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Health resource utilization pattern and costs associated with herpes simplex virus diagnosis and management : a global systematic review

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Health resource utilization pattern and costs associated with herpes simplex virus diagnosis and management : a global systematic review

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ABSTRACT

Objectives: The World Health Organization (WHO) highlights the need for a vaccine against herpes simplex virus (HSV) partly due to a high disease burden globally. Little is known about its economic burden across countries. This article aims to summarize existing evidence on estimates of costs and resource utilization associated with genital and neonatal HSV and its methodological variation in healthcare systems.

Methods: We searched seven databases without language restriction. Studies reported either resource utilization or cost associated with HSV-related healthcare, including screening, diagnosis and treatment of genital HSV infection and neonatal herpes prevention and treatment. Studies published from inception to August, 31st 2020 were included. A focused search was also performed to supplement the results. Data were extracted and summarized descriptively.

Results: Out of 11,443 articles, 38 were included. Most studies (35/38, 94.6%) were conducted in high income countries, primarily the United States, and were more often related to the prevention or management of neonatal herpes (n=21) than HSV genital ulcer disease (n=17). Most analyses were conducted before 2010. There was substantial heterogeneity in the reporting of HSV-related healthcare resource utilization and associated costs. Economic burden estimates based on these costs were similarly heterogeneous, with wide variation in methodology, assumptions, and outcome measures between studies. For example, lifetime costs of neonatal herpes ranged from USD\$48,519 to as much as USD\$1,296,792, depending on whether long-term disability care costs were included.

Conclusions: A paucity of evidence exists on health resource utilization and costs associated with HSV infection, especially among low- and middle-income countries. Future research is needed on costs and healthcare utilization patterns to improve overall understanding of the global economic burden of HSV.

(271/300 words)

Keywords: herpes simplex virus; healthcare resource utilization; neonatal herpes; pregnancy; genital ulcer

Strengths and limitations of this study

- Herpes simplex virus infections are common and can cause genital ulcer disease, neonatal herpes, increased HIV risk, and psychosocial consequences, but current prevention interventions are limited.
- This systematic review demonstrated that there were only limited studies describing economic burden of HSV.
- Most studies were conducted in high income countries related to the prevention and management of neonatal herpes compared to genital ulcer disease.
- Results from this study form a repository to inform future economic evaluations, which will be crucial to determine the potential value of interventions for HSV, such as vaccines
- Further research on the healthcare resource utilization patterns and cost of HSV is needed, especially from other low-middle income countries.

INTRODUCTION

Herpes simplex virus (HSV)-1 and HSV-2 are DNA viruses that belong to Alphaherpesviridae, a subfamily of the Herpesviridae family.¹ Both viruses can cause genital infection, which can have a profound impact on sexual and reproductive health. HSV-2 is almost entirely transmitted during sexual activity and is the most common cause of genital herpes, affecting more than one in every 8 individuals, or 491.5 million people, aged 15-49 years in 2016.² HSV-1 is the main cause of oral herpes but can also be transmitted to the genital area through oral sex. HSV-1 affects an estimated 3.7 billion people under age 50 globally, of which over 120 million may have genital infection.² While the prevalence of HSV infection is high globally, it varies widely by region, with the highest prevalence of both HSV-1 and HSV-2 in the African region, which is primarily comprised of low- and middle-income countries (LMIC).^{1,2}

Genital HSV infection is lifelong and characterised by periodic reactivation. Many infections are asymptomatic or unrecognized, but up to a third of people may develop painful, recurrent genital sores known collectively as genital ulcer disease (GUD).³ Antiviral medications can be taken episodically to shorten GUD outbreaks or taken daily (suppressive therapy) to reduce the number of outbreaks, but they are not curative. Pregnant women with genital HSV infection can also transmit the virus to their infants in the peripartum period, resulting in neonatal herpes.⁴ Although this occurs only rarely, neonatal herpes has a high fatality and disability rate among surviving infants. As such, particularly in high-income countries (HIC), prevention measures such as caesarean section are often undertaken if a mother has active HSV lesions at delivery. Genital HSV-2 infection has also been linked to an increased risk of acquisition and transmission of HIV infection.⁵

The World Health Organization (WHO) has highlighted the need for a vaccine against HSV-2, due to large numbers of infections globally and the resulting disease consequences including GUD, neonatal herpes, and increased risk of HIV acquisition.⁶ Multiple vaccine candidates have been studied to date with modelling studies showing that prevention of HSV-2 infection with a vaccine could potentially also reduce the incidence of HIV infection.⁷ Vaccines targeting HSV-2 might also have benefits against HSV-1.⁸ Understanding the potential value of HSV vaccines requires not only predicting the impact of the vaccines on HSV-related disease burden, but also on its economic burden. However, little is known about the economic burden of HSV globally. As a first step in estimating HSV-related

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3 economic burden, we conducted a broad systematic review with the aim of summarizing all available
4 evidence on costs and resource utilization associated with diagnosing, treating, and managing HSV
5 infection and disease, and specific cost drivers across healthcare systems.
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METHODS

Data Sources and Search Strategy

We electronically searched for relevant articles published from database inception to August 31st 2020 in 7 databases: PubMed, PsychINFO, EMBASE, Centre for Review and Dissemination, EconLit, CEA registry and WHO Library Database (WHOLIS). The search strategy was based on a broad combined search string “Herpes Simplex Virus” AND “cost” OR “resource utilization” OR “econ*”, with no language restriction. A complete search strategy is detailed in Appendix 1. In addition, bibliographies of relevant articles were examined to identify potential studies not indexed in the aforementioned databases.

Study Selection

Studies were included if they were original articles that investigated resource utilization patterns and costs related to HSV infection including the cost of any diagnostic tools, consultation time, treatment and hospital cost related to detecting and managing all types of HSV-1 or HSV-2 related neonatal and genital infections and associated disease outcomes. We included articles which were published in any languages. A focused supplemental search was performed using the keywords listed in Appendix 2 based upon the inclusion above.

Data Extraction and Quality Assessment

The study followed a 2-stage process, where two independent reviewers screened the titles and abstracts for relevant studies, before the full texts were screened by another two independent reviewers for eligibility. Relevant information from the identified studies was extracted independently by two reviewers using a standardized data extraction sheet. At all stages, any disagreement was resolved by discussion between reviewers through consensus. Information collected from the data extraction sheet included: 1) general study information including country of the study, 2) HSV subtype and disease, 3) study design, 4) healthcare resource utilization, 5) costs of relevant tests, clinical care, hospitalisation, and medications, and 6) summary estimates of HSV-related economic burden. Methodological quality of all included economic studies was assessed using the Consensus Health Economic Criteria (CHEC) list. This checklist has been recommended for critically appraising published economic evaluations. The checklist has 19 domains and includes reporting standards for economic model characteristics (population, time horizon, perspective and

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3 discount rate), identification and valuation of costs and outcomes, discussion points, conclusions as
4 well as funding and conflicts of interest. All cost of illness studies were evaluated for risk of bias
5 using the Larg and Moss's checklist. No quality appraisal was performed on studies reporting
6 healthcare resource utilization.
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10 11 12 **Data Analysis**

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15 A component-based analysis was used to describe and synthesise the overall findings from all
16 included studies. Specifically, tabulation methods were used to report on study characteristics,
17 outcomes and costs. Tables for resource utilization and disaggregated costs were presented and
18 summarized. All costs were presented according to the recommendations of Turner et al., 2019⁹. For
19 studies that did not provide the year of cost data, the year of publication was used. Adjustment for
20 inflation was done using the Gross Domestic Product deflator (GDP deflator) of the studied country.
21 Cost estimates were then converted and reported in 2017 United States Dollars (USD). GDP deflator
22 and exchange rates were obtained from the World Bank.¹⁰
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32 **Patient and public involvement**

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34 Patients were not involved in this systematic review. Their input was not sought in the design,
35 interpretation or writing of the document.
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RESULTS

Study Selection

Our search yielded a total of 11,443 articles of which 8,779 articles were excluded as they were not relevant for this review based on title screening. The remaining 2,664 articles were further screened by title and abstract and 299 articles were assessed for inclusion. We excluded 261 articles (n= 98 for not related to HSV, n =44 review articles/case report, n =116 not reporting resource utilization or cost, n =3 available only in abstract), leaving a total of 38 studies included in this review, as shown in Figure 1.

Overview of Study Characteristics

Of the 38 included articles, 14 studies¹¹⁻²⁴ described resource utilization only, 12 studies²⁵⁻³⁶ reported on costs, and 12 studies³⁷⁻⁴⁸ reported both resource utilization and costs of HSV diagnosis/management. These studies, published from 1989 to 2020, reported resource utilization or costs related to the diagnosis and management of HSV-related GUD among adults/adolescents^{14-18 24 26-30 33-36 40 48} (n=17), neonatal herpes prevention in pregnant mothers (n=13)^{19-21 23 25 31 32 38 39 42-45} and neonatal herpes management^{11-13 22 37 41 46 47} (n=8). The majority of studies were conducted in HIC (35/38, 94.6%) including the United States^{11 13 16 18 21 23 25 26 30 31 34-48} (n= 26), Canada^{14 15 22 32} (n=4), United Kingdom^{19 29} (n=2), France^{12 24} (n=2) and Ireland²⁰ (n=1)), while only one study (1/38, 2.6%) was conducted in a middle-income country, in particular South Africa²⁸. A global survey focusing on the experiences of patients receiving care for genital herpes in 78 countries included some data on healthcare utilization.¹⁷ In addition, a modelling study estimated the costs of implementing the Global Health Sector Strategy on Sexually Transmitted Infections (STIs), 2016-2021, in 117 LMICs, including costs related to syndromic management of GUD, the vast majority of which is caused by HSV-2.³³

Methodological Heterogeneity

There was substantial heterogeneity in the reporting of the included studies. Most studies were cost or resource utilization studies (n=23), while the remaining were cost-effectiveness studies (n=15). Among cost or resource utilization studies, data were collected retrospectively (n=13), prospectively (n=7), or not reported (n=7). The number of participants in each study varied, which could be as few as 39 participants to as large as 42 million in studies that analysed claims datasets. Twenty-one studies

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3 (21/38, 55.3%) included participants who had either HSV-1 or 2, ten studies (10/37, 27.0%) specifically
4 included participants with HSV-2, while the remaining eight studies (8/38, 21.1%) did not specify which
5 type of HSV they examined. A summary of the characteristics of these studies is presented in Table 1,
6 and study findings are presented in Tables 2 and 3 (See appendix for detailed unit cost tables and
7 accompanying references).
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15 **Cost and health resource utilization pattern of genital herpes infection**

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17 Among all 17 studies^{14-18 24 26-30 33-36 40 48} investigating cost and health resource utilization pattern of
18 genital herpes, 11 studies reported some cost components of care for genital herpes infection<sup>26-30 33-
19 36 40 48</sup> (Tables 1 and 2). All but one of these studies were conducted in HIC and only one LMIC study
20 (from South Africa) was found. The cost components of the included studies were variably
21 reported. Three studies^{27 30 48} reported laboratory testing costs associated with diagnosing HSV. Eight
22 studies^{26 27 29 30 33 36 40 48} described costs associated with syndromic management of GUD. In four
23 studies^{28 29 33 48}, the authors describe the drug charges associated with treatment or prevention of
24 HSV using oral acyclovir (doses of 200mg-400mg). The cost reported varied considerably, ranging
25 between USD\$0.53 to USD\$16 for a 5 to 7 day treatment course for episodic GUD and USD\$40 for a
26 month of suppressive therapy with acyclovir. Two studies^{27 40} provided the total drug charges
27 associated with overall management of GUD, but no details related to the treatment regimen,
28 duration or HSV of HSV being treated (Table 2). Seven studies^{27-29 33 43 44 48} described labour and
29 service delivery costs such as cost of physician visits, drug procurement cost, counselling cost and
30 clinical examination associated with HSV. Similarly, there was variation in terms of reported labour
31 and service delivery cost, which could be as low as USD\$0.28 for 10-minute counselling²⁹ to as high
32 as USD\$120 for consultation and lost wages of patient time⁴⁸. Indirect costs were considered only by
33 Szucs *et al*, who estimated HSV-related productivity losses, which was estimated at USD\$60 a visit²⁷.
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50 Considering the cost components together, Owusu-Edusei *et al* estimated that the lifetime direct
51 medical cost per case of genital HSV infection in the U.S. (considering only GUD-related costs and
52 adjusted to 2017 USD) was USD\$855 among men (range: USD\$428- USD\$1,284) and USD\$698
53 among women (range: USD\$350- USD\$1,047)²⁶. This translated to a total cost of USD\$607.3 million
54 (range: USD\$303.59 million – USD\$ 910.89 million in 2017 USD) for lifetime management of new or
55 newly diagnosed cases of HSV-2 in the United States occurring in 2008. Szucs *et al* meanwhile
56 estimated that the annual direct and indirect medical costs in the United States would amount to
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3 USD\$983 million, based upon an estimated 3.1 million symptomatic genital HSV episodes (both new
4 and recurrent) a year²⁷.
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10 The only middle income country study, from South Africa²⁸, reported the diagnostic/ operational
11 costs associated with medication, staff and laboratory costs for daily HSV-2 suppressive therapy
12 among people living with HIV²⁸. The median cost for HSV-2 suppressive therapy per life-year gained
13 ranged between USD \$685 to USD \$951 (adjusted to 2017 dollar) among HIV-1 infected anti-
14 retroviral naïve women. The authors estimated that this could be a cost-effective method for
15 delaying HIV disease progression, especially when the price of acyclovir was lower than the price of
16 USD \$0.026/day for a twice daily 400mg dose. However, this study was conducted when ART use
17 was recommended only when CD4 count fell below a threshold of <200 cells/ μ L or <350 cell/ μ L
18 (Appendix Table 2). On a more global level, in Korenromp *et al*'s cost estimates for implementing the
19 Global STI Strategy in 117 LMIC over 2016 to 2021, the authors reported that it would cost
20 approximately USD\$109 million to diagnose and treat HSV-related GUD episodes seen in clinical
21 care, not including service delivery costs.³³ These costs were estimated despite assuming that only
22 about 4% of all HSV-2 infected people would seek care for GUD (15% recognizing symptoms and 28%
23 of those seeking care).
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36 A total of 8 studies described health resource utilization patterns for genital herpes infection^{14-18 27 36}
37 ⁴⁰, and all were from high income countries (Tables 1 and 3). Five of these studies^{14 16-18 36} reported
38 the population rate of seeking medical care for HSV, based upon retrospective analyses of databases
39 of patients from health surveys¹⁶⁻¹⁸. In the study by Xia and colleagues, the authors found that the
40 total genital herpes associated ED use have increased from 24,747 visits in 2006 to 36,518 in 2013³⁶.
41 It is important to note that none of the studies reported the proportion of those seeking medical
42 care among HSV-infected individuals. Most of these consultations were relatively short in nature,
43 and were less than 15 minutes (79%)¹⁷. Two studies described the diagnostic methods used to
44 determine HSV among their population. In the first study conducted in 2004, Patrick *et al.* surveyed
45 physicians in 78 countries and reported that the most commonly used test was viral culture, which
46 was performed in 49% of the individuals¹⁷ (Table 3). At the time of the study, the use of PCR was not
47 yet common in clinical practice. A recent study in France by Heggarty *et al.* in 2020 found that PCR is
48 now more commonly used, with 43.3% of respondents in their survey stated that they would
49 conduct PCR in addition to HSV serology while another 39.9% would conduct PCR only to confirm a
50 HSV diagnosis²⁴.
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8 Treatment patterns of individuals with genital herpes were also reported in four studies^{15 17 24 40}. The
9 study by DesHarnais *et al* in 1996 reported on antiviral use only among hospitalized patients with
10 herpes infections, which is unlikely to be representative of the vast majority of people with HSV
11 infection. Patrick *et al* in their survey found that 65% of people with genital herpes had ever been
12 treated with antivirals, while 18% used topical prescription medication and 13% used over the
13 counter topical cream. Among these individuals, 67% had received episodic therapy while 31%
14 received chronic suppressive therapy (Table 2). Another study on herpes-related quality of life
15 reported that 76.9% of respondents had ever been treated with antivirals, and 33.3% of the
16 respondents with HSV were on suppressive antiviral therapy when the survey was administered¹⁵.
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26 **Cost and health resource utilization pattern of prevention of neonatal herpes among pregnant** 27 **mothers**

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30 Nine studies reported costs for neonatal herpes prevention among pregnant mothers^{25 31 32 38 39 42-45}
31 (Tables 1 and 2). Seven studies^{31 32 38 39 42 43 45} provided estimates on the cost for treatment and
32 childbirth delivery options, including caesarean and vaginal delivery in addition to inpatient costs.
33 The cost of hospitalisation ranged considerably, and could be as low as USD\$300 to as high as
34 USD\$32,483, while the cost of delivery ranged between USD\$2,300 - \$9,490. The costs associated
35 with different laboratory tests used, such as ELISA screening or viral cultures^{32 39} were reported,
36 while detailed listing of the cost component of different delivery methods and hospital care were
37 included in some studies (Appendix Table 3). The cost-effectiveness studies examined the impact of
38 either acyclovir suppressive therapy^{25 31 42 43} or routine antenatal screening^{32 38 39 44 45} for prevention
39 of neonatal herpes. In a study by Randolph *et al* in 1996⁴³, the authors found that prophylaxis with
40 acyclovir during late pregnancy could be a cost-effective strategy to reduce the need for caesarean
41 delivery due to genital herpes outbreaks during labour. Baker and colleagues in 2004 further
42 expanded this work and estimated that adding serological testing to antiviral suppressive therapy
43 had an incremental cost per quality-adjusted life year gained (QALY) of \$18,680, compared with no
44 screening or suppressive therapy³⁸. A modelling study by Tuite *et al* in 2010 had similar findings
45 related to screening for HSV in pregnancy³².
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3 Our focused search found a total of 10 studies which reported resource utilization among pregnant
4 mothers to prevent neonatal herpes^{19-24 38 39 42 44}. Among these, four were cost-effectiveness studies
5 which had provided some information regarding resource utilization based upon estimates from
6 literature or assumptions.^{38 39 42 44} In one of the earliest studies by Brocklehurst in 1995, a survey of
7 British obstetrician-gynaecologists revealed that most would recommend some form of antenatal
8 screening for HSV using viral cultures usually by week 34 of gestation¹⁹. However, such screening is
9 no longer recommended in the UK. Studies within HICs that have national obstetrics guidelines
10 recommending caesarean delivery when HSV lesions are present at delivery have shown that most
11 clinicians follow this guidance²⁰⁻²³. For example, in a Canadian study, caesarean section was offered
12 "most of the time" to women with HSV lesions at delivery by 92% of obstetricians and 82% of family
13 physicians²². In addition, in these settings women with genital herpes are often offered antiviral
14 suppressive therapy in the third trimester^{20 22}. Both valacyclovir and acyclovir have been used, with
15 difference in preference by country. In the most recent survey of clinicians managing pregnant
16 women with HSV by Heggarty *et al* in 2020, the authors noted that 68.4% "always" prescribe
17 suppressive antiviral therapy during the third trimester and an additional 11.6% "often" prescribe it
18 for women with symptomatic primary HSV infection during pregnancy.²⁵ For women with recurrent
19 symptoms during pregnancy, 55.1% of providers "always" prescribe and 12.9% "often" prescribe
20 antiviral prophylaxis in the third trimester.²⁴

21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 **Cost and health resource utilization pattern of neonatal herpes management**

38 Four studies^{37 41 46 47} reported cost of neonatal herpes management and reported only direct medical
39 costs (Tables 1 and 2). One study reported direct non-medical cost for long-term care of individuals
40 with neurological disability due to sequelae of HSV³⁹. All studies were in HIC. The reported cost of
41 hospitalisation of neonatal HSV ranged considerably, from S27,843 to \$92,664. One study reported
42 the cost associated with hospital readmission, which was reportedly similar to the first
43 hospitalisation episode⁴⁶. Six studies^{32 42-45 48} accounted for the costs of informal care in their
44 calculation. Informal caregiving was defined as care provided by caregivers for infants who had
45 neurological sequelae following neonatal herpes. In total, seven studies^{32 39 42-45 48} estimated long-
46 term care costs of neonatal herpes patients. One of these, by Thung *et al*⁴⁵, provided the estimated
47 cost for long term care of neonates with mild neurological deficit due to HSV, which cost
48 USD\$17,304.61 after adjusting for inflation to 2017 values. Six studies^{39 42-45 48} provided estimates for
49 the lifetime cost of caring for a child with moderate and severe disability, and fall within the range
50 USD\$68,894 to USD\$432,263 and USD\$232,698 to USD\$ 1,296,792 respectively. It is important to
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3 note that all studies relied on estimation of long-term costs calculated by Weitzman⁴⁹ with some
4 different assumptions, while one study³⁹ used other sources of data.
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10 A total of 7 studies^{11-13 37 41 46 47} described resource utilization among individuals with neonatal herpes
11 (Tables 1 and 3). These studies described the length of stay for hospitalization which varied
12 considerably, with median hospital stays ranging from 6-34 days^{11 12}. Ahmad *et al* noted that nearly
13 9.4 to 9.8% of neonates who had HSV required ICU stay¹¹. None of the studies reported the number
14 of days for ICU hospitalization.
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DISCUSSION

Our review revealed a heterogeneous body of evidence on the health resource utilization and costs associated with genital and neonatal HSV infection, as well as some summary economic estimates and cost-effectiveness studies of HSV intervention strategies, such as use of antivirals or screening, which included unit cost data. While the evidence base provides a starting point for understanding, several gaps remain. Despite the broad search strategy and inclusion criteria, we identified only 38 papers, which shows the paucity of data on HSV-related healthcare resource utilization as well as economic costs, especially from LMIC settings. The lack of data from LMIC is particularly concerning, as these countries bear the greatest burden of HSV infection and disease.^{2 3 50} The current review only identified one cost-effectiveness analysis from a middle income country²⁸ focused on people living with HIV only, and one high-level modelling study predicting costs of implementing care for HSV GUD across 117 LMIC globally³³. In addition, many of the studies we found were relatively old and may not reflect current practices such as the use of newer diagnostics (e.g. PCR) and newer care recommendations.

