




Review Paper

Unsafe fecal disposal practices in children and the nexus with childhood diarrhea in low- and middle-income countries: a systematic review and meta-analysis

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ABSTRACT

In household environments, the improper handling of children's feces can be a significant contaminant, raising a high risk of child exposure. Thus, the objective of this study was to pool the available evidence on the prevalence of safe child feces disposal practices and their association with reported childhood diarrhea in low-income and middle-income countries. PubMed, Science Direct, Cochrane Library databases, Ovid Medline, Google Scholar, and references of other studies were searched. The search was limited to studies published in English-language literature. Two independent reviewers used an appropriate tool to critically appraise the selected studies. Stata version 16 was used for the analysis. The pooled prevalence of unsafe disposal of children's feces among 20 studies was 52.63% (95% CI: 0.43–0.62). Overall, the meta-analysis found that unsafe disposal practices insignificantly increased the risk of diarrhea by 4% (OR: 1.04, 95% CI: 0.84–1.24). In the subgroup analysis, unsafe disposal of children's feces decreased the risk of diarrhea in Oceania (OR = 0.75, 95% CI = 0.62–0.88) and increased in Asia (OR = 1.33, 95% CI = 1.25–1.41). In conclusion, the prevalence of unsafe child feces disposal practices was high. There was no significant association between unsafe child feces disposal practices and diarrhea.

Key words: association, child, diarrhea, feces disposal, low-income, middle-income countries, pooled prevalence

HIGHLIGHTS

- This study aimed to pool the extent of disposal of children's feces and its association with diarrhea in children.
- This systematic review and meta-analysis included 19 published articles and 1 unpublished study.
- The pooled prevalence of unsafe maternal/guardian disposal practices for child feces in this study was high.
- Unsafe disposal practices for children's feces insignificantly increased the likelihood of diarrhea in children.

BACKGROUND

Each year, 829,000 people in low- and middle-income countries die as a result of inadequate water, sanitation, and hygiene, accounting for 60% of all diarrhoeal deaths (WHO 2022). Unsafe sanitation is one of the world's most serious health and environmental problems, particularly for the poorest people. In 2017, an estimated 775,000 people died as a result of unsafe sanitation. This accounted for 1.4% of all deaths worldwide. Unsafe sanitation also accounts for 5% of deaths in low-income countries (Hannah & Roser 2021). It is estimated to cause 432,000 diarrheal deaths each year and is also a major contributor to numerous neglected tropical diseases such as intestinal worms, schistosomiasis, and trachoma, as well as contributing to malnutrition (WHO 2019).

Globally, over 1.7 billion people do not have access to basic sanitation services such as private toilets and latrines. Of these, 494 million continue to defecate in the open, such as in street gutters, behind bushes, or in open bodies of water (WHO 2022). Adopting safe child feces disposal practices necessitates the availability of improved latrines (Majorin *et al.* 2014; Sara &

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Graham 2014). A previous study, however, showed that some respondents who had a latrine practiced unsafe child feces disposal, suggesting that improvement and the provision of physical infrastructure are insufficient to ensure the adoption of appropriate hygiene practices (Sahiledengle 2020).

Fecal contamination from children aged 3 months to 5 years old in the home environment was widespread both inside and outside the home, according to studies conducted in an urban slum in Nairobi, Kenya, and rural Odisha, India (Bauza *et al.* 2017, 2020). According to studies, leaving child feces out in the open or failing to dispose of it is a common child feces disposal practice (Sultana *et al.* 2013; Majorin *et al.* 2014). Findings showed that the prevalence of unsafe child feces disposal varies from country to country. The highest prevalence was reported in Nigeria (80.33%) (Aluko *et al.* 2017), Bangladesh (80.33%) (Islam *et al.* 2020), and India (79.00%) (Bawankule *et al.* 2017). In contrast, studies from Ethiopia (9.20%) (Alemayehu *et al.* 2021), Kenya (30%) (World Bank/UNICEF 2015), and Cambodia (29.27%) (Vong *et al.* 2021) reported the lowest prevalence.

Improper disposal of children's feces can be a major contaminant in household settings and pose a high risk of exposure to infants. The study reported from Indonesia showed that households that do not dispose of children's feces safely are significantly more likely to have diarrhea than households that practice safe disposal (Cronin *et al.* 2016; Majorin *et al.* 2019). According to a meta-analysis study, unsafe child feces disposal practices like open defecation, stool disposal in the open, stools not removed from soil, and feces observed on the ground increased the risk of diarrheal diseases by 23% (Gil *et al.* 2004). Several studies done in Nepal (Lamichhane *et al.* 2018), Indonesia (Cronin *et al.* 2016), Thailand (Wilunda & Alessio 2009), Cambodia (Vong *et al.* 2021), India (Bawankule *et al.* 2017), and Kenya (World Bank/UNICEF 2015) have linked unsafe fecal disposal to an increased risk of childhood diarrhea. However, studies conducted in Ethiopia (Sahiledengle 2020), Papua New Guinea (Seidu *et al.* 2020), Nigeria (Aluko *et al.* 2017), and Eswatini (Simelane *et al.* 2020) found that unsafe fecal disposal in children reduces the risk of childhood diarrhea. It might be that the availability of physical infrastructure alone is insufficient to assure the adoption of safe child feces disposal practices.

Previously conducted studies in various low- and middle-income countries revealed that the prevalence of unsafe practices for disposing of children's feces, as well as the association of unsafe fecal disposal with diarrhea, had conflicting results, and no attempts have been made to systematically review this. Thus, the current study aimed to synthesize the available evidence on unsafe fecal disposal practices in children and its association with diarrhea in children in low- and middle-income countries based on this evidence. In this study, the research questions addressed in this review were: (1) What is the extent of unsafe practices for disposal of child feces in low- and middle-income countries? (2) Is there a link between unsafe child feces disposal practices and diarrhea in low- and middle-income countries?

METHODS AND ANALYSIS

Study design and protocol

This systematic review and meta-analysis was written following the reporting guidelines in the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-analyses) (Moher *et al.* 2009). The four phases drawn from the PRISMA flowchart were documented in the results to show the study selection process from the initially identified records to the eventually included studies (Moher *et al.* 2009). The review protocol was registered in the PROSPERO database (Registration ID: CRD42020189034).

