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Promoting, seeking, and reaching vaccination services: A systematic review of costs to immunization programs, beneficiaries, and caregivers

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Abstract

Introduction: Understanding the costs to increase vaccination demand among under-vaccinated populations, as well as costs incurred by beneficiaries and caregivers for reaching vaccination sites, is essential to improving vaccination coverage. However, there have not been systematic analyses documenting such costs for beneficiaries and caregivers seeking vaccination.

Methods: We searched PubMed, Scopus, and the Immunization Delivery Cost Catalogue (IDCC) in 2019 for the costs for beneficiaries and caregivers to 1) seek and know how to access vaccination (i.e., costs to immunization programs for social mobilization and interventions to increase vaccination demand), 2)take time off from work, chores, or school for vaccination (i.e., productivity costs), and 3) travel to vaccination sites. We assessed if these costs were specific to

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Appendix A. Supplementary material
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populations that faced other non-cost barriers, based on a framework for defining hard-to-reach and hard-to-vaccinate populations for vaccination.

Results: We found 57 studies describing information, education, and communication (IEC) costs, social mobilization costs, and the costs of interventions to increase vaccination demand, with mean costs per dose at $0.41 (standard deviation (SD) $0.83), $18.86 (SD $50.65) and $28.23 (SD $76.09) in low-, middle-, and high-income countries, respectively. Five studies described productivity losses incurred by beneficiaries and caregivers seeking vaccination ($38.33 per person; SD $14.72; n = 3). We identified six studies on travel costs incurred by beneficiaries and caregivers attending vaccination sites ($11.25 per person; SD $9.54; n = 4). Two studies reported social mobilization costs per dose specific to hard-to-reach populations, which were 2–3.5 times higher than costs for the general population. Eight studies described barriers to vaccination among hard-to-reach populations.

Conclusion: Social mobilization/IEC costs are well-characterized, but evidence is limited on costs incurred by beneficiaries and caregivers getting to vaccination sites. Understanding the potential incremental costs for populations facing barriers to reach vaccination sites is essential to improving vaccine program financing and planning.

Keywords

Hard-to-reach; Hard-to-vaccinate; Immunization; Vaccination; Costs

1. Introduction

Global vaccination coverage of Diphtheria-tetanus-pertussis (DTP3) has hovered between 84% and 85% since 2010, and there have been calls for tailored strategies to increase vaccination coverage [1,2]. More recently, coronavirus disease 2019 (COVID-19) mitigation efforts early in the pandemic interrupted mass vaccination campaigns and hindered caregivers' ability to take children to health facilities for routine vaccinations [3], further increasing the need for efforts to increase immunization coverage. One of the challenges in increasing coverage is ensuring that potential beneficiaries and caregivers are informed, motivated, and able to get to the vaccination sites. Understanding the costs for promoting vaccination and ensuring that beneficiaries and caregivers can reach vaccination services is key to planning effective interventions to improve vaccination coverage. For example, a beneficiary in a geographically remote area may incur extra travel expenses to reach a vaccination location or the health system may incur additional social mobilization costs, and these costs will need to be factored in when planning interventions to improve vaccination coverage.

We identified three steps that are essential for beneficiaries and caregivers to reach vaccination sites that may result in costs: (1) beneficiary/caregiver seeks and knows how to access vaccination; (2) beneficiary/caregiver takes time off from work/chores/school for vaccination; and (3) beneficiary/caregiver travels to the vaccination site [4]. In order for beneficiaries and caregivers to reach vaccination sites to receive vaccines, all three of these essential steps must be met. These costs are typically incurred by different stakeholders –

while the costs for the first step are typically incurred by immunization programs, the costs associated with the other two steps are typically incurred by beneficiaries and caregivers.

For example, the very first step involves the costs of providing information to the beneficiary/caregiver and interventions to reinforce or increase beneficiary/caregiver motivation to seek vaccination. These costs are mainly incurred by vaccination programs to inform beneficiaries and caregivers about when and where to get vaccinated (e.g., hiring social mobilizers, distributing leaflets) [5]. There may also be intervention costs to increase vaccination demand, such as telephone outreach to educate and remind beneficiaries about vaccinations [5,9].

Moreover, beneficiaries/caregivers may incur productivity losses associated with taking time off from work/chores/school for vaccination [6]. Additionally, beneficiaries/caregivers may incur direct costs associated with other individuals (non-primary caregivers) taking care of other children or animals while the beneficiaries and primary caregivers seek vaccination. Finally, beneficiaries and caregivers may incur transport costs when traveling to vaccination sites. Hence, in order to ensure that beneficiaries and caregivers reach vaccination sites, we need to understand costs holistically by considering both costs incurred by vaccination programs and by beneficiaries/caregivers.

Several studies have described overall vaccination program costs or delivery costs, including the costs of interventions to increase vaccination coverage [7–11,17]. However, there are no systematic analyses documenting the full sequence of costs for beneficiaries and caregivers to be informed, motivated, and able to reach vaccination sites. Further, costs from the beneficiary perspective, including productivity losses associated with seeking vaccination, may be a barrier to people getting vaccinated. Decision-makers of vaccination programs can benefit from understanding the costs associated with people getting to vaccination locations, both from the perspectives of vaccination programs and the beneficiaries/caregivers. If costs incurred by beneficiaries and caregivers to seek vaccination may be prohibitive, then programs and policy makers need to know to plan interventions and policies to defray such costs.

Efforts to increase vaccination coverage have also focused on reaching under-vaccinated subpopulations [12,13], including hard-to-reach and hard-to-vaccinate populations. Understanding the costs to reach these populations, also known as high-risk or marginalized populations, or to reach the last mile, is essential to allocate resources appropriately [14]. Hard-to-reach populations denote those facing supply-side barriers to vaccination. These barriers may include geography by distance or terrain, transient or nomadic movement, healthcare provider discrimination, lack of healthcare provider recommendations, inadequate vaccination systems, war and conflict, home births, or other home-bound mobility limitations, or legal restrictions [14].

Meanwhile, we describe hard-to-vaccinate populations as those facing demand-side barriers to vaccination (e.g., distrust, religious beliefs, gender-based discrimination, lack of awareness, poverty, or low-socioeconomic status, or lack of time) [14]. It is important to note that the distinction between hard-to-reach and hard-to-vaccinate populations exists on a continuum, as supply-side barriers to vaccination can in turn affect demand for vaccination or magnify demand-side barriers [14]. The same population could be classified as hard-to-reach, hard-to-vaccinate, or both, based on the processes or factors that result in them being unvaccinated. Under-vaccination of hard-to-reach and hard-to-vaccinate populations results in high preventable disease burden and can be an impediment to disease control efforts [15]. Thus, it is also important to understand the economic evidence around beneficiaries and caregivers who face hard-to-reach and hard-to-vaccinate barriers to reach vaccination sites, as there may be higher costs associated with their vaccination compared to the general population [16,19].

This systematic review focused on documenting the state of the evidence on the costs associated with getting beneficiaries and caregivers to vaccination sites, including how these costs may vary for hard-to-reach and hard-to-vaccinate populations. Our review included costs from any perspective, aiming to reflect the total costs of promoting, seeking and reaching vaccination services.

2. Methods

We developed search strings for steps involved in beneficiaries and their caregivers reaching vaccination sites that result in costs. Namely, these were related to the beneficiaries and caregivers: (1) seeking and knowing how to access vaccination; (2) taking time off from work, chores, or school for vaccination; and (3) traveling to the vaccination site. All three searches included terms related to cost and immunization/vaccination, in addition to specific terms related to each step for beneficiaries to reach vaccination sites. Specific search terms included social mobilization, information, education, and communication (IEC) efforts to ensure that beneficiaries and their caregivers knew when and where to get vaccinated, as well as interventions to increase vaccination demand such as recall-reminders and incentive programs (including monetary incentives). We also included search terms to capture productivity losses associated with beneficiaries and caregivers seeking vaccination, and travel costs incurred by them to reach vaccination sites (see Appendix for complete search strategy and terms). The search was conducted and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) reporting guidelines [18].

All searches were conducted in the PubMed and Scopus databases on May 20, 2019. We restricted the search results to human studies that were published in English since 2000. For costs associated with beneficiaries/caregivers seeking and knowing how to access vaccination, we additionally supplemented our search by reviewing all references compiled in the Immunization Delivery Cost Catalogue (IDCC) by the Immunization Costing Action Network (ICAN) as of October 2019 [19]. The IDCC is a catalogue of immunization delivery costs across low- and middle-income countries (LMICs) extracted from a systematic review of peer-reviewed literature, reports, and grey literature [19]. We abstracted additional social mobilization and IEC costs not captured in our initial search, but included in the IDCC.

A team of five study members independently screened titles and abstracts and assessed full texts for eligibility, with at least two reviewers screening each study. The study team reached a consensus for the inclusion of discrepant studies, based on inclusion and exclusion criteria, which were decided *a priori*. We first screened the titles and abstracts of identified studies for relevance, excluding studies that did not describe the costs associated with our mechanisms of interest. We reviewed the full text of articles for which we could not determine relevance based on the title and abstract alone. We included studies that described costs related to the steps for beneficiaries and caregivers to reach vaccination sites, across all target populations (i.e. children, adolescents, and adult vaccination) [4]. We excluded the following studies: 1) those that did not describe social mobilization, IEC costs, or the costs of interventions to increase immunization demand (including incentives), productivity losses for beneficiaries and caregivers to obtain a vaccination, or travel costs for vaccination; 2) studies with no costing information related to these mechanisms; 3) those that reported or combined social mobilization or communication costs with other cost categories as part of broader ‘delivery costs’, where social mobilization or communication costs could not be disaggregated. If not explicitly stated, we assumed that all social mobilization and IEC activities included information on when and where beneficiaries and caregivers could get vaccinated. We reviewed systematic reviews for additional studies that might meet our inclusion/exclusion criteria.

For each study included, we extracted descriptive information, including the setting and context in which relevant costs were collected or interventions were costed. For example, we noted whether the study estimated social mobilization costs for an entire immunization program or for a small-scale pilot. We extracted information across several fields: the types of vaccines targeted or delivered through the intervention or for which beneficiaries/-caregivers incurred costs; the size of target populations for programs and interventions; the vaccine delivery mode (routine immunization or supplementary immunization activities (SIA)/-campaigns); and the number of doses delivered. We abstracted all study-reported costs, including overall financial costs for the program or intervention, and overall economic and financial costs for beneficiaries and caregivers. We also abstracted costs per dose administered, costs per person vaccinated, costs per person targeted, and costs per person in intervention groups. For studies that only reported overall costs, we used the reported number of doses delivered or the size of target populations to calculate the cost per dose administered or the cost per person vaccinated/targeted.