While data on resource utilization and costing were most comprehensive from the US, large gaps remain in many areas. For example, Gilbert and colleagues¹⁶ described the proportions of individuals seeking care for genital herpes among adults aged 18 to 24 from 2000 to 2006, but since then there have been no new updates. In terms of costing, we noticed similar trends, as studies²⁶ mostly referenced cost data collected in 2001 by Szucs *et al*²⁷. This lack of data is similarly noted related to HSV infection during pregnancy. While some information from health surveys exists, healthcare resource utilization information is rarely tracked or reported. Our search demonstrated that for most of the world, data on HSV related resource utilization are sparse. As such, new data sources and better data collection efforts are needed to collect these standardized non-fatal data from diverse healthcare settings. One major need is an understanding of how closely clinicians follow national guidelines on HSV care and treatment, such as the studies by Kenny *et al*²² and Heggarty *et al*²⁴ from Canada and France respectively.

Our review was also constrained in summarizing findings across studies or countries and in conducting across-study comparisons, due to the limited data and differing methodologies, healthcare settings, and practices, particularly for healthcare resource utilization. Another concern was the heterogeneity in data presentation in many studies identified. For example, the length of

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3 hospital stay reported in studies varied considerably, with different assumptions used by authors,
4 and as a result, the cost of hospitalisation varied significantly even within the United States, which
5 limits the potential generalizability of these findings across different settings^{12 37 41 47}. Healthcare
6 practices also differ between LMIC and HIC with respect to how HSV is managed, eg, most HSV cases
7 in LMICs are treated as part of syndromic management for GUD, without diagnostic testing. This may
8 mean that additional testing costs might need to be considered for HICs, whereas additional
9 treatment, for example for syphilis and chancroid, which can also cause GUD syndromes, might need
10 to be considered for LMICs. The focus on GUD more generally in LMICs may have made it more
11 challenging to identify potentially relevant HSV-specific studies for LMIC settings.
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21 In order to estimate the global economic burden of HSV to contribute to the understanding of the
22 potential value of HSV interventions, research on HSV-related costs and healthcare utilization
23 patterns is urgently needed, especially from LMIC settings. Standardization of methods for the
24 measurement and reporting of economic costs would enhance across-study comparisons and inform
25 prioritization strategies of global funders. Only one study broadly attempted to quantify the
26 economic burden of HSV, which the authors estimated would require a projected investment of
27 around USD\$109 million from 2016 to 2021, just for the management of HSV-associated GUD, not
28 considering service delivery costs³³. However, this analysis only modelled treatment of HSV GUD for
29 a small proportion of people with HSV-2 infection (approximately 4%: assuming 15% would
30 recognize symptoms and 28% of those would seek care) and did not account for HSV recurrences
31 within a given year. New global estimates of HSV GUD suggest this is likely an underestimate.³ In
32 addition, as this model lacked country-level estimates of baseline disease and did not take into
33 account the full spectrum of disease outcomes related to HSV nor the burden on health systems, the
34 costing estimates remain imprecise and incomplete, suggesting the need for a more comprehensive
35 model.
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50 This is the first systematic review of scientific literature on the healthcare resource utilization for
51 HSV. We conducted a comprehensive literature search and included grey literature through our
52 focused search. Nevertheless, most studies were only conducted in HIC especially from the USA. We
53 did not find any study that originated from the Asia region. As the practice and thus utilization of
54 resources will vary between setting and countries due to epidemiological and health systems, this
55 will limit the generalisability of findings. We assessed study quality of all included studies, which
56 allows for readers to assess the internal validity of these studies. The literature search was also
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limited to English language. As data on healthcare resource utilization may be published in government reports, or book chapters, these may not have been retrieved and included into this review.

For peer review only

CONCLUSION

This review is the first attempt and a key step towards providing data needed to understand the global economic burden of HSV infection, for both HICs and LMICs. Available economic estimates, primarily from HICs, suggest the economic burden of HSV infection could be substantial. However, the global picture remains incomplete. Results obtained from this study will form a repository which can inform future economic evaluations of interventions for HSV infection, including HSV vaccines, microbicides, or new antiviral medications.⁵¹ These types of economic data are crucial not only to improve the planning and development of any future HSV-related healthcare interventions, but also to optimize the allocation of healthcare expenditures and medical resources.

Contributors

SWHL served as the lead author, conducted the research, conducted the analyses, integrated the input from all team members and drafted the initial manuscript. SG directed the initial research and contributed to the initial draft, integrated her view points and served as an expert in this work.. NC conducted the research, mediated the discussion and helped refine the draft. All authors approved the final manuscript.

Data sharing statement

All relevant information and data have been presented in this article and its accompanying supplement.

Table 1: Summary of included studies reporting healthcare costs and/or resource utilization related to HSV infection

| Author, year Country | Population and setting | Study design | Study objective | Sample size | HSV-subtype | | Cost data | | Healthcare resource utilization | |
|---|---|-------------------------|---|----------------|-------------|---|------------------------------------|---------------|------------------------------------|---------------|
| | | | | | 1 | 2 | Healthcar e delivery process | Treat ment | Healthcar e delivery process | Treat ment |
| HSV genital ulcer disease among adults/adolescents | | | | | | | | | | |
| Almonte- Vega, 2020 USA ³⁵ | General population aged 15-49 years old | Cost-analysis | To study the dynamics of HSV-2 transmission, control and impact of treatment policies | - | | x | | x | | |
| Aslam, 2012 Canada ¹⁴ | Records of individuals in the Canadian Disease and Therapeutic Index (CDTI) | Retrospectiv e study | To investigate the rates of diagnosed cases of GH in Canada from 2002 to 2007 | 652 | | | | | x | |
| Desharnais, 1996 USA ⁴⁰ | Adults with herpes diagnosis from the HCIA Clinical Pathways Data Base | Retrospectiv e study | To describe patterns of antiviral drug use for patients hospitalized with chickenpox, herpes simplex, and herpes zoster infections, and also for a subgroup of herpes patients with severe infections (systemic infections, eye infections, encephalitis, hemorrhagic pneumonitis, and other severe conditions) | 3011 | x | x | | x | | x |
| Fisman, 2002 USA ³⁴ | Individuals aged 15 to 39 years | Cost- effectiveness | To project the future burden of HSV-2 infection in the | - | | x | | x | | |

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| | | | United States, using a mathematical model that incorporated epidemiologic trends documented between 1976 and 1994 | | | | | | |
| Fisman, 2003 USA ⁴⁸ | Heterosexual couples | Modelling study | To evaluate the projected cost effectiveness of strategies to prevent HSV-2 transmission in couples with no history of HSV-2 infection | - | | x | | x | |
| Fisman, 2005 Canada ¹⁵ | Individuals with recurrent genital ulcer | Prospective study | To estimate the impact on health-related quality of life associated with both symptomatic and asymptomatic GH | 39 | x | x | | | x |
| Gilbert, 2010 USA ¹⁶ | Young adults | Retrospective study | To investigate characteristics associated with GH screening and diagnosis in sexually active young adults aged 18 to 24 | Add Health Data: 11,570 NCHA: 222,740 | x | x | | x | |
| Korenromp, 2017 ³³ | People 15-49 year old living with HSV-2 | Modelling study | To estimate the costs of reaching the 2020 STI strategy milestones for the period 2016–2021, to support policy, planning, implementation, and future cost-benefit evaluation of the global STI strategy 2016–2021. | - | | x | | x | |
| Owusu-Edusei, 2013a | People aged 15-25 years | Retrospective study | To examine the utilization and cost of the diagnostic methods used for STI screening among | - | | x | | | |

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| USA ³⁰ | | | privately insured adolescent and young adult population | | | | | | |
| Owusu-Edusei, 2013b USA ²⁶ | - | Cost of illness analysis | To update the estimates of lifetime direct medical cost for 8 major STI | - | | | | x | |
| Patrick, 2004 Worldwide survey from 78 countries ¹⁷ | Subjects with genital herpes | Survey | To describe patient experiences and views regarding genital herpes management | 2075 | x | x | | | x |
| Szucs, 2001 USA ²⁷ | General population | Economic analysis | To estimate the economic burden of GH in the USA, using two different costing approaches | 465,075 | | | | x | |
| Tao, 2000 USA ¹⁸ | General population | Cost-of-illness analysis | To assess the US direct medical expenditures for genital herpes and its complications to assist policy makers in allocating limited STD resources efficiently | - | | x | | | x |
| Vickerman, 2008 UK ²⁹ | - | Cost-effectiveness | To compare the cost per ulcer treated of using the 1994 and 2003 algorithms amongst individuals presenting with GUD | - | | x | | x | |
| Vickerman, 2011 South Africa ²⁸ | HIV+ women | Cost-effectiveness | To estimate the cost-effectiveness of daily acyclovir for delaying HIV-1 disease progression in women not eligible for antiretroviral therapy (ART) | 300 | | x | | x | |

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| | army and community hospitals | | serological status and delivery route on risk of transmission of HSV from mother to infant | | | | | | |
| Heggarty, 2020 France ²⁴ | Healthcare providers for pregnant women | Survey | To evaluate health care provider knowledge, and collect information on management of genital herpes during pregnancy and infants born to mothers with herpes | 354 | x | x | | x | x |
| Kenny, 2013 Canada ²² | Obstetrician, gynaecologist and family physicians offering maternity care practicing in Alberta | Survey | To identify the practice patterns of physicians providing prenatal care in Alberta with respect to prevention of neonatal HSV infection, including their prescribing of antiviral therapy to pregnant women in the third trimester. | 183 | x | x | | x | x |
| Little, 2005 USA ⁴² | Women with a history of diagnosed genital HSV | Cost-effectiveness | To determine the clinical benefits and cost-effectiveness of prophylactic acyclovir in women with a history of HSV but no recurrence during pregnancy | - | x | x | | x | x |
| Lynn, 2017 Ireland ²⁰ | Pregnant women with genital HSV from a university hospital | Antenatal chart review | To describe the HSV management in pregnancy at a joint antenatal genital maternity hospital | 107 | x | x | | x | x |
| Randolph, 1996 USA ⁴³ | Antenatal women with recurrent genital HSV | Cost-effectiveness | To compare the cost-effectiveness of oral acyclovir prophylaxis in late pregnancy compared to caesarean delivery for genital herpes | 10,000 | | | | x | |

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| | | | lesions in the prevention of neonatal herpes transmission from mothers with recurrent genital infections | | | | | | |
| Rouse, 2000 USA ⁴⁴ | Antenatal women | Cost-effectiveness | To evaluate the potential cost effectiveness of herpes simplex virus antibody screening | 8,538 | x | x | | x | x |
| Scott, 1998 USA ³¹ | - | Cost-effectiveness | To determine whether acyclovir suppression provides a greater cost savings over no medical therapy in the management of recurrent genital herpes (HSV) in pregnancy | - | x | x | | x | |
| Stankiewicz Karita, 2017 USA ²¹ | Pregnant women from a hospital | Retrospective study | To investigate the frequency of invasive obstetric procedures and caesarean deliveries for women with known HSV infection | 449 | | x | | | x |
| Thung, 2005 USA ⁴⁵ | Married women | Cost-effectiveness | To determine the cost-effectiveness of routine antenatal screening for HSV-1 and HSV-2 in women without a known history of genital herpes. | 100,000 | x | x | | x | |
| Tuite, 2010 Canada ³² | Pregnant women | Cost-effectiveness | To assess the effectiveness and cost effectiveness of identifying pregnant women at risk of de novo HSV acquisition to prevent vertical HSV transmission | 100,000 | x | x | | x | |

| Neonatal herpes management | | | | | | | | | | |
|------------------------------------|--|---------------------|--|-------------|---|---|--|---|--|---|
| Ahmad, 2015 USA ¹¹ | Neonates who sought care in emergency department | Retrospective study | To evaluate whether guideline implementation affected the ED's decision to test for HSV, ED use of HSV polymerase chain reaction (PCR) and acyclovir | 308 | x | x | | | | x |
| Ambroggio, 2009 USA ³⁷ | Neonates with HSV and received intravenous acyclovir and discharge from Paediatric Health Information System | Retrospective study | To quantify the economic burden of neonatal HSV during initial hospitalization while focusing on factors, such as congenital anomalies and HSV-associated complications, which increase hospital charges and length of hospital stay among neonates with HSV | 406 | x | x | | x | | x |
| Bernard, 2013 France ¹² | Patients aged 28 days and above from the French national hospital discharge database | Prospective study | To compare the data from the French national hospital discharge database (Programme de Medicalisation des Systemes d'Information; PMSI) and from the prospective study conducted in 2007 and evaluate the reliability of PMSI as a tool to assess the trends of encephalitis in France | 1,947 | x | x | | | | x |
| Donda, 2019 USA ⁴¹ | Neonates with ICD-9 codes for neonatal HSV in the National | Retrospective study | To examine the temporal trends in the incidence and outcomes of neonatal HSV in the United States | 42,726, 336 | | | | x | | x |

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| | Inpatient Sample from 2003-2014 | | | | | | | | | |
| Flagg, 2011 USA ⁴⁷ | Inpatient records of infants aged 60 days or younger from the Healthcare Cost and Utilization Project Kids' Inpatient Database | Retrospective study | To estimate the incidence of HSV infections for the United States during 2006, as well as demographic-specific rates, by using nationally and regionally weighted estimates from a population-based sample of inpatient data | 4,106,488 | x | x | | x | | x |
| Mahant, 2019 USA ⁴⁶ | Records of neonates from the Medicaid claims database from 2009 - 2015 | Retrospective study | To examine the incidence, mortality, and health care use related to neonatal herpes HSV infection. | 2,107,124 | | | | x | | x |
| Owusu-Edusei, 2015 USA ¹³ | Insurance claim data on inpatient admission from the Truven Health Analytics MarketScan Commercial Claims and Encounters Database | Cost-of-illness analysis | To estimate the average excess inpatient cost of neonatal herpes simplex virus (NHSV) infection from 2005 to 2009 insurance claims data | 474,743 | x | x | | | | x |

Table 2: Detailed description of studies reporting cost (unit cost)

| Author, year Country | Population and setting | Diagnostic costs (range) | Treatment costs* in original year of value (range) | Hospitalisation costs (range) | Other healthcare delivery costs (range) | Lifetime management cost (range) |
|---|--|---|--|-------------------------------|---|---|
| Genital ulcer disease among adults/adolescents | | | | | | |
| Almonte-Vega, 2020 USA ³⁵ | General population aged 15-49 years old | Microbiological lab test (unspecified): \$80.17 | Acyclovir treatment (duration not specified): \$86.33 | NR | Consultation, clinical examination and diagnostic: \$161.85 | NR |
| Desharnais, 1996 ⁴⁰ | Adults with herpes diagnosis identified from the HCIA database | NR | Total drug charges: \$1941 Antiviral drug charges (not specified): \$1070 | Hospital charges: \$5637 | NR | NR |
| Fisman, 2002 ³⁴ | Individuals aged 15 to 39 years | NR | Cost of treatment for primary syndrome Male: \$470 (\$370-5\$60) Female: \$830 (\$670-\$1000) Antiviral therapy Relapse: \$17 (\$9-\$36) Monthly suppressive therapy: \$40 (\$20-\$220) | NR | Clinic visit: \$120 (\$90-\$150) Obstetrical care: \$310 (\$130-\$800) | Initial cost of caring for neonates with HSV: \$42,600 Lifetime medical and long-term care cost for infants with moderate neurological sequelae: \$97,000 Lifetime medical and long-term care cost for infants with severe neurological sequelae: \$291,000 |

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|-----------------------------------|---|---|--|----|---|--|
| Fisman, 2003 ⁴⁸ | Heterosexual couples | Western blot: \$60 (\$45-\$90) ELISA: \$5 (\$3-\$35) | Cost of treatment for primary syndrome Male: \$450 (\$360-5\$40) Female: \$800 (\$640-\$960) Acyclovir (per episode): \$16 (\$9-\$35) Acyclovir (monthly suppressive): \$40 (\$20-\$215) | NR | Clinic visit: \$120 (\$90-\$145) Labour: \$120 (\$90-\$145) | Lifetime cost of care of neonatal HSV-2: \$110,000 (\$85,000-\$860,000) |
| Korenromp, 2017 ³³ | People 15-49 year old living with HSV-2 | NR | Acyclovir 400mg per tab: \$0.04 | NR | Treatment service delivered (not specified): \$10 Procurement cost: \$0.21 | NR |
| Owusu-Edusei, 2013a ³⁰ | People aged 15-25 years | Laboratory test (unspecified): \$24.30-27.05 | NR | NR | NR | NR |
| Owusu-Edusei, 2013b ²⁶ | - | NR | NR | NR | NR | Lifetime medical cost per case, median(range): Men: \$761 (381-1,142) Women: \$621(311 - 932) Lifetime cost of new infections acquired in 2008: \$435.9 million |

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|--|--------------------|--|--|--------------------------|---|--|
| Szucs, 2001 ²⁷ | General population | Laboratory test: \$1.5-76.50 | Drug: \$64-131 | Hospitalisation: \$669 | Labour: \$39.8 -62.6 Clinic visit: \$36.20-73 Day off work: \$144 | NR |
| Vickerman, 2008 ²⁹ | - | NR | Acyclovir 200mg tds for 5 days: \$0.53- 5.24 | NR | Counseling cost: \$0.28 | NR |
| Vickerman, 2011 ²⁸ | HIV+ women | NR | Acyclovir 400mg: \$0.07 Yearly ART cost: \$1700 (1359-2000) | NR | Staff costs/women 3m treatment cycle: \$15.60 | NR |
| Xia, 2018 ³⁶ | General population | NR | NR | ED: \$1,069 | | |
| Neonatal herpes prevention among pregnant mothers | | | | | | |
| Baker, 2004 ³⁸ | - | Laboratory test with labor cost for HSV-2: 15.58 – 60.00 | Average antiviral daily cost (assuming 50% on generic acyclovir 400mg tds and 50% on valacyclovir qd): \$1.70-7.90 Acyclovir 400mg: \$0.366- 1.955 Valacyclovir 500mg/tab: \$3.95 Valacyclovir 1g/tab: \$6.49 | Delivery: \$4,779-22,838 | Labour cost: \$15.58 – \$60 Counseling cost: \$5.98- \$6.67 | Lifetime cost of care of neonatal HSV: \$54,516- \$129,576 |

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| Barnabas, 2002 ²⁵ | - | Diagnostic cost: \$16- \$100 | Drug cost per couple per pregnancy: \$37 Acute neonatal herpes treatment \$1,500- 50,000 | C/S cost (personnel, supplies, surgery and ward care): \$11,084 | Labour cost: \$200- 1628 Counseling cost: \$12-\$18 | Neonatal care after C/S: \$884 Long term care for neonatal herpes: \$140,766 - \$273,712 |
| Binkin, 1989 ³⁹ | Pregnant women with HSV | Viral culture: \$30 | NR | Hospitalisation for complication: \$300- 698 Hospital care associated with neonatal herpes: \$25,000 Delivery: \$2,300-3,600 | NR | Long term care for neonatal herpes: \$125,000-\$250,000 |
| Little, 2005 ⁴² | Women with a history of diagnosed genital HSV | NR | Acyclovir (prophylaxis) from 36 weeks of gestation: \$46 | Delivery: \$4,939-9,490 Hospitalisation: \$32,483 | NR | Lifetime cost of care of neonatal HSV: \$349,7533- \$1,049,260 |
| Randolph, 1996 ⁴³ | Antenatal women with recurrent genital HSV | Laboratory: \$35 | Acyclovir 400mg (200caps): \$228 | Delivery: \$3,500 | Labour \$74 | Lifetime cost of care of neonatal HSV: \$85,000- 255,000 |
| Rouse, 2000 ⁴⁴ | Antenatal women | Laboratory: \$4 – 13 | NR | Hospitalisation for neonatal care: \$11,126 | Labour \$3.50-10.50 | Lifetime cost of care of neonatal HSV: \$48,519- 163,879 |
| Scott, 1998 ³¹ | - | HSV culture: \$80 | Acyclovir 400mg tds for 4 weeks: \$180 | Hospitalisation for neonatal care: \$480- 1470 Delivery: \$5,321 – 9,039 | NR | NR |

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|--|-----------------------------------|--|----------------------------|---|----------------------------------|-----------------------|---|
| 1 2 3 4 5 6 7 | Thung, 2005 ⁴⁵ | Married women | HSV screening: \$37.5-\$75 | Acyclovir 400mg tds for 4 weeks: \$71 | Delivery: \$4,281 - 9,283 | Counseling cost: \$13 | Lifetime cost of care of neonatal HSV: \$13,202 – 325,602 |
| 8 9 10 11 12 | Tuite, 2010 ³² | Pregnant women | ELISA test: \$7-\$14 | NR | Delivery: \$5680- 8780 | NR | Lifetime cost and consequence of neonatal HSV: \$164,870 |
| 13 | Neonatal herpes management | | | | | | |
| 14 15 16 17 18 19 20 21 22 23 24 25 26 | Ambroggio, 2009 ³⁷ | Neonates with HSV and received intravenous acyclovir and discharge from Paediatric Health Information System | NR | Median pharmaceutical (not specified): \$4,231 Median Imaging: \$2,010 | Median hospital charge: \$37,431 | NR | NR |
| 27 28 29 30 31 32 33 34 35 | Donda, 2019 ⁴¹ | Patients aged 28 days and above from the French national hospital discharge database | NR | NR | Hospitalisation: \$27,843 | NR | NR |
| 36 37 38 39 40 41 42 | Flagg, 2011 ⁴⁷ | Neonates with ICD-9 codes for neonatal HSV | NR | NR | Hospitalisation: \$92,664 | NR | NR |

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| | in the National Inpatient Sample from 2003-2014 | | | | | |
| Mahant, 2019 ⁴⁶ | Records of neonates from the Medicaid claims database from 2009 - 2015 | NR | NR | Hospitalisation: \$32,683 Hospital readmission: \$31,531 ED visit: \$527 | NR | NR |

*All costs are mean costs except where explicitly labelled as median costs.