Eligibility criteria

The systematic review and meta-analysis included published and unpublished observational studies conducted in low- and middle-income countries that examined the magnitude of unsafe child feces disposal practices and its association with reported diarrhea. Our population of interest were mothers/guardians with children under 5 years of age, regardless of gender, race, and socio-economic status. The outcome of interest was the pooled prevalence of unsafe disposal practices for children's feces and its association with reported diarrhea. The review includes only reports prepared in English, regardless of the year of publication. Previously published systematic reviews and qualitative studies were not included.

Information sources and search strategy

PubMed, Science Direct, Cochrane Library databases, and Ovid Medline electronic resources were used to find relevant literature for this review. In addition, we searched Google Scholar and references from other studies. The literature search was carried out by the first author in July 2021. The search strategy was limited to studies published in English literature. We used

terms from Medical Subject Headings (MeSH) from PubMed and combined keywords to identify studies in the databases ('unsafe' and 'child' and 'feces disposal' and 'association' and 'diarrhea' and 'low-income and middle-income countries'). A complete search strategy for PubMed is given in Supplementary Material, Table S1.

Study selection process

The search results were exported to Mendeley Desktop reference management software, version 1.19.5 (Mendeley Ltd, Elsevier, The Netherlands) and then duplicates were eliminated. The studies were screened by two independent review authors (NES and DBG). Articles found through database searches were evaluated for inclusion at three levels, i.e., by title, then by abstract, and finally by full text. The full texts of selected studies were retrieved and assessed in detail against the inclusion criteria. Discrepancies were discussed between the reviewers, and the inclusion criteria were refined. In the case of uncertainty in the decision to include or exclude an item, the reviewer included that item for the next level of screening. The documents without abstracts were viewed at the full-text level.

Data extraction

The JBI Adapted Data Extraction Form was used to extract the study characteristics and status of children's fecal disposal practices and the odds ratios showing the association between unsafe disposal of children's feces and reported diarrhea. A structured extraction excel sheet was created, and information from each record was collected using this excel sheet for the systematic review. For each study, the author's name and year of publication, country of origin and group of included studies, type of included study, sample size, description of child fecal disposal practices, and results of included studies were extracted by two reviewers. Any disagreements between the reviewers were resolved through discussion or with a third reviewer.

Outcome of interest

The primary outcome of this review was the pooled prevalence of unsafe disposal of children's feces, and the secondary outcome of this study was the estimate of the association between unsafe disposal of children's feces and reported diarrhea. Disposal of children's feces was defined based on the WHO/UNICEF-JMP on water supply and sanitation (WHO/UNICEF 2006) as safe disposal when households responded that they were collected and disposed of in a latrine or buried, and unsafe disposal when they said they were put down a drain or ditch, thrown in the trash, or left open. Whereas diarrhea is defined as three or more loose or watery stools in a 24-hour period, or any loose stool that contains blood or mucus.

Evaluation of study quality

The methodological quality of all studies that met the selection criteria was independently assessed by two authors (NES and DBG) using the Critical Appraisal Tools of the Joanna Briggs Institute (JBI) (Aromataris & Munn 2020). Each study was individually and independently assessed by the two reviewers, both at the outcome and study level, to generate an overall risk of bias score. The two authors' scores for each bias criterion were then compared. Disagreements between the two authors regarding individual bias criteria were identified and discussed to reach consensus. Studies with a score of ≥ 7 were considered high quality, studies with a score of 4–6 were considered moderate quality, and studies with a score of ≤ 3 were considered low quality.

Data synthesis and statistical analysis

The individual studies were concisely described using an overview table. The summary table describes in particular the characteristics of the included studies and the most important results. Based on the summary table, we first performed a narrative synthesis to describe the characteristics of the included studies and the main findings. Then, using Stata Version 16 (College Station, TX 77845, USA), a random effects model was used to perform a meta-analysis. If the included study did not provide a 95% confidence interval (CI) for the prevalence of child feces disposal practices, the 95% CI was derived using the standard error (SE) and prevalence of child feces disposal practices from each included study. SE was calculated using the formula $SE = \sqrt{p(1-p)/n}$ for studies that did not present it. The calculated SE and prevalence of each study were then entered into Stata software to calculate the overall pooled prevalence of unsafe child feces disposal practices and its 95% CI. Similarly, the association between unsafe child feces disposal practices and reported diarrhea was summarized using statistical estimates of effect size, odds ratio (OR), and 95% CI of the study factors. Subgroup analyses were conducted depending

on the study region/continent and data source (demographic and health surveys (DHS) or not). After excluding one study (leave-one-out), a sensitivity analysis was performed to determine the impact of each study on the pooled estimate.

Heterogeneity was assessed statistically using a chi-square test (Q -test) for statistics and an inverse variance index (I^2) (Higgins & Thompson 2002). The I^2 values were classified as follows: no relevant heterogeneity (0–25%), moderate heterogeneity (25–50%), and significant heterogeneity (50–100%). The data were considered homogeneous when I^2 was $\leq 50\%$. Fixed effects models were used to construct summary ORs and 95% CIs where there was no heterogeneity. Where there was statistical heterogeneity, random effects models were applied. Forest plots were created to show the pooled estimates with a 95% CI. In a forest plot, the box in the middle of each horizontal line (confidence interval, CI) represents the point estimate of the effect for a single study. The box's size reflects how much the study weighs in comparison to the combined estimate. The diamond represents the overall effect estimate of the meta-analysis. The pooled effect point estimate is represented by the diamond's center on the x -axis, and the 95% CI around that point estimate is shown by the diamond's width (Chang *et al.* 2022). A funnel plot and the Eggers test for publication bias were used to assess publication bias. The symmetrical funnel plot and the insignificant Eggers test were used to argue no serious publication.

