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RESEARCH ARTICLE

Cost-effectiveness of a behavioral insights-informed digital campaign to increase HPV vaccination in Bangladesh

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ABSTRACT

Digital platforms like social media are increasingly used to promote vaccine uptake in low- and middle-income countries (LMICs), yet limited evidence exists on their economic value. This study estimates the cost-effectiveness of a behavioral insights-informed social media campaign designed to increase HPV vaccine uptake among adolescent girls ages 9–14 in Bangladesh. A static cost-effectiveness analysis was conducted from the health system perspective. Inputs included campaign delivery costs, vaccine procurement and distribution, and treatment costs averted through cervical cancer prevention. Disability-adjusted life years (DALYs) averted per vaccinated girl were modeled using global burden-of-disease parameters. Effectiveness estimates were drawn from a quasi-experimental evaluation of the campaign, which reported a 9.5 percentage-point increase in vaccine uptake in one study arm and a 5.3 percentage-point increase in another, relative to a control group. These findings were preceded by a posttest study in Dhaka Division, which showed a strong association between campaign exposure and vaccination behavior. The incremental cost per vaccinated girl was $6.02, and the cost per DALY averted – i.e. the Incremental Cost-Effectiveness Ratio (ICER) – was $39.57. This falls well below established cost-effectiveness thresholds, including 40% of GDP per capita, commonly applied in LMICs. The findings suggest that digital campaigns guided by behavioral insights can represent a highly cost-effective approach to addressing persistent immunization coverage gaps. These results support the integration of such strategies into national immunization programs, particularly in contexts where traditional outreach methods may face financial constraints.

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Introduction

Cervical cancer remains a leading cause of cancer-related mortality among women in low- and middle-income countries (LMICs), accounting for over 90% of global cervical cancer deaths.[1] Infection with the human papillomavirus (HPV) – the primary cause of cervical cancer – is disproportionately high in LMICs, where HPV prevalence is several times higher than in high-income countries and is believed to be rising.[2] In response, the World Health Organization (WHO) recommends routine HPV vaccination for girls aged 9–14 years in all countries, as part of its global strategy to eliminate cervical cancer. Over 100 countries have adopted this recommendation.[1,3]

Supported by the Gavi Alliance, the global introduction of the single-dose HPV vaccine has recently accelerated, with Bangladesh and Nigeria among the first countries to launch national HPV vaccination programs with UNICEF, WHO and Gavi support in 2023.[4] These programs have been accompanied by targeted communication efforts to promote vaccine uptake.

In Bangladesh, a behavioral insights-informed digital campaign was initially piloted in Dhaka Division alongside the national vaccine rollout. A cross-sectional, posttest, evaluation survey found a powerful, dose-response relationship between caregiver exposure to the campaign and vaccine uptake: caregivers exposed to the campaign reported a 29-percentage point difference in HPV vaccination among the children they cared for.[5] While this provided early correlational evidence of behavioral impact, the study design likely led to a substantial overestimation of campaign effects. Moreover, the absence of a control group limited causal inference.

A foundational behavioral insights survey was conducted in November – December 2023 with 2,369 caregivers of adolescent girls across the remaining six divisions of Bangladesh.[5] Designed using the Fogg Behavior Model,[6] the survey gathered data on caregivers' motivation, ability, and social norms related to HPV vaccination. The primary outcome variable was caregivers' expectation that their girl child would receive the HPV vaccination in the next 12 months.

Findings from the behavioral insights survey revealed that:

- Caregivers who believed the vaccine promised their girl a brighter future were 8 percentage points more likely to expect that their child would get vaccinated within the next 12 months.
- Perceived social norms were strongly associated with vaccination expectations, with a 6 percentage-point difference in the expectation that their girl would be vaccinated between caregivers who perceived family and

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community approval of HPV vaccination compared to others.
- An adolescent's agency was strongly correlated with the caregiver's expectation that she would get vaccinated: caregivers whose girls communicated their interest in getting vaccinated showed a 21 percentage-point higher expectation that the girl would get vaccinated.

These findings directly informed the design and content of the social media messaging.