C/S – Caesarean section; ED - Emergency department; NR – Not reported

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Table 3: Detailed description of studies reporting resource utilization

| Author, year | Healthcare seeking and diagnosis | Treatment phase |
|--|---|--|
| Genital ulcer disease among adults/adolescents | | |
| Aslam, 2012 ¹⁴ | <ul style="list-style-type: none"> 74.1-93.2% sought care once within 12 months 6.8-25.9% sought care twice to 8x a year | |
| Desharnais, 1996 ⁴⁰ | | <ul style="list-style-type: none"> Oral treatment only: 16.1% IV treatment: 16.2% Hospital stay: 5.4 days |
| Fisman, 2005 ¹⁵ | | <ul style="list-style-type: none"> 33.3% used antiviral drugs for HSV 15.8% had pregnancy complicated by HSV |
| Gilbert, 2010 ¹⁶ | <ul style="list-style-type: none"> 1.32% of young adults ever tested for genital herpes | |
| Patrick, 2004 ¹⁷ | <ul style="list-style-type: none"> 49% had viral culture performed 9% had antibody test 34% had physical examination | <ul style="list-style-type: none"> 65% received oral antiviral therapy 18% received topical antiviral therapy 17% obtained alternative therapy |
| Tao, 2000 ¹⁸ | <ul style="list-style-type: none"> Estimated annual genital herpes visit 499,655 yearly 2% were inpatient visit 9% outpatient & ED visit 20% public STD clinic 69% private office based visit | |
| Xia, 2018 ³⁶ | <p>From 2006-2013</p> <ul style="list-style-type: none"> 245,484 ED visits with primary diagnosis of genital herpes or 37.3% of total ED visits for HSV Total charges: \$278,335,295 <p>ED visits trend from 2006 – 2013</p> <ul style="list-style-type: none"> 24,747 (33.8%); 26,440 (34.1%); 27,484 (36.1%), 28,440 (36.5%); 33,258 (37.8%); 33,095 (38.3%); 35,501 (40.0%); 36,518 (40.3%) | |
| Neonatal herpes prevention among pregnant mothers | | |
| Baker, 2004 ³⁸ | <p>Estimates used in model</p> <ul style="list-style-type: none"> 75% of partners will be willing to undergo HSV screening | <p>Estimates used in model</p> <ul style="list-style-type: none"> 1.32% women HSV-2 negative acquiring HSV during last 8 weeks of pregnancy 57% women or partner offered and accept antiviral therapy with testing |

| | | |
|----------------------------------|---|---|
| | | <ul style="list-style-type: none"> 82% women taking antivirals from week 36 compliant |
| Binkin, 1989 ³⁹ | <p>Estimates used in model</p> <ul style="list-style-type: none"> Average number of cultures per patient: 8 | |
| Brocklehurst, 1995 ¹⁹ | <ul style="list-style-type: none"> 60% of obstetricians advocated some form of antenatal screening <p>Among those performing screening</p> <ul style="list-style-type: none"> 64% perform regular viral cultures 54% recommend screening ≤ 34 weeks of gestation | <ul style="list-style-type: none"> 92% of providers: visible active lesions at labor are cause for caesarean delivery |
| Brown, 2003 ²³ | | <ul style="list-style-type: none"> All women with HSV genital lesions noted at delivery had caesarean delivery (n=60) unless lesions not noted until too late to proceed with caesarean or lesions noted after delivery (n=14) |
| Heggarty, 2020 ²⁴ | <p>For suspected primary genital HSV:</p> <ul style="list-style-type: none"> 43.3% would conduct PCR of lesions plus HSV serology 39.9% would conduct PCR of lesions alone 0.4% would conduct HSV serology only | <ul style="list-style-type: none"> If primary HSV GUD during pregnancy, 68.4% "always" and 11.6% "often" prescribe antiviral prophylaxis in 3rd trimester If recurrent HSV GUD during pregnancy, 55.1% "always" and 12.9% "often" prescribe antiviral prophylaxis in 3rd trimester 83% recommend caesarean delivery if genital HSV lesions suspected during labour |
| Kenny, 2013 ²² | <ul style="list-style-type: none"> 30% physicians will perform type-specific serology "most of the time" for patients with no history of herpes but partner with known HSV | <ul style="list-style-type: none"> Antiviral suppressive therapy prescribed in third trimester by 90% of doctors (97% of obstetricians and 84% family physicians) <ul style="list-style-type: none"> 62% prescribed for any past history of GUD including pre-pregnancy 28% only after outbreak during pregnancy More commonly prescribed acyclovir (63%) than valacyclovir (38%) 65% offer elective caesarean if primary HSV in third trimester 95% of obstetricians and 84% of family physicians recommend caesarean delivery if HSV lesions during labour |
| Little, 2005 ⁴² | | <p>Estimates used in model</p> <ul style="list-style-type: none"> 24% of women will undergo caesarean delivery if no lesion was present |

| | | |
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| Lynn, 2017 ²⁰ | <ul style="list-style-type: none"> 89% of patients had type-specific serology sent | <ul style="list-style-type: none"> 63% received antiviral prophylaxis <ul style="list-style-type: none"> 98.5% received valacyclovir 1.5% received acyclovir Mean for initiating: week 36 29% of patients underwent caesarean delivery, none for HSV |
| Rouse, 2000 ⁴⁴ | Estimates used in model <ul style="list-style-type: none"> 75% of partners will be willing to undergo HSV screening | |
| Stankiewicz Karita, 2017 ²¹ | | <ul style="list-style-type: none"> Antiviral suppressive therapy: <ul style="list-style-type: none"> 55% HSV-2 antibody-positive only 65% history of symptomatic GUD Similar caesarean section rates for women with/without history of HSV/genital herpes: <ul style="list-style-type: none"> 25% without history of HSV-2/GH 30% on suppressive treatment 28% without suppressive treatment |
| Neonatal herpes management | | |
| Ahmad, 2015 ¹¹ | <ul style="list-style-type: none"> CSF PCR performed in 92.3% Blood PCR performed in 48.7% | <ul style="list-style-type: none"> 9.4 – 9.8% require ICU stay Hospital stay: 83.1-84.6hr 71.8% received acyclovir |
| Ambroggio, 2009 ³⁷ | | <ul style="list-style-type: none"> Median length of stay: 13 days (IQR 4-21) |
| Bernard, 2013 ¹² | | <ul style="list-style-type: none"> Mean hospital admission: 28 -34 days |
| Donda, 2019 ⁴¹ | | <ul style="list-style-type: none"> Median length of stay: 20 |
| Flagg, 2011 ⁴⁷ | | <ul style="list-style-type: none"> Mean length of stay: 22 days Median length of stay: 2- days |
| Mahant, 2019 ⁴⁶ | | <ul style="list-style-type: none"> Median hospital stay: 18 days Post discharge, <ul style="list-style-type: none"> 45.7% required ED visit 16.2% required rehospitalisation |
| Owusu-Edusei, 2015 ¹³ | | <ul style="list-style-type: none"> Mean hospital stay: 10.8 (11.5) Mean hospital stay among those with admission >7 days: 18.5 (12.5) |

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Figure legend

Figure 1. Flow diagram of study selection process

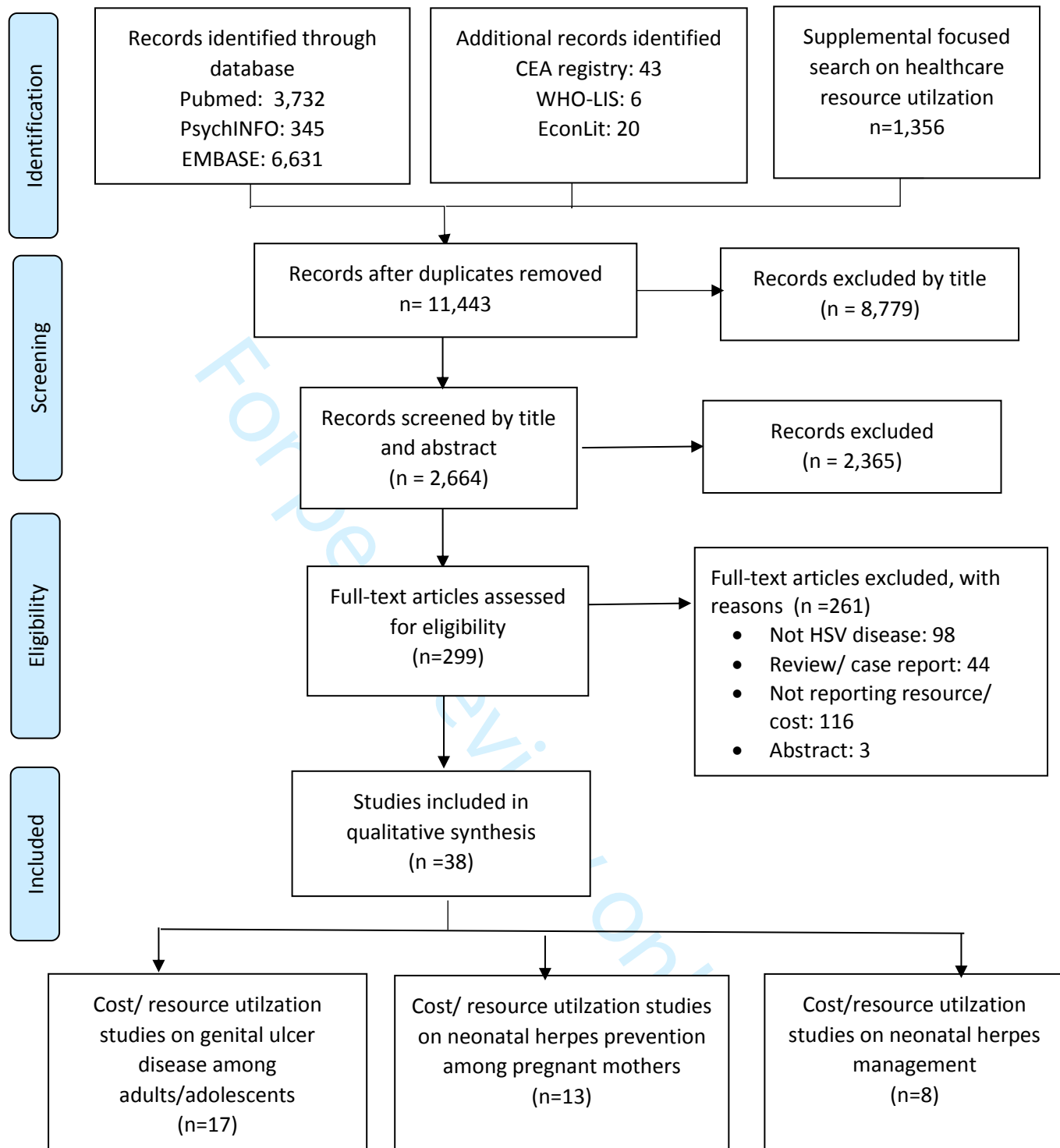
For peer review only

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5 **APPENDIX**
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Search methodology

1. Search strategy

- The current search strategy was developed based upon keywords which have been used in previous existing HSV reviews commissioned by WHO. All search keywords used were subsequently cross-checked with the following articles to ensure comprehensiveness
 - Looker, 2017. Effect of HSV-2 infection on subsequent HIV acquisition: an updated systematic review and meta-analysis
 - Khard, 2019. The Epidemiology of Herpes Simplex Virus Type 1 in Asia: Systematic Review, Meta-analyses, and Meta-regressions
 - Looker, 2012. Global estimates of prevalent and incident herpes simplex virus type 2 infections in 2012. PLoS One 2015;10(1) : e114989-e89. Doi: 10.1371/journal.pone.0114989
- The following databases were identified for the search including: PubMed, PsychINFO, EMBASE, Centre for Review and Dissemination, EconLit, CEA registry and WHO Library Database (WHOLIS)

2. **Keywords search** was revised to compare between a) search including exploding terms and b) search including title and abstract. A total of 10,113 articles was found for search when terms were exploded versus 5,966 when these terms were not exploded. As such, the methods will only use search including exploding terms to minimize the risk of missing relevant study despite its low specificity. The initial search was performed in April 2019, with an updated search in October 2019.

3. Neonate search

- We also conducted search over again using all relevant HSV terms with neonate as keyword. All articles identified in the search overlapped with existing broader search, thereby there is no need to add neonate as key words

Text 1: Keyword terms used in the search

| No. | Keyword |
|-----|--|
| #1 | Genital ulcer disease.mp. |
| #2 | Herpes labialis.mp. |
| #3 | Herpes genitalis.mp. |
| #4 | Genital herpes.mp. |
| #5 | Herpesvirus.mp. |
| #6 | Herpes virus.mp. |
| #7 | HSV.mp. |
| #8 | Herpes simplex.mp. |
| #9 | 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 |
| #10 | Healthcare util*ation.mp. |
| #11 | Util*ation.mp. |
| #12 | Physician visit.mp. |
| #13 | General practitioner visit.mp. |
| #14 | Hospital visit.mp. |
| #15 | Clinic visit.mp. |
| #16 | Hospital stay.mp. |
| #17 | Hospitali*ation.mp. |
| #18 | Hospital readmission.mp. |
| #19 | Cost.mp. |
| #20 | Cost-effectiveness.mp. |
| #21 | Cost-utility.mp. |
| #22 | Cost-benefit.mp. |
| #23 | Cost-minimi*ation.mp. |
| #24 | Counselling.mp. |
| #25 | Seek care.mp. |
| #26 | Behavio*r.mp. |
| #27 | 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 |
| #28 | 9 and 27 |

Text 2: Keywords used in focused search using exploding terms.

| No. | Keyword |
|-----|--------------------------------------|
| #1 | Genital ulcer disease.mp. |
| #2 | Herpes labialis.mp. |
| #3 | Herpes genitalis.mp. |
| #4 | Genital herpes.mp. |
| #5 | Herpesvirus.mp. |
| #6 | Herpes virus.mp. |
| #7 | HSV.mp. |
| #8 | Herpes simplex.mp. |
| #9 | 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 |
| #10 | pregnancy.mp. |
| #11 | pregnant.mp. |
| #12 | c*esarean.mp. |
| #13 | delivery.mp. |
| #14 | 10 or 11 |
| #15 | 12 or 13 |
| #16 | 9 AND 14 AND 15 |

Table 1: Detailed cost incurred in genito-ulcer diseases due to HSV

| Author,year | Outcomes | Unit cost (\$) in original year | Unit cost in 2018 (\$) |
|-------------------------|--|---------------------------------|------------------------|
| Medication costs | | | |
| Vickerman, 2008 | One dose of IV benzathine penicillin 2.4MU | 0.15 - 0.48 | 0.19-0.59 |
| Vickerman, 2008 | One tab of 500mg ciprofloxacin | 0.10 - 0.21 | 0.12 - 0.26 |
| Vickerman, 2008 | One cap of 200mg acyclovir | 0.53- 5.24 | 0.66 – 6.48 |
| Fisman, 2003 | Acyclovir therapy for relapse patients | 16.00 | 22.72 |
| Fisman, 2003 | Acyclovir cost for suppressive monthly therapy | 40.00 | 56.80 |
| Almonte-Vega, 2020 | Acyclovir therapy | 86.33 | 86.33 |
| Fisman, 2003 | Condom cost | 0.10 | 0.14 |
| Szucs, 2001 | Pharmacological treatment 1 st episode (NS) | 64.00 | 94.86 |
| Szucs, 2001 | Pharmacological treatment recurrent episode (NS) | 131.00 | 194.18 |
| Vickerman, 2008 | Needle and syringe cost | 0.15 | 0.19 |
| Tao, 2000 | Pharmacy claim | 52.00 | 73.84 |
| Laboratory test | | | |
| Szucs, 2001 | Antibiotic testing based on expert opinion | 76.50 | 113.39 |
| Szucs, 2001 | Antibiotic testing in first episode based on claims | 12.80 | 18.97 |
| Szucs, 2001 | Antibiotic testing in subsequent episode based on claims | 6.50 | 9.63 |
| Szucs, 2001 | Complete blood count based on expert opinion | 21.29 | 31.56 |
| Szucs, 2001 | Complete blood count in first episode based on claims | 4.60 | 6.82 |
| Szucs, 2001 | Complete blood count in subsequent episode based on claims | 1.50 | 2.22 |
| Szucs, 2001 | Microbiological test for first GUD episode | 17.60 | 26.09 |
| Szucs, 2001 | Microbiological test for subsequent GUD episode | 6.70 | 9.93 |
| Szucs, 2001 | Microbiological test based on expert opinion | 38.39 | 56.90 |
| Almonte-Vega, 2020 | Microbiological lab test | 80.17 | 80.17 |

| | | | |
|-----------------------------|--|----------|---------|
| Fisman, 2003 | Western blot | 60.00 | 85.20 |
| Szucs, 2001 | Urine analysis based on expert opinion | 12.59 | 18.66 |
| Szucs, 2001 | Urine analysis in first episode based on claims | 4.60 | 6.82 |
| Szucs, 2001 | Urine analysis in subsequent episode based on claims | 3.20 | 4.74 |
| Hospitalisation cost | | | |
| Fisman, 2003 | Excess obstetrical cost associated with history of symptomatic HSV2 infection | 300.00 | 425.98 |
| Fisman, 2003 | Excess obstetrical cost due to symptomatic HSV2 infection | 310.00 | 440.18 |
| Tao, 2000 | Inpatient cost | 2,530.00 | 3592.46 |
| Szucs, 2001 | Hospital day | 669.00 | 991.63 |
| Clinic visit | | | |
| Fisman, 2003 | Clinic visit related to GUD (for physician time, test, lost wages due to 2hr patient time) | 120.00 | 170.39 |
| Szucs, 2001 | Clinical examination based on expert opinion | 40.33 | 59.78 |
| Szucs, 2001 | Clinical examination first episode based on claims | 39.80 | 58.99 |
| Szucs, 2001 | Clinical examination on subsequent episode based on claims | 36.20 | 53.66 |
| Szucs, 2001 | Physician consultation based on expert opinion | 73.00 | 108.21 |
| Szucs, 2001 | Physician consultation in first episode based on claims | 62.60 | 92.79 |
| Szucs, 2001 | Physician consultation in subsequent episode based on claims | 59.60 | 88.34 |
| Tao, 2000 | Outpatient and ED | 59.00 | 83.78 |
| Fisman, 2003 | Outpatient visit | 120.00 | 170.39 |
| Tao, 2000 | Office based physician and public clinic | 67.00 | 95.14 |
| Almonte-Vega, 2020 | Consultation, clinical examination and diagnostic | 161.85 | 161.85 |
| Vickerman, 2008 | Counselling cost | 0.28 | 0.35 |
| Other costs | | | |
| Szucs, 2001 | Others miscellaneous cost related to first GUD episode(not reported) | 33.00 | 48.91 |

| | | | |
|--------------|---|--------|---------|
| Szucs, 2001 | Others miscellaneous cost related to recurrent GUD episode(not reported) | 12.30 | 18.23 |
| Szucs, 2001 | Production losses | 60.00 | 88.94 |
| Szucs, 2001 | Total cost of active GUD | 355.00 | 526.20 |
| Szucs, 2001 | Total cost of incident GUD | 235.00 | 348.33 |
| Szucs, 2001 | Total cost of prevalent GUD | 166.00 | 246.06 |
| Szucs, 2001 | Total cost of recurrent GUD | 499.00 | 739.65 |
| Fisman, 2003 | Treatment cost for men assuming 2 clinic visit, 7 day course of acyclovir (400mg tds) and 2 days off work | 450.00 | 638.97 |
| Fisman, 2003 | Treatment cost for women assuming 2 clinic visit, 7 day course of acyclovir (400mg tds) and 2 days off work | 800.00 | 1135.95 |

Table 2: Detailed cost associated with genital ulcer disease prevention in people living with HIV

| Author, year | Outcomes | Unit cost (\$) in original year | Unit cost in 2018 (\$) |
|-----------------|--|---------------------------------|------------------------|
| Vickerman, 2011 | Acyclovir 400mg | 0.07 | 0.07 |
| Vickerman, 2011 | Staff cost- for default tracer over 3 months | 24.00 | 22.32 |
| Vickerman, 2011 | Staff cost for training for STI diagnosis and default tracer | 0.46 | 0.43 |
| Vickerman, 2011 | Labour cost for senior nurse | 2.52 | 2.34 |
| Vickerman, 2011 | Counselling cost (10 mins) | 0.88 | 0.82 |
| Vickerman, 2011 | CD-4 count test | 7.90 | 7.35 |

NB- Cost reported after adjustment in 2017 were lower than those in the original study due to exchange rates at the time of study.

