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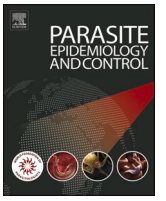

Prevalence and factors associated with intestinal parasitic infections among preschool-aged children in Ethiopia: A systematic review and meta-analysis

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ABSTRACT

Intestinal parasitic infections (IPIs) pose a serious public health threat across the globe, particularly in children residing in poor and most deprived communities like Ethiopia. Many published articles were available separately, and a detailed nationwide review was essential to combine all the results to draw a conclusion and avoid any informational conflicts, ambiguities, or misunderstandings. Therefore, this systematic review and meta-analysis aimed to provide pooled estimates for the individually available data on IPIs and its determinant factors among preschool-aged children (PSAC) in Ethiopia. Published and unpublished articles from various electronic databases were accessed using MeSH terms and keywords. I^2 and sensitivity analysis tests were used to assess potential sources of heterogeneity across studies. Funnel plot, Begg's, and Egger's regression tests were used to check publication bias. A random-effects model with a 95% confidence interval (CI) was used to calculate the pooled estimate of IPI. In this meta-analysis, a total of 14,994 PSAC were included in the 32 eligible studies. The pooled national prevalence of IPIs among PSAC was 32.52% (95% CI: 26.24, 38.80). Of these, single and mixed infections contribute 31.08% and 1.44%, respectively. According to the subgroup analysis, the highest prevalence was observed in simple random studies (39.61%; 95% CI: 29.19, 50.03), the Tigray region (58.00%; 95% CI: 54.10, 61.90), studies conducted in >384 (39.47%; 95% CI: 27.73, 51.20) sample sizes, cross-sectional studies (32.76%), community-based studies (42.33%; 95% CI: 31.93, 52.74), and from 2005 to 2016 (34.53%; 95% CI: 20.13, 48.92) study periods. Intestinal parasites were significantly associated with eating raw fruits and vegetables (aOR = 3.21; 95%CI: 1.11–5.31). The high prevalence of STHs observed in this systematic review and meta-analysis underscores the need for appropriate control and prevention strategies suitable for PSAC in Ethiopia.

1. Introduction

Intestinal parasitic infections (IPIs) are among the most prevalent infections in low- and middle-income countries, carry a high burden of morbidity and mortality in these areas, and constitute a significant public health issue (Houweling et al., 2016). Particularly, economically deprived children living in tropical and subtropical regions with unsafe and inadequate access to safe drinking water, poor sanitation and unhygienic living conditions, the habit of defecating openly and walking barefoot, and substandard housing are the most affected ones (Harhay et al., 2010). According to the estimations of epidemiological evidence, 2 billion people in the world were

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infected with protozoan species like *Entamoeba histolytica* and *Giardia lamblia,* helminthic species like *Ascaris lumbricoides*, and *Trichuris trichiura,* and hookworms (*Necator americanus* and *Ancylostoma duodenale*) (Bethony et al., 2006). Preschool-aged children (PSAC) are one of the World Health Organization's (WHO)-identified risk groups for IPIs. >267 million PSAC live in areas where IPIs are intensively transmitted and need treatment and preventive interventions (Who., 2020).

Studies conducted on intestinal helminths and protozoan infections among PSAC lead to serious effects (illness and death), particularly in children. The negative effects of IPI among PSAC extended beyond morbidity and mortality to include nutritional issues (such as malnutrition, malabsorption, anemia, intestinal obstruction, and diarrhea) as well as mental and physical growth retardation, weight loss, impaired work capacity, and stunted growth rate, constituting important health and social problems (Faria et al., 2017; Nguyen et al., 2012; Girma and Genet, 2024; Chelkeba et al., 2020).

International epidemiological research has demonstrated that the socioeconomic status of the population is the primary factor contributing to the regional distribution and prevalence differences of IPIs among PSAC. Furthermore, it is known that many infectious diseases spread because of inadequate environmental and sanitary conditions, climate, and socio-cultural factors, especially in community settings (Daryani et al., 2017).

Ethiopia has favorable conditions for the activity of various ecto and *endo*-parasites because of its geographical location, climate, and biological and cultural characteristics (Girma and Genet, 2024). Many primary studies investigated in Ethiopia had great variety and inconsistency related to the prevalence of IPIs and associated risk factors among PSAC in the country; however, there is a lack of systematically synthesized and analyzed information for policymakers and stakeholders. The aim of this study was to provide summary estimates for the available data on IPI among PSAC in Ethiopia.

