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Cost-Effectiveness of Nutritional Support and Follow-Up Intervention for Pregnant Women in Southern Benin

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Abstract

Background: Low birth weight is a major public health indicator, reflecting maternal health and influencing neonatal survival. Although preventable, it significantly increases the risk of infant mortality. This study aimed to evaluate the cost-effectiveness of an integrated nutritional intervention for high-risk pregnant women, compared to a nutrition education and follow-up program. **Methods:** This study is based on an observational and comparative analysis that adopts a multisectoral perspective (projects, beneficiaries, and partners). The intervention group received weekly supplementation of fortified flour, protein biscuits, and oranges from the third month of pregnancy until delivery, along with health education and home visits. The control group received the same follow-up, except for the food kits. The economic evaluation incorporated direct costs into the primary ratio calculation, while indirect costs related to participant time were reported separately to ensure analytical consistency. The Incremental Cost-Effectiveness Ratio (ICER) was calculated relative to the WHO threshold after converting avoided low-birth-weight cases into Disability-Adjusted Life Years (DALYs). Finally, the robustness of the results was tested using a univariate sensitivity analysis, with key parameters varied by ±20%. **Results:** The intervention reduced the incidence of low birth weight from 12.5% to 2.5% (RR = 0.2; 95% CI [0.023 - 0.58]). With a total cost of 3,273,000 FCFA, the incremental cost-effectiveness ratio (ICER) is 245,750 FCFA per additional case of low birth weight averted. When converted, the ICER is 98,300 FCFA per DALY averted—a figure more than eight times lower than the WHO threshold for a "highly cost-effective" intervention (798,974 FCFA). While sensitivity analysis confirms the model's economic viability, the ICER is sensitive to production costs, causing an −18.68% variance, with a range of 64,590 to 132,010 FCFA per DALY. **Conclusion:** In resource-limited settings like Benin, this supplementation strategy shows strong potential to reduce preterm deaths. Its proven perinatal benefits and low cost justify immediate inclusion in national maternal health policies to significantly reduce the incidence of low birth weight.

Keywords

Cost-Effectiveness, Pregnant Women, Low Birth Weight, Benin

1. Introduction

Low birth weight (LBW) is a vital public health indicator that reflects maternal health, nutritional status, and the quality of prenatal care [1]. While largely preventable, LBW remains a major threat to child survival and development. Newborns with LBW face a mortality risk roughly 20 times higher than those of normal weight [2]. Furthermore, the impact extends into adulthood, increasing the risk of chronic, non-communicable diseases [3].

The epidemiological situation remains concerning, particularly in sub-Saharan Africa, where prevalence reached 13.9% in 2020 [4]. In Ethiopia, data highlight significant temporal and geographical shifts, with rates climbing from 10.06% in 2020 [5] to 19.16% by 2023 [6].

Similarly, while Benin's national prevalence was estimated at 8.92% in 2020, this figure obscures sharp internal disparities. For instance, the Littoral department reported a much higher rate of 13.30% [7], peaking at 17.40% in the Cotonou 1 to Cotonou 4 health zone, nearly double the national average [8].

This prevalence is fueled by a multitude of risk factors, such as rural residence, extreme maternal ages, multiple pregnancies, and obstetric complications. These are compounded by chronic or infectious diseases in the mother, inadequate prenatal care, and, crucially, poor maternal nutrition during pregnancy [9].

In response to these challenges, international efforts have intensified. The World Health Assembly (WHA) launched a global action plan to improve maternal and child nutrition, specifically aiming to reduce the prevalence of low birth weight by 30% between 2012 and 2025. These vital commitments to neonatal health have since been integrated into the 2030 Sustainable Development Goals (SDGs) [10].

Maternal health and pregnancy outcomes are fundamentally tied to the mother's nutritional status, which is a primary driver of fetal growth from conception through birth [11]. Although hospital-based nutritional interventions and counseling are known to improve health for both mother and child, structural barriers often limit their success [12]. Specifically, inequitable access to quality care and healthy food disproportionately affects the most socioeconomically vulnerable populations [13].

To address these disparities, an integrated strategy combining food support and education was piloted. This program is based on the weekly distribution of a kit containing fortified flour made from local products (130 g/day), protein biscuits (70 g/day), and an orange, covering the period from the third month of pregnancy until delivery. This nutritional component is reinforced by local support, including health education sessions, personalized follow-up, and home visits.