Table 3: Detailed cost associated with neonatal herpes prevention/management

| Author,year | Outcomes | Unit cost (USD\$) | Unit cost in 2017 (\$) |
|-----------------------------|--|-------------------|------------------------|
| Medication costs | | | |
| Randolph, 1996 | One cap of acyclovir 400mg | 1.14 | 1.72 |
| Baker, 2004 | Pharmaceutical cost for pregnant women | 6.18 | 8.10 |
| Baker, 2004 | Pharmaceutical cost for partner | 3.93 | 5.15 |
| Baker, 2004 | Valacyclovir 500mg | 3.95 | 5.18 |
| Baker, 2004 | Valacyclovir 1000mg | 6.49 | 8.51 |
| Baker, 2004 | Acyclovir 400mg | 1.96 | 2.57 |
| Barnabas, 2002 | Acyclovir treatment for a couple for one pregnancy | 37.00 | 51.37 |
| Scott, 1998 | Acyclovir 400mg | 1.71 | 2.58 |
| Laboratory test | | | |
| Randolph, 1996 | Screening using herpes culture | 35.00 | 52.83 |
| Thung, 2005 | HSV1 or 2 screening cost | 37.50 | 49.15 |
| Thung, 2005 | HSV 1 and 2 screening | 75.00 | 98.31 |
| Rouse, 2000 | HSV-2 antibody assay | 4.00 | 5.68 |
| Rouse, 2000 | HSV-2 labour and reagent cost, QC etc | 9.00 | 12.78 |
| Tuite, 2010 | ELISA screening for HSV | 7.00 | 7.96 |
| Scott, 1998 | HSV culture | 80.00 | 120.75 |
| Baker, 2004 | Labor and supplies for HSV-2 specific test | 15.58 | 20.42 |
| Baker, 2004 | HSV test for partner | 40.53 | 53.12 |
| Barnabas, 2002 | Diagnostic kit cost | 70.00 | 97.18 |
| Binkin, 1989 | Viral culture | 30.00 | 52.97 |
| Hospitalisation cost | | | |
| Scott, 1998 | Vaginal delivery with metritis, includes labour, delivery, postpartum and professional | 8439.00 | 12,737.15 |

| | | | |
|----|---------------------|---|-----------|
| 1 | | | |
| 2 | | | |
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| 4 | Scott, 1998 | Vaginal delivery without metritis, includes labour, delivery, postpartum and professional | 5,321.00 |
| 5 | | | 8,031.09 |
| 6 | Ambroggio, 2009 | Hospital charges | 62,050.90 |
| 7 | | | 70,544.69 |
| 8 | Tuite, 2010 | Vaginal delivery | 5,680.00 |
| 9 | | | 6,457.50 |
| 10 | Little, 2005 | Vaginal delivery | 4,939.00 |
| 11 | | | 6,104.17 |
| 12 | Randolph, 1996 | Caesarean delivery over vaginal | 3,500.00 |
| 13 | | | 5,282.62 |
| 14 | Tuite, 2010 | Caesarean section | 8,780.00 |
| 15 | | | 9,981.84 |
| 16 | Tao, 1999 | Caesarean attributable to genital herpes | 1,922.00 |
| 17 | | | 2729.13 |
| 18 | Little, 2005 | Caesarean delivery | 9,490.00 |
| 19 | | | 11,728.80 |
| 20 | Little, 2005 | Caesarean delivery with lesion | 7,608.00 |
| 21 | | | 9,402.82 |
| 22 | Scott, 1998 | Caesarean delivery with metritis, includes labour, delivery, postpartum and professional | 9,039.00 |
| 23 | | | 13,642.74 |
| 24 | Scott, 1998 | Caesarean delivery without metritis, includes labour, delivery, postpartum and professional | 10,553.00 |
| 25 | | | 15,927.85 |
| 26 | Thung, 2005 | Elective caesarean | 7,425.00 |
| 27 | | | 9,732.37 |
| 28 | Thung, 2005 | Labour caesarean | 9,283.00 |
| 29 | | | 12,167.75 |
| 30 | Little, 2005 | Hospital care due to neonatal herpes infection | 32,483.00 |
| 31 | | | 40,146.12 |
| 32 | Rouse, 2000 | Hospital care due to neonatal herpes infection | 11,126.00 |
| 33 | | | 15,798.28 |
| 34 | Baker, 2004 | Caesarean delivery | 5,021.00 |
| 35 | | | 6,581.31 |
| 36 | Binkin, 1989 | Hospital stay due to complication | 698.00 |
| 37 | | | 1,232.38 |
| 38 | Binkin, 1989 | Hospital care due to neonatal herpes infection | 25,000.00 |
| 39 | | | 44,139.53 |
| 40 | Barnabas, 2002 | Caesarean delivery with lesion | 11,084.00 |
| 41 | | | 15,388.48 |
| 42 | Clinic visit | | |
| 43 | Scott, 1998 | Clinic visit | 39.50 |
| 44 | | | 59.62 |
| 45 | Thung, 2005 | Counselling cost | 13.00 |
| 46 | | | 17.04 |
| 47 | Rouse, 2000 | Counselling cost (10 mins) | 3.50 |
| 48 | | | 4.97 |
| 49 | Rouse, 2000 | Counselling cost for couple (30 mins) | 10.50 |
| 50 | | | 14.91 |
| 51 | Randolph, 1996 | Follow-up call and office visit following screening | 74.00 |
| 52 | | | 111.69 |
| 53 | Barnabas, 2002 | Pharmacy dispensing and education cost | 3.00 |
| 54 | | | 4.17 |
| 55 | Barnabas, 2002 | Obstetrician counselling and testing salary for screening | 19.00 |
| 56 | | | 26.38 |

| | | | |
|----------------------------|---|--------------|--------------|
| Barnabas, 2002 | Obstetrician counselling and testing salary for treatment | 12.00 | 16.66 |
| Long-term care cost | | | |
| Scott, 1998 | Infant treated for HSV (include drug and culture) | 1,470.00 | 2,218.70 |
| Scott, 1998 | Neonatal care if using caesarean delivery | 821.00 | 1,239.15 |
| Scott, 1998 | Neonatal care if using vaginal delivery | 480.00 | 724.47 |
| Randolph, 1996 | Neonatal herpes acute hospital care | 10,160.00 | 15,334.69 |
| Thung, 2005 | Acute and long term care for normal/mild deficit | 13,202.00 | 17,304.61 |
| Randolph, 1996 | Long term medical cost for moderate disability (Y1-Y65) | 85,000.00 | 128,292.20 |
| Thung, 2005 | Acute and long term care for moderate deficit | 134,202.00 | 175,906.12 |
| Little, 2005 | Lifetime cost and care for moderately disabled child | 349,753.00 | 432,263.77 |
| Rouse, 2000 | Lifetime cost and care for moderately disabled child 1999 | 48,519.00 | 68,894.21 |
| Baker, 2004 | Lifetime medical and institutionalised cost for neonatal herpes | 92,350.00 | 121,048.35 |
| Binkin, 1989 | Lifetime cost and care for moderately disabled child | 125,000.00 | 220,697.66 |
| Fisman, 2003 | Lifetime cost of neonatal HSV with moderate neurological sequel | 97,000.00 | 13,7734.46 |
| Randolph, 1996 | Long term medical cost for severe disability (Y1-Y65) | 255,000.00 | 384,876.59 |
| Thung, 2005 | Acute and long term care for severe deficit | 325,602.00 | 426,784.88 |
| Little, 2005 | Lifetime cost and care for severely disabled child | 1,049,260.00 | 1,296,792.56 |
| Rouse, 2000 | Lifetime cost and care for severely disabled child | 163,879.00 | 232,698.82 |
| Binkin, 1989 | Lifetime cost and care for severely disabled child | 250,000.00 | 441,395.33 |
| Fisman, 2003 | Lifetime cost of neonatal HSV with severe neurological sequel | 291,000.00 | 413,203.38 |
| Tuite, 2010 | Lifetime cost of neonatal HSV | 164,870.00 | 187,438.10 |
| Fisman, 2003 | Lifetime cost of neonatal HSV | 110,000.0 | 156,193.72 |
| Baker, 2004 | Counselling cost nurse (15 mins) | 5.98 | 7.84 |
| Baker, 2004 | Counselling cost physician (5 mins) | 6.67 | 8.74 |
| Baker, 2004 | Labour cost and supplies | 15.58 | 20.42 |
| Baker, 2004 | Total cost without screening program | 1,181.35 | 1,548.46 |
| Baker, 2004 | Total cost with screening for women | 1,211.95 | 1,588.57 |
| Baker, 2004 | Total cost with screening for women and partner | 1,267.24 | 1,661.04 |

| | | | |
|----------------|--|------------|------------|
| Barnabas, 2002 | Maternal mortality cost | 443,858.00 | 616,230.57 |
| Thung, 2005 | Mortality cost | 13,202.00 | 17,304.61 |
| Barnabas, 2002 | Neonatal care after caesarean | 885.00 | 1228.69 |
| Barnabas, 2002 | Medical services for care of neonatal herpes | 273,712.00 | 380,008.25 |
| Barnabas, 2002 | Long term care for neonatal herpes | 140,766.00 | 195,432.58 |
| Barnabas, 2002 | Caregiver cost for neonates due to neonatal herpes | 149,943.00 | 208,173.47 |

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Figure 1: Methodological quality of included economic studies using CHEC Checklist

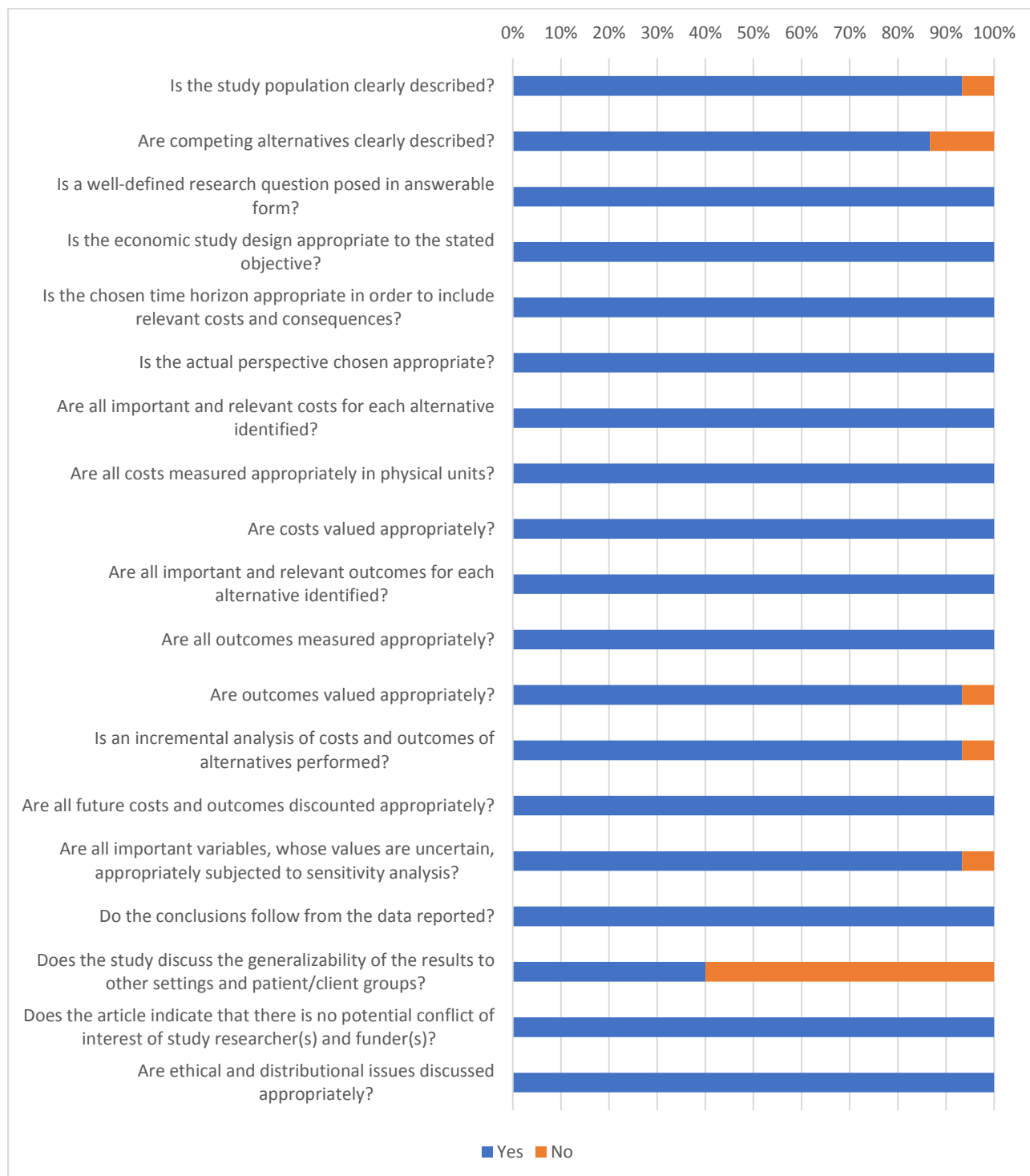
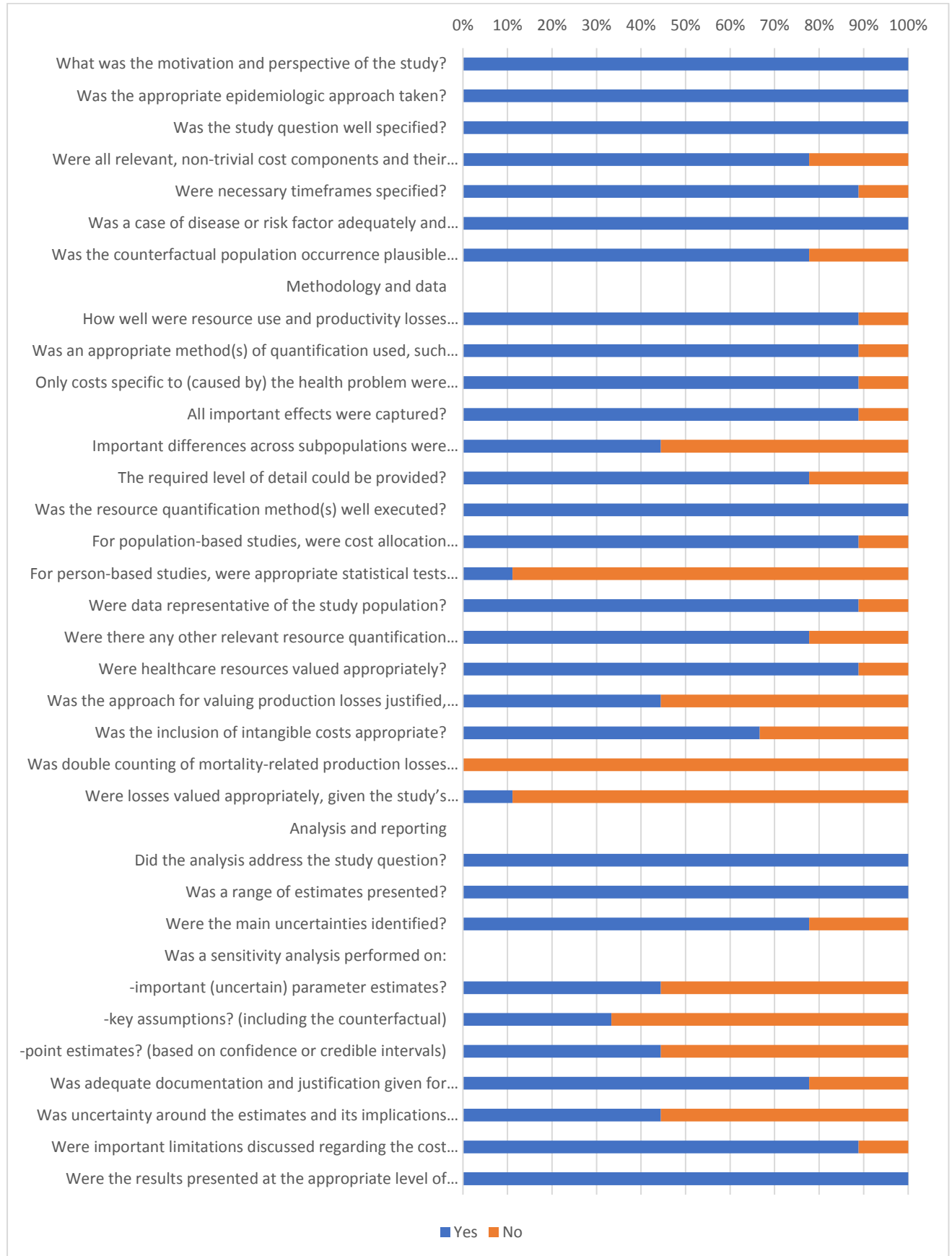


Figure 2: Methodological quality of included costing studies using Larg and Moss Checklist





PRISMA 2009 Checklist

| Section/topic | # | Checklist item | Reported on page # |
|------------------------------------|----|---|--------------------|
| TITLE | | | |
| Title | 1 | Identify the report as a systematic review, meta-analysis, or both. | 1 |
| ABSTRACT | | | |
| Structured summary | 2 | Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number. | 2 |
| INTRODUCTION | | | |
| Rationale | 3 | Describe the rationale for the review in the context of what is already known. | 4 |
| Objectives | 4 | Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS). | 4-5 |
| METHODS | | | |
| Protocol and registration | 5 | Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number. | 6 |
| Eligibility criteria | 6 | Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale. | 6 |
| Information sources | 7 | Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched. | 6 |
| Search | 8 | Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated. | 6 |
| Study selection | 9 | State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis). | 6 |
| Data collection process | 10 | Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators. | 7 |
| Data items | 11 | List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made. | 7 |
| Risk of bias in individual studies | 12 | Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis. | 7 |
| Summary measures | 13 | State the principal summary measures (e.g., risk ratio, difference in means). | 7 |
| Synthesis of results | 14 | Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis. | 7 |



PRISMA 2009 Checklist

| Section/topic | # | Checklist item | Reported on page # |
|-------------------------------|----|--|--------------------|
| Risk of bias across studies | 15 | Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies). | 7 |
| Additional analyses | 16 | Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified. | 7 |
| RESULTS | | | |
| Study selection | 17 | Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram. | 8 |
| Study characteristics | 18 | For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations. | 8 |
| Risk of bias within studies | 19 | Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12). | 8-9 |
| Results of individual studies | 20 | For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot. | 8-9 |
| Synthesis of results | 21 | Present results of each meta-analysis done, including confidence intervals and measures of consistency. | - |
| Risk of bias across studies | 22 | Present results of any assessment of risk of bias across studies (see Item 15). | 8 |
| Additional analysis | 23 | Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]). | 8-13 |
| DISCUSSION | | | |
| Summary of evidence | 24 | Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers). | 14-16 |
| Limitations | 25 | Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias). | 15-16 |
| Conclusions | 26 | Provide a general interpretation of the results in the context of other evidence, and implications for future research. | 17 |
| FUNDING | | | |
| Funding | 27 | Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review. | 1 |

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

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Healthcare resource utilization pattern and costs associated with herpes simplex virus diagnosis and management : a systematic review

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7 **Healthcare resource utilization pattern and costs associated with herpes simplex virus diagnosis**
8 **and management : a systematic review**
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15 Shaun Wen Huey Lee^{1,2,3} , Sami L. Gottlieb⁴, Nathorn Chaiyakunapruk^{1,5}
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ABSTRACT

Objectives: Little is known about the economic burden of HSV across countries. This article aims to summarize existing evidence on estimates of costs and healthcare resource utilization associated with genital and neonatal HSV infection.

Design: Systematic literature review

Data sources: Seven databases were searched from inception to August 31st 2020. A focused search was performed to supplement the results.

Eligibility criteria: Studies which reported either healthcare resource utilization or costs associated with HSV-related healthcare, including screening, diagnosis and treatment of genital HSV infection and neonatal herpes prevention and treatment

Data extraction and synthesis: Two independent reviewers extracted data and assessed the risk of bias using the Larg and Moss's checklist. All data were summarized narratively

Results: Out of 11,443 articles, 38 were included. Most studies (35/38, 94.6%) were conducted in high income countries, primarily the United States, and were more often related to the prevention or management of neonatal herpes (n=21) than HSV genital ulcer disease (n=17). Most analyses were conducted before 2010. There was substantial heterogeneity in the reporting of HSV-related healthcare resource utilization, with 74% to 93% individuals who sought care for HSV, 11.6% to 68.4% individuals who received care, while neonates with herpes required a median of 6 to 34 hospitalisation days. The costs reported were similarly heterogeneous, with wide variation in methodology, assumptions, and outcome measures between studies. Cost for screening ranged from \$7 to \$100, treatment ranged from \$0.53 to \$35 for an episodic therapy, \$240 to \$2580 yearly for suppressive therapy, while hospitalisation for neonatal care ranged from \$5,321-\$32,683.

Conclusions: A paucity of evidence exists on healthcare resource utilization and costs associated with HSV infection, especially among low- and middle-income countries. Future research is needed on costs and healthcare utilization patterns to improve overall understanding of the global economic burden of HSV.

(298/300 words)

Keywords: herpes simplex virus; healthcare resource utilization; neonatal herpes; pregnancy; genital ulcer

Strengths and limitations of this study

- This is the first systematic review to assess the healthcare resource utilisation and costs associated with herpes simplex virus (HSV) infections.
- Comprehensive literature searches were conducted, which were supplemented by a focused search.
- Heterogeneity of study designs and outcome measures limited the meta-analysis of study results.
- Relatively few studies described the healthcare resource utilization patterns and cost of HSV, especially from low-middle income countries.