RESULTS

Study selection process

A total of 865 published and unpublished records were discovered in our initial literature search through electronic databases and additional hand searches. Two hundred and twenty-three records were removed due to overlap. After removing duplicates, 642 studies were searched for titles and abstracts. After excluding 603 irrelevant articles, the full texts of 39 articles were examined. Since the records were irrelevant to this review, 19 of the 39 articles examined for full text were excluded. Finally, this systematic review and meta-analysis included 20 (19 published and 1 unpublished) records (Figure 1).

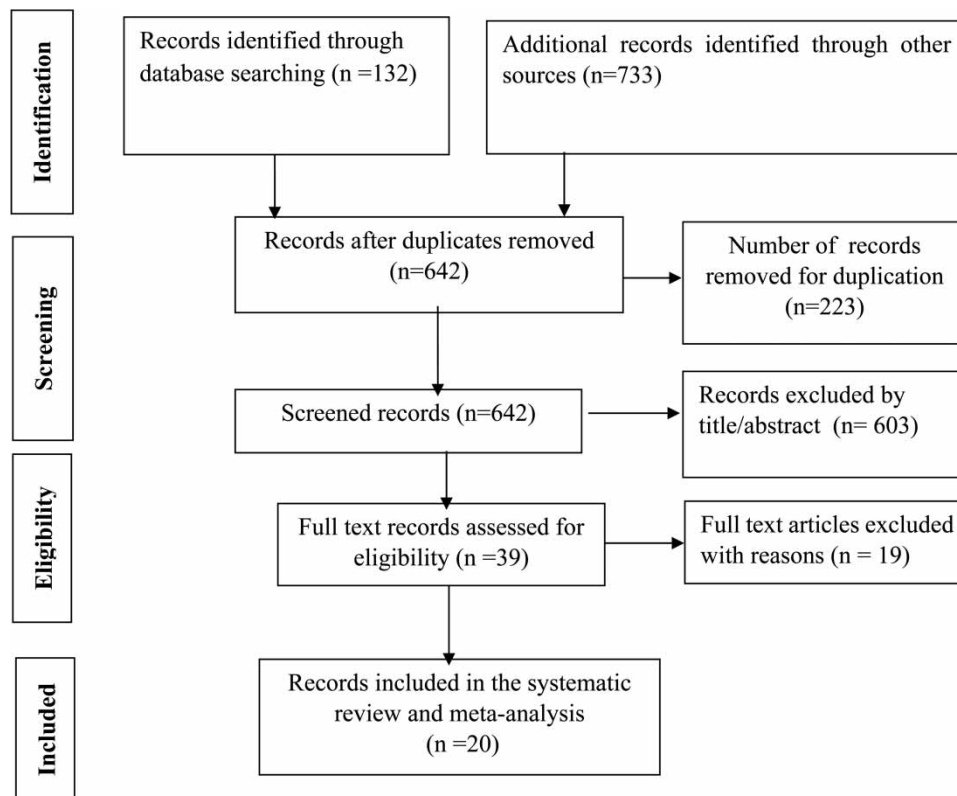


Figure 1 | Flowchart of study selection for systematic review and meta-analysis of unsafe child feces disposal practices and its association with childhood diarrhea.

Characteristics of the included studies

In a total of 865 published and unpublished records, 20 cross-sectional studies that met the inclusion criteria and focused on the prevalence of unsafe fecal disposal practices in children and their association with childhood diarrhea were included in the analysis. The current meta-analysis included eight studies from Ethiopia (Mihrete *et al.* 2014; Azage & Haile 2015; Sahiledengle 2019, 2020; Alemayehu *et al.* 2021; Getahun & Adane 2021; Soboksa 2021; Soboksa *et al.* 2021), two studies from Nigeria (Aluko *et al.* 2017; Aliyu & Dahiru 2019), two studies from Indonesia (Cronin *et al.* 2016; Sidabalok *et al.* 2019), one each from India (Bawankule *et al.* 2017), Papua New Guinea (Seidu *et al.* 2020), Eswatini (Simelane *et al.* 2020), Cambodia (Vong *et al.* 2021), Thailand (Wilunda & Alessio 2009), Bangladesh (Islam *et al.* 2020), Kenya (Siruri 2013), and a study that compiled DHS from 15 sub-Saharan African countries (Seidu *et al.* 2021) were represented. The sample size of the study ranged from 221 to 128,096 participants. The prevalence of unsafe disposal of child feces ranged from 9.20 to 80.33%. The lowest prevalence of unsafe disposal of children's feces was reported in a study conducted by Alemayehu *et al.* (2021) in Ethiopia (Alemayehu *et al.* 2021), whereas the highest prevalence of unsafe disposal of child feces was reported in a study conducted in Nigeria by Aluko *et al.* (2017) (Table 1).

Risk of bias

The quality of the included studies was assessed using the JBI checklist for analytical cross-sectional studies (Moola *et al.* 2020). Among the 20 included studies, 14 of the included studies were high-quality studies (Azage & Haile 2015; Cronin *et al.* 2016; Bawankule *et al.* 2017; Islam *et al.* 2018; Aliyu & Dahiru 2019; Sahiledengle 2019, 2020; Seidu *et al.* 2020, 2021; Simelane *et al.* 2020; Getahun & Adane 2021; Soboksa 2021; Soboksa *et al.* 2021; Vong *et al.* 2021), while 6 studies were of moderate (Wilunda & Alessio 2009; Siruri 2013; Mihrete *et al.* 2014; Aluko *et al.* 2017; Sidabalok *et al.* 2019; Alemayehu *et al.* 2021) according to our assessment (Supplementary Material, Table S2).

