months after which active vitamin D supplementation is no more required. From the study conducted at Jimma University Specialized Hospital (JUSH), the prevalence of rickets was found to be 10.5% among children admitted to the pediatric ward (Chala et al.,2014). 170 rachitic children were identified out of 1620 children admitted over a 3-year period (Chala et al.,2014). However, it is to be noted that this figure is an over estimation as the estimation was made from hospital admitted pediatric patients, which clearly is much higher than the prevalence of Rickets in the general population. Therefore, since the prevalence of Rickets in the general population was not found we have decided to use the rickets prevalence range of an approximate 5% as indicated in a study of rickets-like bone deformities obtained in 6221 rural Gambian children aged < 5 years (Helen et al. 2015). As of 2024, Ethiopia's

total population is approximately 128.4 million. Assuming about 16% of the population is under 5 years old, which is a common estimate for developing countries, according to the 2024 UNICEF estimate(Children in Ethiopia | UNICEF Ethiopia, n.d.);

128.4 million * 0.16 = 20.54 million children under 5 is the total number of under 5 children in Ethiopia.

Subsequently to find the total number of children under 5 with Rickets in Ethiopia;

Total number of under 5 children in Ethiopia (20.54 million) * the prevalence (0.05) = 1.02 million.

Status quo

This paper defines the status quo as an exclusive sunlight exposure. Depending on mere sunlight exposure to suffice the Vitamin D requirement of newly born neonates and infants and its high incidence of Rickets along the complications can explain the status quo well. When speaking of the status quo in this paper, it is extremely important to put the overall clinical implications of the gap that prevails by depending on sole sunlight exposure into context. Clinical implications can be understood to include the cost of treating rickets, treating other Rickets caused complications, and the calculated drop in one's life expectancy due to Rickets.

Proposed intervention

The proposed intervention is providing preventive vitamin D supplement in the form of droplets. An infant's vitamin D requirement can be well sufficed by giving a single drop of 400IU unit of vitamin D daily until the child is able to walk by his/her own— which commonly happens in between 11 months and 12 months of an infant's life. This modality of vitamin D supplementation is more objective, measurable, reliable, and easy to adhere to. In addition, it is convenient

irrespective to the geographical area and assures the provision of adequate vitamin D to children. Providing children under the age of 1 year with oral vitamin D supplement droplet will significantly decrease the incidence of Rickets and its associated medical complications. The detailed numbers supporting the above idea are presented in the objective part of the abstract in the upcoming parts of the paper.

Methodology

The cost-effectiveness model assessment done on this paper— for both proposed intervention and status quo—was mainly based on researches done in Ethiopia specifically from Jima University, other reliable literatures whose sources have been mentioned in the designated place within the paper, and data from WHO and UNICEF. After a hypothetical numeric prediction was done mainly based on the aforementioned mechanism for the proposed intervention, it was subsequently compared to the cost of the status quo analyzed based on current available data. After that the data and results from the two interventions were compared and contrasted. This analysis has a time scope of 12 months. The calculation for the DALY and DALY averted was done using the following formula

DALY= YLD+YLL

YLD=P Prevalence*DW (DISABILITY WEIGHT)

YLL = Number of Deaths * Life expectancy at age of death (Because Rickets is a chronic illness with musculoskeletal abnormality, it does not directly cause death and therefore, we assume the direct case fatality rate to be zero)

YLL= 0

DALY of the Status Quo BECOMES=2.1+0= 2.1 per 100 children.

And with same approach DALY of the proposed intervention will be;

YLD= 0.09*0.372=0.033

YLL=0*67.2= 0

DALY= 0.033+ 0=0.033 per 100 children

The DALY of vitamin D supplementation would be 0.033

Cost Analysis

The standard treatment is 400 international units daily for 12 months (Misra et al., 2008). The exact pricing of vitamin D supplementation was not available. The supplementation would be provided in the same way as vitamin A. Administration, monitoring, training and wages are assumed to be similar. There was no specific data found in Ethiopia. We found a cost-effective analysis done for vitamin A supplementation in three Sub-Saharan African Countries (Kannan et al., 2022). The cost for a single person per day, including the capsule, training, wages, transportation, and administration was $0.60. The paper was published in 2022, and it is quite recent, and we only need to consider inflation for two years. In the case of vitamin D supplementation, monitoring and evaluation would be less frequent than for vitamin A, and the treatment would be in droplet form. The major difference with vitamin D Supplementation is the reduced need for healthcare worker involvement and monitoring, which would offset any cost increases from inflation and formulation change making the price $0.6 plus or minus $0.1 per day for a single person. For one year intervention we would multiply it by 365, the result would be $219. To estimate the national cost of supplementation, we need to consider the target population. Most countries aim for one hundred percent coverage of micronutrient supplementation which includes vitamin D. The current coverage of Ethiopia is 59 percent (Gebremedhin et al., 2021). Our target population is infants below the age of one year. Using the UNICEF data for children under the age of five we tried to get a rough estimate. From the 2018 UNICEF report (Children in Ethiopia | UNICEF Ethiopia, n.d.) the total number of under 5 children represent 16 percent of the total population. Assuming uniform distribution for children who are under 5, the number of children under one year can be estimated by dividing the under-five population by five. Consequently, children under five can be found by multiplying 126,527,060(World Bank, 2023) by 0.16 and divide it by five. The result is 4,045,866 children.