To build on these insights, a quasi-experimental study was conducted in six divisions of Bangladesh during October-November 2024, leveraging real-time digital tracking and comparison with a control group. The evaluation demonstrated that exposure to the digital campaign led to a 9.5 percentage-point increase in the HPV vaccination rate, over and above the impact of the national communication campaign, in one study arm and a 5.3 percentage-point increase in the HPV vaccination rate in a second study arm.[7] The social media campaign was at scale and implemented in six out of seven divisions of Bangladesh. These findings are reported in detail elsewhere and provide the effectiveness inputs used in the current study.

Despite growing evidence of impact, there remains limited documentation of the cost-effectiveness of digital health interventions for vaccine promotion in LMICs.[8] This study addresses that gap by estimating the cost per disability-adjusted life year (DALY) averted as a result of the nationwide HPV social media campaign in Bangladesh. Using real-world cost data and effectiveness data from a quasi-experimental study, the study offers timely and policy-relevant evidence to inform scale-up of digital strategies in global immunization programming.

This study addresses a critical gap in the evidence base: while digital platforms are increasingly used to promote vaccine uptake, there is little rigorous data on their cost-effectiveness, especially in low- and middle-income countries (LMICs). Understanding the economic value of such interventions is essential for a) informing national immunization strategies, b) optimizing resource allocation, and c) justifying investments in digital health.

The general purpose of this study is to assess whether digital, behavioral insights-informed campaigns can be a scalable and cost-effective strategy to increase vaccine uptake in LMICs. In doing so, it seeks to contribute to a broader understanding of how digital health innovations can be integrated into public health delivery systems.

Specifically, the study estimates the cost-effectiveness of a nationwide, social media – based HPV vaccine promotion campaign in Bangladesh by calculating the cost per disability-adjusted life year (DALY) averted. Using real-world implementation costs and effectiveness data from a quasi-experimental study, the analysis provides timely and policy-relevant insights into the value of digital demand generation for immunization programs.

Methods

This study employed a cost-effectiveness analysis (CEA) to estimate the incremental cost-effectiveness ratio (ICER) of a nationwide social media campaign designed to increase uptake of the human papillomavirus (HPV) vaccine among adolescent girls in Bangladesh. The objective was to determine the cost per disability-adjusted life year (DALY) averted from the perspective of the health system. The CEA was conducted from a health system perspective.

A simplified proportional outcomes model was used, consistent with prior studies such as Vodicka et al.[2] This approach uses static, one-time estimates to derive average costs and health outcomes per vaccinated girl. The unit of analysis was a single vaccinated girl, with lifetime health impacts modeled through averted cervical cancer cases.

Cost inputs

The analysis uses a single-dose HPV vaccination schedule, introduced nationally in Bangladesh in 2023 with Gavi and WHO support. To capture the cost for the cost-effectiveness analysis, we considered three cost components, which included: (1) the HPV vaccination cost; (2) the cost of the social media campaign; and (3) the cost of treating cervical cancer cases.

The cost of HPV vaccination per vaccinated girl

The cost of HPV vaccination included:

- HPV vaccine procurement: $4.60,[9,10]
- Supply chain and service delivery: $0.92 (assumed as 20% of vaccine cost, as a more conservative measure of the average (16.7%)[11,12]

The cost of social media campaign delivery

The total cost of the campaign was $284,150, based on the project implementation expenditure. It included all components of strategy, design, implementation, and evaluation. Figure 1 shows the spending structure for the social media campaign.

Based on national census data, the 9.5 percentage-point increase in HPV vaccination in 3 divisions of Bangladesh and the 5.3 percentage points increase in HPV vaccination in the other 3 divisions translated into **429,120 additional girls ages 9–14** vaccinated as a result of the campaign. Dividing total social campaign cost by additional vaccinations yields $0.66 per vaccinated girl.

This all-inclusive cost reflects the real-world financial requirements of launching a behavioral insights-informed digital health intervention at scale. It is notably lower than similar demand generation efforts reported in the literature, emphasizing both the efficiency and scalability of social media – based approaches.