While this intervention package shows clinical success, therapeutic efficacy alone does not guarantee policy adoption. Although efficacy confirms a treatment's relevance, cost analysis is vital to ensure its budgetary viability within public health priorities. Consequently, this study provides a rigorous cost-effectiveness analysis to support scaling this model both nationally and internationally.

2. Methods

2.1. Type and Population of the Study

Adopting a societal perspective, this research is based on an observational and comparative cost-effectiveness analysis. The analytical scope encompasses the costs related to the project, the beneficiaries, and the implementing partners, for a cohort of pregnant women followed within the Cotonou 1 - 4 health zone.

2.2. Study Design

The selection of study sites was based on data from the baseline survey on the nutritional profile of pregnant women in the Cotonou 1 - 4 health zone [14]. Women were assigned to intervention and control sites prospectively and non-randomly on a geographical basis, determined by their consultation health center; this approach was utilized to prevent inter-group contamination. To ensure data comparability, two study sites were established by matching intervention sites (beneficiaries) with control sites based on geographic, socioeconomic, and ethnic diversity criteria. Each site was structured homogeneously to systematically include both a public and a private health facility. Thus, the first comparison site includes the Ahouansori health center and the John Hot clinic, while the second combines the Aïdjedo health center and the La Confiance clinic.

2.3. Swimming Sample

Before the intervention, an early prediction tool for low birth weight (LBW) risk was developed using key determinants, including socioeconomic and nutritional status, energy intake, occupation, and education level [15]. Participants were classified as "high-risk" if they scored ≥ 5 on the predictive tool. Inclusion criteria consisted of pregnant women residing in the study area who were at less than 14 weeks of gestation and had provided written informed consent. Exclusion criteria included multiple pregnancies, preterm birth, and the presence of severe chronic conditions (such as heart disease or renal failure). This tool accurately identified high-risk women within the study population. Using the initial survey database, we applied these criteria to select all eligible at-risk pregnant women. The final sample consisted of 80 participants, prospectively distributed across the study and comparison sites.

2.4. Intervention

The intervention is based on a combined approach that integrates nutritional supplementation and educational support. The nutritional component consists of the weekly distribution of a kit containing fortified flour made from local products, protein biscuits, and oranges. This support begins in the third month of pregnancy and continues until delivery, covering a follow-up period of approximately six months.

The implementation of this program relies on rigorous, close support, including personalized follow-up and home visits. Nutritional education sessions are integrated into the selected health facilities. To ensure the participation of pregnant women and the effectiveness of the intervention, the midwives in charge of the centers were closely involved in the coordination.

The educational program is structured around a communication plan comprising five thematic sessions with specific objectives. Each session, lasting approximately one hour, is conducted in the local language and uses visual aids to optimize message comprehension. In addition to nutrition, the intervention includes a comprehensive health education component. This covers stress and sleep management, as well as adherence to prenatal care protocols, including the use of insecticide-treated bed nets (ITNs), monitoring of intermittent preventive treatment (Sulfadoxine/Pyrimethamine), deworming, and compliance with iron and folic acid supplementation.

2.5. Measuring Results

The primary outcome of this study is the incidence of low birth weight (LBW) within the source population. To ensure data reliability, experienced nutritionists measure each newborn's weight within 72 hours of delivery using high-precision SECA scales. For analysis, birth weights are treated as a dichotomous variable: infants weighing less than 2500 g are classified as LBW, while those at or above this threshold are categorized as having a normal birth weight.

2.6. Cost Assessment

We assessed costs by comparing the direct and indirect expenses of the intervention and control groups. Direct costs are subdivided into two categories: health costs and non-health costs. The reference year for calculation is 2024. The evaluation sources are based on project expenditure records and local market prices. The unit quantities per participant amount to 130 g/day of fortified flour, 70 g/day of biscuits, and 1 orange per day for an average duration of 180 days. Direct health costs encompass all operational expenses related to the intervention, including inputs for formulating flours and biscuits, the purchase of oranges, logistical costs to distribution sites, and the value of staff time dedicated to nutrition and health education activities. Direct non-health costs comprise ancillary expenses such as travel to distribution sites and logistics for home visits. Indirect costs, or lost productivity, were calculated by multiplying the time mothers or caregivers spent at education sessions by the average local daily wage. To ensure the internal consistency of the economic evaluation, participant time and productivity losses (indirect costs) were excluded from the primary Incremental Cost-Effectiveness Ratio (ICER) calculation and are reported separately.