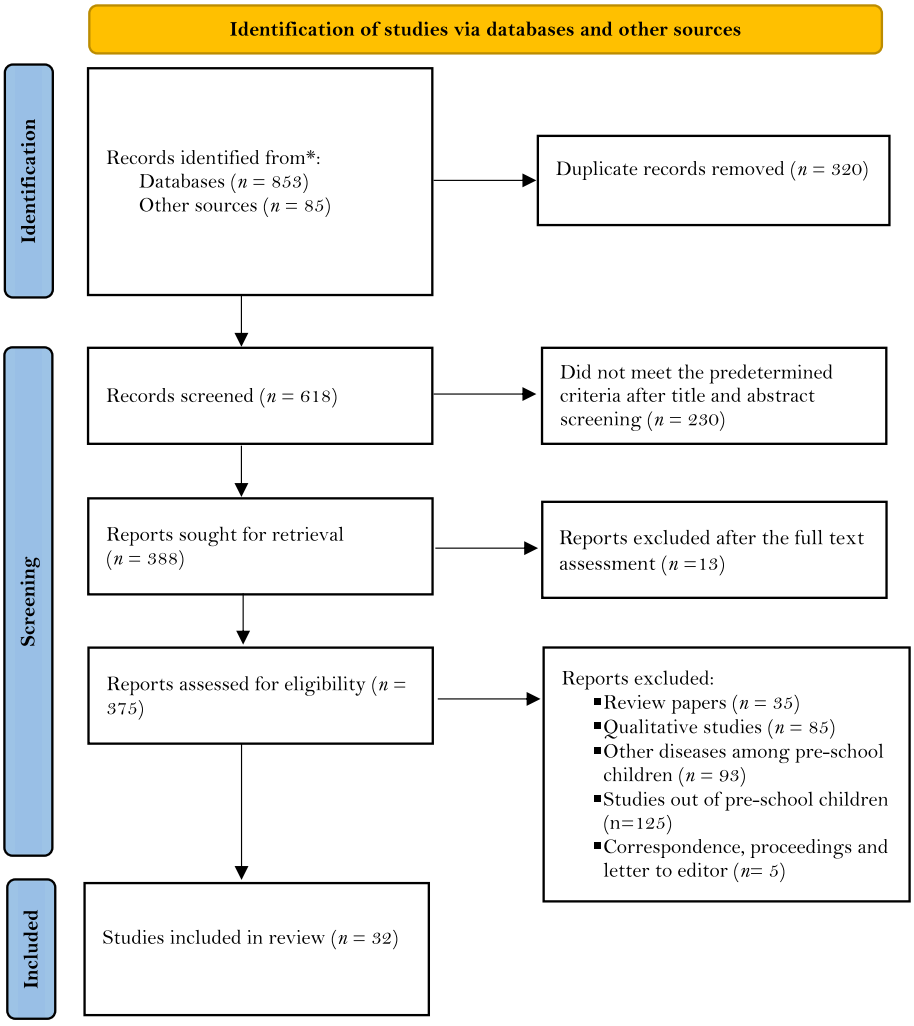

Fig. 1. Flow diagram summarizing the selection of eligible studies.

2. Methodology

This systematic review and meta-analysis were conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guideline (Page et al., 2021) (**S1 PRISMA Checklist**). The protocol for the development of this systematic review and meta-analysis was registered on the International Prospective Register of Systematic Reviews (PROSPERO) under reference number (CRD42024548426).

2.1. Search strategy

A systematic search of research articles was carried out in PubMed/Medline, Scopus, ScienceDirect, Web of Science, Google Scholar, ResearchGate, and African Journals Online electronic databases. The search for published studies was not restricted by language or time, and all published and unpublished studies up to August 2023 were included. Reference lists of articles were searched to identify any studies that were not retrieved from electronic databases. The research articles were searched using the following key terms and phrases taken from the MeSH keywords in combination or separately using Boolean operators ("OR" or "AND"): "Prevalence"/ "Epidemiology"/ "Incidence", "Parasitic Infection", "Parasitic Diseases", "Parasites", "Helminths", "Intestinal Diseases, Parasitic", "Child", "Child, Preschool", "Preschool-aged Children", "determinants"/ "Risk Factors", and "Ethiopia". The study was carried out from January to May 2024. The search process was presented according to the PRISMA-2020 flow diagram guidelines, together with the included and excluded items and reasons for exclusion (Fig. 1).