For each cost per dose or cost per person vaccinated/targeted estimate, we calculated a proportion, as a percentage, of the cost estimate compared to the respective country’s gross domestic product (GDP) per capita [20]. Further, for each cost per dose estimate from a LMIC, we calculated a percentage as compared to the respective country’s predicted delivery cost per dose for routine delivery of childhood vaccines [21]. We classified country income status according to income levels of countries where the studies occurred, using World Bank classifications from 2020 [22]. Under the World Bank country income level classifications, studies were classified as being conducted in high-income, upper-middle income, lower-middle income, or low-income countries. We converted and report all intervention costs in 2019 US dollars ($). For studies that reported costs in US$, we used the U.S. consumer price index to inflate costs to 2019 US$ [23]. For studies that reported costs in other currencies, we used the local country's consumer price index to inflate costs to 2019, and then converted to US$ using foreign currency exchange rates [24,25]. For studies on social mobilization, IEC, or other interventions to increase immunization demand, we adopted a prior classification of immunization interventions [9]. We classified interventions as utilizing education, reminders, immunization information systems (IIS), incentives, expanding current routine immunization services (e.g. social mobilization as part of new vaccine introductions), or conducting SIA/campaigns [9]. We summarized mean costs per dose by these intervention classifications.

We reviewed full texts of each included study to determine whether it reported costs related to beneficiaries/caregivers who faced barriers to vaccination that made them 'hard-to-reach' or 'hard-to-vaccinate,' based on a proposed framework for defining hard-to-reach populations for vaccination [14]. In classifying whether a study reported costs specific to a hard-to-reach or a hard-to-vaccinate population, we included any study that described barriers to vaccination that made populations hard-to-reach or hard-to-vaccinate, even though the study may not necessarily have been explicitly focused on the barriers. For each study that described hard-to-reach or hard-to-vaccinate barriers to vaccination, we noted the relevant hard-to-reach or hard-to-vaccinate mechanism(s) and abstracted any costs that were specific to hard-to-reach or hard-to-vaccinate populations.

3. Results

Fig. 1 summarizes our literature search process that led to the final inclusion of 64 unique studies [26–83]. Our PubMed and Scopus search initially returned 7,531 unique articles across the three searches for costs associated with vaccine beneficiaries and care-givers getting to vaccination sites. This included 5,215 articles from the search on beneficiary and caregiver seeking and knowing how to access vaccination; 1,516 articles from the search on beneficiary and caregiver taking time off work, chores, or school; and 773 articles from the search for beneficiary and caregiver traveling to vaccination sites. We identified an additional 14 relevant studies in the IDCC catalogue, and 13 more studies from reviewing articles included in previous systematic reviews on the costs of vaccination interventions [9,84,85]. Following our initial screening of all titles and abstracts, we identified 228 studies for full-text review. This included 144 articles from the search for social mobilization costs, IEC costs, and the costs of interventions to increase vaccination demand, 34 articles from the search for productivity loss incurred by beneficiaries and caregivers, and 50 articles from the search for travel costs incurred by beneficiaries and caregivers to get to vaccination sites. We excluded 97 studies that did not describe the mechanisms of interest in our study. We further excluded 59 studies that described the mechanisms of interest but did not report specific costs, including studies that combined other immunization cost categories. Four studies that were published before 2000, three systematic reviews, and one study that did not discuss human vaccination were excluded.

Of the 64 unique studies included, 57 featured costs associated with beneficiaries and caregivers seeking and knowing how to access vaccination. Five studies focused on costs associated with beneficiaries and caregivers taking time off from work, chores, or school to seek vaccination, and six studies estimated the travel costs incurred by beneficiaries and caregivers for vaccination. Only eight out of 64 studies (12.5%) described the costs for beneficiaries and caregivers who faced hard-to-reach barriers to vaccination. Six studies reported on the costs for populations that were hard-to-reach for vaccination due to geography by distance or terrain, while the remaining two described costs for those who were hard-to-reach for vaccination due to inadequate vaccination systems.

3.1. Costs for beneficiaries and caregivers to seek and know how to access vaccination

Table 1 summarizes the data we extracted from 57 studies that reported the financial costs incurred by immunization programs to conduct social mobilization, IEC, and other interventions to increase vaccination demand [26,28–30,32–41,43,44,46,48–53,5 5–83,86–89]. Most of the studies were conducted in high-income countries (n = 24), followed by low-income (n = 17), lower-middle income (n = 13), and upper-middle income countries (n = 3). Reminder/recall interventions were the most common study topic with 23 studies reporting the costs of interventions that used reminder and/or recall systems to inform beneficiaries and caregivers about vaccination [35,56,63–69,71–74,76–83,86,8 7]. The reminder and recall systems included telephone-based text messaging, phone calls, emails, and post-card/letter-based reminders. Mass vaccination campaigns delivering cholera vaccines were the next most common study type with nine studies reporting social mobilization costs for cholera vaccine campaigns [32,40,42,43,50,55,57,58,60], followed by 14 studies on social mobilization costs for human papillomavirus (HPV), hepatitis B, measles, meningococcal, pentavalent, pneumococcal, polio, and rotavitus vaccine introductions [29,30,33,34,36,38,39,44,46,48,49,52,53,89].

Three studies costed entire routine national immunization programs, including the social mobilization cost components of programs in Colombia, India, and China [41,51,61]. Five studies reported the costs of educational interventions informing beneficiaries and caregivers about vaccination [26,28,59,70,75], and three studies reported the costs of interventions that used incentives (both monetary and nonmonetary) as an intervention component [62,75,88]. None of the studies had estimated the costs for beneficiaries and caregivers to search for information on vaccination, such as time to attend health education meetings delivered by community health workers.

The costs of social mobilization, IEC, and interventions to increase vaccination demand ranged widely, as did the scale and contexts of the interventions and programmatic efforts. In low-income countries, the mean cost per dose of such interventions was $0.41 (range $0.02-$2.97; standard deviation (SD) $0.83) among 11 studies that reported on or for which we could calculate a cost per dose. These costs on average amounted to 0.019% (range 0.001%− 0.057%; SD 0.020%) of low-income countries' GDP per capita. In high-income countries, the mean cost per dose of such interventions was $28.28 across 21 studies (range $0.24–$360.05; SD $76.08), accounting for 0.045% (range 0.0004%–0.573%; SD 0.121%) of high-income countries' GDP per capita. Mean costs per dose across lower- and upper-middle income countries (n = 11) were $18.86 (range $0.01–$178; SD $50.65). Lower- and upper-middle income countries incurred the highest costs as a proportion of their GDP per capita at 0.959% (range 0.001%−8.862%; SD 2.518%).

Across 21 cost per dose estimates from LMICs, the average cost per dose was 9.5 times higher (range 0.005–169.65, SD 36.05) than the respective country's predicted delivery cost per dose for routine delivery of childhood vaccines. Average intervention costs across six studies involving education, mostly in high-income countries, were $46.13 per dose (SD $57.83), followed by 12 studies involving reminders, which cost $40.90 per dose (SD $101.56). Average costs for IIS interventions in high-income countries were $2.20 per dose (SD $1.48) across five studies. For interventions mostly in LMICs, average costs were $0.55 (SD $0.93) across eight interventions that expanded routine immunization services, and $0.09 per dose (SD $0.07) across 11 interventions that were part of SIA/campaigns.

We identified seven studies that reported the costs of social mobilization, IEC, and demand-generation programs and interventions, targeting beneficiaries and caregivers who were classified as hard-to-reach for vaccination [37,46,55,57,62,68,72]. Of the seven studies, three studies were conducted in low-income countries [46,55,57], another three studies were conducted in lower-middle income countries [37,62,68], and one study was conducted in a high-income country [72]. Geography by distance or terrain was the most commonly reported barrier that made beneficiaries and caregivers hard-to-reach for vaccination across three lower-middle income and two low-income countries (n = 5). Inadequate health systems was another reported barrier in two countries (lower-middle income and high-income countries). Among the studies with beneficiaries and caregivers facing hard-to-reach barriers, overall average costs per dose for studies in low-income and lower-middle income countries were $0.08 (range $0.02-$0.18; SD $0.07) and $7.79 (range $0.03-$15.55; SD $7.76), respectively. One study in a high-income country reported the average cost per dose at $11.57 targeting hard-to-reach populations.

Most of these studies (5 of 7) did not provide estimates that compared the costs of reaching hard-to-reach populations as opposed to general populations.; however, two studies reported such costs. The first study, conducted in a district of Cameroon, reported social mobilization costs for vaccination outreach for beneficiaries who were hard-to-reach due to geography by distance (i.e. those living in villages over 20 km from the nearest health facility) [37]. Average costs per dose to reach this hard-to-reach population was $0.14, compared to average costs per dose of $0.04 (incremental cost $0.10) reported for the population that lived near health facilities and did not face the distance barrier to vaccination. The second study, conducted in Haiti, reported social mobilization costs for vaccination outreach in a mass vaccination campaign targeting beneficiaries who were hard-to-reach due to geography by terrain (i.e. those who lived in a mountainous region that was difficult to traverse) [57]. The average costs per dose for the hard-to-reach population was $0.04, compared to average costs per dose of $0.02 (incremental cost $0.02) in a population that lived in an urban area and did not face similar terrain-related barriers to vaccination.

3.2. Costs by beneficiaries and caregivers to take time off from work, chores, or school

We identified five studies that reported the economic costs associated with beneficiaries and caregivers taking time off from work, chores, or school for vaccination (Table 2) [27,31,45,47,90]. One study conducted a household survey to estimate the costs of receiving a free dose of cholera vaccine in a mass campaign in India and reported the productivity losses incurred by beneficiaries and their family members [47]. The productivity losses were measured, using three methods: reported wage losses, minimum wage, and GDP per capita. Productivity losses related to work were calculated based on lost income from self-reported time off work, while time lost for other non-market activities such as school, chores, or leisure was measured by applying an activity-specific fraction of daily wages [47]. Individual productivity losses incurred for a single dose of vaccine ranged from $0.18 to $0.34, while productivity losses for the family ranged from $0.70 to $1.34, depending on the valuation method used. These productivity losses along with out-of-pocket travel costs constituted 24.6–38.0% of the overall vaccine delivery costs of the campaign. Productivity losses ranged between 17.1% and 127.6% of the predicted delivery costs per dose for routine delivery of childhood vaccines in LMICs.