Table 1 | Descriptive summary of 20 studies included in the systematic review and meta-analysis

S.No	Author, publication year	Study site	Study design	Sample size	Age group included	Prevalence of unsafe disposal (%) with 95% CI
1.	Aliyu & Dahiru (2019)	Nigeria	Cross-sectional	19,288	<5	40.60 (39.91–41.30)
2.	Azage & Haile (2015)	Ethiopia	Cross-sectional	11,126	<5	66.32 (65.44–67.20)
3.	Bawankule <i>et al.</i> (2017)	India	Cross-sectional	35,273	<5	79.00 (78.57–79.42)
4.	Cronin <i>et al.</i> (2016)	Indonesia	Cross-sectional	4,909	<2	52.80 (51.39–54.21)
5.	Sahiledengle (2020)	Ethiopia	Cross-sectional	20,629	<5	77.70 (76.30–79.00)
6.	Sahiledengle (2019)	Ethiopia	Cross-sectional	4,145	<5	63.10 (59.50–66.60)
7.	Seidu <i>et al.</i> (2020)	Papua New Guinea	Cross-sectional	2,095	<5	56.00 (54.50–58.00)
8.	Seidu <i>et al.</i> (2021)	15 Sub-Sahara Africa countries	Cross-sectional	128,096	<5	41.27 (41.00–41.54)
9.	Simelane <i>et al.</i> (2020)	Eswatini	Cross-sectional	2,765	<3	41.80 (39.30–44.40)
10.	Vong <i>et al.</i> (2021)	Cambodia	Cross-sectional	5,745	<5	29.27 (27.51–31.09)
11.	Mihrete <i>et al.</i> (2014)	Ethiopia	Cross-sectional	925	<5	55.40 (51.86–58.37)
12.	Sidabalok <i>et al.</i> (2019)	Indonesia	Cross-sectional	1,007	<5	42.70 (39.62–45.82)
13.	Alemayehu <i>et al.</i> (2021)	Ethiopia	Cross-sectional	620	<5	9.20 (7.04–11.75)
14.	Wilunda & Alessio (2009)	Thailand	Cross-sectional	5,658	<5	35.35 (34.10–36.61)
15.	Soboksa (2021)	Ethiopia	Cross-sectional	9,754	<5	75.20 (74.30–76.02)
16.	Islam <i>et al.</i> (2018)	Bangladesh	Cross-sectional	803	<5	80.00 (76.75–82.43)
17.	Getahun & Adane (2021)	Ethiopia	Cross-sectional	485	<5	43.20 (38.84–47.84)
18.	Aluko <i>et al.</i> (2017)	Nigeria	Cross-sectional	300	<5	80.33 (75.38–84.68)
19.	Soboksa <i>et al.</i> (2021)	Ethiopia	Cross-sectional	756	<5	69.58 (66.16–72.89)
20.	Siruri (2013)	Kenya	Cross-sectional	221	<5	13.57 (9.35–18.81)

Prevalence of unsafe child feces disposal

As shown in Figure 2, based on 20 studies with 240,706 participants, the pooled prevalence of unsafe children’s feces disposal practice among mothers/guardians was 52.63% (95% CI: 0.43–0.62) (Wilunda & Alessio 2009; Siruri 2013; Mihrete *et al.* 2014; Azage & Haile 2015; Cronin *et al.* 2016; Aluko *et al.* 2017; Bawankule *et al.* 2017; Aliyu & Dahiru 2019; Sahiledengle 2019, 2020; Islam *et al.* 2020; Seidu *et al.* 2020, 2021; Simelane *et al.* 2020; Alemayehu *et al.* 2021; Getahun & Adane 2021; Soboksa 2021; Soboksa *et al.* 2021; Vong *et al.* 2021). The studies included in this systematic review and meta-analysis were highly heterogeneous ($I^2 = 99.94, p = 0.001$). Therefore, a random effects model was used to estimate the pooled prevalence of unsafe disposal practices for child feces among mothers/guardians. In this analysis, the lowest prevalence of unsafe disposal of infant feces was reported from Ethiopia (9.20%) (Alemayehu *et al.* 2021), while the highest was reported from a study conducted in Nigeria (80.33%) (Aluko *et al.* 2017; Figure 2).

Association between unsafe disposal practice child feces and diarrhea

The association between unsafe disposal of children’s feces and diarrhea has been assessed in 20 studies (Wilunda & Alessio 2009; Siruri 2013; Mihrete *et al.* 2014; Azage & Haile 2015; Cronin *et al.* 2016; Aluko *et al.* 2017; Bawankule *et al.* 2017; Aliyu & Dahiru 2019; Sahiledengle 2019, 2020; Islam *et al.* 2020; Seidu *et al.* 2020, 2021; Simelane *et al.* 2020; Alemayehu *et al.* 2021; Getahun & Adane 2021; Soboksa 2021; Soboksa *et al.* 2021; Vong *et al.* 2021). Individual studies in Ethiopia (OR: 0.38, 95% CI: 0.25–0.51) and Nigeria (OR: 0.24, 95% CI: 0.06–0.42) showed a lower risk of diarrhea, while studies