2.2. Inclusion and exclusion criteria

Studies were included if they focused on (1) studies conducted in Ethiopia with a specified region; (2) cross-sectional or longitudinal studies which documented the prevalence of IPIs; (3) studies involving PSAC; (4) reported the sample size, IPI cases, or prevalence; (5) peer-reviewed studies published from 2005 to 2023; (6) undertook experimental work and reported types of laboratory tests. Studies were excluded if (i) studies conducted outside Ethiopia, (ii) studies with a sample size lower than 50, (iii) reports on other pathogens and IPI prevalence in other patient groups or not linked to IPI prevalence among PSAC in Ethiopia, (iv) studies reported the knowledge, socioeconomic impacts, and practices taken against IPIs, (v) incomplete data, inaccessible full-text articles after twice mail to the corresponding author; (vi) commentary, correspondence, proceedings, and letter to the editor; (vii) review articles, duplicate publications, or extensions of analysis from original studies.

2.3. Data extraction

Relevant studies that met the eligibility criteria were subjected to data extraction and summarized in an Excel spreadsheet independently by the two authors (AmG and AbG). The data extraction protocol consists of the author, year of publication, region, study area, study settings, method of diagnosis, patient type, response rate, sample size, number of positive cases, prevalence of IPIs, and quality score.

2.4. Study selection and quality appraisal

The downloaded articles were imported to Endnote Citation Manager software version X9 for Windows, and duplicate and irrelevant articles were removed. The title and abstract of every relevant study were reviewed independently by both authors. After the full text evaluation, articles that were found to be eligible were included in this systematic review. AG and IA independently screened the full texts for eligibility, and the disagreements were resolved by scientific consensus. The JBI critical appraisal checklist for prevalence (Munn et al., 2017) and diagnostic test accuracy (Campbell et al., 2015) studies was used for quality appraisal using 9 and 10 criteria, respectively, and rated as yes, no, not applicable, and classified risks of bias as low, medium, and high quality based on the points awarded. The details of the risk of bias assessment are included as a supplementary file (**S1 Table**).

2.5. Statistical analysis

A random-effects model was used to estimate the pooled effect size (Borenstein et al., 2010). Subgroup analysis based on sample size, regions, study design, sampling method, study settings, and year of publication was performed to explore the possible source of heterogeneity. Inverse variance (I^2) and funnel plot symmetry were used to assess the existence of statistical heterogeneity (Rücker et al., 2008; Sterne and Egger, 2001), while publication bias was measured by using Begg's (Begg and Mazumdar, 1994)and Egger's (Egger et al., 1997) test at the 5% significance level; a 0.05 p-value denotes the presence of publication bias. For I^2, heterogeneity is categorized as high when it exceeds 75%, substantial when it is between 50% and 75%, moderate when it is between 25 and 50%, and low when it is below 25% (Higgins and Thompson, 2002). For a funnel plot, a symmetric dot with an inverted funnel shape denotes that there is no publishing bias, and each dot represents a single study (Sterne and Egger, 2001). Sensitivity analysis was used to examine the impact of a single study on the overall prevalence. To find the association between dependent and independent variables, the pooled adjusted odd ratio (AOR) was estimated using the AOR and 95% confidence interval for each factor. Meta-analysis was performed using Stata software version 14, where $P < 0.05$ was considered statistically significant.

Table 1
General characteristics of studies included in systematic review and meta-analysis.