INTRODUCTION

Herpes simplex virus (HSV)-1 and HSV-2 are DNA viruses that belong to Alphaherpesviridae, a subfamily of the Herpesviridae family.¹ Both viruses can cause genital infection, which can have a profound impact on sexual and reproductive health. HSV-2 is almost entirely transmitted during sexual activity and is the most common cause of genital herpes, affecting more than one in every 8 individuals, or 491.5 million people, aged 15-49 years in 2016.² HSV-1 is the main cause of oral herpes but can also be transmitted to the genital area through oral sex. HSV-1 affects an estimated 3.7 billion people under age 50 globally, of which over 120 million may have genital infection.² While the prevalence of HSV infection is high globally, it varies widely by region. The highest prevalence of both HSV-1 (88% in females and males) and HSV-2 (44% in females; 25% in males) is in the African region, which is primarily comprised of low- and middle-income countries (LMIC).^{1,2}

Genital HSV infection is lifelong and characterised by periodic reactivation. Many infections are asymptomatic or unrecognized, but up to a third of people may develop painful, recurrent genital sores known collectively as genital ulcer disease (GUD).³ Antiviral medications can be taken episodically to shorten GUD outbreaks or taken daily (suppressive therapy) to reduce the number of outbreaks, but they are not curative. Pregnant women with genital HSV infection can also transmit the virus to their infants in the peripartum period, resulting in neonatal herpes.⁴ Although this occurs only rarely, neonatal herpes has a high fatality and disability rate among surviving infants. As such, particularly in high-income countries (HIC), prevention measures such as caesarean section are often undertaken if a mother has active HSV lesions at delivery. Genital HSV-2 infection has also been linked to an increased risk of acquisition and transmission of human immunodeficiency virus (HIV) infection.⁵

The World Health Organization (WHO) has highlighted the need for a vaccine against HSV-2, due to large numbers of infections globally and the resulting disease consequences including GUD, neonatal herpes, and increased risk of HIV acquisition.⁶⁻⁸ Multiple vaccine candidates have been studied to date with modelling studies showing that prevention of HSV-2 infection with a vaccine could potentially also reduce the incidence of HIV infection.⁹ Vaccines targeting HSV-2 might also have benefits against HSV-1.¹⁰ Understanding the potential value of HSV vaccines requires not only

1
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3 predicting the impact of the vaccines on HSV-related disease burden, but also on its economic
4 burden. However, little is known about the economic burden of HSV globally. As a first step in
5 estimating HSV-related economic burden, we conducted a broad systematic review with the aim of
6 summarizing all available evidence on costs and resource utilization associated with diagnosing,
7 treating, and managing genital and neonatal HSV infection.
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METHODS

The current study followed the guidelines of the Cochrane Handbook for Systematic Reviews of Intervention.¹¹ The review was reported in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analyses.¹²

Data Sources and Search Strategy

We electronically searched for relevant articles published from database inception to August 31st 2020 in 7 databases: PubMed, PsychINFO, EMBASE, Centre for Review and Dissemination, EconLit, CEA registry and WHO Library Database (WHOLIS). The search strategy was based on a broad combined search string “Herpes Simplex Virus” AND “cost” OR “resource utilization” OR “econ*”, with no language restriction. A complete search strategy is detailed in Appendix Text 1. In addition, bibliographies of relevant articles were examined to identify potential studies not indexed in the aforementioned databases. A focused supplemental search on Google Scholar was performed using the keywords listed in Appendix Text 2 based upon the inclusion above.

Study Selection

Studies were included if they were original articles that investigated resource utilization patterns and costs related to HSV infection including the cost of any diagnostic tools, consultation time, treatment and hospital cost related to detecting and managing all types of HSV-1 or HSV-2 related neonatal and genital infections and associated disease outcomes. We included articles which were published in English languages.

Data Extraction and Quality Assessment

The study followed a 2-stage process, where two independent reviewers screened the titles and abstracts for relevant studies, before the full texts were screened by another two independent reviewers for eligibility. Relevant information from the identified studies was extracted independently by two reviewers using a standardized data extraction sheet. At all stages, any disagreement was resolved by discussion between reviewers through consensus. Information

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3 collected from the data extraction sheet included: 1) general study information including country of
4 the study, 2) HSV subtype and disease, 3) study design, 4) healthcare resource utilization, 5) costs of
5 relevant tests, clinical care, hospitalisation, and medications, and 6) summary estimates of HSV-
6 related economic burden. Methodological quality of all included economic studies was assessed
7 using the Consensus Health Economic Criteria (CHEC) list. This checklist has been recommended for
8 critically appraising published economic evaluations. The checklist has 19 domains and includes
9 reporting standards for economic model characteristics (population, time horizon, perspective and
10 discount rate), identification and valuation of costs and outcomes, discussion points, conclusions as
11 well as funding and conflicts of interest. All cost of illness studies were evaluated for risk of bias
12 using the Larg and Moss's checklist. No quality appraisal was performed on studies reporting
13 healthcare resource utilization.
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25 **Data Analysis**

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27 A component-based analysis was used to describe and synthesise the overall findings from all
28 included studies. Specifically, tabulation methods were used to report on study characteristics,
29 outcomes and costs. Tables for resource utilization and disaggregated costs were presented and
30 summarized. All costs were presented according to the recommendations of Turner et al., 2019¹³.
31 For studies that did not provide the year of cost data, the year of publication was used. Adjustment
32 for inflation was done using the Gross Domestic Product deflator (GDP deflator) of the studied
33 country. Cost estimates were then converted and reported in 2017 United States Dollars (USD). GDP
34 deflator and exchange rates were obtained from the World Bank.¹⁴
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44 **Patient and public involvement**

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46 Patients were not involved in this systematic review. Their input was not sought in the design,
47 interpretation or writing of the document.
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RESULTS

Study Selection

Our search yielded a total of 11,443 articles of which 8,779 articles were excluded as they were not relevant for this review based on title screening. The remaining 2,664 articles were further screened by title and abstract and 299 articles were assessed for inclusion. We excluded 261 articles (n= 98 for not related to HSV, n =44 review articles/case report, n =116 not reporting resource utilization or cost, n =3 available only in abstract), leaving a total of 38 studies included in this review, as shown in Figure 1.

Overview of Study Characteristics

Of the 38 included articles, 14 studies¹⁵⁻²⁸ described resource utilization only, 12 studies²⁹⁻⁴⁰ reported on costs, and 12 studies⁴¹⁻⁵² reported both resource utilization and costs of HSV diagnosis/management. These studies, published from 1989 to 2020, reported resource utilization or costs related to the diagnosis and management of HSV-related GUD among adults/adolescents^{18-22 28 30-34 37-40 44 52} (n=17), neonatal herpes prevention in pregnant mothers (n=13)^{23-25 27 29 35 36 42 43 46-49} and neonatal herpes management^{15-17 26 41 45 50 51} (n=8). The majority of studies were conducted in HIC (35/38, 94.6%) including the United States^{15 17 20 22 25 27 29 30 34 35 38-52} (n= 26), Canada^{18 19 26 36} (n=4), United Kingdom^{23 33} (n=2), France^{16 28} (n=2) and Ireland²⁴ (n=1)), while only one study (1/38, 2.6%) was conducted in a middle-income country, in particular South Africa³². A global survey focusing on the experiences of patients receiving care for genital herpes in 78 countries included some data on healthcare utilization.²¹ In addition, a modelling study estimated the costs of implementing the Global Health Sector Strategy on Sexually Transmitted Infections (STIs), 2016-2021, in 117 LMICs, including costs related to syndromic management of GUD, the vast majority of which is caused by HSV-2.³⁷ The quality of included studies are summarised in Appendix Figure 1 and Figure 2.

Methodological Heterogeneity

There was substantial heterogeneity in the reporting of the included studies. Most studies were cost or resource utilization studies (n=23), while the remaining were cost-effectiveness studies (n=15). Among cost or resource utilization studies, data were collected retrospectively (n=13), prospectively (n=7), or not reported (n=7). The number of participants in each study varied, which could be as few

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3 as 39 participants to as large as 42 million in studies that analysed claims datasets. Twenty-one studies
4 (21/38, 55.3%) included participants who had either HSV-1 or 2, ten studies (10/37, 27.0%) specifically
5 included participants with HSV-2, while the remaining eight studies (8/38, 21.1%) did not specify which
6 type of HSV they examined. A summary of the characteristics of these studies is presented in Appendix
7 Table 1, and study findings are presented in Appendix Tables 2 and Appendix Table 3 (See appendix
8 for detailed unit cost tables and accompanying references).
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16 **Cost and healthcare resource utilization pattern of genital herpes infection**

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18 Among all 17 studies^{18-22 28 30-34 37-40 44 52} investigating cost and healthcare resource utilization pattern
19 of genital herpes, 11 studies reported some cost components of care for genital herpes infection³⁰⁻³⁴
20 ^{37-40 44 52} (Appendix Tables 1, 2 and 4). All but one of these studies were conducted in HIC and only
21 one LMIC study (from South Africa) was found. The cost components of the included studies were
22 variably reported. Three studies^{31 34 52} reported laboratory testing costs associated with diagnosing
23 HSV. Eight studies^{30 31 33 34 37 40 44 52} described costs associated with syndromic management of GUD. In
24 four studies^{32 33 37 52}, the authors describe the drug charges associated with treatment or prevention
25 of HSV using oral acyclovir (doses of 200mg-400mg). The cost reported varied considerably, ranging
26 between USD\$0.53 to USD\$16 for a 5 to 7 day treatment course for episodic GUD and USD\$40 for a
27 month of suppressive therapy with acyclovir. Two studies^{31 44} provided the total drug charges
28 associated with overall management of GUD, but no details related to the treatment regimen,
29 duration or HSV of HSV being treated (Appendix Table 2). Seven studies^{31-33 37 47 48 52} described labour
30 and service delivery costs such as cost of physician visits, drug procurement cost, counselling cost
31 and clinical examination associated with HSV. Similarly, there was variation in terms of reported
32 labour and service delivery cost, which could be as low as USD\$0.28 for 10-minute counselling³³ to
33 as high as USD\$120 for consultation and lost wages of patient time⁵². Indirect costs were considered
34 only by Szucs *et al*, who estimated HSV-related productivity losses, which was estimated at USD\$60
35 a visit³¹.
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52 Considering the cost components together, Owusu-Edusei *et al* estimated that the lifetime direct
53 medical cost per case of genital HSV infection in the U.S. (considering only GUD-related costs and
54 adjusted to 2017 USD) was USD\$855 among men (range: USD\$428- USD\$1,284) and USD\$698
55 among women (range: USD\$350- USD\$1,047)³⁰. This translated to a total cost of USD\$607.3 million
56 (range: USD\$303.59 million – USD\$ 910.89 million in 2017 USD) for lifetime management of new or
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3 newly diagnosed cases of HSV-2 in the United States occurring in 2008. Scuzs *et al* meanwhile
4 estimated that the annual direct and indirect medical costs in the United States would amount to
5 USD\$983 million, based upon an estimated 3.1 million symptomatic genital HSV episodes (both new
6 and recurrent) a year³¹.
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12 The only middle income country study, from South Africa³², reported the diagnostic/ operational
13 costs associated with medication, staff and laboratory costs for daily HSV-2 suppressive therapy
14 among people living with HIV³². The median cost for HSV-2 suppressive therapy per life-year gained
15 ranged between USD \$685 to USD \$951 (adjusted to 2017 dollar) among HIV-1 infected anti-
16 retroviral naïve women. The authors estimated that this could be a cost-effective method for
17 delaying HIV disease progression, especially when the price of acyclovir was lower than the price of
18 USD \$0.026/day for a twice daily 400mg dose. However, this study was conducted when ART use
19 was recommended only when CD4 count fell below a threshold of <200 cells/ μ L or <350 cell/ μ L
20 (Appendix Table 5). On a more global level, in Korenromp *et al*'s cost estimates for implementing the
21 Global STI Strategy in 117 LMIC over 2016 to 2021, the authors reported that it would cost
22 approximately USD\$109 million to diagnose and treat HSV-related GUD episodes seen in clinical
23 care, not including service delivery costs.³⁷ These costs were estimated despite assuming that only
24 about 4% of all HSV-2 infected people would seek care for GUD (15% recognizing symptoms and 28%
25 of those seeking care).
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40 A total of 8 studies described healthcare resource utilization patterns for genital herpes infection¹⁸⁻²²
41 ^{31 40 44}, and all were from high income countries (Appendix Tables 1 and 3). Five of these studies^{18 20-}
42 ^{22 40} reported the population rate of seeking medical care for HSV, based upon retrospective analyses
43 of databases of patients from health surveys²⁰⁻²². In the study by Xia and colleagues, the authors
44 found that the total genital herpes associated ED use increased from 24,747 visits in 2006 to 36,518
45 in 2013⁴⁰. It is important to note that none of the studies reported the proportion of those seeking
46 medical care among HSV-infected individuals. Most of these consultations were relatively short in
47 nature, and were less than 15 minutes (79%)²¹. Two studies described the diagnostic methods used
48 to determine HSV among their population. In the first study conducted in 2004, Patrick *et al*.
49 surveyed physicians in 78 countries and reported that the most commonly used test was viral
50 culture, which was performed in 49% of the individuals²¹ (Appendix Table 3). A recent study in
51 France by Heggarty *et al*. in 2020 found that 43.3% of respondents in their survey stated that they
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3 would conduct PCR plus HSV serology and another 39.9% would conduct PCR only to confirm a HSV
4 diagnosis²⁸.
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12 Treatment patterns of individuals with genital herpes were also reported in four studies^{19 21 28 44}. The
13 study by DesHarnais *et al* in 1996 reported on antiviral use only among hospitalized patients with
14 herpes infections, which is unlikely to be representative of the vast majority of people with HSV
15 infection. Patrick *et al* in their survey found that 65% of people with genital herpes had ever been
16 treated with antivirals, while 18% used topical prescription medication and 13% used over the
17 counter topical cream. Among these individuals, 67% had received episodic therapy while 31%
18 received chronic suppressive therapy (Appendix Table 2). Another study on herpes-related quality of
19 life reported that 76.9% of respondents had ever been treated with antivirals, and 33.3% of the
20 respondents with HSV were on suppressive antiviral therapy when the survey was administered¹⁹.
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30 **Cost and healthcare resource utilization pattern of prevention of neonatal herpes among pregnant** 31 **mothers** 32

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34 Nine studies reported costs for neonatal herpes prevention among pregnant mothers^{29 35 36 42 43 46-49}
35 (Appendix Tables 1, 2 and 6). Seven studies^{35 36 42 43 46 47 49} provided estimates on the cost for
36 treatment and childbirth delivery options, including caesarean and vaginal delivery in addition to
37 inpatient costs. The cost of hospitalisation ranged considerably, and could be as low as USD\$300 to
38 as high as USD\$32,483, while the cost of delivery ranged between USD\$2,300 -\$9,490. The costs
39 associated with different laboratory tests used, such as ELISA screening or viral cultures^{36 43} were
40 reported, while detailed listing of the cost component of different delivery methods and hospital
41 care were included in some studies (Appendix Table 6). The cost-effectiveness studies examined the
42 impact of either acyclovir suppressive therapy^{29 35 46 47} or routine antenatal screening^{36 42 43 48 49} for
43 prevention of neonatal herpes. In a study by Randolph *et al* in 1996⁴⁷, the authors found that
44 prophylaxis with acyclovir during late pregnancy could be a cost-effective strategy to reduce the
45 need for caesarean delivery due to genital herpes outbreaks during labour. Baker and colleagues in
46 2004 further expanded this work and estimated that adding serological testing to antiviral
47 suppressive therapy had an incremental cost per quality-adjusted life year gained (QALY) of \$18,680,
48 compared with no screening or suppressive therapy⁴². A modelling study by Tuite *et al* in 2010 had
49 similar findings related to screening for HSV in pregnancy³⁶.
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6 Our focused search found a total of 10 studies which reported resource utilization among pregnant
7 mothers to prevent neonatal herpes^{23-28 42 43 46 48}. Among these, four were cost-effectiveness studies
8 which had provided some information regarding resource utilization based upon estimates from
9 literature or assumptions.^{42 43 46 48} In one of the earliest studies by Brocklehurst in 1995, a survey of
10 British obstetrician-gynaecologists revealed that most would recommend some form of antenatal
11 screening for HSV using viral cultures usually by week 34 of gestation²³. However, such screening is
12 no longer recommended in the UK. Studies within HICs that have national obstetrics guidelines
13 recommending caesarean delivery when HSV lesions are present at delivery have shown that most
14 clinicians follow this guidance²⁴⁻²⁷. For example, in a Canadian study, caesarean section was offered
15 "most of the time" to women with HSV lesions at delivery by 92% of obstetricians and 82% of family
16 physicians²⁶. In addition, in these settings women with genital herpes are often offered antiviral
17 suppressive therapy in the third trimester^{24 26}. Both valacyclovir and acyclovir have been used, with
18 difference in preference by country. In the most recent survey of clinicians managing pregnant
19 women with HSV by Heggarty *et al* in 2020, the authors noted that 68.4% "always" prescribe
20 suppressive antiviral therapy during the third trimester and an additional 11.6% "often" prescribe it
21 for women with symptomatic primary HSV infection during pregnancy.²⁵ For women with recurrent
22 symptoms during pregnancy, 55.1% of providers "always" prescribe and 12.9% "often" prescribe
23 antiviral prophylaxis in the third trimester.²⁸

38 39 **Cost and healthcare resource utilization pattern of neonatal herpes management**

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41 Four studies^{41 45 50 51} reported cost of neonatal herpes management and reported only direct medical
42 costs (Appendix Tables 1 and 2). One study reported direct non-medical cost for long-term care of
43 individuals with neurological disability due to sequelae of HSV⁴³. All studies were in HIC. The
44 reported cost of hospitalisation of neonatal HSV ranged considerably, from \$27,843 to \$92,664. One
45 study reported the cost associated with hospital readmission, which was reportedly similar to the
46 first hospitalisation episode⁵⁰. Six studies^{36 46-49 52} accounted for the costs of informal care in their
47 calculation. Informal caregiving was defined as care provided by caregivers for infants who had
48 neurological sequelae following neonatal herpes. In total, seven studies^{36 43 46-49 52} estimated long-
49 term care costs of neonatal herpes patients. One of these, by Thung *et al*⁴⁹, provided the estimated
50 cost for long term care of neonates with mild neurological deficit due to HSV, which cost
51 USD\$17,304.61 after adjusting for inflation to 2017 values. Six studies^{43 46-49 52} provided estimates for
52 the lifetime cost of caring for a child with moderate and severe disability, and fall within the range
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3 USD\$68,894 to USD\$432,263 and USD\$232,698 to USD\$ 1,296,792 respectively. It is important to
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5 note that all studies relied on estimation of long-term costs calculated by Weitzman⁵³ with some
6
7 different assumptions, while one study⁴³ used other sources of data.
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11 A total of 7 studies^{15-17 41 45 50 51} described resource utilization among individuals with neonatal herpes
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13 (Appendix Tables 1 and 3). These studies described the length of stay for hospitalization which varied
14
15 considerably, with median hospital stays ranging from 6-34 days^{15 16}. Ahmad *et al* noted that nearly
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17 9.4 to 9.8% of neonates who had HSV required ICU stay¹⁵. None of the studies reported the number
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19 of days for ICU hospitalization.
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DISCUSSION

Our review revealed a heterogeneous body of evidence on the healthcare resource utilization and costs associated with genital and neonatal HSV infection, as well as some summary economic estimates and cost-effectiveness studies of HSV intervention strategies, such as use of antivirals or screening, which included unit cost data. While the evidence base provides a starting point for understanding, several gaps remain. Despite the broad search strategy and inclusion criteria, we identified only 38 papers, which shows the paucity of data on HSV-related healthcare resource utilization as well as economic costs, especially from LMIC settings. The lack of data from LMIC is particularly concerning, as these countries bear the greatest burden of HSV infection and disease.²³⁵⁴ The current review only identified one cost-effectiveness analysis from a middle income country³² focused on people living with HIV only, and one high-level modelling study predicting costs of implementing care for HSV GUD across 117 LMIC globally³⁷. In addition, many of the studies we found were relatively old and may not reflect current practices such as the use of newer diagnostics (e.g. PCR) and newer care recommendations. For example, the global study by Patrick *et al.* reported that viral culture was the most common test used to diagnose HSV but this is likely because the use of PCR was not yet common in clinical practice at the time of the study. The 2020 study in France by Heggarty *et al.* reveals that PCR is now the most commonly used test, at least in this HIC setting, with and without HSV serology²⁸.