Another study conducted a post-intervention survey of productivity costs incurred by patients seeking the measles, mumps and rubella (MMR) vaccine in the United Kingdom [90]. Productivity losses were measured based on lost income by taking time off work to attend MMR vaccination appointments. Average productivity losses due to lost income per person incurred by caregivers in the intervention was $56.96 [90]. Similarly, a study in Israel estimated costs incurred by parents for work absences in order for their child to receive a second dose of Hepatitis A vaccine at $7.87 [27]. Finally, two studies in the United States estimated average costs of caregiver time away from work at $21 and $37, based on the assumption that caregivers needed two hours away from work for children's vaccination [31,45].

We did not identify any studies that reported the productivity losses associated with time taken off non-productive work, chores, or school by beneficiaries and caregivers for vaccination, or other family members providing care in households. We also did not identify any studies reporting the costs associated with beneficiaries and caregivers classified as hard-to-reach or hard-to-vaccinate taking time off from work, chores, or school for vaccination.

3.3. Costs by beneficiaries and caregivers to travel to vaccination sites

We found six studies that reported financial travel costs associated with beneficiaries and caregivers traveling to vaccination sites (Table 2) [27,31,45,47,54,90]. Four studies were conducted in high-income countries (one in Israel, one in the United Kingdom, and two in the United States) [27,31,45,90]. One study was in a lower-middle income country (India) [47], and another was in a low-income country (Guinea-Bissau) [54]. Among studies conducted in high-income countries, the study in Israel modelled travel costs for beneficiaries and caregivers to receive an additional dose of the Hepatitis A vaccine ($0.22 per dose) based on public and private transport costs [27]. Transport costs for beneficiaries and caregivers receiving the MMR vaccine in the United Kingdom was reported at $14.48 per person [90]. Two studies in the United States estimated overall travel costs for caregivers of beneficiaries receiving vaccines in the routine immunization schedule at $5.05 and $25.75 per person [31,45].

The two LMIC studies conducted household surveys to measure self-reported travel costs for caregivers of beneficiaries receiving a dose of cholera vaccine in India ($0.01 per individual and $0.02 per family) [47] and travel costs to receive measles doses in Guinea-Bissau ($1.15 per person) [54]. Travel costs in India represented 0.9%−1.9% of the predicted delivery cost per dose for routine delivery of childhood vaccines.

Only one study in Guinea-Bissau described vaccination travel costs for beneficiaries and caregivers who faced supply-side barriers that made them hard-to-reach for vaccination due to geographical terrain-related barriers. Poor road infrastructure increased travel times and often became impassable during the rainy season, making villages inaccessible [54]. Due to the methods of the study, it was not possible to separate out the incremental costs specific to hard-to-reach populations. We did not identify any studies reporting the travel costs for beneficiaries and caregivers who faced demand-side barriers to vaccination that made them hard-to-vaccinate.

4. Discussion

Our synthesis found that the costs of programmatic and intervention efforts to ensure that beneficiaries and caregivers seek and know how to access vaccination were relatively well characterized in the literature. However, fewer studies documented the costs associated with beneficiaries and caregivers taking time off from work or chores for vaccination or traveling to vaccination sites. Evidence on the costs for beneficiaries and caregivers who faced hard-to-reach or hard-to-vaccinate barriers to vaccination was particularly limited, with only eight out of 64 studies (12.5%) describing beneficiaries and caregivers who faced such barriers and only two studies describing the costs specific to hard-to-reach populations. Extending vaccination to hard-to-reach and hard-to-vaccinate populations is important for reasons of equity and disease control, such as controlling polio outbreaks among populations who are hard-to-reach due to war and conflict [91], and transient migrant populations [92]. While prior systematic reviews have documented the costs of immunization programs and of interventions to improve immunization coverage [7,9,10,93], our study is the first to include a synthesis of costs from the perspective of beneficiaries and caregivers. Moreover, none of the prior studies have specifically characterized the costs for populations that are hard-to-reach or hard-to-vaccinate.

The paucity of studies describing the costs associated with some of the mechanisms associated with beneficiaries and caregivers getting to vaccination sites, and for hard-to-reach or hard-to-vaccinate beneficiaries and caregivers, suggests gaps in the literature. This highlights the need for further studies to document these costs. In contrast to limited literature on the costs associated with seeking vaccination or getting to vaccination sites, there is considerable literature on productivity losses and travel costs incurred by beneficiaries and caregivers due to vaccine-preventable diseases [94–96]. The limited literature on costs incurred by beneficiaries and caregivers in seeking vaccination, particularly on productivity losses from non-work-related activities, may also reflect inherent difficulty in measuring such costs. We found one study that measured productivity losses from forgoing non-work-related activities, such as time for leisure and chores, by applying a fraction of wages [47]. However, there may be a need to develop more precise costing methods to measure these costs.

Persistence of these gaps in the literature associated with beneficiaries and caregivers getting to vaccination sites could potentially hamper immunization program planning and efforts to improve immunization coverage, especially among hard-to-reach and hard-to-vaccinate populations. Greater evidence for the costs associated with these mechanisms would help decision-makers better understand the hidden costs of vaccination, especially among hard-to-reach populations. For example, interventions to improve vaccination demand and uptake may consider the use of incentives or other compensatory mechanisms to offset and minimize productivity losses associated with beneficiaries and caregivers seeking vaccination [62,97]. Likewise, knowing the costs of social mobilization, IEC, and interventions to increase vaccination demand, especially for hard-to-reach and hard-to-vaccinate populations, can help with program planning and better ensure the allocation of adequate resources. Our finding that average costs per dose of social mobilization/IEC interventions and interventions to increase vaccination demand were substantially higher than overall predicted delivery cost per dose in some countries could indicate higher resource needs, beyond the predicted delivery costs.

Failure of vaccination programs to account for the costs that potentially differ by hard-to-reach populations can also thwart efforts to vaccinate these populations because there is a need to quantify any additional resources needed by immunization programs for social mobilization and IEC efforts taregeting populations that face various barriers to vaccination. As suggested by the evidence from the two studies with costs specific to hard-to-reach populations [37,57], social mobilization costs, communication costs, and the costs for interventions to increase demand for vaccination incurred by the vaccination system could be much higher for populations facing barriers that make them hard-to-reach. Understanding the productivity losses and travel costs incurred by beneficiaries and caregivers is particularly important for decision-makers because these may determine a person’s decision to vaccinate, and if prohibitive, lead to under-vaccination [54,98,99]. Some people might lack the job security needed to take time off from work to get vaccinated, or beneficiaries and caregivers may incur high productivity losses when they take time off [100]. Such costs may be prohibitive of persons reaching vaccination sites, leading to missed opportunities for vaccination, resulting in under-vaccination, and increasing the potential to spread vaccine-preventable diseases.

The costs incurred by beneficiaries and caregivers illustrate the overlap between hard-to-reach and hard-to-vaccinate barriers to vaccination. Some beneficiaries and caregivers need to travel long distances or traverse difficult terrain to reach clinics, hospitals, or other locations for vaccination [101–104]. Due to these geographical factors, travel costs to reach vaccination sites may be higher for populations in geographically remote areas compared to more urban settings or areas where vaccination sites are closer to populations. The costs of such travel could make a person hard-to-reach and affect their likelihood to get vaccinated. At the same time, the higher travel costs related to geographic or other factors could reduce individuals’ demand for vaccination, simultaneously becoming a demand-side barrier to vaccination. While the same populations may face multiple demand- and supply-side barriers to vaccination, characterizing these populations based on processes or factors that impede vaccination facilitates better estimation of the size of target groups, as well as help target appropriate interventions to remove these barriers.

We note some limitations to our study. First, our systematic literature search did not include the gray literature. While we supplemented our PubMed and Scopus searches by reviewing studies compiled in IDCC [19] and references of prior systematic reviews [9–11], we may have missed studies beyond these databases. Operationalizing a systematic search for costs incurred by beneficiaries and caregivers is also particularly difficult, and because our systematic search terms initially searched study titles and abstracts, we may have missed the nuanced descriptions of such costs in the full text of articles. Further, we limited our search to studies published in English language since year 2000. Second, differences in study methods and contexts in which the studies were conducted limited our ability to synthesize and compare cost information across studies. Some studies included modelled costs whereas others gathered cost information from surveys. Extracted costs ranged from costs of small-scale pilot interventions to costs of national-level immunization programs. Thus, caution should be applied in the interpretation of costs across studies, given the range of different interventions and settings. Although costs across settings may differ in absolute terms, the differences may be smaller in purchasing power parity terms. Costs per dose for different interventions also do not provide the cost-effectiveness of interventions.

Third, the lack of consistent use of the definition of hard-to-reach or hard-to-vaccinate populations [14] may have impacted our classification of the costs among populations facing immunization barriers. Specifically, studies characterizing immunization-related costs or interventions may implicitly target or include hard-to-reach populations, but not explicitly state that in the study objective, making it difficult to classify the study. For example, a study describing the costs of an intervention to increase demand for vaccination may not describe the barriers that led to the low demand or to the reasons beneficiaries were not aware of when and where to get vaccinated. Moreover, this review focused on costs of demand-side interventions that directly relate to beneficiaries and caregivers seeking and knowing how to access vaccination. Our review does not consider the costs of vaccines and their impact on beneficiaries and caregivers’ willingness to travel to health facilities. Finally, in a few studies that described beneficiaries and caregivers facing hard-to-reach barriers to vaccination, most study designs did not allow for explicit comparisons of the costs to reach the hard-to-reach population as opposed to the general population. Therefore, future studies aiming to cost efforts for beneficiaries and caregivers to reach vaccination sites or measuring costs incurred by beneficiaries and caregivers should employ study designs that measure these potential differential costs.