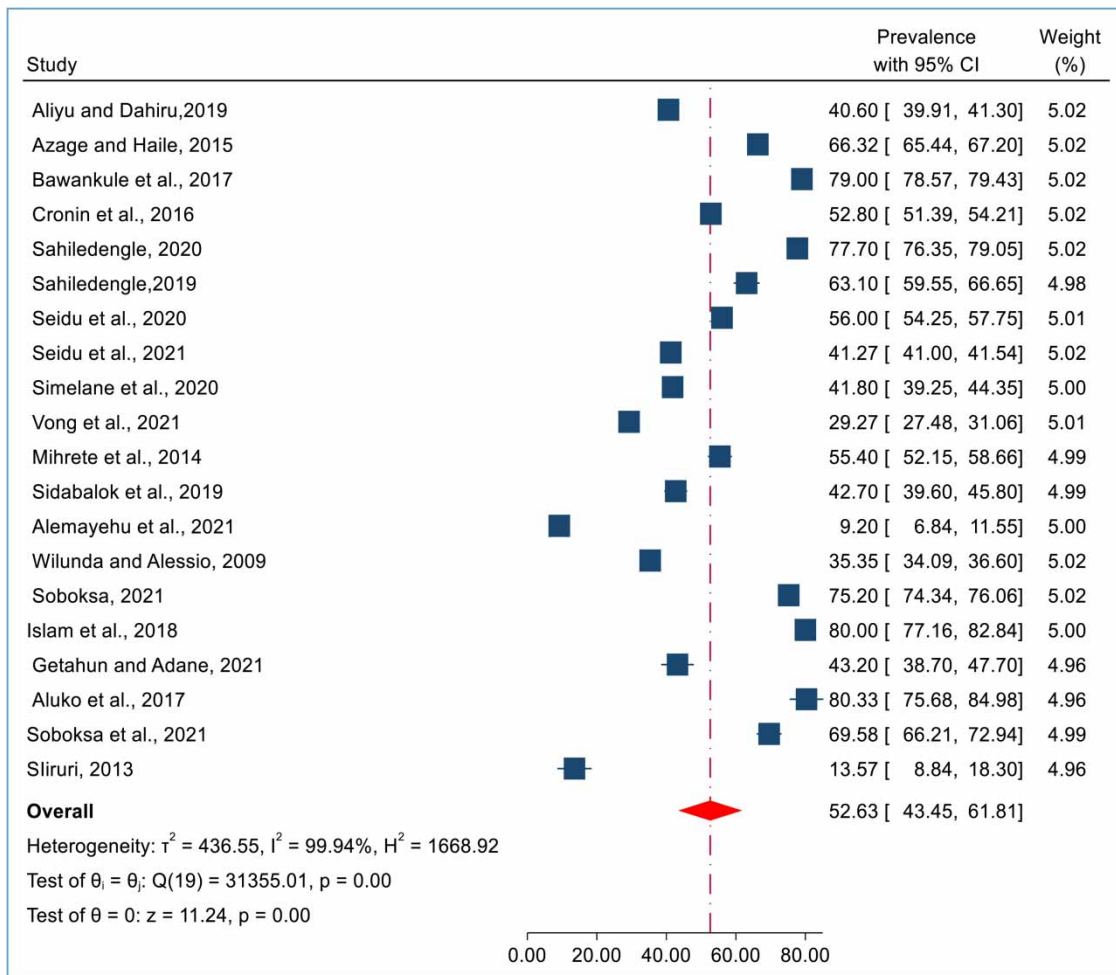


Figure 2 | Forest plot of the pooled prevalence of unsafe child feces disposal practices of 20 studies included in the systematic review and meta-analysis.

in Ethiopia of Alemayehu *et al.* (OR: 3.82, 95% CI: 1.58–6.06) and Getahun and Adane (OR: 3.31, 95% CI: 1.60–5.01) showed a higher likelihood of diarrhea in children. The overall meta-analysis showed that children whose mothers/guardians engaged in improper disposal of children’s feces were 1.04 times more likely to have diarrhea (OR: 1.04, 95% CI: 0.84–1.24). However, the results showed that there was no significant association and that there was a high degree of heterogeneity (97.38%) between the included studies (Figure 3).

Subgroup analysis

Subgroup analyses were performed in this study based on study region/continent and data source (DHS or not). Accordingly, studies conducted in Africa, despite high heterogeneity ($I^2 = 96.28\%$, $p = 0.001$), found no significant association between unsafe methods of disposal of children’s feces and diarrhea in children (OR = 0.84, 95% CI = 0.64–1.05). However, as a collective of studies conducted in Asia, unsafe disposal of child feces was significantly associated with diarrhea risk (OR = 1.33, 95% CI = 1.25–1.41), with no significant heterogeneity between included studies ($I^2 = 0\%$, $p = 0.46$) (Figure 4).

Looking at the subgroup analysis by data source (DHS or not), according to DHS data, maternal/guardian unsafe disposal practices for child feces increase the likelihood of child diarrhea slightly but not significantly (OR = 1.01, 95% CI = 0.85–1.17), and there was significant heterogeneity between the included studies ($I^2 = 95.58\%$, $p = 0.001$). In studies using primary data (non-DHS), also there was also no association between unsafe disposal of children’s feces and diarrhea (OR = 1.27, 95% CI = 0.63–1.91). However, in the non-DHS subgroup analysis, there was an increase in childhood diarrhea and significant heterogeneity between included studies ($I^2 = 94.77\%$, $p = 0.001$) (Figure 5).

Sensitivity analysis

The sensitivity analysis of the relationship between unsafe methods of disposing of children’s feces and diarrhea in children is presented in Table 2. To identify the potential source of heterogeneity in the analysis, a leave-one-out sensitivity analysis