The Cost of Treating Rickets includes treatment for acute conditions and chronic complications. Accurate cost of investigation and treatment for Ethiopia and developing countries could not be found. However, according to the paper done in Yeka kotebe Hospital in Ethiopia in 2020 (Memirie et al., 2022) and England (Zipitis et al., 2006) we were able to estimate the average price of treatment for rickets and it complications. The average duration of full course treatment of rickets including admission, if required, would range from 3 to 6 months (Ngari et al., 2017). For 3 months the average cost is estimated as follows.

Items		**Unit cost**
Lab	X-ray	41 $
	Electrolyte	14.28 $
	Parathyroid Hormone	29.87$
	Vitamin D level	29.87
	Full blood Count	14.28
Treatment	Vitamin D	31.4$
	Calcium Supplement	4.4$
	Phosphate Supplement	4.27
In Patient care	Bed	119 $
Subsequent Follow up	Including lab	238.4$
Total		$526.77 per person

Since Rickets is a chronic illness, the morbidity associated with long term complications is significant. The average treatment time for acute complications is 3 month depending on complication and severity (Ngari et al., 2017). One parent typically misses work to care for the hospitalized child, reducing the family income. The GNI (Gross national income) per capita of an Ethiopian is 1130 dollars per year (World Bank, 2023). If the average time the parents spend at the hospital is 3 months the average income of the family would be reduced by $283. Since Rickets is a chronic musculoskeletal illness, it might be life-long illness, even with adequate treatments. In a cohort study of children with severe acute malnutrition in Kenya, 34% of children who initially

had clinical signs of rickets still showed signs of the condition at the 3-month follow-up, despite receiving treatment. So, the impact could continue to affect the working capacity of a patient in the long run.

The overall cost of rickets would be much higher, but according to our analysis 809.8 dollars per person would be spent both from the direct cost in indirect cost of managing rickets.

Effectiveness Analysis

DALY (Disability Adjusted life years) - is a measure used to quantify the burden of a disease.

DALY= YLD+YLL

Source of pic ("Understanding Summary Measures Used to Estimate the Burden of Disease," 2015)

Since Rickets is a chronic illness we chose to prevalence to calculate the DALY.

YLD=P(Prevalence)*DW (DISABILITY WEIGHT)

According to a research done in Jimma university specialized hospital the prevalence of rickets in children admitted to pediatric ward is 10.5 percent (Chala et al." 2014).We could not find a data that shows the prevalence rate for the whole country. Since the data is from a specialized hospital where chronic cases are referred it might overestimate the prevalence. Kenya, located to the south of Ethiopia, has similar sun exposure and economic conditions. According to research conducted in Kenya using data from a multiple hospital clinical network (a peer reviewed research) the prevalence ranged from 0.92 to 4.01 percent (Karuri et al., 2017). We also found another West African country with the same economic a level and similar urban condensed population. The research is conducted in Gambia. The used clinical diagnosis of rickets is the definition we are using for rickets. Accordingly, the prevalence rate is 3.3 percent for age less than 18 years of age and 5.7 percent for age less than 5 year (Helen et al. 2015).

Rickets primarily affects the musculoskeletal system. Since Rickets represents one of the most moderate musculoskeletal illness disability weight of 0.372 was used (Global Burden of Disease, 2013).

YLD= P*DW

= 5.7 *0.372= 2.1

YLL = Number of Deaths * Life expectancy at age of death

Because it is a chronic illness with musculoskeletal abnormality, it does not directly cause death. Rickets predisposes individuals to complications such as pneumonia and growth delay, but it is not directly related to death. Therefore, we assumed the direct case fatality rate of Rickets to be zero.

NUMBER OF DEATH=0

So, the YLL=0

DALY BECOMES=2.1+0= 2.1 per 100 children.

The prevalence of rickets decreased from 6 percent in 1998 to 0.1 percent in 2008(Yeşiltepe-Mutlu et al., 2020). It is a 98.33 percent decrease. Using this evidence, if Vitamin D supplementation is introduced, we expect a 98.3 percent decrease from the current 5.7 percent prevalence. The prevalence would be 0.09percent.

YLD= 0.09*0.372=0.033

YLL=0*67.2= 0

DALY= 0.033+ 0=0.033 per 100 children

The DALY of vitamin D supplementation would be 0.033 per 100 children.

Daly Averted= 2.1 - 0.033= 2.0667 Averted per 100 children.