While data on resource utilization and costing were most comprehensive from the US, large gaps remain in many areas. For example, Gilbert and colleagues²⁰ described the proportions of individuals seeking care for genital herpes among adults aged 18 to 24 from 2000 to 2006, but since then there have been no new updates. In terms of costing, we noticed similar trends, as studies³⁰ mostly referenced cost data collected in 2001 by Szucs *et al.*³¹. This lack of data is similarly noted related to HSV infection during pregnancy. While some information from health surveys exists, healthcare resource utilization information is rarely tracked or reported. Our search demonstrated that for most of the world, data on HSV related resource utilization are sparse. As such, new data sources and better data collection efforts are needed to collect these standardized non-fatal data from diverse healthcare settings. One major need is an understanding of how closely clinicians follow national guidelines on HSV care and treatment, such as the studies by Kenny *et al.*²⁶ and Heggarty *et al.*²⁸ from Canada and France respectively. For example, while there are structured guidelines for the workup of neonatal herpes and its related management, our review did not identify any studies

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3 that described the compliance to these guidelines. Such information can provide us with vital clues
4 into the economic burden of neonatal HSV as there is substantial cost due to the high mortality rates
5 neonatal HSV was not treated.
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11 Our review was also constrained in summarizing findings across studies or countries and in
12 conducting across-study comparisons, due to the limited data and differing methodologies,
13 healthcare settings, and practices, particularly for healthcare resource utilization. Another concern
14 was the heterogeneity in data presentation in many studies identified. For example, the length of
15 hospital stay reported in studies varied considerably, with different assumptions used by authors,
16 and as a result, the cost of hospitalisation varied significantly even within the United States, which
17 limits the potential generalizability of these findings across different settings^{16 41 45 51}. Healthcare
18 practices also differ between LMIC and HIC with respect to how HSV is managed, e.g., most HSV
19 cases in LMICs are treated as part of syndromic management for GUD, without diagnostic testing.
20 This may mean that additional testing costs might need to be considered for HICs, whereas
21 additional treatment, for example for syphilis and chancroid, which can also cause GUD syndromes,
22 might need to be considered for LMICs. The focus on GUD more generally in LMICs may have made it
23 more challenging to identify potentially relevant HSV-specific studies for LMIC settings.
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36 In order to estimate the global economic burden of HSV to contribute to the understanding of the
37 potential value of HSV interventions, research on HSV-related costs and healthcare utilization
38 patterns is urgently needed, especially from LMIC settings. Standardization of methods for the
39 measurement and reporting of economic costs would enhance across-study comparisons and inform
40 prioritization strategies of global funders. Only one study broadly attempted to quantify the
41 economic burden of HSV, which the authors estimated would require a projected investment of
42 around USD\$109 million from 2016 to 2021, just for the management of HSV-associated GUD, not
43 considering service delivery costs³⁷. However, this analysis only modelled treatment of HSV GUD for
44 a small proportion of people with HSV-2 infection (approximately 4%: assuming 15% would
45 recognize symptoms and 28% of those would seek care) and did not account for HSV recurrences
46 within a given year. New global estimates of HSV GUD suggest this is likely an underestimate.³ In
47 addition, as this model lacked country-level estimates of baseline disease and did not take into
48 account the full spectrum of disease outcomes related to HSV nor the burden on health systems, the
49 costing estimates remain imprecise and incomplete, suggesting the need for a more comprehensive
50 model.
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6 This is the first systematic review of scientific literature on the healthcare resource utilization for
7 HSV. We conducted a comprehensive literature search and included grey literature through our
8 focused search. Nevertheless, most studies were only conducted in HIC especially from the USA. As
9 the practice and thus utilization of resources will vary between settings and countries due to
10 epidemiological and health systems differences, this will limit the generalisability of findings.
11 Nevertheless, results of this study will serve as a future repository for studies that wish to examine
12 the economic evaluations of any public health interventions for HSV. This review also highlights the
13 importance and need for more studies to describe on the healthcare resource utilization and
14 associated cost of HSV, especially from LMIC. We assessed study quality of all included studies,
15 which allows readers to assess the internal validity of these studies. The literature search was also
16 limited to studies published in English language. As data on healthcare resource utilization may be
17 published in government reports, or book chapters, these may not have been retrieved and included
18 in this review, which may partly explain the lack of studies describing healthcare resource utilization
19 from LMIC.
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CONCLUSION

This review is the first attempt and a key step towards providing data needed to understand the global economic burden of HSV infection, for both HICs and LMICs. Available economic estimates, primarily from HICs, suggest the economic burden of HSV infection could be substantial. However, the global picture remains incomplete. Nevertheless, results obtained from this study will form a repository which can inform future economic evaluations of interventions for HSV infection, including HSV vaccines, microbicides, or new antiviral medications.⁵⁵ These types of economic data are crucial not only to improve the planning and development of any future HSV-related healthcare interventions, but also to optimize the allocation of healthcare expenditures and medical resources.

Contributors

SWHL served as the lead author, conducted the research, conducted the analyses, integrated the input from all team members and drafted the initial manuscript. SG directed the initial research and contributed to the initial draft, integrated her view points and served as an expert in this work.. NC conducted the research, mediated the discussion and helped refine the draft. All authors approved the final manuscript.

Data sharing statement

All relevant information and data have been presented in this article and its accompanying supplement.

Competing interest

All authors have no competing interest to report

Ethics Statement

This systematic review did not require ethical approval.

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7 **Figure legend**
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10 Figure 1. Flow diagram of study selection process
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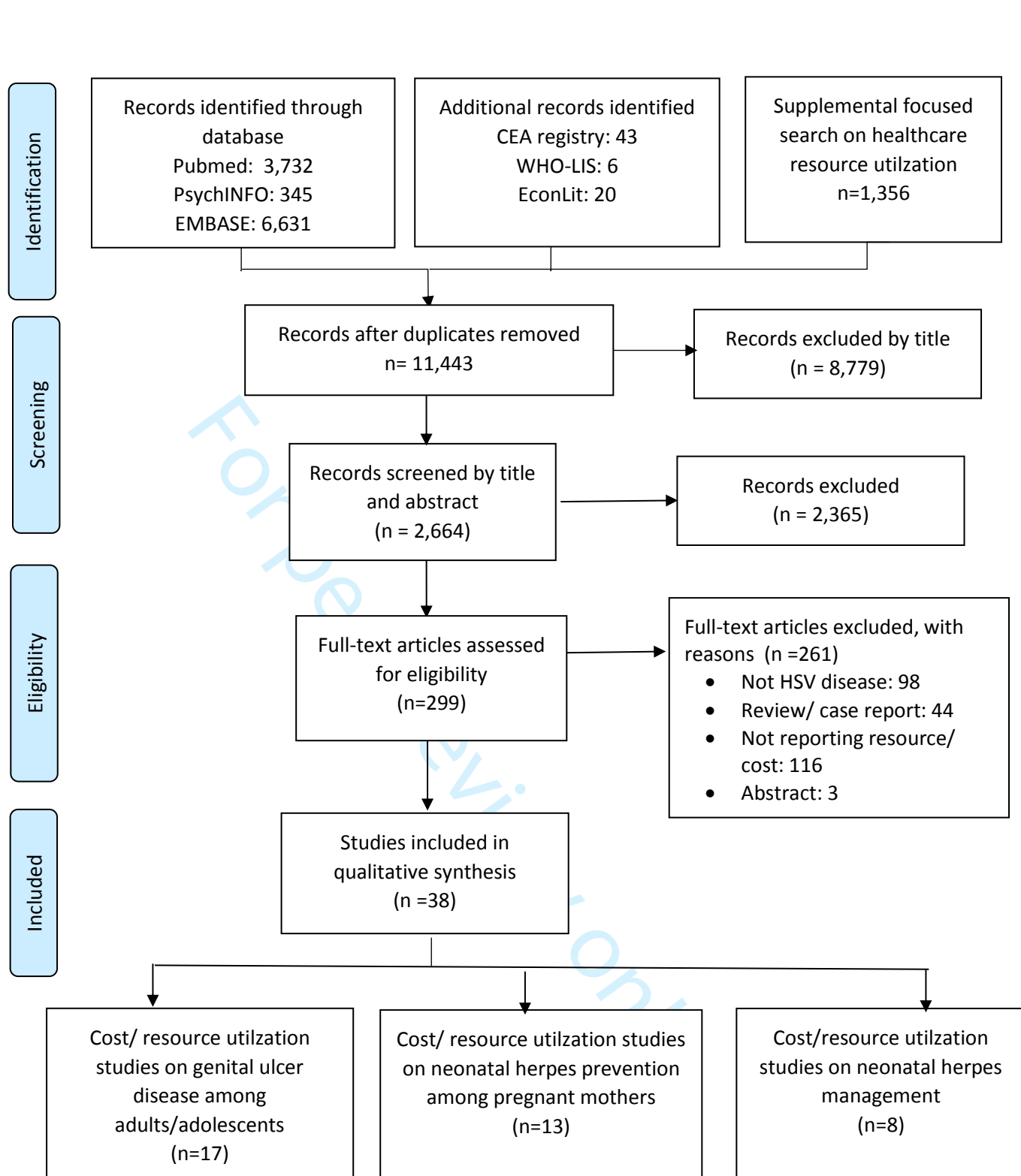
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5 **APPENDIX**
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Search methodology

1. Search strategy

- The current search strategy was developed based upon keywords which have been used in previous existing HSV reviews commissioned by WHO. All search keywords used were subsequently cross-checked with the following articles to ensure comprehensiveness
 - Looker, 2017. Effect of HSV-2 infection on subsequent HIV acquisition: an updated systematic review and meta-analysis
 - Khard, 2019. The Epidemiology of Herpes Simplex Virus Type 1 in Asia: Systematic Review, Meta-analyses, and Meta-regressions
 - Looker, 2012. Global estimates of prevalent and incident herpes simplex virus type 2 infections in 2012. PLoS One 2015;10(1) : e114989-e89. Doi: 10.1371/journal.pone.0114989
- The following databases were identified for the search including: PubMed, PsychINFO, EMBASE, Centre for Review and Dissemination, EconLit, CEA registry and WHO Library Database (WHOLIS)

2. **Keywords search** was revised to compare between a) search including exploding terms and b) search including title and abstract. A total of 10,113 articles was found for search when terms were exploded versus 5,966 when these terms were not exploded. As such, the methods will only use search including exploding terms to minimize the risk of missing relevant study despite its low specificity. The initial search was performed in April 2019, with an updated search in October 2019.

3. Neonate search

- We also conducted search over again using all relevant HSV terms with neonate as keyword. All articles identified in the search overlapped with existing broader search, thereby there is no need to add neonate as key words

Text 1: Keyword terms used in the search

| No. | Keyword |
|-----|--|
| #1 | Genital ulcer disease.mp. |
| #2 | Herpes labialis.mp. |
| #3 | Herpes genitalis.mp. |
| #4 | Genital herpes.mp. |
| #5 | Herpesvirus.mp. |
| #6 | Herpes virus.mp. |
| #7 | HSV.mp. |
| #8 | Herpes simplex.mp. |
| #9 | 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 |
| #10 | Healthcare util*ation.mp. |
| #11 | Util*ation.mp. |
| #12 | Physician visit.mp. |
| #13 | General practitioner visit.mp. |
| #14 | Hospital visit.mp. |
| #15 | Clinic visit.mp. |
| #16 | Hospital stay.mp. |
| #17 | Hospitali*ation.mp. |
| #18 | Hospital readmission.mp. |
| #19 | Cost.mp. |
| #20 | Cost-effectiveness.mp. |
| #21 | Cost-utility.mp. |
| #22 | Cost-benefit.mp. |
| #23 | Cost-minimi*ation.mp. |
| #24 | Counselling.mp. |
| #25 | Seek care.mp. |
| #26 | Behavio*r.mp. |
| #27 | 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 |
| #28 | 9 and 27 |

Text 2: Keywords used in focused search using exploding terms.

| No. | Keyword |
|-----|--------------------------------------|
| #1 | Genital ulcer disease.mp. |
| #2 | Herpes labialis.mp. |
| #3 | Herpes genitalis.mp. |
| #4 | Genital herpes.mp. |
| #5 | Herpesvirus.mp. |
| #6 | Herpes virus.mp. |
| #7 | HSV.mp. |
| #8 | Herpes simplex.mp. |
| #9 | 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 |
| #10 | pregnancy.mp. |
| #11 | pregnant.mp. |
| #12 | c*esarean.mp. |
| #13 | delivery.mp. |
| #14 | 10 or 11 |
| #15 | 12 or 13 |
| #16 | 9 AND 14 AND 15 |

Table 1: Summary of included studies reporting healthcare costs and/or resource utilization related to HSV infection

| Author, year Country | Population and setting | Study design | Study objective | Sample size | HSV-subtype | | Cost data | | Healthcare resource utilization | |
|---|---|-------------------------|---|----------------|-------------|---|------------------------------------|---------------|------------------------------------|---------------|
| | | | | | 1 | 2 | Healthcar e delivery process | Treat ment | Healthcar e delivery process | Treat ment |
| HSV genital ulcer disease among adults/adolescents | | | | | | | | | | |
| Almonte- Vega, 2020 USA ³⁹ | General population aged 15-49 years old | Cost-analysis | To study the dynamics of HSV-2 transmission, control and impact of treatment policies | - | | x | | x | | |
| Aslam, 2012 Canada ¹⁸ | Records of individuals in the Canadian Disease and Therapeutic Index (CDTI) | Retrospectiv e study | To investigate the rates of diagnosed cases of GH in Canada from 2002 to 2007 | 652 | | | | | x | |
| Desharnais, 1996 USA ⁴⁴ | Adults with herpes diagnosis from the HCIA Clinical Pathways Data Base | Retrospectiv e study | To describe patterns of antiviral drug use for patients hospitalized with chickenpox, herpes simplex, and herpes zoster infections, and also for a subgroup of herpes patients with severe infections (systemic infections, eye infections, encephalitis, hemorrhagic pneumonitis, and other severe conditions) | 3011 | x | x | | x | | x |
| Fisman, 2002 USA ³⁸ | Individuals aged 15 to 39 years | Cost- effectiveness | To project the future burden of HSV-2 infection in the United States, using a | - | | x | | x | | |

| | | | | | | | | | |
|---------------------------------------|--|---------------------|--|--|---|---|--|---|---|
| | | | mathematical model that incorporated epidemiologic trends documented between 1976 and 1994 | | | | | | |
| Fisman, 2003 USA ⁵² | Heterosexual couples | Modelling study | To evaluate the projected cost effectiveness of strategies to prevent HSV-2 transmission in couples with no history of HSV-2 infection | - | | x | | x | |
| Fisman, 2005 Canada ¹⁹ | Individuals with recurrent genital ulcer | Prospective study | To estimate the impact on health-related quality of life associated with both symptomatic and asymptomatic GH | 39 | x | x | | | x |
| Gilbert, 2010 USA ²⁰ | Young adults | Retrospective study | To investigate characteristics associated with GH screening and diagnosis in sexually active young adults aged 18 to 24 | Add Health Data: 11,570 NCHA: 222,740 | x | x | | x | |
| Korenromp, 2017 ³⁷ | People 15-49 year old living with HSV-2 | Modelling study | To estimate the costs of reaching the 2020 STI strategy milestones for the period 2016–2021, to support policy, planning, implementation, and future cost-benefit evaluation of the global STI strategy 2016–2021. | - | | x | | x | |
| Owusu-Edusei, 2013a USA ³⁴ | People aged 15-25 years | Retrospective study | To examine the utilization and cost of the diagnostic methods used for STI screening among | - | | x | | | |

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|--|------------------------------|--------------------------|---|---------|---|---|--|---|---|---|
| | | | privately insured adolescent and young adult population | | | | | | | |
| Owusu-Edusei, 2013b USA ³⁰ | - | Cost of illness analysis | To update the estimates of lifetime direct medical cost for 8 major STI | - | | | | x | | |
| Patrick, 2004 Worldwide survey from 78 countries ²¹ | Subjects with genital herpes | Survey | To describe patient experiences and views regarding genital herpes management | 2075 | x | x | | | x | x |
| Szucs, 2001 USA ³¹ | General population | Economic analysis | To estimate the economic burden of GH in the USA, using two different costing approaches | 465,075 | | | | x | | |
| Tao, 2000 USA ²² | General population | Cost-of-illness analysis | To assess the US direct medical expenditures for genital herpes and its complications to assist policy makers in allocating limited STD resources efficiently | - | | x | | | x | |
| Vickerman, 2008 UK ³³ | - | Cost-effectiveness | To compare the cost per ulcer treated of using the 1994 and 2003 algorithms amongst individuals presenting with GUD | - | | x | | x | | |
| Vickerman, 2011 South Africa ³² | HIV+ women | Cost-effectiveness | To estimate the cost-effectiveness of daily acyclovir for delaying HIV-1 disease progression in women not eligible for antiretroviral therapy (ART) | 300 | | x | | x | | |

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|--|--|---------------------|---|-----------|---|---|--|--|---|---|
| Xia, 2018 United States ⁴⁰ | General population | Retrospective study | To determine the utilization and cost burden associated with HSV infection visits to U.S. EDs in recent years from 2006-2013 | 704,728 | | | | | x | |
| Neonatal herpes prevention among pregnant women | | | | | | | | | | |
| Baker, 2004 USA ⁴² | - | Cost-effectiveness | To determine whether serologic testing for herpes simplex virus type 2 (HSV-2) in pregnant women and their partners is cost-effective | 100,000 | | x | | | x | x |
| Barnabas, 2002 ²⁹ USA | - | Cost-effectiveness | To assess the potential effectiveness, cost effectiveness, and benefit of suppressive therapy among herpes simplex virus serodiscordant sex partners during pregnancy | | x | x | | | x | |
| Binkin, 1989 USA ⁴³ | Pregnant women with HSV | Cost-effectiveness | To present a reanalysis of the cost effectiveness of maternal herpes screening and a review of the changes that have occurred in the screening recommendations since 1980 | 3,600,000 | x | x | | | x | x |
| Brocklehurst, 1995 UK ²³ | All members and Fellows of the Royal College of Obstetricians and Gynaecologist resident | Survey | To determine the clinical practice among obstetricians in the antepartum and intrapartum management of women with recurrent genital herpes infection | 2252 | x | x | | | | x |
| Brown, 2003 USA ²⁷ | Pregnant women from university, | Cohort study | To determine the effects of viral shedding, maternal HSV | 58362 | x | x | | | | x |

| | | | | | | | | | |
|-------------------------------------|---|------------------------|---|--------|---|---|--|---|---|
| | army and community hospitals | | serological status and delivery route on risk of transmission of HSV from mother to infant | | | | | | |
| Heggarty, 2020 France ²⁸ | Healthcare providers for pregnant women | Survey | To evaluate health care provider knowledge, and collect information on management of genital herpes during pregnancy and infants born to mothers with herpes | 354 | x | x | | x | x |
| Kenny, 2013 Canada ²⁶ | Obstetrician, gynaecologist and family physicians offering maternity care practicing in Alberta | Survey | To identify the practice patterns of physicians providing prenatal care in Alberta with respect to prevention of neonatal HSV infection, including their prescribing of antiviral therapy to pregnant women in the third trimester. | 183 | x | x | | x | x |
| Little, 2005 USA ⁴⁶ | Women with a history of diagnosed genital HSV | Cost-effectiveness | To determine the clinical benefits and cost-effectiveness of prophylactic acyclovir in women with a history of HSV but no recurrence during pregnancy | - | x | x | | x | x |
| Lynn, 2017 Ireland ²⁴ | Pregnant women with genital HSV from a university hospital | Antenatal chart review | To describe the HSV management in pregnancy at a joint antenatal genital maternity hospital | 107 | x | x | | x | x |
| Randolph, 1996 USA ⁴⁷ | Antenatal women with recurrent genital HSV | Cost-effectiveness | To compare the cost-effectiveness of oral acyclovir prophylaxis in late pregnancy compared to caesarean delivery for genital herpes | 10,000 | | | | x | |

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|--|--------------------------------|---------------------|---|---------|---|---|--|---|---|
| | | | lesions in the prevention of neonatal herpes transmission from mothers with recurrent genital infections | | | | | | |
| Rouse, 2000 USA ⁴⁸ | Antenatal women | Cost-effectiveness | To evaluate the potential cost effectiveness of herpes simplex virus antibody screening | 8,538 | x | x | | x | x |
| Scott, 1998 USA ³⁵ | - | Cost-effectiveness | To determine whether acyclovir suppression provides a greater cost savings over no medical therapy in the management of recurrent genital herpes (HSV) in pregnancy | - | x | x | | x | |
| Stankiewicz Karita, 2017 USA ²⁵ | Pregnant women from a hospital | Retrospective study | To investigate the frequency of invasive obstetric procedures and caesarean deliveries for women with known HSV infection | 449 | | x | | | x |
| Thung, 2005 USA ⁴⁹ | Married women | Cost-effectiveness | To determine the cost-effectiveness of routine antenatal screening for HSV-1 and HSV-2 in women without a known history of genital herpes. | 100,000 | x | x | | x | |
| Tuite, 2010 Canada ³⁶ | Pregnant women | Cost-effectiveness | To assess the effectiveness and cost effectiveness of identifying pregnant women at risk of de novo HSV acquisition to prevent vertical HSV transmission | 100,000 | x | x | | x | |

| Neonatal herpes management | | | | | | | | | | |
|---------------------------------------|--|---------------------|--|-------------|---|---|--|---|--|---|
| Ahmad, 2015 USA ¹⁵ | Neonates who sought care in emergency department | Retrospective study | To evaluate whether guideline implementation affected the ED's decision to test for HSV, ED use of HSV polymerase chain reaction (PCR) and acyclovir | 308 | x | x | | | | x |
| Ambroggio, 2009 USA ⁴¹ | Neonates with HSV and received intravenous acyclovir and discharge from Paediatric Health Information System | Retrospective study | To quantify the economic burden of neonatal HSV during initial hospitalization while focusing on factors, such as congenital anomalies and HSV-associated complications, which increase hospital charges and length of hospital stay among neonates with HSV | 406 | x | x | | x | | x |
| Bernard, 2013 France ¹⁶ | Patients aged 28 days and above from the French national hospital discharge database | Prospective study | To compare the data from the French national hospital discharge database (Programme de Medicalisation des Systemes d'Information; PMSI) and from the prospective study conducted in 2007 and evaluate the reliability of PMSI as a tool to assess the trends of encephalitis in France | 1,947 | x | x | | | | x |
| Donda, 2019 USA ⁴⁵ | Neonates with ICD-9 codes for neonatal HSV in the National | Retrospective study | To examine the temporal trends in the incidence and outcomes of neonatal HSV in the United States | 42,726, 336 | | | | x | | x |

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| | Inpatient Sample from 2003-2014 | | | | | | | | | |
| Flagg, 2011 USA ⁵¹ | Inpatient records of infants aged 60 days or younger from the Healthcare Cost and Utilization Project Kids' Inpatient Database | Retrospective study | To estimate the incidence of HSV infections for the United States during 2006, as well as demographic-specific rates, by using nationally and regionally weighted estimates from a population-based sample of inpatient data | 4,106,488 | x | x | | x | | x |
| Mahant, 2019 USA ⁵⁰ | Records of neonates from the Medicaid claims database from 2009 - 2015 | Retrospective study | To examine the incidence, mortality, and health care use related to neonatal herpes HSV infection. | 2,107,124 | | | | x | | x |
| Owusu-Edusei, 2015 USA ¹⁷ | Insurance claim data on inpatient admission from the Truven Health Analytics MarketScan Commercial Claims and Encounters Database | Cost-of-illness analysis | To estimate the average excess inpatient cost of neonatal herpes simplex virus (NHSV) infection from 2005 to 2009 insurance claims data | 474,743 | x | x | | | | x |