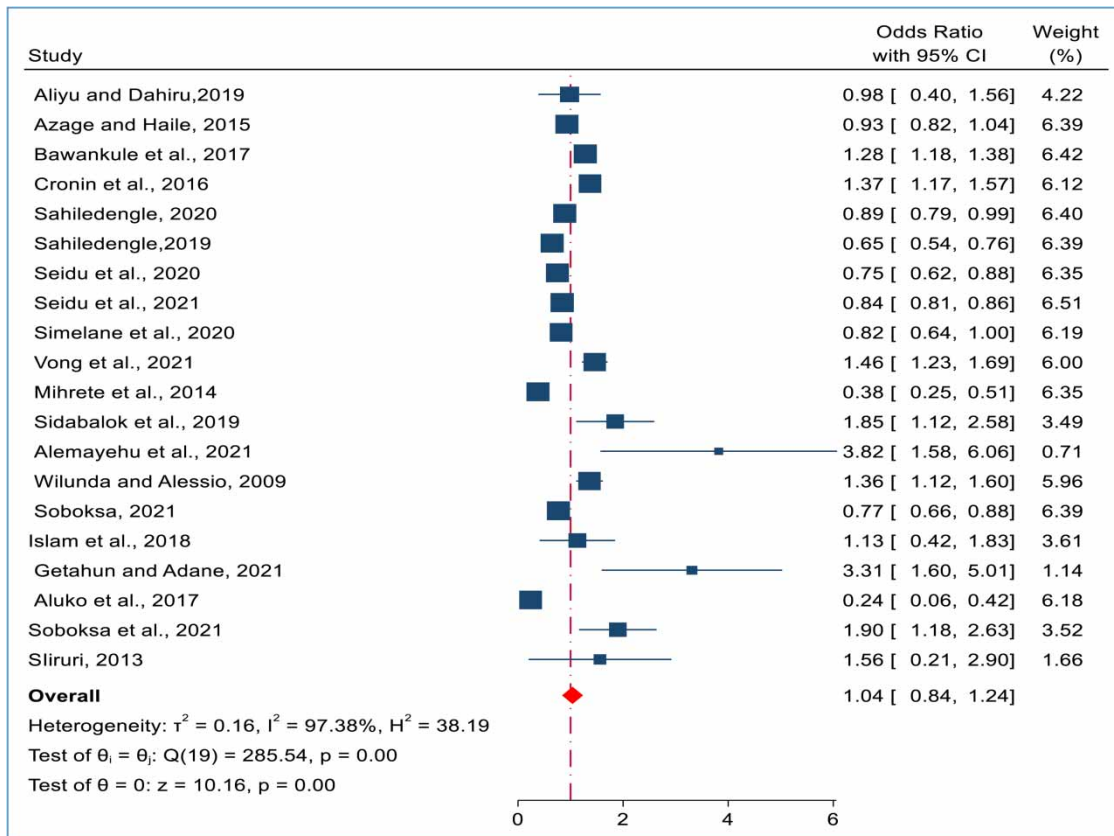


Figure 3 | Forest plot of the pooled odds ratio of unsafe child feces disposal practices and childhood diarrhea.

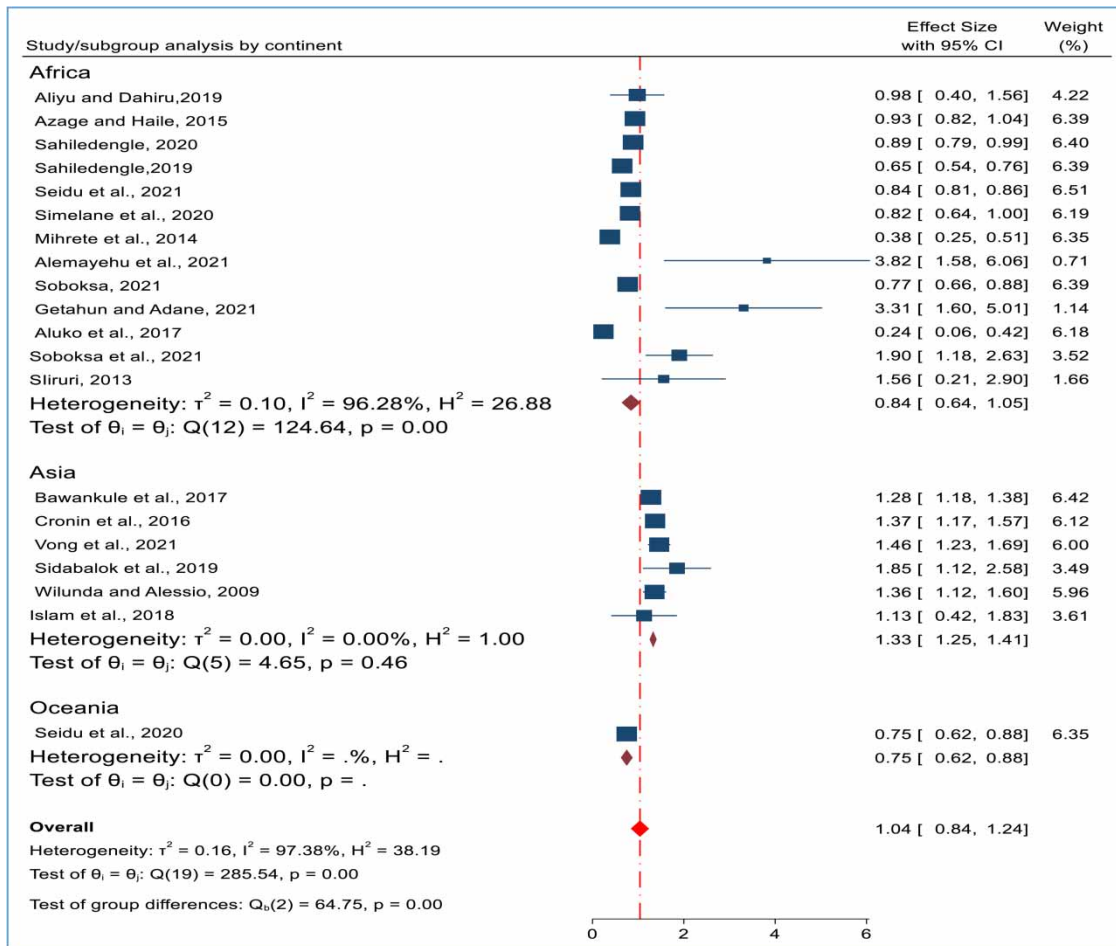


Figure 4 | Forest plot of the subgroup analysis by region pooled odds ratio of unsafe child feces disposal practices and childhood diarrhea.

related to unsafe methods of disposing of childhood feces and childhood diarrhea was performed. According to the results, not a single study had an effect on overall childhood diarrhea.

Publication bias

A visual inspection of the funnel plot is revealed that the distribution of studies was asymmetric, indicating that there was a publication bias (Figure 6). In addition, we used Eggers’ tests to detect the presence of publication bias due to small study effect, and the results showed that there is statistically significant publication bias in assessing the association between unsafe child feces disposal practices and diarrhea due to small study effect (*p*-values of 0.001).

DISCUSSION

The aim of this study was to pool the available evidence on the extent of unsafe child feces disposal practices and its association with reported diarrhea in children in low- and middle-income countries. According to this systematic review and meta-analysis, the pooled prevalence of unsafe child feces disposal practices in low- and middle-income countries was 52.63% (95% CI: 0.43–0.62). Our study finding is almost similar to a Water Safety Plans (WSP) and UNICEF investigation of 24 countries, which found that over 50% of households in 14 of the 24 countries did not dispose of their children’s feces in any type of toilet or latrine; that is, the feces were disposed of unsafely (World Bank Group and UNICEF 2014). Despite the fact that we found a high prevalence of unsafe disposal in our analysis, the sustainable development goal (SDG) number 6, which aims to end open defecation by 2030, is important for reducing unsafe disposal of child feces (Le Blanc 2015; Bárcena et al. 2018).