2.7. Economic Evaluation

The economic evaluation was based on a cost-effectiveness analysis to determine the incremental cost per case of low birth weight (LBW) averted and per disability-adjusted life year (DALY) saved, using a benchmark indicator that met WHO standards and was comparable to the thresholds. To do this, the incremental cost-effectiveness ratio (ICER) was established by dividing the cost difference (direct costs only) between the group receiving nutritional supplementation and the control group by the difference in observed effectiveness (the incremental number of low-birth-weight cases actually averted in the sample, then converted into DALYs based on a factor of 2.5 DALYs averted per LBW case prevented, to allow for the rigorous application of the GDP-based threshold). This ratio thus expresses the marginal cost per QALY gained through the support intervention compared to standard care. The cost-effectiveness ratio was compared to the WHO threshold: 1 × GDP per capita (798,974 FCFA) for "very cost-effective" and 3 × GDP per capita (2,396,922 FCFA) for cost-effective [16], while the costs related to productivity losses were treated separately in order to avoid biasing the calculation of the main ICER.

2.8. Sensitivity Analysis

To test result robustness, we performed a univariate deterministic sensitivity analysis by varying key parameters, specifically direct unit costs and estimated productivity losses, by ±20%. This approach aligns with CHEERS (Consolidated Health Economic Evaluation Reporting Standards) guidelines, ensuring the evaluation meets international publication standards [17].

2.9. Ethical Considerations

The research protocol received approval from the Health Sciences Research Ethics Board (CERS) under number 003-2023/CERS. Written informed consent was obtained from each participant before inclusion. They were informed that their refusal to participate would not entail any harm or risk to them.

3. Results

3.1. Effectiveness of the Intervention

The intervention reduced the incidence of low birth weight (LBW) to 0.025, representing 39 normal-weight births out of 40 deliveries (only 1 case of LBW). For comparison, the control group, receiving the standard nutrition and health education intervention, had an incidence of 0.125, or 35 normal-weight births out of 40 (5 cases of LBW). This improvement represents an absolute decrease in the incidence of LBW of 10% in favor of the intervention group, which corresponds to an incremental number of 4 cases of low birth weight actually avoided in our sample (5 cases in the control group minus 1 case in the intervention group). These results are confirmed by a relative risk of 0.2 with a 95% confidence interval between 0.023 and 0.58, demonstrating a significant 80% reduction in the risk of LBW among women who received the new intervention (Table 1).

Table 1. Effectiveness of the intervention.

Groups	Weight < 2500 g	Weight ≥ 2500 g	Total
Intervention	1	39	40
Control	5	35	40
Total	6	74	80

3.2. Costs of Implementing the Intervention

The total intervention cost was 3,273,000 FCFA, split between direct and indirect expenses. Direct costs accounted for 70.66% (2,313,000 FCFA) of the budget, driven largely by input procurement, specifically flour, biscuits, and oranges, which totaled 1,983,000 FCFA (85.73% of direct costs). The remaining 14.26% of direct funds supported operations, including 130,000 FCFA for logistics and 200,000 FCFA for facilitator per diems. Indirect costs, representing participant time, were estimated at 960,000 FCFA. In contrast, the control group's standard program cost significantly less at 1,330,000 FCFA, covering facilitation, midwifery follow-up, and participant time compensation. Consistent with our methodological approach, indirect costs related to participant time have been excluded from the primary ICER calculation presented below.

3.3. Cost-Effectiveness Ratio of the Intervention

The cost-effectiveness analysis indicates that the standard nutritional intervention costs 1,330,000 FCFA to achieve 35 normal-weight births. When comparing the food support program to the nutrition education program alone, the difference in direct costs amounts to 983,000 FCFA (2,313,000 FCFA versus 1,330,000 FCFA). The Incremental Cost-Effectiveness Ratio (ICER), calculated based on the actual number of cases prevented, is 245,750 FCFA per additional low-birth-weight case avoided (983,000 FCFA divided by the 4 additional cases prevented within the sample).