5. Conclusion

Our systematic review of the costs for beneficiaries and caregivers to reach vaccination sites found significant gaps in information about the costs of social mobilization, IEC, and interventions to increase vaccination demand in populations facing barriers to vaccination that make them hard-to-reach. Estimates of these costs were available for populations that were not hard-to-reach across a range of settings. These costs per dose to reach populations facing hard-to-reach barriers to vaccination were 2–3.5 times higher than those of the general population in the two studies identified. However, further evidence is needed to generalize these findings. There is also a lack of information on the costs incurred by beneficiaries and caregivers to get to vaccination sites, including productivity losses, and travel costs associated with seeking vaccination, especially for populations who are hard-to-reach or hard-to-vaccinate. This might reflect the inherent difficulty in measuring these costs from the perspective of beneficiaries and caregivers seeking vaccination, requiring different data collection methods [47]. The dearth of studies on productivity losses may reflect the lack of policy prioritization to try to understand beneficiaries and caregivers' costs, in order to remove additional barriers to vaccination. As countries reach higher levels of immunization coverage, the costs incurred by beneficiaries and caregivers may become more salient barriers to vaccination. Future studies should collect additional evidence on these costs to aid the design of interventions and programs to increase immunization coverage and reach hard-to-reach and hard-to-vaccinate populations with vaccination.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Declaration of Competing Interest

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References

[1]. World Health Organization. WHO-UNICEF estimates of DTP3 coverage. Geneva, Switzerland: World Health Organization; 2020. https://apps.who.int/immunization_monitoring/globalsummary/timeseries/tswucoveragedtp3.html.

[2]. Peck M, Gacic-Dobo M, Diallo MS, Nedelec Y, Sodha SS, Wallace AS. Global Routine Vaccination Coverage, 2018. MMWR Morb Mortal Wkly Rep 2019;68:937–42. [PubMed: 31647786]

[3]. United Nations Children's Fund (UNICEF). Immunization coverage: Are we losing ground? New York, NY: UNICEF; 2020. https://data.unicef.org/resources/immunization-coverage-are-we-losing-ground/.

[4]. Cox SN, Wedlock PT, Pallas SW, Mitgang EA, Yemeke TT, Bartsch SM, et al. A systems map of the economic considerations for vaccination: Application to hard-to-reach populations. Vaccine 2021;S0264–410X(21):00605–8–00608.

[5]. World Health Organization. Improving vaccination demand and addressing hesitancy. Geneva, Switzerland: World Health Organization; 2020.

[6]. World Health Organization. WHO guide for standardization of economic evaluations of immunization programmes. Geneva, Switzerland: World Health Organization; 2019. Accessed April 8, 2021: https://apps.who.int/iris/bitstream/handle/10665/329389/WHO-IVB-19.10-eng.pdf?ua=1.

[7]. Pegurri E, Fox-Rushby JA, Damian W. The effects and costs of expanding the coverage of immunisation services in developing countries: a systematic literature review. Vaccine 2005;23:1624–35. [PubMed: 15694515]

[8]. Batt K, Fox-Rushby JA, Castillo-Riquelme M. The costs, effects and cost-effectiveness of strategies to increase coverage of routine immunizations in low- and middle-income countries: systematic review of the grey literature. Bull World Health Organ 2004;82:689–96. [PubMed: 15628207]

[9]. Ozawa S, Yemeke TT, Thompson KM. Systematic review of the incremental costs of interventions that increase immunization coverage. Vaccine 2018;36:3641–9. [PubMed: 29754699]

[10]. Munk C, Portnoy A, Suharlim C, Clarke-Deelder E, Brenzel L, Resch SC, et al. Systematic review of the costs and effectiveness of interventions to increase infant vaccination coverage in low- and middle-income countries. BMC Health Serv Res 2019;19:741. [PubMed: 31640687]

[11]. Vaughan K, Ozaltin A, Mallow M, Moi F, Wilkason C, Stone J, et al. The costs of delivering vaccines in low- and middle-income countries: Findings from a systematic review. Vaccine: X. 2019;2:100034.

[12]. Sodha SV, Dietz V. Strengthening routine immunization systems to improve global vaccination coverage. Br Med Bull 2015;113:5–14. [PubMed: 25649959]

[13]. Oyo-Ita A, Wiysonge CS, Oringanje C, Nwachukwu CE, Oduwole O, Meremikwu MM. Interventions for improving coverage of childhood immunisation in low- and middle-income countries. Cochrane Database Syst Rev. 2016;7:Cd008145.

[14]. Ozawa S, Yemeke TT, Evans DR, Pallas SE, Wallace AS, Lee BY. Defining hard-to-reach populations for vaccination. Vaccine 2019;37:5525–34. [PubMed: 31400910]

[15]. Bhutta ZA. The last mile in global poliomyelitis eradication. Lancet 2011;378:549–52. [PubMed: 21664681]

[16]. Lee BY, Brown ST, Haidari LA, Clark S, Abimbola T, Pallas SE, et al. Economic value of vaccinating geographically hard-to-reach populations with measles vaccine: A modeling application in Kenya. Vaccine 2019;37:2377–86. [PubMed: 30922700]

[17]. Ozawa S, Grewal S, Portnoy A, Sinha A, Arilotta R, Stack ML, et al. Funding gap for immunization across 94 low- and middle-income countries. Vaccine 2016;34:6408–16. [PubMed: 28029541]

[18]. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med 2009;6:e1000097.

[19]. Immunization Costing Action Network (ICAN). Immunization Delivery Cost Catalogue. Washington, DC: ThinkWell ICAN; 2019. http://immunizationeconomics.org/ican-idcc.

[20]. The World Bank. World Development Indicators. Washington, DC: The World Bank; 2020. https://databank.worldbank.org/source/world-development-indicators.

[21]. Portnoy A, Vaughan K, Clarke-Deelder E, Suharlim C, Resch SC, Brenzel L, et al. Producing Standardized Country-Level Immunization Delivery Unit Cost Estimates. Pharmacoeconomics 2020;38:995–1005. [PubMed: 32596785]

[22]. The World Bank.. World Bank Countryand Lending Groups. Washington, DC: The World Bank; 2017. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups.

[23]. US Department of Labor. Consumer Price. Index Washington, DC: US Bureau of Labor Statistics; 2017. https://www.bls.gov/cpi/.

[24]. OANDA. Currency Converter. OANDA Corporation; 2021. Accessed: April 8, 2021. https://www1.oanda.com/currency/converter/.

[25]. Turner HC, Lauer JA, Tran BX, Teerawattananon Y, Jit M. Adjusting for Inflation and Currency Changes Within Health Economic Studies. Value Health 2019;22:1026–32. [PubMed: 31511179]

[26]. Deuson RR, Brodovicz KG, Barker L, Zhou F, Euler GL. Economic analysis of a child vaccination project among Asian Americans in Philadelphia. Pa Arch Pediatr Adolesc Med 2001;155:909–14. [PubMed: 11483118]

[27]. Ginsber GM, Slater PE, Shouval D. Cost-benefit analysis of a nationwide infant immunization programme against hepatitis A in an area of intermediate endemicity. J Hepatol 2001;34:92–9. [PubMed: 11211913]

[28]. Zhou F, Euler GL, McPhee SJ, Nguyen T, Lam T, Wong C, et al. Economic analysis of promotion of hepatitis B vaccinations among Vietnamese-American children and adolescents in Houston and Dallas. Pediatrics 2003;111:1289–96. [PubMed: 12777543]

[29]. Griffiths UK, Hutton G, Das Dores Pascoal E. The cost-effectiveness of introducing hepatitis B vaccine into infant immunization services in Mozambique. Health Policy Plan. 2005;20:50–9. [PubMed: 15689430]

[30]. Mascarenas A, Salinas J, Tasset-Tisseau A, Mascarenas C, Khan MM. Polio immunization policy in Mexico: economic assessment of current practice and future alternatives. Public Health 2005;119:542–9. [PubMed: 15826896]

[31]. Zhou F, Santoli J, Messonnier ML, Yusuf HR, Shefer A, Chu SY, et al. Economic evaluation of the 7-vaccine routine childhood immunization schedule in the United States, 2001. Arch Pediatr Adolesc Med 2005;159:1136–44. [PubMed: 16330737]

[32]. Cavailler P, Lucas M, Perroud V, McChesney M, Ampuero S, Guerin PJ, et al. Feasibility of a mass vaccination campaign using a two-dose oral cholera vaccine in an urban cholera-endemic setting in Mozambique. Vaccine 2006;24:4890–5. [PubMed: 16298025]

[33]. Hutton G, Tediosi F. The costs of introducing a malaria vaccine through the expanded program on immunization in Tanzania. Am J Trop Med Hyg 2006;75:119–30. [PubMed: 16931823]

[34]. Griffiths UK, Korczak VS, Ayalew D, Yigzaw A. Incremental system costs of introducing combined DTwP-hepatitis B-Hib vaccine into national immunization services in Ethiopia. Vaccine 2009;27:1426–32. [PubMed: 19146901]

[35]. Vora S, Verber L, Potts S, Dozier T, Daum RS. Effect of a novel birth intervention and reminder-recall on on-time immunization compliance in high-risk children. Hum Vaccin 2009;5:395–402. [PubMed: 19029825]

[36]. Colombini A, Badolo O, Gessner BD, Jaillard P, Seini E, Da Silva A. Costs and impact of meningitis epidemics for the public health system in Burkina Faso. Vaccine 2011;29:5474–80. [PubMed: 21641952]

[37]. Ebong CE, Levy P. Impact of the introduction of new vaccines and vaccine wastage rate on the cost-effectiveness of routine EPI: lessons from a descriptive study in a Cameroonian health district. Cost Eff Resour Alloc 2011;9:9. [PubMed: 21619674]

[38]. Hutubessy R, Levin A, Wang S, Morgan W, Ally M, John T, et al. A case study using the United Republic of Tanzania: costing nationwide HPV vaccine delivery using the WHO Cervical Cancer Prevention and Control Costing Tool. BMC Med 2012;10:136. [PubMed: 23146319]

[39]. Quentin W, Terris-Prestholt F, Changalucha J, Soteli S, Edmunds WJ, Hutubessy R, et al. Costs of delivering human papillomavirus vaccination to schoolgirls in Mwanza Region. Tanzania BMC Med 2012;10:137. [PubMed: 23148516]

[40]. Schaetti C, Weiss MG, Ali SM, Chaignat CL, Khatib AM, Reyburn R, et al. Costs of illness due to cholera, costs of immunization and cost-effectiveness of an oral cholera mass vaccination campaign in Zanzibar. PLoS Negl Trop Dis 2012;6:e1844. [PubMed: 23056660]