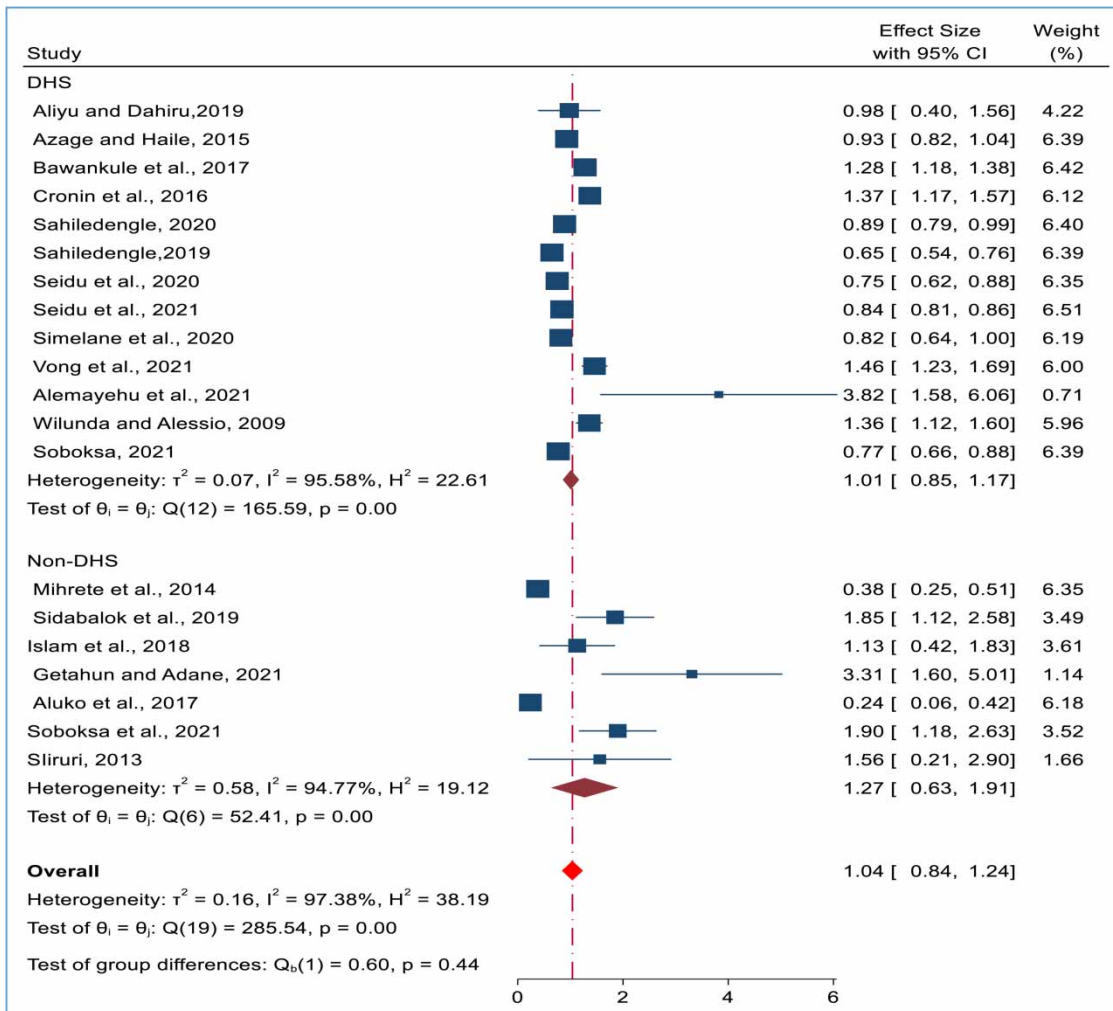


Figure 5 | Forest plot of the subgroup analysis by data source pooled odds ratio of unsafe child feces disposal practices and childhood diarrhea.

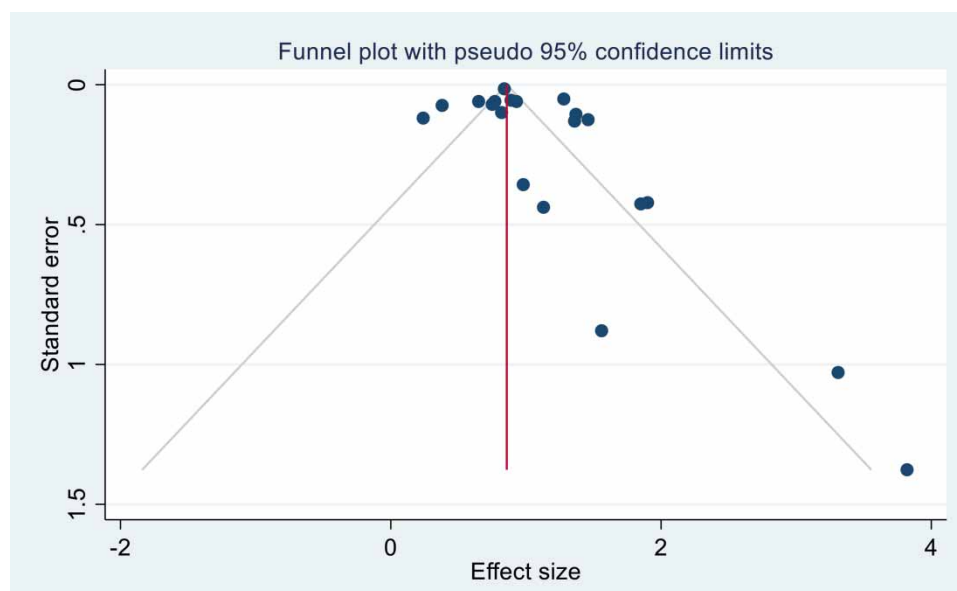
Generally, children are at a higher risk than adults of getting infected by enteric pathogens when their feces are left in the open. Studies have shown improper disposal of children’s feces leads to a greater risk of diarrhea in children under 5 years of age (Gil *et al.* 2004; Majorin *et al.* 2014; Bawankule *et al.* 2017). In the current systematic review and meta-analysis, the risk of diarrhea increased by 4% due to unsafe child feces disposal practices by mothers/guardians even though statistically not significant. Our study finding was supported by a meta-analysis done on children’s feces disposal practices, which showed that unsafe child feces disposal practices increased the risk of diarrheal diseases by 23% (Gil *et al.* 2004). Additionally, our study finding was supported by an intervention study conducted in the city of Bangladesh, which showed a 26% reduction in pediatric diarrhea from improved safe disposal of infant feces, although the amount of risk reduction varied widely (Stanton & Clemens 1987). The possible explanation for the above-observed discrepancy between the current meta-analysis and comparable findings might be due to the difference in the socio-demographic characteristics of the study participants, sample size or study design.