Costs from cervical cancer cases averted

We expected that the HPV vaccination would reduce the incidence of cervical cancer cases and thus reduce the associated treatment costs. The incidence of cervical cancer, the efficacy of the HPV vaccine, the treatment cost per cervical

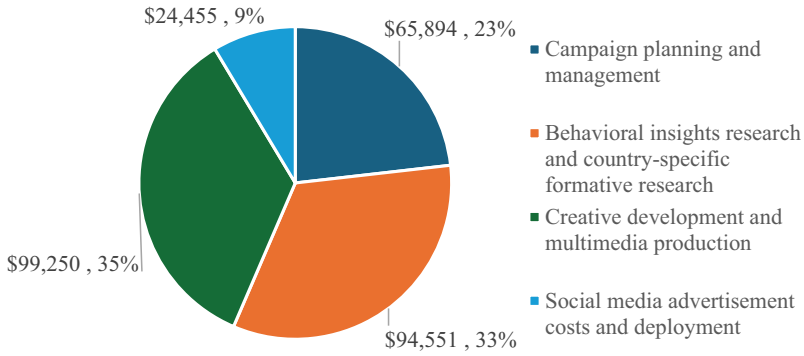

Figure 1. Cost of social media campaign.

cancer case per year, and the average survival time per cervical cancer case were obtained to estimate the cost savings per vaccinated girl. These parameters were:

- Cervical cancer incidence: 0.000106 cases per girl (HPV Information Center, 2023)
- Vaccine efficacy: 97.5%[13]
- Treatment cost per case: $477.00[14]
- Average survival post-diagnosis: 3.35 years[15]

The cost saving per vaccinated girl was calculated using the formula:

Incidence × Efficacy × Treatment Cost × Survival Duration = $0.17.

Effectiveness inputs

Effectiveness data were sourced from a quasi-experimental impact evaluation conducted from October to November 2024 across six divisions in Bangladesh. The evaluation found that exposure to the digital campaign led to a 9.5 percentage-point increase in the HPV vaccination rate in 3 divisions and a 5.3 percentage point increase in the HPV vaccination rate in the other 3 divisions beyond what was achieved through the national introduction.[7]

While randomized controlled trials (RCTs) are considered the gold standard for establishing causality due to their ability to eliminate bias through randomization, conducting RCTs at scale presents challenges including high costs, and logistical complexities. As a result, quasi-experimental designs have emerged as practical alternatives in real-world settings. They allow for the assessment of interventions without random assignment, making them more flexible and cost-efficient in real world settings.[16,17] However, quasi-experiments are more likely to suffer from biases, such as selection bias, due to the lack of randomization and differential exposure to the intervention within geographic areas. This may reduce the internal validity of their findings. In spite of their limitations, however, quasi-experiments may offer better external validity than RCTs because they assess the real-world effectiveness of interventions implemented by regular staff rather than under controlled research conditions. Use of using advanced techniques like control groups or time series designs enhance the validity of findings from quasi-experiments. Given the rapidly changing political and programmatic situation in Bangladesh in 2023 culminating in a change in government in 2024, it would not have been possible to implement an RCT at national scale for the purpose of evaluating HPV vaccine introduction in Bangladesh at that time.[16,17]

We obtained the estimate of DALY averted per vaccinated girl directly from a prior model, which provided global, regional and national estimates of DALY's averted.[18] We applied the estimate of 0.152 DALYs per vaccinated girl from Bangladesh for the main analysis. No discounting was applied due to the single-period structure of the model. All costs are expressed in 2024 USD.

Sensitivity analysis

A sensitivity analysis was conducted by altering the value of DALYs averted per vaccinated girls obtained from Abbas et al. using the estimate from the Southeast Asian and European regions. Bangladesh is located in South Asia and adjacent to Southeast Asia, and serves as a geographic and cultural bridge between the two regions. Thus, the selection of DALYs averted per vaccinated girl from Southeast Asia would provide some insights into the cost-effectiveness of HPV vaccine introduction if it were scaled up in the region. We selected the effectiveness measure from the European region to show the upper bound of the cost-effectiveness estimate from the intervention given the lower effectiveness outcome.

Results

The averted treatment cost per vaccinated girl was estimated at $0.165, based on the modeled cervical cancer incidence, vaccine efficacy, treatment cost, and survival duration. Subtracting the averted treatment cost from the total intervention cost ($6.18) yielded an incremental cost of $6.02 per vaccinated girl.