[41]. Castaneda-Orjuela C, Romero M, Arce P, Resch S, Janusz CB, Toscano CM, et al. Using standardized tools to improve immunization costing data for program planning: the cost of the Colombian Expanded Program on Immunization. Vaccine 2013;31(Suppl 3):C72–9. [PubMed: 23777695]

[42]. Khan IA, Saha A, Chowdhury F, Khan AI, Uddin MJ, Begum YA, et al. Coverage and cost of a large oral cholera vaccination program in a high-risk cholera endemic urban population in Dhaka. Bangladesh Vaccine 2013;31: 6058–64. [PubMed: 24161413]

[43]. Kar SK, Sah B, Patnaik B, Kim YH, Kerketta AS, Shin S, et al. Mass vaccination with a new, less expensive oral cholera vaccine using public health infrastructure in India: the Odisha model. PLoS Negl Trop Dis 2014;8:e2629. [PubMed: 24516675]

[44]. Usuf E, Mackenzie G, Lowe-Jallow Y, Boye B, Atherly D, Suraratdecha C, et al. Costs of vaccine delivery in the Gambia before and after, pentavalent and pneumococcal conjugate vaccine introductions. Vaccine 2014;32:1975–81. [PubMed: 24503271]

[45]. Zhou F, Shefer A, Wenger J, Messonnier M, Wang LY, Lopez A, et al. Economic evaluation of the routine childhood immunization program in the United States, 2009. Pediatrics 2014;133:577–85. [PubMed: 24590750]

[46]. Kaucley L, Levy P. Cost-effectiveness analysis of routine immunization and supplementary immunization activity for measles in a health district of Benin. Cost Eff Resour Alloc 2015;13:14. [PubMed: 26300696]

[47]. Mogasale V, Kar SK, Kim JH, Mogasale VV, Kerketta AS, Patnaik B, et al. An Estimation of Private Household Costs to Receive Free Oral Cholera Vaccine in Odisha. India PLoS Negl Trop Dis 2015;9:e0004072.

[48]. Ngabo F, Levin A, Wang SA, Gatera M, Rugambwa C, Kayonga C, et al. A cost comparison of introducing and delivering pneumococcal, rotavirus and human papillomavirus vaccines in Rwanda. Vaccine 2015;33:7357–63. [PubMed: 26519548]

[49]. Ruhago GM, Ngalesoni FN, Robberstad B, Norheim OF. Cost-effectiveness of live oral attenuated human rotavirus vaccine in Tanzania. Cost Eff Resour Alloc 2015;13:7. [PubMed: 25949216]

[50]. Sarker AR, Islam Z, Khan IA, Saha A, Chowdhury F, Khan AI, et al. Estimating the cost of cholera-vaccine delivery from the societal point of view: A case of introduction of cholera vaccine in Bangladesh. Vaccine 2015;33:4916–21. [PubMed: 26232545]

[51]. Chatterjee S, Pant M, Haldar P, Aggarwal MK, Laxminarayan R. Current costs & projected financial needs of India's Universal Immunization Programme. Indian J Med Res 2016;143:801–8. [PubMed: 27748306]

[52]. Griffiths UK, Bozzani FM, Chansa C, Kinghorn A, Kalesha-Masumbu P, Rudd C, et al. Costs of introducing pneumococcal, rotavirus and a second dose of measles vaccine into the Zambian immunisation programme: Are expansions sustainable?. Vaccine 2016;34:4213–20. [PubMed: 27371102]

[53]. Botwright S, Holroyd T, Nanda S, Bloem P, Griffiths UK, Sidibe A, et al. Experiences of operational costs of HPV vaccine delivery strategies in Gavi-supported demonstration projects. PloS One. 2017;12:e0182663.

[54]. Byberg S, Fisker AB, Rodrigues A, Balde I, Enemark U, Aaby P, et al. Household experience and costs of seeking measles vaccination in rural Guinea-Bissau. Trop Med Int Health 2017;22:12–20. [PubMed: 27717100]

[55]. Ilboudo PG, Le Gargasson JB. Delivery cost analysis of a reactive mass cholera vaccination campaign: a case study of Shanchol vaccine use in Lake Chilwa. Malawi BMC Infect Dis 2017;17:779. [PubMed: 29258447]

[56]. Mokaya E, Mugoya I, Raburu J, Shimp L. Use of cellular phone contacts to increase return rates for immunization services in Kenya. Pan Afr Med J 2017;28:24. [PubMed: 29138660]

[57]. Routh JA, Sreenivasan N, Adhikari BB, Andrecy LL, Bernateau M, Abimbola T, et al. Cost Evaluation of a Government-Conducted Oral Cholera Vaccination Campaign-Haiti, 2013. Am J Trop Med Hyg 2017;97:37–42. [PubMed: 29064362]

[58]. Poncin M, Zulu G, Voute C, Ferreras E, Muleya CM, Malama K, et al. Implementation research: reactive mass vaccination with single-dose oral cholera vaccine. Zambia Bull World Health Organ 2018;96:86–93. [PubMed: 29403111]

[59]. Powell-Jackson T, Fabbri C, Dutt V, Tougher S, Singh K. Effect and cost-effectiveness of educating mothers about childhood DPT vaccination on immunisation uptake, knowledge, and perceptions in Uttar Pradesh, India: A randomised controlled trial. PLoS Med 2018;15:e1002519.

[60]. Teshome S, Desai S, Kim JH, Belay D, Mogasale V. Feasibility and costs of a targeted cholera vaccination campaign in Ethiopia. Hum Vaccin Immunother 2018;14:2427–33. [PubMed: 29648523]

[61]. Yu W, Lu M, Wang H, Rodewald L, Ji S, Ma C, et al. Routine immunization services costs and financing in China, 2015. Vaccine 2018;36:3041–7. [PubMed: 29685593]

[62]. Banerjee AV, Duflo E, Glennerster R, Kothari D. Improving immunisation coverage in rural India: clustered randomised controlled evaluation of immunisation campaigns with and without incentives. BMJ 2010;340: c2220. [PubMed: 20478960]

[63]. Hambidge SJ, Phibbs SL, Chandramouli V, Fairclough D, Steiner JF. A stepped intervention increases well-child care and immunization rates in a disadvantaged population. Pediatrics 2009;124:455–64. [PubMed: 19651574]

[64]. Szilagyi PG, Albertin C, Humiston SG, Rand CM, Schaffer S, Brill H, et al. A randomized trial of the effect of centralized reminder/recall on immunizations and preventive care visits for adolescents. Acad Pediatr 2013;13:204–13. [PubMed: 23510607]

[65]. Szilagyi PG, Humiston SG, Gallivan S, Albertin C, Sandler M, Blumkin A. Effectiveness of a citywide patient immunization navigator program on improving adolescent immunizations and preventive care visit rates. Arch Pediatr Adolesc Med 2011;165:547–53. [PubMed: 21646588]

[66]. Winston CA, Mims AD, Leatherwood KA. Increasing pneumococcal vaccination in managed care through telephone outreach. Am J Manag Care 2007;13:581–8. [PubMed: 17927463]

[67]. Bangure D, Chirundu D, Gombe N, Marufu T, Mandozana G, Tshimanga M, et al. Effectiveness of short message services reminder on childhood immunization programme in Kadoma,

Zimbabwe - a randomized controlled trial, 2013. BMC Public Health 2015;15:137. [PubMed: 25885862]

[68]. Haji A, Lowther S, Ngan'ga Z, Gura Z, Tabu C, Sandhu H, et al. Reducing routine vaccination dropout rates: evaluating two interventions in three Kenyan districts, 2014. BMC Public Health 2016;16:152. [PubMed: 26880141]

[69]. Stockwell MS, Kharbanda EO, Martinez RA, Vargas CY, Vawdrey DK, Camargo S. Effect of a text messaging intervention on influenza vaccination in an urban, low-income pediatric and adolescent population: a randomized controlled trial. JAMA 2012;307:1702–8. [PubMed: 22535855]

[70]. Andersson N, Cockcroft A, Ansari NM, Omer K, Baloch M, Ho Foster A, et al. Evidence-based discussion increases childhood vaccination uptake: a randomised cluster controlled trial of knowledge translation in Pakistan. BMC Int Health Hum Rights 2009;9:S8. [PubMed: 19828066]

[71]. Dombkowski KJ, Costello LE, Harrington LB, Dong S, Kolasa M, Clark SJ. Age-specific strategies for immunization reminders and recalls: a registry-based randomized trial. Am J Prev Med 2014;47:1–8. [PubMed: 24750973]

[72]. Hannan J, Brooten D, Page T, Galindo A, Torres M. Low-Income First-Time Mothers: Effects of APN Follow-up Using Mobile Technology on Maternal and Infant Outcomes. Global Pediatric Health. 2016;3:2333794X16660234.

[73]. Herrett E, Williamson E, van Staa T, Ranopa M, Free C, Chadborn T, et al. Text messaging reminders for influenza vaccine in primary care: a cluster randomised controlled trial (TXT4FLUJAB). BMJ Open 2016;6:e010069.

[74]. Lemstra M, Rajakumar D, Thompson A, Moraros J. The effectiveness of telephone reminders and home visits to improve measles, mumps and rubella immunization coverage rates in children. Paediatr Child Health 2011;16:e1–5. [PubMed: 22211079]

[75]. Lin CJ, Nowalk MP, Zimmerman RK. Estimated costs associated with improving influenza vaccination for health care personnel in a multihospital health system. Jt Comm J Qual Patient Saf 2012;38:67–72. [PubMed: 22372253]

[76]. Morris J, Wang W, Wang L, Peddecord KM, Sawyer MH. Comparison of reminder methods in selected adolescents with records in an immunization registry. J Adolesc Health 2015;56:S27–32.

[77]. O'Leary ST, Lee M, Lockhart S, Eisert S, Furniss A, Barnard J, et al. Effectiveness and Cost of Bidirectional Text Messaging for Adolescent Vaccines and Well Care. Pediatrics 2015;136:e1220–7. [PubMed: 26438703]

[78]. Stockwell MS, Westhoff C, Kharbanda EO, Vargas CY, Camargo S, Vawdrey DK, et al. Influenza vaccine text message reminders for urban, low-income pregnant women: a randomized controlled trial. Am J Public Health 2014;104 (Suppl 1):e7–e12.