Table 2: Detailed description of studies reporting cost (unit cost)

| Author, year Country | Population and setting | Diagnostic costs (range) | Treatment costs* in original year of value (range) | Hospitalisation costs (range) | Other healthcare delivery costs (range) | Lifetime management cost (range) |
|---|--|---|--|-------------------------------|---|---|
| Genital ulcer disease among adults/adolescents | | | | | | |
| Almonte-Vega, 2020 USA ³⁹ | General population aged 15-49 years old | Microbiological lab test (unspecified): \$80.17 | Acyclovir treatment (duration not specified): \$86.33 | NR | Consultation, clinical examination and diagnostic: \$161.85 | NR |
| Desharnais, 1996 ⁴⁴ | Adults with herpes diagnosis identified from the HCIA database | NR | Total drug charges: \$1941 Antiviral drug charges (not specified): \$1070 | Hospital charges: \$5637 | NR | NR |
| Fisman, 2002 ³⁸ | Individuals aged 15 to 39 years | NR | Cost of treatment for primary syndrome Male: \$470 (\$370-5\$60) Female: \$830 (\$670-\$1000) Antiviral therapy Relapse: \$17 (\$9-\$36) Monthly suppressive therapy: \$40 (\$20-\$220) | NR | Clinic visit: \$120 (\$90-\$150) Obstetrical care: \$310 (\$130-\$800) | Initial cost of caring for neonates with HSV: \$42,600 Lifetime medical and long-term care cost for infants with moderate neurological sequelae: \$97,000 Lifetime medical and long-term care cost for infants with severe neurological sequelae: \$291,000 |

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|-----------------------------------|---|---|--|----|---|--|
| Fisman, 2003 ⁵² | Heterosexual couples | Western blot: \$60 (\$45-\$90) ELISA: \$5 (\$3-\$35) | Cost of treatment for primary syndrome Male: \$450 (\$360-5\$40) Female: \$800 (\$640-\$960) Acyclovir (per episode): \$16 (\$9-\$35) Acyclovir (monthly suppressive): \$40 (\$20-\$215) | NR | Clinic visit: \$120 (\$90-\$145) Labour: \$120 (\$90-\$145) | Lifetime cost of care of neonatal HSV-2: \$110,000 (\$85,000-\$860,000) |
| Korenromp, 2017 ³⁷ | People 15-49 year old living with HSV-2 | NR | Acyclovir 400mg per tab: \$0.04 | NR | Treatment service delivered (not specified): \$10 Procurement cost: \$0.21 | NR |
| Owusu-Edusei, 2013a ³⁴ | People aged 15-25 years | Laboratory test (unspecified): \$24.30-27.05 | NR | NR | NR | NR |
| Owusu-Edusei, 2013b ³⁰ | - | NR | NR | NR | NR | Lifetime medical cost per case, median(range): Men: \$761 (381-1,142) Women: \$621(311 - 932) Lifetime cost of new infections acquired in 2008: \$435.9 million |

| | | | | | | |
|--|--------------------|--|--|--------------------------|--|--|
| Szucs, 2001 ³¹ | General population | Laboratory test: \$1.5-76.50 | Drug: \$64-131 | Hospitalisation: \$669 | Labour: \$39.8 -62.6 Clinic visit: \$36.20-73 Day of work: \$144 | NR |
| Vickerman, 2008 ³³ | - | NR | Acyclovir 200mg tds for 5 days: \$0.53- 5.24 | NR | Counseling cost: \$0.28 | NR |
| Vickerman, 2011 ³² | HIV+ women | NR | Acyclovir 400mg: \$0.07 Yearly ART cost: \$1700 (1359-2000) | NR | Staff costs/women 3m treatment cycle: \$15.60 | NR |
| Xia, 2018 ⁴⁰ | General population | NR | NR | ED: \$1,069 | | |
| Neonatal herpes prevention among pregnant mothers | | | | | | |
| Baker, 2004 ⁴² | - | Laboratory test with labor cost for HSV-2: 15.58 – 60.00 | Average antiviral daily cost (assuming 50% on generic acyclovir 400mg tds and 50% on valacyclovir qd): \$1.70-7.90 Acyclovir 400mg: \$0.366- 1.955 Valacyclovir 500mg/tab: \$3.95 Valacyclovir 1g/tab: \$6.49 | Delivery: \$4,779-22,838 | Labour cost: \$15.58 – \$60 Counseling cost: \$5.98 – \$6.67 | Lifetime cost of care of neonatal HSV: \$54,516- \$129,576 |

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| Barnabas, 2002 ²⁹ | - | Diagnostic cost: \$16-\$100 | Drug cost per couple per pregnancy: \$37 Acute neonatal herpes treatment \$1,500-50,000 | C/S cost (personnel, supplies, surgery and ward care): \$11,084 | Labour cost: \$200-1628 Counseling cost: \$12-\$18 | Neonatal care after C/S: \$884 Long term care for neonatal herpes: \$140,766 - \$273,712 |
| Binkin, 1989 ⁴³ | Pregnant women with HSV | Viral culture: \$30 | NR | Hospitalisation for complication: \$300-698 Hospital care associated with neonatal herpes: \$25,000 Delivery: \$2,300-3,600 | NR | Long term care for neonatal herpes: \$125,000-\$250,000 |
| Little, 2005 ⁴⁶ | Women with a history of diagnosed genital HSV | NR | Acyclovir (prophylaxis) from 36 weeks of gestation: \$46 | Delivery: \$4,939-9,490 Hospitalisation: \$32,483 | NR | Lifetime cost of care of neonatal HSV: \$349,7533-\$1,049,260 |
| Randolph, 1996 ⁴⁷ | Antenatal women with recurrent genital HSV | Laboratory: \$35 | Acyclovir 400mg (200caps): \$228 | Delivery: \$3,500 | Labour: \$74 | Lifetime cost of care of neonatal HSV: \$85,000- 255,000 |
| Rouse, 2000 ⁴⁸ | Antenatal women | Laboratory: \$4 – 13 | NR | Hospitalisation for neonatal care: \$11,126 | Labour: \$3.50-10.50 | Lifetime cost of care of neonatal HSV: \$48,519- 163,879 |
| Scott, 1998 ³⁵ | - | HSV culture: \$80 | Acyclovir 400mg tds for 4 weeks: \$180 | Hospitalisation for neonatal care: \$480-1470 Delivery: \$5,321 – 9,039 | NR | NR |

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|--|-----------------------------------|--|----------------------------|---|----------------------------------|-----------------------|---|
| 1 2 3 4 5 6 7 | Thung, 2005 ⁴⁹ | Married women | HSV screening: \$37.5-\$75 | Acyclovir 400mg tds for 4 weeks: \$71 | Delivery: \$4,281 - 9,283 | Counseling cost: \$13 | Lifetime cost of care of neonatal HSV: \$13,202 – 325,602 |
| 8 9 10 11 12 | Tuite, 2010 ³⁶ | Pregnant women | ELISA test: \$7-\$14 | NR | Delivery: \$5680- 8780 | NR | Lifetime cost and consequence of neonatal HSV: \$164,870 |
| 13 | Neonatal herpes management | | | | | | |
| 14 15 16 17 18 19 20 21 22 23 24 25 26 | Ambroggio, 2009 ⁴¹ | Neonates with HSV and received intravenous acyclovir and discharge from Paediatric Health Information System | NR | Median pharmaceutical (not specified): \$4,231 Median Imaging: \$2,010 | Median hospital charge: \$37,431 | NR | NR |
| 27 28 29 30 31 32 33 34 35 | Donda, 2019 ⁴⁵ | Patients aged 28 days and above from the French national hospital discharge database | NR | NR | Hospitalisation: \$27,843 | NR | NR |
| 36 37 38 39 40 41 42 | Flagg, 2011 ⁵¹ | Neonates with ICD-9 codes for neonatal HSV | NR | NR | Hospitalisation: \$92,664 | NR | NR |

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|----------------------------|--|----|----|--|----|----|
| | in the National Inpatient Sample from 2003-2014 | | | | | |
| Mahant, 2019 ⁵⁰ | Records of neonates from the Medicaid claims database from 2009 - 2015 | NR | NR | Hospitalisation: \$32,683 Hospital readmission: \$31,531 ED visit: \$527 | NR | NR |

*All costs are mean costs except where explicitly labelled as median costs.

C/S – Caesarean section; ED - Emergency department; NR – Not reported

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Table 3: Detailed description of studies reporting resource utilization

| Author, year | Healthcare seeking and diagnosis | Treatment phase |
|--|---|--|
| Genital ulcer disease among adults/adolescents | | |
| Aslam, 2012 ¹⁸ | <ul style="list-style-type: none"> 74.1-93.2% sought care once within 12 months 6.8-25.9% sought care twice to 8x a year | |
| Desharnais, 1996 ⁴⁴ | | <ul style="list-style-type: none"> Oral treatment only: 16.1% IV treatment: 16.2% Hospital stay: 5.4 days |
| Fisman, 2005 ¹⁹ | | <ul style="list-style-type: none"> 33.3% used antiviral drugs for HSV 15.8% had pregnancy complicated by HSV |
| Gilbert, 2010 ²⁰ | <ul style="list-style-type: none"> 1.32% of young adults ever tested for genital herpes | |
| Patrick, 2004 ²¹ | <ul style="list-style-type: none"> 49% had viral culture performed 9% had antibody test 34% had physical examination | <ul style="list-style-type: none"> 65% received oral antiviral therapy 18% received topical antiviral therapy 17% obtained alternative therapy |
| Tao, 2000 ²² | <ul style="list-style-type: none"> Estimated annual genital herpes visit 499,655 yearly 2% were inpatient visit 9% outpatient & ED visit 20% public STD clinic 69% private office based visit | |
| Xia, 2018 ⁴⁰ | <p>From 2006-2013</p> <ul style="list-style-type: none"> 245,484 ED visits with primary diagnosis of genital herpes or 37.3% of total ED visits for HSV Total charges: \$278,335,295 <p>ED visits trend from 2006 – 2013</p> <ul style="list-style-type: none"> 24,747 (33.8%); 26,440 (34.1%); 27,484 (36.1%), 28,440 (36.5%); 33,258 (37.8%); 33,095 (38.3%); 35,501 (40.0%); 36,518 (40.3%) | |
| Neonatal herpes prevention among pregnant mothers | | |
| Baker, 2004 ⁴² | <p>Estimates used in model</p> <ul style="list-style-type: none"> 75% of partners will be willing to undergo HSV screening | <p>Estimates used in model</p> <ul style="list-style-type: none"> 1.32% women HSV-2 negative acquiring HSV during last 8 weeks of pregnancy 57% women or partner offered and accept antiviral therapy with testing |

| | | |
|----------------------------------|---|---|
| | | <ul style="list-style-type: none"> 82% women taking antivirals from week 36 compliant |
| Binkin, 1989 ⁴³ | <p>Estimates used in model</p> <ul style="list-style-type: none"> Average number of cultures per patient: 8 | |
| Brocklehurst, 1995 ²³ | <ul style="list-style-type: none"> 60% of obstetricians advocated some form of antenatal screening <p>Among those performing screening</p> <ul style="list-style-type: none"> 64% perform regular viral cultures 54% recommend screening ≤ 34 weeks of gestation | <ul style="list-style-type: none"> 92% of providers: visible active lesions at labor are cause for caesarean delivery |
| Brown, 2003 ²⁷ | | <ul style="list-style-type: none"> All women with HSV genital lesions noted at delivery had caesarean delivery (n=60) unless lesions not noted until too late to proceed with caesarean or lesions noted after delivery (n=14) |
| Heggarty, 2020 ²⁸ | <p>For suspected primary genital HSV:</p> <ul style="list-style-type: none"> 43.3% would conduct PCR of lesions plus HSV serology 39.9% would conduct PCR of lesions alone 0.4% would conduct HSV serology only | <ul style="list-style-type: none"> If primary HSV GUD during pregnancy, 68.4% "always" and 11.6% "often" prescribe antiviral prophylaxis in 3rd trimester If recurrent HSV GUD during pregnancy, 55.1% "always" and 12.9% "often" prescribe antiviral prophylaxis in 3rd trimester 83% recommend caesarean delivery if genital HSV lesions suspected during labour |
| Kenny, 2013 ²⁶ | <ul style="list-style-type: none"> 30% physicians will perform type-specific serology "most of the time" for patients with no history of herpes but partner with known HSV | <ul style="list-style-type: none"> Antiviral suppressive therapy prescribed in third trimester by 90% of doctors (97% of obstetricians and 84% family physicians) <ul style="list-style-type: none"> 62% prescribed for any past history of GUD including pre-pregnancy 28% only after outbreak during pregnancy More commonly prescribed acyclovir (63%) than valacyclovir (38%) 65% offer elective caesarean if primary HSV in third trimester 95% of obstetricians and 84% of family physicians recommend caesarean delivery if HSV lesions during labour |
| Little, 2005 ⁴⁶ | | <p>Estimates used in model</p> <ul style="list-style-type: none"> 24% of women will undergo caesarean delivery if no lesion was present |

| | | |
|--|---|---|
| Lynn, 2017 ²⁴ | <ul style="list-style-type: none"> 89% of patients had type-specific serology sent | <ul style="list-style-type: none"> 63% received antiviral prophylaxis <ul style="list-style-type: none"> 98.5% received valacyclovir 1.5% received acyclovir Mean for initiating: week 36 29% of patients underwent caesarean delivery, none for HSV |
| Rouse, 2000 ⁴⁸ | <p>Estimates used in model</p> <ul style="list-style-type: none"> 75% of partners will be willing to undergo HSV screening | |
| Stankiewicz Karita, 2017 ²⁵ | | <ul style="list-style-type: none"> Antiviral suppressive therapy: <ul style="list-style-type: none"> 55% HSV-2 antibody-positive only 65% history of symptomatic GUD Similar caesarean section rates for women with/without history of HSV/genital herpes: <ul style="list-style-type: none"> 25% without history of HSV-2/GH 30% on suppressive treatment 28% without suppressive treatment |
| Neonatal herpes management | | |
| Ahmad, 2015 ¹⁵ | <ul style="list-style-type: none"> CSF PCR performed in 92.3% Blood PCR performed in 48.7% | <ul style="list-style-type: none"> 9.4 – 9.8% require ICU stay Hospital stay: 83.1-84.6hr 71.8% received acyclovir |
| Ambroggio, 2009 ⁴¹ | | <ul style="list-style-type: none"> Median length of stay: 13 days (IQR 4-21) |
| Bernard, 2013 ¹⁶ | | <ul style="list-style-type: none"> Mean hospital admission: 28 -34 days |
| Donda, 2019 ⁴⁵ | | <ul style="list-style-type: none"> Median length of stay: 20 |
| Flagg, 2011 ⁵¹ | | <ul style="list-style-type: none"> Mean length of stay: 22 days Median length of stay: 2- days |
| Mahant, 2019 ⁵⁰ | | <ul style="list-style-type: none"> Median hospital stay: 18 days Post discharge, <ul style="list-style-type: none"> 45.7% required ED visit 16.2% required rehospitalisation |
| Owusu-Edusei, 2015 ¹⁷ | | <ul style="list-style-type: none"> Mean hospital stay: 10.8 (11.5) Mean hospital stay among those with admission >7 days: 18.5 (12.5) |

Table 4: Detailed cost incurred in genito-ulcer diseases due to HSV

| Author, year | Outcomes | Unit cost (\$) in original year | Unit cost in 2018 (\$) |
|-------------------------|--|---------------------------------|------------------------|
| Medication costs | | | |
| Vickerman, 2008 | One dose of IV benzathine penicillin 2.4MU | 0.15 - 0.48 | 0.19-0.59 |
| Vickerman, 2008 | One tab of 500mg ciprofloxacin | 0.10 - 0.21 | 0.12 - 0.26 |
| Vickerman, 2008 | One cap of 200mg acyclovir | 0.53- 5.24 | 0.66 – 6.48 |
| Fisman, 2003 | Acyclovir therapy for relapse patients | 16.00 | 22.72 |
| Fisman, 2003 | Acyclovir cost for suppressive monthly therapy | 40.00 | 56.80 |
| Almonte-Vega, 2020 | Acyclovir therapy | 86.33 | 86.33 |
| Fisman, 2003 | Condom cost | 0.10 | 0.14 |
| Szucs, 2001 | Pharmacological treatment 1 st episode (NS) | 64.00 | 94.86 |
| Szucs, 2001 | Pharmacological treatment recurrent episode (NS) | 131.00 | 194.18 |
| Vickerman, 2008 | Needle and syringe cost | 0.15 | 0.19 |
| Tao, 2000 | Pharmacy claim | 52.00 | 73.84 |
| Laboratory test | | | |
| Szucs, 2001 | Antibiotic testing based on expert opinion | 76.50 | 113.39 |
| Szucs, 2001 | Antibiotic testing in first episode based on claims | 12.80 | 18.97 |
| Szucs, 2001 | Antibiotic testing in subsequent episode based on claims | 6.50 | 9.63 |
| Szucs, 2001 | Complete blood count based on expert opinion | 21.29 | 31.56 |
| Szucs, 2001 | Complete blood count in first episode based on claims | 4.60 | 6.82 |
| Szucs, 2001 | Complete blood count in subsequent episode based on claims | 1.50 | 2.22 |
| Szucs, 2001 | Microbiological test for first GUD episode | 17.60 | 26.09 |
| Szucs, 2001 | Microbiological test for subsequent GUD episode | 6.70 | 9.93 |
| Szucs, 2001 | Microbiological test based on expert opinion | 38.39 | 56.90 |
| Almonte-Vega, 2020 | Microbiological lab test | 80.17 | 80.17 |

| | | | |
|-----------------------------|--|----------|---------|
| Fisman, 2003 | Western blot | 60.00 | 85.20 |
| Szucs, 2001 | Urine analysis based on expert opinion | 12.59 | 18.66 |
| Szucs, 2001 | Urine analysis in first episode based on claims | 4.60 | 6.82 |
| Szucs, 2001 | Urine analysis in subsequent episode based on claims | 3.20 | 4.74 |
| Hospitalisation cost | | | |
| Fisman, 2003 | Excess obstetrical cost associated with history of symptomatic HSV2 infection | 300.00 | 425.98 |
| Fisman, 2003 | Excess obstetrical cost due to symptomatic HSV2 infection | 310.00 | 440.18 |
| Tao, 2000 | Inpatient cost | 2,530.00 | 3592.46 |
| Szucs, 2001 | Hospital day | 669.00 | 991.63 |
| Clinic visit | | | |
| Fisman, 2003 | Clinic visit related to GUD (for physician time, test, lost wages due to 2hr patient time) | 120.00 | 170.39 |
| Szucs, 2001 | Clinical examination based on expert opinion | 40.33 | 59.78 |
| Szucs, 2001 | Clinical examination first episode based on claims | 39.80 | 58.99 |
| Szucs, 2001 | Clinical examination on subsequent episode based on claims | 36.20 | 53.66 |
| Szucs, 2001 | Physician consultation based on expert opinion | 73.00 | 108.21 |
| Szucs, 2001 | Physician consultation in first episode based on claims | 62.60 | 92.79 |
| Szucs, 2001 | Physician consultation in subsequent episode based on claims | 59.60 | 88.34 |
| Tao, 2000 | Outpatient and ED | 59.00 | 83.78 |
| Fisman, 2003 | Outpatient visit | 120.00 | 170.39 |
| Tao, 2000 | Office based physician and public clinic | 67.00 | 95.14 |
| Almonte-Vega, 2020 | Consultation, clinical examination and diagnostic | 161.85 | 161.85 |
| Vickerman, 2008 | Counselling cost | 0.28 | 0.35 |
| Other costs | | | |
| Szucs, 2001 | Others miscellaneous cost related to first GUD episode(not reported) | 33.00 | 48.91 |

| | | | |
|--------------|---|--------|---------|
| Szucs, 2001 | Others miscellaneous cost related to recurrent GUD episode(not reported) | 12.30 | 18.23 |
| Szucs, 2001 | Production losses | 60.00 | 88.94 |
| Szucs, 2001 | Total cost of active GUD | 355.00 | 526.20 |
| Szucs, 2001 | Total cost of incident GUD | 235.00 | 348.33 |
| Szucs, 2001 | Total cost of prevalent GUD | 166.00 | 246.06 |
| Szucs, 2001 | Total cost of recurrent GUD | 499.00 | 739.65 |
| Fisman, 2003 | Treatment cost for men assuming 2 clinic visit, 7 day course of acyclovir (400mg tds) and 2 days off work | 450.00 | 638.97 |
| Fisman, 2003 | Treatment cost for women assuming 2 clinic visit, 7 day course of acyclovir (400mg tds) and 2 days off work | 800.00 | 1135.95 |

Table 5: Detailed cost associated with genital ulcer disease prevention in people living with HIV

| Author, year | Outcomes | Unit cost (\$) in original year | Unit cost in 2018 (\$) |
|-----------------|--|---------------------------------|------------------------|
| Vickerman, 2011 | Acyclovir 400mg | 0.07 | 0.07 |
| Vickerman, 2011 | Staff cost- for default tracer over 3 months | 24.00 | 22.32 |
| Vickerman, 2011 | Staff cost for training for STI diagnosis and default tracer | 0.46 | 0.43 |
| Vickerman, 2011 | Labour cost for senior nurse | 2.52 | 2.34 |
| Vickerman, 2011 | Counselling cost (10 mins) | 0.88 | 0.82 |
| Vickerman, 2011 | CD-4 count test | 7.90 | 7.35 |

NB- Cost reported after adjustment in 2017 were lower than those in the original study due to exchange rates at the time of study.