ICER= (cost of intervention- Cost of status quo)/ (DALY intervention- DALY of status quo)

ICER= (219-526.7) / (0.033 -2.1)

ICER= 148

An ICER 148 means for each DALY averted giving vitamin D supplementation, we save 148 dollars compared to the status quo.

Sensitive analysis

To see the impact of variables like change in cost, prevalence, and disability weight we can do sensitivity analysis.

Variable	Base	Five percent change	10percent change	ICER
cost	0.6	0.63	0.66	Between 138 and 144
		0.57	0.54	Between 154.68 and 160
Prevalnce	5.7	5.98	6.27	Between 140 and 133
		5.415	5.13	Between 155.4 and 164
Disability weight	0.372	0.39	0.40	Between 138 and 137.3
		0.35	0.33	Between 157 and 166

The sensitive analysis shows the ICER remains within reasonable range when the major variables change.

Discussion

The main aim of our paper is to analyze the cost effectiveness of treating rickets, and its short- and long-term complications—which is high likely to happen if we solely rely on mere sunlight exposure (which in this case is our status quo) as explained earlier—in contrast to the cost effectiveness of vitamin D supplementation in droplet form. The cost effectiveness model that has been investigated on this paper was specifically based on supplemental vitamin D drops. As it is a wide spread problem in Ethiopia with a prevalence rate of around 10.5%, an efficient and effective way of dealing with this problem will really help in cost aversion of significant budget. Currently in Ethiopia the majority of the society relies on sunlight exposure to suffice the nutritional vitamin D requirement. And relying on this mode of vitamin D provision has its flaws leading to high burden of vitamin D deficiency which is called rickets when it happens in children under the age of 5. Rickets is mainly a musculoskeletal problem which can predispose children to recurrent pneumonia, delayed growth, poor immune system, different cardiorespiratory problems, reduction of life expectations etc. By providing 400IU of supplemental vitamin D droplets daily for the first 11 to 12 months of an infant's life we have been able to hypothetically decrease the incidence by 98.3%. This is mainly due to the fact that this mechanism of supplying vitamin D is more objective, measurable, reliable, and easy to adhere to. In addition, it is convenient irrespective to the geographical area.

Policy implication

It is imperative to clearly present that this paper stands for policy level impact. Our cost-effectiveness analysis shows that providing preventive supplemental vitamin D droplets is highly cost effective and efficient in reducing the incidence of Rickets which is a significant health burden in Ethiopia. The Millennium Development Goal which stratifies plan to decrease the prevalence of rickets should be well maximized and adopted as a policy in Ethiopia.

Limitations

As we have been working on the cost-effectiveness of vitamin D supplementation in preventing Rickets we have come across some difficulties. One of the challenges we faced was finding the specific cost of vitamin D droplet per child for a year. We tried to maneuver through this specific limitation by approximating the cost of vitamin D to the cost of vitamin A supplementation from a research done in three sub Saharan African countries (Kannan et al., 2022). Other limitation that we have faced was the absence of recent data on the cost of hospital stay and investigations when analyzing the expense of rickets and its complications for the status quo. We tried to tackle this adversity by collecting a recent data of hospital stay expense from a research published by Yeka Kotebe Hospital in Ethiopia (Memirie et al., 2022). In addition we tried to calculate the average expense of treating rickets and its complications from a research done in England on this specific topic (Zipitis et al., 2006). The difficulty we faced in gathering census results was not one to be overlooked. Since Ethiopia has not had recent total population census due to some political problems it was difficult for us to get the number of children below the age of 5 and 1. However, we have been able to mitigate the situation by using World Bank (World Bank, 2023 and UNICEF data (Children in Ethiopia | UNICEF Ethiopia, n.d.).

Limitations are anticipated to be experienced in this interventional process. Mainly, the fact that Rickets mainly resides in the rural area of country, which in turn appear to have a poor culture of adapting to new things, holds the lion share. Thus, cultural resistance will probably be a difficulty to be faced. In addition, logistical shortcomings are of considerable challenge. Wide scale health education and massive advertisements will be compulsory in solving the aforementioned barriers. However, the expense of involving health professionals should be covered by the already set fund for the primary health centers and posts as it has been well elaborated on the calculation of the cost part. Even though the drawbacks and barriers are worth considering and setting plans ahead for, these barriers probably will not end up being severe enough to halt the proposed strategy. Moreover, strategies within the paper tried to mitigate the above mentioned limitations as much as possible.

Conclusion

Our cost-effectiveness analysis shows that providing preventive supplemental vitamin D droplets is highly cost effective and efficient in reducing the incidence of Rickets which is a significant health burden in Ethiopia. When compared to the status quo, which predisposes millions of children to develop Rickets and its high probable medical complications, it has been shown to be better. Therefore, as the financial and clinical burden of Rickets has been well depicted in this paper, policies should be directed towards administering a wide scale daily preventive vitamin D droplet for the first year of a child's life.

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