Based on an estimate of 0.152 DALYs averted per vaccinated girl for Bangladesh,[18] the incremental cost-effectiveness ratio (ICER) was calculated as:

$$ICER = \frac{\$6.02}{0.152} = \$39.57 \ per \ DALY \ averted$$

Table 1. Model inputs and outcomes – HPV vaccine promotion via social media, Bangladesh.

Parameter	Value	Source/Assumption
Cervical cancer incidence (per girl)	0.000106	From[24]
Vaccine efficacy	97.5%	From[13]
Vaccine cost (single dose)	$4.60	Gavi/WHO-supported procurement price
Supply chain & delivery cost	$0.92	Assumed as 20% of vaccine cost
Social media campaign cost per girl reached	$0.66	From[7]
Treatment cost per cervical cancer case	$477.00	From[14]
Average survival post-diagnosis (years)	3.35	Derived from survival estimates in LMIC settings
DALYs averted per vaccinated girl	0.152	Based on global burden of disease parameters
Treatment cost averted per girl	$0.17	Incidence × Efficacy × Treatment Cost × Survival Duration
Incremental cost per vaccinated girl	$6.02	Total cost – Treatment cost averted
Cost per DALY averted (ICER)	$39.57	$6.02/0.152

Table 1 shows the key model inputs and ICER estimates for the main analysis. To contextualize this value, Bangladesh's projected GDP per capita in 2024 is $2,620.[19] A widely used threshold for cost-effectiveness in LMICs is 40% of GDP per capita, which equals $1,048 for Bangladesh. The ICER of $40 per DALY averted from this study falls far below this benchmark, confirming the intervention's high cost-effectiveness.

Comparable estimates from Vodicka et al.[2] who used the UNIVAC model to evaluate HPV vaccine introduction in Ghana, placed the cost per DALY averted for a two-dose HPV vaccine schedule at $158–$890, depending on vaccine type and delivery strategy. Their average across all scenarios was approximately $430 per DALY averted, with the most cost-effective option being the bivalent vaccine plus one-time campaign at $158/DALY. These values reflect standard two-dose assumptions and do not include the impact of digital demand generation.

In comparison, the $40/DALY estimate for Bangladesh's campaign – delivered via social media and based on a single-dose schedule – is highly favorable. While the inclusion of digital campaign costs does raise total program cost slightly, the results suggest that digital strategies can remain extremely cost-effective, particularly when paired with single-dose vaccination. The cost-effectiveness of social media – based demand generation appears to be on the high side, and the transition to a single-dose schedule further enhances its economic efficiency.

A sensitivity analysis was conducted using a higher estimate of 0.236 DALYs averted per vaccinated girl and a lower estimate of 0.121 DALYs averted per vaccinated girl. Based on an estimate of 0.236 DALYs averted per vaccinated girl for the Southeast Asia Region,[18] ICER was calculated as:

$$ICER = \frac{\$6.02}{0.236} = \$25.49 \; per \; DALY \; averted$$

Based on an estimate of 0.121 DALYs averted per vaccinated girl for the European region,[18] ICER was calculated as:

$$ICER = \frac{\$6.02}{0.121} = \$49.71 \; per \; DALY \; averted$$

This yielded a ICER range of $25–$50 per DALY averted, reinforcing the high cost-effectiveness of the digital campaign under different health impact assumptions.

Discussion

This study contributes new evidence on the cost-effectiveness of digital demand generation strategies for increasing HPV vaccine uptake in low- and middle-income countries (LMICs). Using a transparent, static model grounded in real-world cost and effectiveness data, we estimate that the incremental cost-effectiveness ratio (ICER) of a nationwide social media campaign in Bangladesh was $40 per DALY averted – well below the threshold of 40% of Bangladesh's GDP per capita. This suggests that digital interventions, when paired with efficient vaccine delivery models such as single-dose HPV vaccination, can offer exceptional value for money.