When applying a standard health indicator conversion, assuming 2.5 DALYs saved per averted case, for a total of 10 DALYs, the incremental cost-effectiveness ratio is 98,300 FCFA per DALY averted. This figure represents the additional cost required to prevent one extra low-birth-weight case or to achieve an additional

QALY/DALY. Although this cost exceeds that of the base intervention, it remains highly competitive, as it is more than eight times lower than the threshold defined by the WHO for interventions considered "highly cost-effective" (798,974 FCFA).

3.4. Sensitivity of the Intervention

The univariate sensitivity analysis, summarized in the table below, assesses the robustness of the Incremental Cost-Effectiveness Ratio (ICER) in response to ±20% variations in key input parameters.

The results indicate that the intervention's economic viability is primarily driven by production costs, with the highest sensitivity observed in the formulation costs of biscuits and flours. Specifically, this parameter exerts a significant -35.3% impact on the Cost/DALY ratio, causing it to fluctuate between 95,700 FCFA and 100,900 FCFA. This classifies it as a high-impact variable for the model, followed by the cost of orange procurement, which shows moderate variation (-6.05%).

Conversely, the system demonstrates resilience to distribution factors. Variations in logistics costs result in only marginal impacts on the final outcome (-2.64). Classified as having low impact, this parameter suggests that transport-related uncertainties do not significantly compromise the intervention's overall efficiency, confirming the model's stability in the face of logistics-related fluctuations (**Table 2**).

Table 2. Sensitivity analysis results.

Settings	Cost/Quality −20%	Cost/Quality +20%	Impact (%)	Categories
Cost of logistics	95,700	196,900	−1.33	Weak
Cost of formulating biscuits and flours	64,590	135,010	−35.3	Pupil
Cost of purchasing oranges	92,350	104,250	−6.05	Average

4. Discussion

This study demonstrates the remarkable efficacy of a combined nutritional intervention (enriched flours, biscuits, and oranges, coupled with nutritional education) in reducing the incidence of Low Birth Weight (LBW, <2500 g). The incidence of LBW was reduced to 2.5% in the intervention group compared to 12.5% in the control group, representing an efficacy of 97.5% and a Relative Risk (RR) of 0.2 (95% CI: 0.023 - 0.58). This 10% absolute reduction in LBW, corresponding to 4 net LBW cases avoided (39 normal-weight births in the intervention arm versus 35 in the control arm), highlights the superiority of this approach compared to nutritional education alone.

These performance metrics surpass those reported in randomized trials across sub-Saharan Africa, where lipid-nutrient supplements reduced LBW by 6% - 10%

[18]. Our intervention, adapted to the Beninese context, achieved an 80% reduction in relative risk, which is comparable to meta-analyses on multiple micronutrient supplements (RR = 0.81; 95% CI: 0.73 - 0.90) [2]. The high proportion of normal-weight newborns (39/40) confirms the preventive impact, aligning with WHO recommendations for low-income countries, where LBW affects 15% - 20% of births and contributes to 20% of neonatal mortality [19]. This efficacy is attributable to the targeted intake of iron, vitamin C (via oranges), and dense energy (flours/biscuits), which optimizes maternal hemoglobin levels and placental transfer, as demonstrated in the iLiNS-DYAD study in Ghana [20].

From an economic perspective, the direct cost of the intervention demonstrates excellent efficiency, falling well below the WHO threshold per Disability-Adjusted Life Year (DALY) gained for "highly cost-effective" interventions in low-income countries [16]. By comparison, standard education costs 38,000 FCFA per normal-weight birth; however, our Incremental Cost-Effectiveness Ratio (ICER) remains competitive against prenatal supplement programs in Ethiopia (ICER approx. 250,000 FCFA/case) [21].

Univariate sensitivity analysis further reinforces the robustness of these findings: a ±20% variation in biscuit/flour formulation costs impacts the ICER by -35.3% (64,590 - 132,010 FCFA/DALY), while logistics shows only a marginal effect (−2.64%), confirming the model's stability against local uncertainties [22].

These results justify the need for scaling up this intervention in Benin, where LBW affects approximately 12% of births. While the primary limitation of this study is its modest sample size (n = 80), which warrants larger-scale trials, this intervention offers a scalable, cost-effective model that is superior to education alone.

5. Conclusion

These results highlight the strategic importance of this intervention for reducing Low Birth Weight in resource-limited settings, such as Benin, at a sustainable cost. These findings support the immediate integration of this strategy into national maternal health programs, with future research warranted to evaluate long-term patient adherence and the broader impact on neonatal morbidity.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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