Table 6: Detailed cost associated with neonatal herpes prevention/management

| Author,year | Outcomes | Unit cost (USD\$) | Unit cost in 2017 (\$) |
|-----------------------------|--|-------------------|------------------------|
| Medication costs | | | |
| Randolph, 1996 | One cap of acyclovir 400mg | 1.14 | 1.72 |
| Baker, 2004 | Pharmaceutical cost for pregnant women | 6.18 | 8.10 |
| Baker, 2004 | Pharmaceutical cost for partner | 3.93 | 5.15 |
| Baker, 2004 | Valacyclovir 500mg | 3.95 | 5.18 |
| Baker, 2004 | Valacyclovir 1000mg | 6.49 | 8.51 |
| Baker, 2004 | Acyclovir 400mg | 1.96 | 2.57 |
| Barnabas, 2002 | Acyclovir treatment for a couple for one pregnancy | 37.00 | 51.37 |
| Scott, 1998 | Acyclovir 400mg | 1.71 | 2.58 |
| Laboratory test | | | |
| Randolph, 1996 | Screening using herpes culture | 35.00 | 52.83 |
| Thung, 2005 | HSV1 or 2 screening cost | 37.50 | 49.15 |
| Thung, 2005 | HSV 1 and 2 screening | 75.00 | 98.31 |
| Rouse, 2000 | HSV-2 antibody assay | 4.00 | 5.68 |
| Rouse, 2000 | HSV-2 labour and reagent cost, QC etc | 9.00 | 12.78 |
| Tuite, 2010 | ELISA screening for HSV | 7.00 | 7.96 |
| Scott, 1998 | HSV culture | 80.00 | 120.75 |
| Baker, 2004 | Labor and supplies for HSV-2 specific test | 15.58 | 20.42 |
| Baker, 2004 | HSV test for partner | 40.53 | 53.12 |
| Barnabas, 2002 | Diagnostic kit cost | 70.00 | 97.18 |
| Binkin, 1989 | Viral culture | 30.00 | 52.97 |
| Hospitalisation cost | | | |
| Scott, 1998 | Vaginal delivery with metritis, includes labour, delivery, postpartum and professional | 8439.00 | 12,737.15 |

| | | | |
|----|---------------------|---|-----------|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | Scott, 1998 | Vaginal delivery without metritis, includes labour, delivery, postpartum and professional | 5,321.00 |
| 5 | | | 8,031.09 |
| 6 | Ambroggio, 2009 | Hospital charges | 62,050.90 |
| 7 | | | 70,544.69 |
| 8 | Tuite, 2010 | Vaginal delivery | 5,680.00 |
| 9 | | | 6,457.50 |
| 10 | Little, 2005 | Vaginal delivery | 4,939.00 |
| 11 | | | 6,104.17 |
| 12 | Randolph, 1996 | Caesarean delivery over vaginal | 3,500.00 |
| 13 | | | 5,282.62 |
| 14 | Tuite, 2010 | Caesarean section | 8,780.00 |
| 15 | | | 9,981.84 |
| 16 | Tao, 1999 | Caesarean attributable to genital herpes | 1,922.00 |
| 17 | | | 2729.13 |
| 18 | Little, 2005 | Caesarean delivery | 9,490.00 |
| 19 | | | 11,728.80 |
| 20 | Little, 2005 | Caesarean delivery with lesion | 7,608.00 |
| 21 | | | 9,402.82 |
| 22 | Scott, 1998 | Caesarean delivery with metritis, includes labour, delivery, postpartum and professional | 9,039.00 |
| 23 | | | 13,642.74 |
| 24 | Scott, 1998 | Caesarean delivery without metritis, includes labour, delivery, postpartum and professional | 10,553.00 |
| 25 | | | 15,927.85 |
| 26 | Thung, 2005 | Elective caesarean | 7,425.00 |
| 27 | | | 9,732.37 |
| 28 | Thung, 2005 | Labour caesarean | 9,283.00 |
| 29 | | | 12,167.75 |
| 30 | Little, 2005 | Hospital care due to neonatal herpes infection | 32,483.00 |
| 31 | | | 40,146.12 |
| 32 | Rouse, 2000 | Hospital care due to neonatal herpes infection | 11,126.00 |
| 33 | | | 15,798.28 |
| 34 | Baker, 2004 | Caesarean delivery | 5,021.00 |
| 35 | | | 6,581.31 |
| 36 | Binkin, 1989 | Hospital stay due to complication | 698.00 |
| 37 | | | 1,232.38 |
| 38 | Binkin, 1989 | Hospital care due to neonatal herpes infection | 25,000.00 |
| 39 | | | 44,139.53 |
| 40 | Barnabas, 2002 | Caesarean delivery with lesion | 11,084.00 |
| 41 | | | 15,388.48 |
| 42 | Clinic visit | | |
| 43 | Scott, 1998 | Clinic visit | 39.50 |
| 44 | | | 59.62 |
| 45 | Thung, 2005 | Counselling cost | 13.00 |
| 46 | | | 17.04 |
| 47 | Rouse, 2000 | Counselling cost (10 mins) | 3.50 |
| 48 | | | 4.97 |
| 49 | Rouse, 2000 | Counselling cost for couple (30 mins) | 10.50 |
| 50 | | | 14.91 |
| 51 | Randolph, 1996 | Follow-up call and office visit following screening | 74.00 |
| 52 | | | 111.69 |
| 53 | Barnabas, 2002 | Pharmacy dispensing and education cost | 3.00 |
| 54 | | | 4.17 |
| 55 | Barnabas, 2002 | Obstetrician counselling and testing salary for screening | 19.00 |
| 56 | | | 26.38 |

| | | | |
|----------------------------|---|--------------|--------------|
| Barnabas, 2002 | Obstetrician counselling and testing salary for treatment | 12.00 | 16.66 |
| Long-term care cost | | | |
| Scott, 1998 | Infant treated for HSV (include drug and culture) | 1,470.00 | 2,218.70 |
| Scott, 1998 | Neonatal care if using caesarean delivery | 821.00 | 1,239.15 |
| Scott, 1998 | Neonatal care if using vaginal delivery | 480.00 | 724.47 |
| Randolph, 1996 | Neonatal herpes acute hospital care | 10,160.00 | 15,334.69 |
| Thung, 2005 | Acute and long term care for normal/mild deficit | 13,202.00 | 17,304.61 |
| Randolph, 1996 | Long term medical cost for moderate disability (Y1-Y65) | 85,000.00 | 128,292.20 |
| Thung, 2005 | Acute and long term care for moderate deficit | 134,202.00 | 175,906.12 |
| Little, 2005 | Lifetime cost and care for moderately disabled child | 349,753.00 | 432,263.77 |
| Rouse, 2000 | Lifetime cost and care for moderately disabled child 1999 | 48,519.00 | 68,894.21 |
| Baker, 2004 | Lifetime medical and institutionalised cost for neonatal herpes | 92,350.00 | 121,048.35 |
| Binkin, 1989 | Lifetime cost and care for moderately disabled child | 125,000.00 | 220,697.66 |
| Fisman, 2003 | Lifetime cost of neonatal HSV with moderate neurological sequel | 97,000.00 | 13,7734.46 |
| Randolph, 1996 | Long term medical cost for severe disability (Y1-Y65) | 255,000.00 | 384,876.59 |
| Thung, 2005 | Acute and long term care for severe deficit | 325,602.00 | 426,784.88 |
| Little, 2005 | Lifetime cost and care for severely disabled child | 1,049,260.00 | 1,296,792.56 |
| Rouse, 2000 | Lifetime cost and care for severely disabled child | 163,879.00 | 232,698.82 |
| Binkin, 1989 | Lifetime cost and care for severely disabled child | 250,000.00 | 441,395.33 |
| Fisman, 2003 | Lifetime cost of neonatal HSV with severe neurological sequel | 291,000.00 | 413,203.38 |
| Tuite, 2010 | Lifetime cost of neonatal HSV | 164,870.00 | 187,438.10 |
| Fisman, 2003 | Lifetime cost of neonatal HSV | 110,000.0 | 156,193.72 |
| Baker, 2004 | Counselling cost nurse (15 mins) | 5.98 | 7.84 |
| Baker, 2004 | Counselling cost physician (5 mins) | 6.67 | 8.74 |
| Baker, 2004 | Labour cost and supplies | 15.58 | 20.42 |
| Baker, 2004 | Total cost without screening program | 1,181.35 | 1,548.46 |
| Baker, 2004 | Total cost with screening for women | 1,211.95 | 1,588.57 |
| Baker, 2004 | Total cost with screening for women and partner | 1,267.24 | 1,661.04 |

| | | | |
|----------------|--|------------|------------|
| Barnabas, 2002 | Maternal mortality cost | 443,858.00 | 616,230.57 |
| Thung, 2005 | Mortality cost | 13,202.00 | 17,304.61 |
| Barnabas, 2002 | Neonatal care after caesarean | 885.00 | 1228.69 |
| Barnabas, 2002 | Medical services for care of neonatal herpes | 273,712.00 | 380,008.25 |
| Barnabas, 2002 | Long term care for neonatal herpes | 140,766.00 | 195,432.58 |
| Barnabas, 2002 | Caregiver cost for neonates due to neonatal herpes | 149,943.00 | 208,173.47 |

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Figure 1: Methodological quality of included economic studies using CHEC Checklist

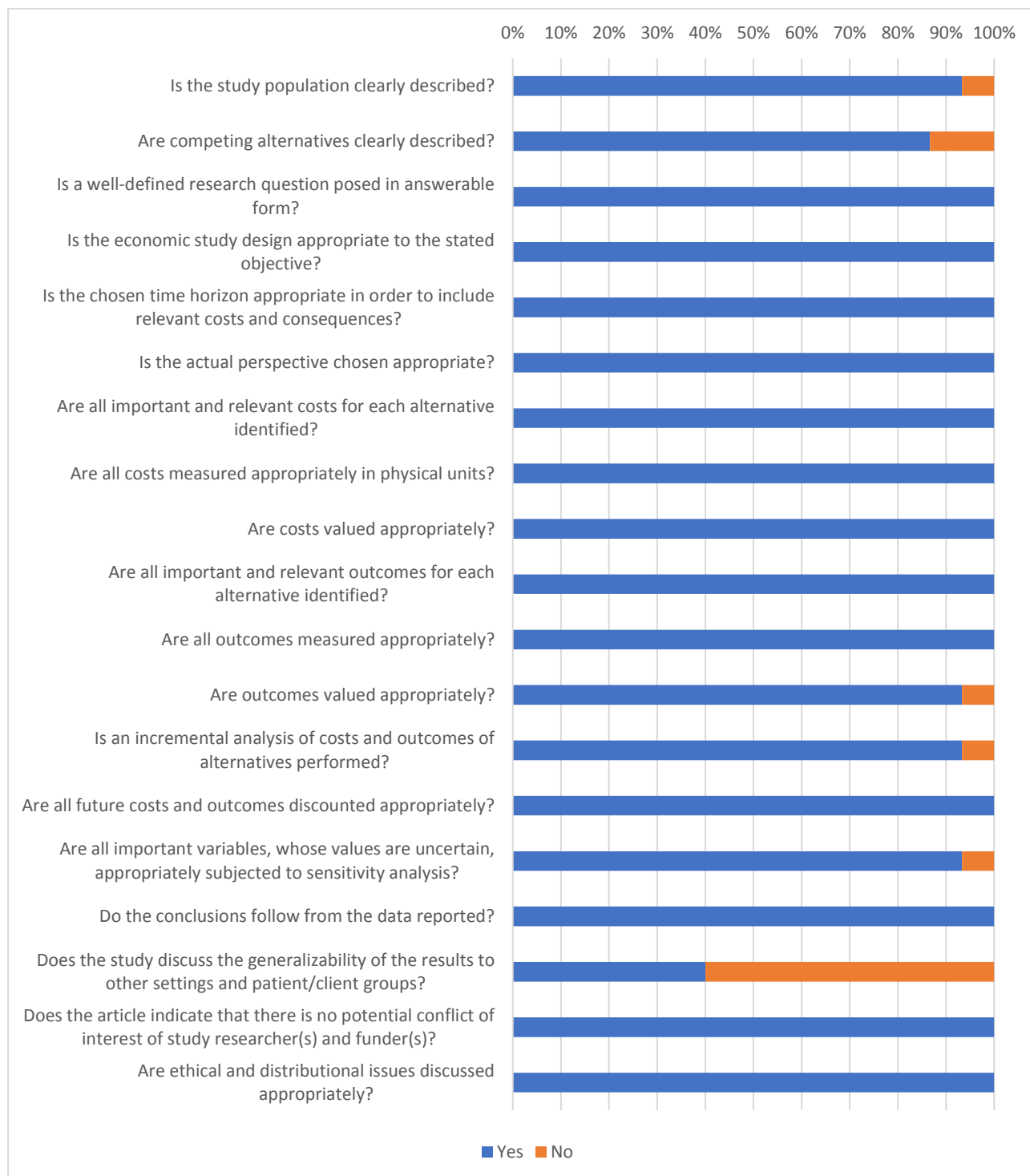
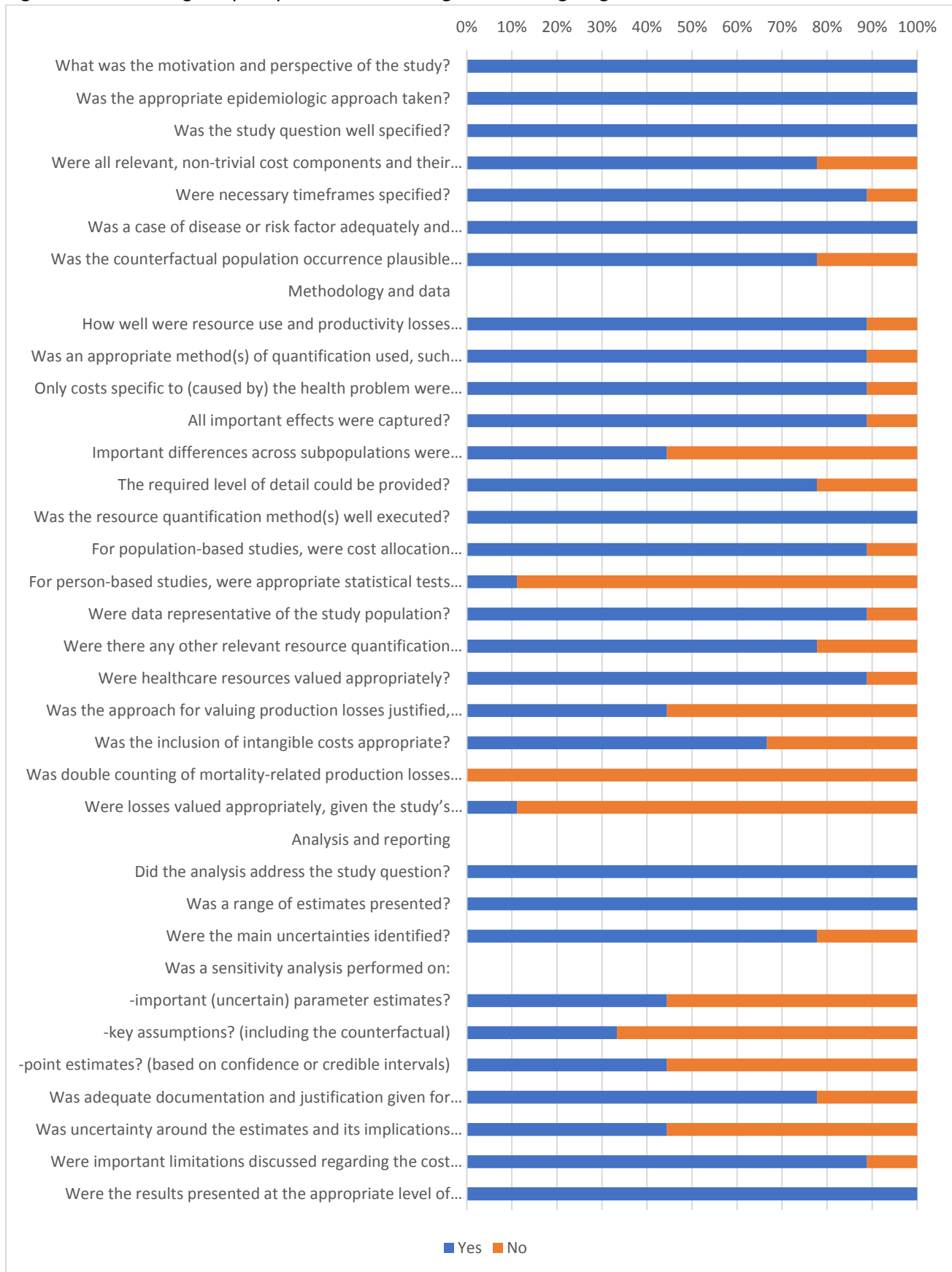


Figure 2: Methodological quality of included costing studies using Larg and Moss Checklist





PRISMA 2020 Checklist

| Section and Topic | Item # | Checklist item | Location where item is reported |
|-------------------------------|--------|--|---------------------------------|
| TITLE | | | |
| Title | 1 | Identify the report as a systematic review. | 1 |
| ABSTRACT | | | |
| Abstract | 2 | See the PRISMA 2020 for Abstracts checklist. | Attachment |
| INTRODUCTION | | | |
| Rationale | 3 | Describe the rationale for the review in the context of existing knowledge. | 5 |
| Objectives | 4 | Provide an explicit statement of the objective(s) or question(s) the review addresses. | 5-6 |
| METHODS | | | |
| Eligibility criteria | 5 | Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses. | 7 |
| Information sources | 6 | Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted. | 7 |
| Search strategy | 7 | Present the full search strategies for all databases, registers and websites, including any filters and limits used. | 7, Appendix |
| Selection process | 8 | Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process. | 7 |
| Data collection process | 9 | Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process. | 7-8 |
| Data items | 10a | List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect. | 8 |
| | 10b | List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information. | 8 |
| Study risk of bias assessment | 11 | Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process. | 8 |
| Effect measures | 12 | Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results. | 8 |
| Synthesis methods | 13a | Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)). | 8 |
| | 13b | Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions. | 8 |
| | 13c | Describe any methods used to tabulate or visually display results of individual studies and syntheses. | 8 |
| | 13d | Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used. | 8 |
| | 13e | Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression). | 8 |
| | 13f | Describe any sensitivity analyses conducted to assess robustness of the synthesized results. | NA |
| Reporting bias assessment | 14 | Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting bias). | 8 |
| Certainty | 15 | Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome. | NA |



PRISMA 2020 Checklist

| Section and Topic | Item # | Checklist item | Location where item is reported |
|--|--------|--|---------------------------------|
| assessment | | | |
| RESULTS | | | |
| Study selection | 16a | Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram. | 9 |
| | 16b | Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded. | 9, Appendix |
| Study characteristics | 17 | Cite each included study and present its characteristics. | 9 |
| Risk of bias in studies | 18 | Present assessments of risk of bias for each included study. | 9 |
| Results of individual studies | 19 | For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots. | 10-14 |
| Results of syntheses | 20a | For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies. | 10-14 |
| | 20b | Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect. | 10-14 |
| | 20c | Present results of all investigations of possible causes of heterogeneity among study results. | 10-14 |
| | 20d | Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results. | 10-14 |
| Reporting biases | 21 | Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed. | 9-10 |
| Certainty of evidence | 22 | Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed. | NA |
| DISCUSSION | | | |
| Discussion | 23a | Provide a general interpretation of the results in the context of other evidence. | 15-17 |
| | 23b | Discuss any limitations of the evidence included in the review. | 15-17 |
| | 23c | Discuss any limitations of the review processes used. | 16 |
| | 23d | Discuss implications of the results for practice, policy, and future research. | 16-17 |
| OTHER INFORMATION | | | |
| Registration and protocol | 24a | Provide registration information for the review, including register name and registration number, or state that the review was not registered. | NA |
| | 24b | Indicate where the review protocol can be accessed, or state that a protocol was not prepared. | NA |
| | 24c | Describe and explain any amendments to information provided at registration or in the protocol. | NA |
| Support | 25 | Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review. | 4 |
| Competing interests | 26 | Declare any competing interests of review authors. | 19 |
| Availability of data, code and other materials | 27 | Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review. | 19 |



PRISMA 2020 Checklist

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PRISMA 2020 for Abstracts Checklist

| YSection and Topic | Item # | Checklist item | Reported (Yes/No) |
|-------------------------|--------|---|-------------------|
| TITLE | | | |
| Title | 1 | Identify the report as a systematic review. | Yes |
| BACKGROUND | | | |
| Objectives | 2 | Provide an explicit statement of the main objective(s) or question(s) the review addresses. | Yes |
| METHODS | | | |
| Eligibility criteria | 3 | Specify the inclusion and exclusion criteria for the review. | Yes |
| Information sources | 4 | Specify the information sources (e.g. databases, registers) used to identify studies and the date when each was last searched. | Yes |
| Risk of bias | 5 | Specify the methods used to assess risk of bias in the included studies. | Yes |
| Synthesis of results | 6 | Specify the methods used to present and synthesise results. | Yes |
| RESULTS | | | |
| Included studies | 7 | Give the total number of included studies and participants and summarise relevant characteristics of studies. | Yes |
| Synthesis of results | 8 | Present results for main outcomes, preferably indicating the number of included studies and participants for each. If meta-analysis was done, report the summary estimate and confidence/credible interval. If comparing groups, indicate the direction of the effect (i.e. which group is favoured). | Yes |
| DISCUSSION | | | |
| Limitations of evidence | 9 | Provide a brief summary of the limitations of the evidence included in the review (e.g. study risk of bias, inconsistency and imprecision). | Yes |
| Interpretation | 10 | Provide a general interpretation of the results and important implications. | Yes |
| OTHER | | | |
| Funding | 11 | Specify the primary source of funding for the review. | Yes |
| Registration | 12 | Provide the register name and registration number. | No |

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;372:n71. doi: 10.1136/bmj.n71

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