[79]. Suh CA, Saville A, Daley MF, Glazner JE, Barrow J, Stokley S, et al. Effectiveness and Net Cost of Reminder/Recall for Adolescent Immunizations. Pediatrics 2012;129:e1437. [PubMed: 22566415]

[80]. Kempe A, Saville A, Dickinson LM, Eisert S, Reynolds J, Herrero D, et al. Population-Based Versus Practice-Based Recall for Childhood Immunizations: A Randomized Controlled Comparative Effectiveness Trial. Am J Public Health 2013;103:1116–23. [PubMed: 23237154]

[81]. Kempe A, Saville AW, Dickinson LM, Beaty B, Eisert S, Gurfinkel D, et al. Collaborative centralized reminder/recall notification to increase immunization rates among young children: a comparative effectiveness trial. JAMA Pediatr 2015;169:365–73. [PubMed: 25706340]

[82]. Regan AK, Bloomfield L, Peters I, Effler PV. Randomized Controlled Trial of Text Message Reminders for Increasing Influenza Vaccination. Ann Fam Med 2017;15:507–14. [PubMed: 29133488]

[83]. Shoup JA, Madrid C, Koehler C, Lamb C, Ellis J, Ritzwoller DP, et al. Effectiveness and cost of influenza vaccine reminders for adults with asthma or chronic obstructive pulmonary disease. Am J Manag Care 2015;21:e405–13. [PubMed: 26295268]

[84]. Manakongtreecheep K. SMS-reminder for vaccination in Africa: research from published, unpublished and grey literature. Pan Afr Med J 2017;27:23.

[85]. Bright T, Felix L, Kuper H, Polack S. Systematic review of strategies to increase access to health services among children over five in low- and middle-income countries. Trop Med Int Health 2018;23:476–507. [PubMed: 29473273]

[86]. Hurley LP, Beaty B, Lockhart S, Gurfinkel D, Breslin K, Dickinson M, et al. RCT of Centralized Vaccine Reminder/Recall for Adults. Am J Prev Med 2018;55:231–9. [PubMed: 29910118]

[87]. Krieger JW, Castorina JS, Walls ML, Weaver MR, Ciske S. Increasing influenza and pneumococcal immunization rates: a randomized controlled study of a senior center-based intervention. Am J Prev Med 2000;18:123–31. [PubMed: 10698242]

[88]. Montejo L, Richesson R, Padilla BI, Zychowicz ME, Hambley C. Increasing Influenza Immunization Rates Among Retail Employees: An Evidence-Based Approach. Workplace Health Saf 2017;65:424–9. [PubMed: 28427302]

[89]. Riewpaiboon A, Pathammavong C, Fox K, Hutubessy R. Cost analysis of pilot school-based HPV vaccination program in two provinces of Lao PDR. Pharm Sci Asia 2019;46:46–53.

[90]. Tubeuf S, Edlin R, Shourie S, Cheater FM, Bekker H, Jackson C. Cost effectiveness of a web-based decision aid for parents deciding about MMR vaccination: a three-arm cluster randomised controlled trial in primary care. Br J Gen Pract 2014;64:e493–9. [PubMed: 25071062]

[91]. Akil L, Ahmad HA. The recent outbreaks and reemergence of poliovirus in war and conflict-affected areas. Int J Infect Dis 2016;49:40–6. [PubMed: 27237735]

[92]. Field V, Gautret P, Schlagenhauf P, Burchard G-D, Caumes E, Jensenius M, et al. Travel and migration associated infectious diseases morbidity in Europe, 2008. BMC Infect Dis 2010;10:330. [PubMed: 21083874]

[93]. Portnoy A, Ozawa S, Grewal S, Norman BA, Rajgopal J, Gorham KM, et al. Costs of vaccine programs across 94 low- and middle-income countries. Vaccine 2015;33(Suppl 1):A99–A108. [PubMed: 25919184]

[94]. Ozawa S, Clark S, Portnoy A, Grewal S, Stack ML, Sinha A, et al. Estimated economic impact of vaccinations in 73 low- and middle-income countries, 2001–2020. Bull World Health Organ 2017;95:629–38. [PubMed: 28867843]

[95]. Ozawa S, Portnoy A, Getaneh H, Clark S, Knoll M, Bishai D, et al. Modeling The Economic Burden Of Adult Vaccine-Preventable Diseases In The United States. Health Aff (Millwood) 2016;35:2124–32. [PubMed: 27733424]

[96]. Petrie JG, Cheng C, Malosh RE, VanWormer JJ, Flannery B, Zimmerman RK, et al. Illness Severity and Work Productivity Loss Among Working Adults With Medically Attended Acute Respiratory Illnesses: US Influenza Vaccine Effectiveness Network 2012–2013. Clin Infect Dis 2016;62:448–55. [PubMed: 26565004]

[97]. Achat H, McIntyre P, Burgess M. Health care incentives in immunisation. Aust N Z J Public Health 1999;23:285–8. [PubMed: 10388173]

[98]. Esposito S, Principi N, Cornaglia G. Barriers to the vaccination of children and adolescents and possible solutions. Clin Microbiol Infect 2014;20:25–31. [PubMed: 24354949]

[99]. Topuzoğlu A, Ay P, Hidiroglu S, Gurbuz Y. The barriers against childhood immunizations: a qualitative research among socio-economically disadvantaged mothers. Eur J Public Health 2006;17:348–52. [PubMed: 17090559]

[100]. McKnight J, Holt DB. Designing the Expanded Programme on Immunisation (EPI) as a service: Prioritising patients over administrative logic. Glob Public Health 2014;9:1152–66. [PubMed: 25363481]

[101]. Okwaraji YB, Mulholland K, Schellenberg JRMA, Andarge G, Admassu M, Edmond KM. The association between travel time to health facilities and childhood vaccine coverage in rural Ethiopia. A community based cross sectional study. BMC Public Health 2012;12:476. [PubMed: 22726457]

[102]. Favin M, Steinglass R, Fields R, Banerjee K, Sawhney M. Why children are not vaccinated: a review of the grey literature. Int Health 2012;4:229–38. [PubMed: 24029668]

[103]. Jani JV, De Schacht C, Jani IV, Bjune G. Risk factors for incomplete vaccination and missed opportunity for immunization in rural Mozambique. BMC Public Health 2008;8:161. [PubMed: 18485194]

[104]. Malande OO, Munube D, Afaayo RN, Annet K, Bodo B, Bakainaga A, et al. Barriers to effective uptake and provision of immunization in a rural district in Uganda. PloS One. 2019;14:e0212270.

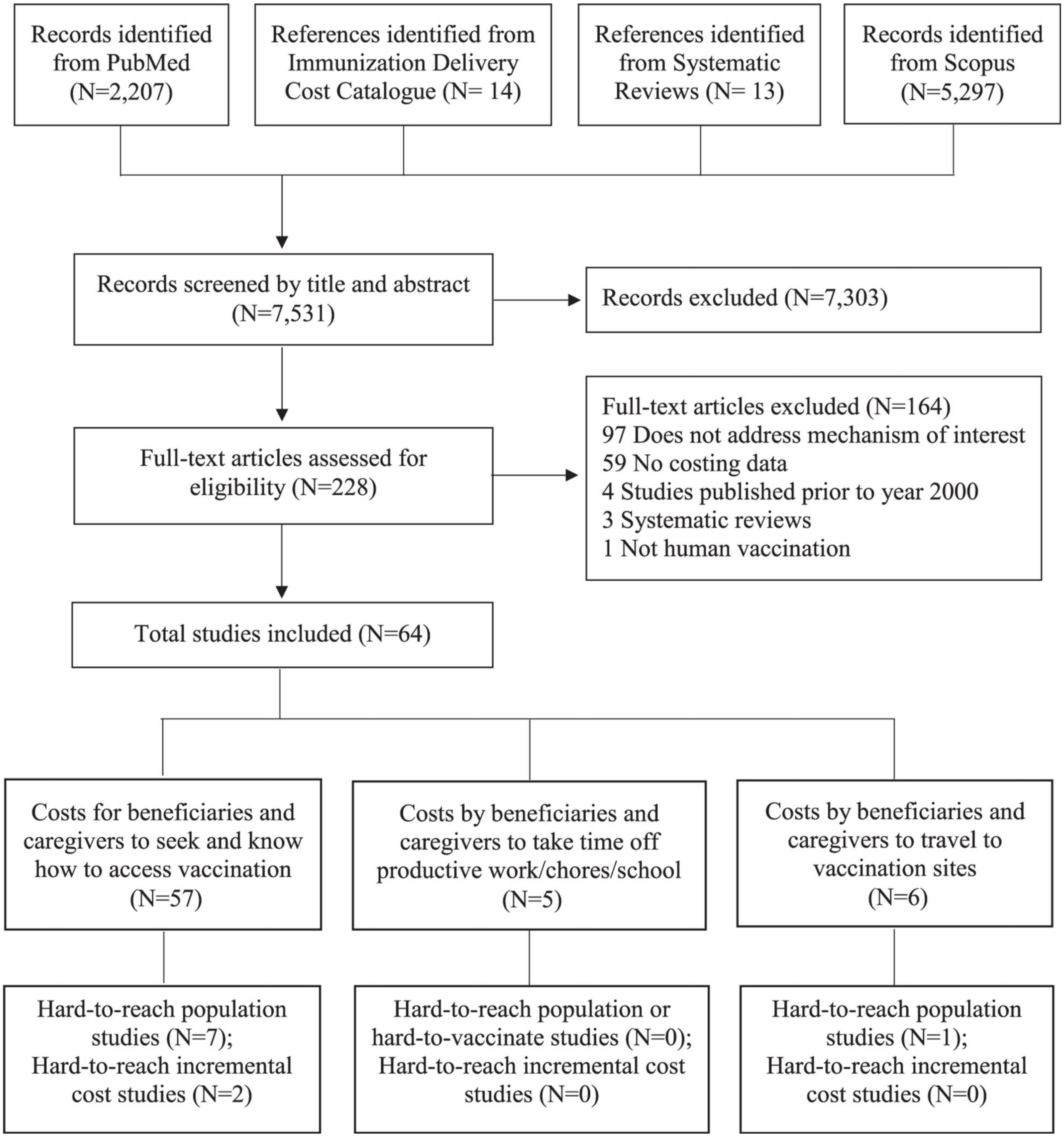

Fig. 1.

Literature search process for systematic review of costs for beneficiaries and caregivers to seek and reach vaccination sites, 2000–2019.