A review of studies found that a considerable number of children’s feces were not removed from their original defecation sites, which are responsible for contamination, could be a major cause of diarrhea (Gil *et al.* 2004). However, in our subgroup analysis of the study, there was no significant association between the presence of diarrhea and unsafe maternal/guardian disposal practices when disposing of children feces in the sub-analysis of studies conducted in African countries. A similar finding was reported by a longitudinal study conducted as part of a randomized controlled trial in rural Bangladesh (Islam *et al.* 2020). In areas where child feces are not removed from their original defecation sites, the presence of diarrhea

Table 2 | Sensitivity analysis of 20 studies included in the systematic review and meta-analysis of unsafe child feces disposal practices and its association with childhood diarrhea

No.	Omitted study	Pooled odds ratio	(95% CI)	I^2	P-value
1	Aliyu & Dahiru (2019)	1.05	0.84–1.26	97.67	0.001
2	Azage & Haile (2015)	1.05	0.84–1.27	97.49	0.001
3	Bawankule <i>et al.</i> (2017)	1.02	0.81–1.24	97.27	0.001
4	Cronin <i>et al.</i> (2016)	1.02	0.81–1.22	97.43	0.001
5	Sahiledengle (2020)	1.06	0.84–1.29	97.68	0.001
6	Sahiledengle (2019)	1.07	0.86–1.29	97.57	0.001
7	Seidu <i>et al.</i> (2020)	1.06	0.85–1.28	97.75	0.001
8	Seidu <i>et al.</i> (2021)	1.07	0.84–1.29	97.22	0.001
9	Simelane <i>et al.</i> (2020)	1.07	0.84–1.29	97.84	0.001
10	Vong <i>et al.</i> (2021)	1.02	0.80–1.23	97.58	0.001
11	Mihrete <i>et al.</i> (2014)	1.08	0.88–1.28	97.23	0.001
12	Sidabalok <i>et al.</i> (2019)	1.00	0.81–1.20	97.23	0.001
13	Alemayehu <i>et al.</i> (2021)	1.01	0.82–1.21	97.35	0.001
14	Wilunda & Alessio (2009)	1.02	0.81–1.23	97.48	0.001
15	Soboksa (2021)	1.07	0.85–1.29	97.66	0.001
16	Islam <i>et al.</i> (2018)	1.04	0.83–1.25	97.63	0.001
17	Getahun & Adane (2021)	1.01	0.81–1.20	97.25	0.001
18	Aluko <i>et al.</i> (2017)	1.07	0.89–1.29	96.69	0.001
19	Soboksa <i>et al.</i> (2021)	1.00	0.80–1.20	97.41	0.001
20	Siruri (2013)	1.03	0.83–1.23	97.52	0.001

may be influenced not only by unsafe stool disposal but also by feeding practices, maternal personal hygiene, and environmental sanitation. This implies that, in addition to sanitation facility improvements, behavior change strategies on feeding practices, maternal/guardian personal hygiene practices, drinking water handling, and proper utilization and increasing latrine access are required.

**Figure 6** | Funnel plot with 95% confidence limits of the association between unsafe child feces disposal practices and childhood diarrhea.

On the other hand, aggregate studies conducted in Asia showed that the likelihood of diarrhea increased significantly when mothers/guardians engaged in unsafe disposal of infant feces. The results of this subgroup analysis confirm a previous systematic review and meta-analysis which found that unsafe practices for disposing of infant feces increase the risk of diarrheal disease (Gil *et al.* 2004). This could be because open feces in the compound, as well as wash-off or run-off from precipitation into other compounds and nearby watercourses (unsafe disposal of child feces), can increase the risk of fecal exposure for compound members, particularly young children who spend time in the courtyard area and have hand contact with feces or soil contaminated by feces (fecal pathogens) that cause diarrhea diseases in children (Gil *et al.* 2004; Kwong *et al.* 2016). These results indicate the need for further systematic review and meta-analysis of intervention studies on the effects of unsafe child fecal disposal practices on diarrhea in children to examine the relationships between child fecal disposal practices and diarrhea.

We recognized some limitations in this systematic review and meta-analysis. The first concern was the use of English-only articles. Another limitation is that because all studies in this review were cross-sectional, the outcome variable may be affected by other confounding variables. In addition, because the articles included were from a limited number of countries, the pooled prevalence and likelihood OR may not represent the entire population in low- and middle-income countries.

CONCLUSIONS

The pooled prevalence of unsafe child feces disposal practices among mothers/guardians was high in low- and middle-income countries according to this study. This meta-analysis also showed that there was no significant association between unsafe child feces disposal practices and childhood diarrhea. According to the subgroup study, there is no significant link between unsafe child feces disposal practices and child diarrhea in Africa. However, when studies from Asia were pooled, unsafe disposal of child feces was found to be significantly associated with the odds of diarrhea. Non-governmental organizations and government organizations should increase their efforts to reduce unsafe child feces disposal in light of the findings. It is also critical to promote the advantages of proper child feces disposal. Strengthening safe child feces disposal is recommended in Asia to reduce childhood diarrhea, whereas in Africa, it is better to focus on sanitation facility improvements, hygiene, and sanitation behavior change strategies rather than safe child feces disposal. Furthermore, additional systematic reviews and meta-analysis are recommended to assess the link between unsafe fecal disposal practices in children and childhood diarrhea.

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AUTHORS' CONTRIBUTIONS

N.E.S. conceptualize the review. N.E.S. and D.B.G. extracted data and, with the support of B.N., conducted a meta-analysis. The manuscript was written by N.E.S., B.N., A.E.H., and B.K.O. contributed to the critical review of the manuscript. All authors read and approved the final manuscript.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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