A key strength of this study lies in its use of actual programmatic cost data from a real-world, national-level intervention. Unlike many economic evaluations of digital health that rely on modeled or pilot-based cost assumptions, the campaign budget and research data used here were drawn directly from the implementation of a quasi-experimental study. This study was explicitly designed to measure the marginal effect of a social media campaign layered on top of a national HPV vaccination effort, providing a rigorous estimate of both effectiveness and cost.

Our findings compare favorably with existing estimates from multi-country analyses. For instance, Vodicka et al.[2] estimated the cost per DALY averted for two-dose HPV vaccination scenarios across Ghana to range from $158 to $890, with an average of $430. While the cost-effectiveness of the Bangladesh campaign compares favorably with findings from Ghana,[2] there remains a significant gap in comparable evidence from other LMICs, particularly in relation to digital demand generation strategies.[20] Most economic evaluations of HPV vaccine delivery in LMICs have focused on traditional delivery platforms and have not isolated the incremental cost or impact of digital communication strategies. Systematic reviews[20] confirm that rigorously evaluated, behavioral insights-informed digital interventions are scarce in LMIC contexts, and published cost-effectiveness analyses of such interventions are virtually nonexistent.[21]

To the best of our knowledge, this study is among the first to provide empirical cost-effectiveness evidence for a social media campaign designed to promote HPV vaccination in an LMIC setting. This highlights a critical gap in the current literature: the need for economic evaluation of digital behavior change approaches across diverse country settings. There is little cost information available on social media campaigns.

This study provided the first estimate of the cost structure for such an intervention. Compared to traditional vaccine campaigns, social media campaigns would significantly reduce the cost of monitoring and evaluation, as well as the cost associated with community mobilization. The main cost of social media campaigns lies in campaign planning and management, content development, and impact assessment. The media advertisement cost is minimal.

Due to data constraints, the effectiveness assessment in this study relies on prior modeled national estimates, which may not necessarily reflect the population and health system characteristics under the social media campaign. As shown in Abbas et al., there is a wide variation of DALYs averted per vaccinated girl across different regions and countries, ranging from 40 to 735 DALYs averted per 1000 vaccinated girls. Thus, variation in ICER among LMICs is expected. Several factors may affect ICER. For example, a region or country with a higher HPV infection rate and better technology coverage is likely to have a lower ICER. A region or country with lower cervical cancer tends to have higher ICER. Future studies in other LMICs – especially those scaling up single-dose HPV vaccination – are needed to validate the findings presented here and explore cost-effectiveness under different epidemiological, technological, and policy conditions.

Despite its strengths, several limitations of this study should be noted. First, the use of a static, one-period model limits our ability to capture long-term effects, including disease progression, herd immunity, or reinfection. Second, the analysis takes a health system perspective, omitting societal costs such as productivity losses or caregiver burden. Third, the study assumes lifelong vaccine protection and does not account for waning immunity, although emerging evidence supports durable protection from a single dose. Fourth, this study could not further break down the cost components. This creates challenges for extrapolating the cost information in other settings. Lastly, DALY estimates are based on modeled averages and not empirical follow-up data, which may affect precision. Moreover, future analyses using dynamic transmission models could better capture community-level effects, including herd immunity and reinfection dynamics, which may further improve cost-effectiveness estimates.

Despite these limitations, this analysis provides a first-order estimate of the economic value of digital health strategies for vaccine demand generation. As more countries transition to single-dose HPV vaccination, understanding how to cost-effectively drive uptake will be critical. Social media campaigns – particularly those informed by behavioral insights and deployed through precision targeting – represent a scalable, cost-effective addition to national immunization strategies.

This study is among the first to rigorously evaluate a social media campaign that explicitly applied behavioral insights in both message design and delivery. This addresses a gap identified in a recent systematic review,[20] which found a near absence of rigorously designed, behavioral insight-informed digital health interventions. While social media has emerged as a widely used channel for vaccine promotion, few campaigns have been rooted in behavioral science frameworks or empirically evaluated for impact.[22] This study advances the field by offering both a methodological template and real-world results.

The results underscore that digital demand generation can be highly cost-effective when deployed in tandem with national vaccine rollouts. Integrating social media into programmatic efforts – rather than as standalone campaigns – may offer the best returns, leveraging existing delivery infrastructure while reaching caregivers at scale.