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Table 1

Literature on costs for beneficiaries and caregivers to seek and know how to access vaccination (i.e. costs of social mobilization, IEC, and interventions to increase vaccination demand), systematic review, 2000–2019

Country, year [Ref]	Country income	Study descriptions	Vaccines (Target population[†]), Delivery mode[¥]	Overall Costs (US $2019)	Cost per person vaccinated/targeted (US$ 2019) (% GDP per capita)	Cost per dose (US$ 2019) (% GDP per capita, % Predicted country delivery cost per dose)	Hard-to-reach mechanism(s)
USA, 2000 [87]	HI	Costing of an educational intervention, including telephone reminders and computerized immunization tracking	Influenza, Pneumococcal (Adults), Routine	$22,988	$36.95 (0.058%)	–	–
USA, 2001 [26]	HI	Program evaluation of an educational intervention	Hepatitis B (Children, Adolescents), Both	$325,301	–	$74.20 (0.118%)	–
USA, 2003 [28]	HI	Costing of community mobilization and education campaign interventions	Hepatitis B (Children, Adolescents), Routine	$407,236	$470.79 (0.750%)	–	–
Mozambique, 2005 [29]	LI	Costing of the incremental costs of adding Hepatitis B to national immunization program	Hepatitis B (Children), Routine	$10,944	–	–	–
Mexico, 2005 [30]	UMI	Costing of a national immunization week programme for polio in one district of Mexico	OPV (Children), SIA	$5,562	–	$0.11 (0.001%, 4.365%)	–
Tanzania, 2006 [33]	LI	Costing of hypothetical vaccine introduction with real baseline costs	All EPI (Children), Routine	$407,301	–	–	–
Mozambique, 2006 [32]	LI	Costing of mass vaccination campaign	Cholera (All), SIA	$13,494	–	$0.14 (0.028%, 11.965%)	–
USA, 2007 [66]	HI	Costing of a telephone outreach intervention in a managed care network	Pneumococcal (Adult), Routine	$56,203	$198.98 (0.317%)	–	–
Ethiopia, 2009 [34]	LI	Costing of national vaccine introduction	Pentavalent (DTP–hepatitis B–Hib) (Children), Routine	$63,728	–	$0.02 (0.003%, 2.564%)	–
USA, 2009 [35]	HI	Costing of a vaccine reminder intervention	All EPI (Children), Routine	–	$389.84 (0.621%)	–	–
USA, 2009 [63]	HI	Costing of a telephone and postcard reminder and recall intervention at a community health center system	All EPI (Children), Routine	$193,022	$472.42 (0.752%)	$360.06 (0.573%)	–
Pakistan, 2009 [70]	LMI	Costing of a structured group discussion education intervention on vaccination benefits with adults in rural communities with low vaccination uptake	Measles, DPT (Children), Routine	$83,269	–	$12.93 (0.873%, 1436.666%)	–
India, 2010 [62]	LMI	Costing of an immunization camp and incentives intervention in rural villages	All EPI (Children), Routine	$16,924	–	$15.55 (0.774%, 1480.952%)	Inadequate Health Systems
Burkina Faso, 2011 [36]	LI	Costing of SIA campaigns in two districts	Meningococcal (All), SIA	$302,174	–	–	–

Country, year [Ref]	Country income	Study descriptions	Vaccines (Target population†), Delivery mode¥	Overall Costs (US $2019)	Cost per person vaccinated/ targeted (US$ 2019) (% GDP per capita)	Cost per dose (US$ 2019) (% GDP per capita, % Predicted country delivery cost per dose)	Hard-to-reach mechanism(s)
Cameroon, 2011 [37]	LMI	Costing of vaccination program in one district of Cameroon	BCG, Pentavalent (Children), Routine	$125	–	$0.03 (0.002%, 1.935%)	Geography by distance
USA, 2011 [65]	HI	Costing of an immunization tracking, telephone or mail reminder/recall, and home visits intervention in health practices	All EPI (Adolescents), Routine	–	$573.57 (0.913%)	$43.27 (0.069%)	–
Canada, 2011 [74]	HI	Costing of a telephone reminder and home visit intervention for children behind in MMR immunizations	MMR (Children), Both	$32,836	$146.85 (0.317%)	$7.17 (0.015%)	–
Tanzania, 2012 [38]	LI	Costing of national vaccine introduction over 5 years	HPV (Adolescents), Routine	$3,336,197	–	$0.60 (0.057%, 26.905%)	–
Zanzibar, 2012 [40]	LI	Costing of mass vaccination campaign	Cholera (All), SIA	$14,305	$0.58 (0.056%)	–	–
Tanzania, 2012 [39]	LI	Costing of vaccine introduction in one district of Tanzania	HPV (Adolescents), Routine	$13,871	$3.29 (0.314%)	–	–
USA, 2012 [69]	HI	Costing of reminder/recall systems with letters and telephone calls for adolescents missing vaccine doses at practices in a metropolitan area	Influenza (Adolescents), Routine	$15,997	$3.43 (0.005%)	–	–
USA, 2012 [75]	HI	Costing of an education, publicity, incentives and mobile vaccination carts intervention for healthcare personnel in a university hospital	Influenza (Adults), Routine	$113,899	$31.14 (0.050%)	$20.31 (0.032%)	–
USA, 2012 [75]	HI	Costing of an education, publicity, and incentives intervention for healthcare personnel in a university hospital	Influenza (Adults), Routine	$41,002	$26.20 (0.042%)	$14.15 (0.023%)	–
USA, 2012 [75]	HI	Costing of an education, publicity, and mobile vaccination carts intervention for healthcare personnel in a university hospital	Influenza (Adults), Routine	$23,429	$29.48 (0.047%)	$15.37 (0.024%)	–
USA, 2012 [75]	HI	Costing of an education, publicity for healthcare personnel in a university hospital	Influenza (Adults), Routine	$5,887	$22.87 (0.036%)	$7.84 (0.012%)	–
USA, 2012 [79]	HI	Costing of a text message reminder intervention for children in a low-income urban area who had not received required vaccine doses	Tdap, MCV4, HPV (Children), Routine	$5,701	$7.13 (0.011%)	$11.05 (0.018%)	–
Bangladesh, 2013 [42]	LMI	Costing of mass vaccination campaign	Cholera (All), SIA	$3,237	–	$0.01 (0.001%, 0.487%)	–
Colombia, 2013 [41]	UMI	Costing of national immunization programme	All EPI (All), Routine	$1,438,362	–	$0.05 (0.001%, 1.655%)	–
USA, 2013 [80]	HI	Costing of a population-based recall intervention using centralized immunization	All EPI (Children), Routine	$47,326	$19.93* (0.032%);	$1.10 (0.002%)	

Country, year [Ref]	Country income	Study descriptions	Vaccines (Target population†), Delivery mode¥	Overall Costs (US $2019)	Cost per person vaccinated/ targeted (US$ 2019) (% GDP per capita)	Cost per dose (US$ 2019) (% GDP per capita, % Predicted country delivery cost per dose)	Hard-to-reach mechanism(s)
		information system for children behind in immunization in urban and rural counties			$3.51 ** (0.006%)		
USA, 2013 [80]	HI	Costing of a practice-based recall intervention using centralized immunization information system for children behind in immunization in urban and rural counties	All EPI (Children), Routine	$15,421	$72.68 * (0.116%); $17.58 ** (0.028%)	$4.04 (0.006%)	–
USA, 2013 [64]	HI	Costing of a centralized reminder/recall intervention using mail reminders in a managed care organization	All EPI (Adolescents), Routine	$31,256	$553.11 * (0.881%); $22.38 ** (0.036%)	–	–
USA, 2013 [64]	HI	Costing of a centralized reminder/recall intervention using telephone reminders in a managed care organization	All EPI (Adolescents), Routine	$28,297	$852.30 * (1.357%); $19.88 ** (0.032%)	–	–
India, 2014 [43]	LMI	Costing of mass vaccination campaign	Cholera (All), SIA	$6,370	–	$0.11 (0.006%, 10.476%)	–
Gambia, 2014 [44]	LI	Costing of introducing PCV into national immunization schedule	PCV (Children), Routine	$21,999	$0.33 (0.047%)	$0.04 (0.006%, 1.139%)	–
USA, 2014 [71]	HI	Costing of a reminder and recall intervention using a statewide immunization information system for urban children missing doses	All EPI (Children), Routine	$38,036	$10.90 (0.017%)	$3.78 (0.006%)	–
USA, 2014 [78]	HI	Costing of a text message reminder intervention for urban, low income pregnant women	Influenza (Adults), Routine	$3,421	$5.77 (0.009%)	$2.87(0.005%)	–
Tanzania, 2015 [49]	LI	Costing of social mobilization as part of adding Rotavirus vaccine to national immunization schedule	Rotavirus (Children), Routine	$2,788	–	$0.38 (0.036%, 17.040%)	–
Benin, 2015 [46]	LI	Costing of social mobilization and communication for routine and SIA delivery of measles	Measles (Children), Both	$879	–	$0.02 (0.003%, 1.360%)	Geography by terrain, Geography by distance
Bangladesh, 2015 [50]	LI	Costing of social mobilization for a cholera vaccination feasibility study in Dhaka	Cholera (All), SIA	$3,237	–	$0.01(0.001%, 0.487%)	–
Rwanda, 2015 [48]	LI	Costing of social mobilization for national Pneumococcal conjugate vaccine introduction	Pneumococcal (Children), Routine	$38,851	–	–	–
Rwanda, 2015 [48]	LI	Costing of social mobilization for national HPV vaccine introduction	HPV (Adolescents), Routine	$88,810	–	–	–
Rwanda, 2015 [48]	LI	Costing of national Rotavirus vaccine introduction	Rotavirus (Children), Routine	$38,851	–	–	–

Country, year [Ref]	Country income	Study descriptions	Vaccines (Target population†), Delivery mode¥	Overall Costs (US $2019)	Cost per person vaccinated/ targeted (US$ 2019) (% GDP per capita)	Cost per dose (US$ 2019) (% GDP per capita, % Predicted country delivery cost per dose)	Hard-to-reach mechanism(s)
USA, 2015 [81]	HI	Costing of a collaborative centralized reminder/recall notifications for children behind in immunization schedule in urban and rural counties	All EPI (Children), Routine	$31,873	$27.53* (0.044%); $13.08** (0.021%)	$1.83 (0.003%)	–
USA, 2015 [81]	HI	Costing of practice-based reminder/recall notifications	All EPI (Children), Routine	$3,049	$138.09* (0.220%); $82.41** (0.131%)	$0.24 (0.0004%)	–
USA, 2015 [83]	HI	Costing of an interactive voice response reminder intervention in a managed care organization	Influenza (Adults), Routine	–	$1.37 (0.002%)	–	–
USA, 2015 [83]	HI	Costing of a postcard reminder intervention in a managed care organization	Influenza (Adults), Routine	–	$0.87 (0.001%)	–	–
USA, 2015 [83]	HI	Costing of a combined postcard and interactive voice response interventions in a managed care organization	Influenza (Adults), Routine	–	$2.15 (0.003%)	–	–
Zimbabwe, 2015 [67]	LMI	Costing of a text message reminder intervention	All EPI (Children), Routine	$65	$0.43 (0.020%)	–	–
USA, 2015 [76]	HI	Costing of a text message reminder intervention for adolescents at private pediatric and safety net practices	HPV, MCV, Tdap, Varicella (Adolescents), Routine	$1,460	$5.18 (0.008%)	$2.81 (0.004%)	–
USA, 2015 [76]	HI	Costing of postcard reminder intervention for parents of adolescents missing vaccine doses in an urban area	HPV, MCV, Tdap, Varicella (Adolescents), Routine	$3,314	$3.44 (0.005%)	$2.07 (0.003%)	–
USA, 2015 [76]	HI	Costing of an email reminder intervention for parents of adolescents missing vaccine doses in an urban area	HPV, MCV, Tdap, Varicella (Adolescents), Routine	$1,900	$3.44 (0.005%)	$1.34 (0.002%)	–
USA, 2015 [77]	HI	Costing of a text message reminder intervention for parents of adolescents missing vaccine doses in an urban area	Tdap, MCV4, HPV (Adolescents), Routine	$9,233	$46.87 (0.075%)	$4.61 (0.007%)	–
India, 2016 [51]	LMI	Costing of entire national immunization program	All EPI (Children), Routine	$55,939,943	–	–	–
Zambia, 2016 [52]	LMI	Costing of one-time national costs of vaccine introduction	Pneumococcal, Rotavirus, Measles second dose (Children), Routine	$736,745	–	$0.26 (0.017%, 10.833%)	–
Kenya, 2016 [68]	LMI	Costing of text message reminder intervention in three districts	All EPI (Children), Routine	$111	$0.30 (0.018%)	–	Geography by distance

Country, year [Ref]	Country income	Study descriptions	Vaccines (Target population†), Delivery mode¥	Overall Costs (US $2019)	Cost per person vaccinated/ targeted (US$ 2019) (% GDP per capita)	Cost per dose (US$ 2019) (% GDP per capita, % Predicted country delivery cost per dose)	Hard-to-reach mechanism(s)
USA, 2016 [72]	HI	Costing of a cellphone and text messaging follow up intervention of first-time mothers by nurse practitioners	DTP, HepB, Hib, IPV, MMR, Pneumococcal, Varicella (Children), Routine	$5,994	$95.14 (0.152%)	$11.57(0.018%)	Inadequate Health Systems
United Kingdom, 2016 [73]	HI	Costing of a text messaging reminder intervention for patients with chronic conditions in general practices	Influenza (Adults), Routine	$82,244	$1.87 (0.004%)	$3.07 (0.007%)	–
Multiple Countries, 2017 [53]	LI	Costing of social mobilization and IEC for vaccine introduction demonstration projects across 12 countries	HPV (Adolescents), Both	–	–	$2.97	–
Malawi, 2017 [55]	LI	Costing of social mobilization for a mass vaccination campaign	Cholera (All), SIA	$31,299	–	$0.18 (0.046%, 9.625%)	–
Kenya, 2017 [56]	LMI	Costing of a cellphone contact intervention to track defaulters	All EPI (Children), Routine	–	$0.08 (0.004%)	–	Geography by terrain
Haiti, 2017 [57]	LI	Costing of social mobilization for a mass vaccination campaign	Cholera (All), SIA	$6,694	–	$0.03 (0.004%, 2.884%)	Geography by terrain
Australia, 2017 [82]	HI	Costing of a text message reminder intervention	Influenza (All), Routine	–	$3.71 (0.006%)	–	–
USA, 2017 [88]	HI	Costing of an incentive and educational intervention on influenza immunization among retail employees	Influenza (Adults), Routine	–	$6.11 (0.009%)	–	–
Zambia, 2018 [58]	LMI	Costing of social mobilization for a mass vaccination campaign	Cholera (All), SIA	$16,250	–	$0.04 (0.002%, 1.666%)	–
USA, 2018 [86]	HI	Costing of a centralized reminder/recall intervention using an Immunization Information System	Influenza, Tdap, Pneumococcal (Adults), Routine	$16,570	$0.93 (0.001%)	–	–
India, 2018 [59]	LMI	Costing of an educational intervention	DPT (Children), Routine	$12,249	–	$178.13 (8.862%, 16964.761%)	–
Ethiopia, 2018 [60]	LI	Costing of sensitization and social mobilization for a mass vaccination campaign	Cholera (All), SIA	$7,344	–	$0.09 (0.011%, 11.538%)	–
China, 2018 [61]	UMI	Costing of communication for a national routine immunization program	All EPI (Children), Routine	$98,212,536	–	–	–
Lao PDR, 2019 [89]	LMI	Costing of social mobilization and IEC for a school-based HPV vaccination pilot program	HPV (Adolescents), SIA	$11,301	–	$0.27 (0.010%, 15.697%)	–

BCG = bacille Calmette-Guérin vaccine; DTP/DPT/Tdap = diphtheria, tetanus, and pertussis vaccine; EPI = Expanded Programme on Immunization; GDP = gross domestic product; HI = high-income; Hib = *Haemophilus influenzae* type b vaccine; HPV = human papillomavirus vaccine; IEC = information, education, and communication; IPV = inactivated polio vaccine; LI = low-income; LMI = lower-middle income; MCV = meningococcal vaccine; MMR = measles, mumps, and rubella vaccine; OPV = oral polio vaccine; PCV = pneumococcal conjugate vaccine; SIA = supplementary immunization activities; UMI = upper-middle income; USA = United States of America.

– Denotes not reported in study.

[*] Cost per fully vaccinated/up-to-date person.

[**] Cost per targeted/eligible person in intervention.

[†] All includes children, adolescent, and adult target populations.

[¥] Both includes routine and SIA delivery.

Note: 69 estimates of costs reflecting 57 studies.

Table 2

Literature on costs by beneficiaries and caregivers to take time off from work, chores, or school, and travel to vaccination sites, systematic review, 2000–2019

Country, year [Ref]	Country income	Study description	Vaccines (Target population*), Delivery mode¥	Cost per person vaccinated/ targeted (US$2019) (% GDP per capita)	Cost per dose (US$2019) (% GDP per capita, % Predicted country delivery cost per dose)	Hard-to-reach mechanism(s)
Productivity losses						
Israel, 2001 [27]	HI	Modelling study estimating costs of parent's absence from work for child to receive an additional Hepatitis A dose	Hepatitis A (Children), Routine	–	$7.87 (0.018%)	–
USA, 2005 [31]	HI	Modelling study estimating overall caregiver costs to take child for vaccination	Diphtheria, Tetanus, Acellular Pertussis, Hib, Poliovirus, MMR; Hepatitis B; and Varicella (Children), Routine	$21 (0.032%)	–	–
United Kingdom, 2014 [90]		Post-intervention survey of productivity costs (lost income) incurred by patients seeking MMR vaccine as part of an intervention involving a decision aid for parents	MMR (Children), Routine	$57 (0.134%)	–	–
USA, 2014 [45]	HI	Modelling study estimating overall caregiver costs to take child for vaccination	Diphtheria, Tetanus, Acellular Pertussis, Hib, Poliovirus, MMR; Hepatitis B; and Varicella (Children), Routine	$37(0.056%)	–	–
India, 2015 [47]	LMI	Household survey of productivity losses incurred by individuals and families to receive cholera vaccines in a mass campaign	Cholera (All), SIA	–	$0.18 (0.009%, 17.142%) to $0.34 (0.017%, 32.380%) Individual costs; $0.70 (0.035%, 66.666%) to $1.34 (0.067%, 127.619%) Family costs	–
Transport costs						
Israel, 2001 [27]	HI	Modelling study estimating travel costs for an additional Hepatitis A dose	Hepatitis A (Children), Routine	–	$0.22 (0.001%)	–
USA, 2005 [31]	HI	Modelling study estimating overall caregiver costs to take child for vaccination	Diphtheria, Tetanus, Acellular Pertussis, Hib, Poliovirus, MMR; Hepatitis B; and Varicella (Children), Routine	$5 (0.008%)	–	–
United Kingdom, 2014 [90]		Post-intervention survey of transport costs incurred by patients seeking MMR vaccine as part of an intervention involving a decision aid for parents	MMR (Children), Routine	$14 (0.030%)	–	–
USA, 2014 [45]	HI	Modelling study estimating overall caregiver costs to take child for vaccination	Diphtheria, Tetanus, Acellular Pertussis, Hib, Poliovirus, MMR;	$26 (0.041%)	–	–

Country, year [Ref]	Country income	Study description	Vaccines (Target population*), Delivery mode¥	Cost per person vaccinated/ targeted (US$2019) (% GDP per capita)	Cost per dose (US$2019) (% GDP per capita, % Predicted country delivery cost per dose)	Hard-to-reach mechanism(s)
			Hepatitis B; and Varicella (Children), Routine			
India, 2015 [47]	LMI	Household survey of individual and family costs to receive vaccine	Cholera (All), SIA	–	$0.01 (0.0005%, 0.952%) Individual cost; $0.02 (0.001%, 1.904%) Family cost	–
Guinea-Bissau, 2017 [54]	LI	Household survey of average transport costs for caregivers across regions	Measles (Children), SIA	$1 (0.129%)	–	Geography by Terrain

GDP = Gross domestic product; HI = high-income; Hib = *Haemophilus influenzae* type b vaccine; LI = low-income; LMI = lower-middle income; MMR = measles, mumps, and rubella vaccine; SIA = supplementary immunization activities; USA = United States of America.

– Denotes not reported in study.

* All includes children, adolescent, and adult target populations.

Note: 11 estimates of costs reflecting 6 studies (5 estimates for productivity costs and 6 estimates for travel costs).