Notably, even in the most successful campaign arm, only 33% of caregivers reported that their daughters had been vaccinated. This highlights significant room for improvement, particularly as programs transition from campaign-style delivery to routine immunization. Digital strategies tailored for routine service contexts – potentially with different costs and effects – could yield even greater returns and merit dedicated evaluation.

Conditions for optimal effectiveness

Digital, behavioral insights-informed campaigns are not universally applicable in all settings. Their effectiveness is likely to be **maximized under specific enabling conditions**, which should guide policy and program design. These include high mobile phone and internet penetration rates, their implementation in more urbanized, better-connected spaces, digital literacy among the target audience and social norms supportive of behavioral adoption.[8]

In contrast, settings with low smartphone penetration, limited digital literacy, or weak infrastructure may require hybrid models that combine digital and offline strategies. Tailoring the approach to local conditions – through formative research and rapid testing – can help ensure impact and cost-effectiveness.

Potential barriers to scaling up

While the results from Bangladesh demonstrate the high cost-effectiveness of behavioral insight-informed digital campaigns, several potential barriers may limit the scalability of similar interventions in other LMICs. These include technological infrastructure, linguistic diversity, trust in government and economic factors.[23]

These considerations underscore the importance of contextual tailoring and pre-implementation assessments when replicating digital interventions across countries. Investing in formative research, building local capacity for behavioral design, and ensuring alignment with national regulatory frameworks will be critical for scaling digital demand generation strategies successfully.

Conclusion

This study provides robust evidence that a behavioral insights-informed social media campaign – delivered nationally to support HPV vaccine uptake among adolescent girls in Bangladesh – was highly cost-effective when paired with a single-dose vaccination strategy. With an ICER of $40 per DALY averted, the campaign falls well below established thresholds for cost-effectiveness in LMICs and offers

a promising model for scaling demand generation through digital platforms.

For policymakers and program implementers, the findings suggest three actionable recommendations. It is important to integrate digital campaigns with national vaccine rollouts rather than treating them as standalone initiatives. The synergy between the national HPV introduction and the social media campaign was likely critical to success, reinforcing key messages through multiple channels. There is a need to use behavioral insights to shape messaging and delivery. Messages designed using behavioral frameworks – such as the Fogg Behavior Model – helped address caregivers' motivation, ability, and social influences. Tailoring content to address these behavioral drivers was a key success factor. Leverage real-time data for targeting and iteration. Digital platforms enabled campaign teams to monitor engagement and optimize content delivery in near-real time. This capacity to iterate and localize messages rapidly increased relevance and likely boosted impact.

Future campaigns should prioritize these elements when planning digital health communication strategies. Investing in local capacity to apply behavioral insights, coordinate across delivery platforms, and analyze digital data in real time may help realize the full potential of digital interventions for public health impact.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Author contributions

CRediT: **Sohail Agha:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Writing – original draft, Writing – review & editing; **Wu Zeng:** Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing.

Ethical approval

This study was reviewed and approved by the Institutional Review Board (IRB) of the Institute for Developing Science and Health Initiatives (ideSHi), Bangladesh. The approval reference number is Research Protocol #PNR-23003, dated 28 October 2023.

Notes on contributor

Sohail Agha PhD is an Affiliate Professor in the Department of Epidemiology at the University of Washington. With over 25 years of experience in both academia and practice, Dr. Agha has focused on evaluating and improving behavior change interventions in public health programs. His work spans vaccination, HIV/AIDS, family planning, reproductive health, and maternal and child health, with a particular emphasis on sub- Saharan Africa and South Asia. Dr. Agha has collaborated with academic institutions and implementing organizations in these regions. As founder of the Behavioral Insights Lab, Dr. Agha is currently involved in the use of behavioral insights to develop digital behavior change interventions to promote HPV Vaccine Uptake in Bangladesh and Nigeria. He is also strongly committed to promoting continuous learning approaches in public health and advancing behavior change models that are easily understood and widely adopted by development professionals. Dr. Agha earned his BA in Anthropology from Yale University in 1989 and his PhD in Population Dynamics from Johns Hopkins University in 1996.

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