Study	Region	Study Settings	Diagnosis method	Sampling method	Response Rate (%)	Sample Size	Case	Prevalence (%)
(Haileamlak, 2005)	Oromia	Community-Based	▪ Formol-ether concentration	Simple random	88	924	530	57.4
(Nyantekyi et al., 2010)	SNNPR	Community-Based	▪ Kato-Katz thick smear method ▪ Formol-ether concentration method	Simple random	100	288	245	85.1
(Ghiwot et al., 2014)	Oromia	Community-Based	▪ Single Kato-Katz method ▪ Single Sodium acetate-acetic acid-formalin (SAF) solution concentration method	Simple random	100	374	91	24.3
(Shumbej et al., 2015)	SNNPR	Community-Based	▪ McMaster technique	Systematic random	96	377	88	23.3
(Mulatu et al., 2015)	SNNPR	Facility-Based	▪ Direct wet mount ▪ Formol-ether concentration ▪ Modifed Ziehl–Neelsen method	Systematic random	100	158	42	26.6
(Aleka et al., 2015)	Amhara	Hospital-Based	▪ Direct wet mount ▪ Formol-ether concentration	Systematic random	100	277	48	17.3
(Alemu et al., 2016)	Amhara	Community-Based	▪ Kato Katz method	Simple random	–	401	141	35.2
(Mohammed et al., 2016)	Amhara	Facility-Based	▪ Direct wet mount ▪ Formol-ether concentration ▪ Modifed Ziehl–Neelsen method	Systematic random	–	422	86	20.4
(Wadilo and Solomon, 2016)	SNNPR	Hospital-Based	▪ Direct wet mount ▪ Formol-ether concentration	Convenient sampling	96.9	423	87	21.2
(Kabeta et al., 2017)	SNNPR	Community-Based	▪ Direct wet mount ▪ Formol-ether concentration	Simple random	100	587	301	51.3
(Gebretsadik et al., 2018)	Amhara	Hospital-Based	▪ Direct wet mount ▪ Formol-ether concentration ▪ Modifed Ziehl–Neelsen method	Simple random	100	232	36	15.5
(Zemene and Shiferaw, 2018)	Amhara	Hospital-Based	▪ Direct wet mount ▪ Formol-ether concentration	Simple random	100	247	43	17.4
(Gizaw et al., 2018)	Amhara	Community-Based	▪ Direct wet mount ▪ Kato-Katz thick smear method	Systematic random	100	225	58	25.8
(Kassaw et al., 2019)	Amhara	Community-Based	▪ Direct wet mount ▪ Formol-ether concentration	Simple random	–	378	196	51.8
(Zelelie et al., 2019)	Amhara	Facility-Based	▪ Direct wet mount	Systematic random	–	163	16	9.8
(Lewetegn et al., 2019)	Amhara	Community-Based	▪ Kato Katz method ▪ Formol-ether concentration	Systematic random	–	214	112	52.3
(Kemal et al., 2019)	Somali	Facility-Based	▪ Double Kato-Katz thick smear	Simple random	–	236	59	25
(Mekonnen and Ekubagewargies, 2019)	Amhara	Institutional-Based	▪ Kato-Katz thick smear method	Systematic random	100	310	58	18.7
(Gizaw et al., 2019)	Amhara	Community-Based	▪ Direct wet mount	Systematic random	100	224	57	25.4
(Gadisa and Jote, 2019)	Oromia	Community-Based	▪ Direct wet mount ▪ Modified formal-ether sedimentation	Simple random	100	561	216	38.5
(Asfaw et al., 2020)	SNNPR	Community-Based	▪ Kato Katz method	Simple random	92	2462	578	23.5
(Wasihun et al., 2020)	Tigray	Community-Based	▪ Direct wet mount ▪ Formal-ethyl acetate concentration ▪ Single Kato–Katz method ▪ Modifed Ziehl–Neelsen method	Simple random	–	610	354	58
(Tsegaye et al., 2020)	SNNPR	Community-Based	▪ Direct wet mount	Simple random	99.9	622	303	48.7
(Gujo and Kare, 2021)	SNNPR	Facility-Based	▪ Formal-ether concentration	Systematic random	100	367	159	43.3

(*continued on next page*)

Table 1 (*continued*)

Study	Region	Study Settings	Diagnosis method	Sampling method	Response Rate (%)	Sample Size	Case	Prevalence (%)
(Eyayu et al., 2021)	Amhara	Institutional-Based	▪ Direct wet mount ▪ Formol-ether concentration	Systematic random	100	322	58	18.0
(Geleto et al., 2022)	SNNPR	Community-Based	▪ Kato Katz method	Simple random	100	405	295	72.8
(Mohammed et al., 2022)	Amhara	Institutional-Based	▪ Direct wet mount	Convenient sampling	100	221	42	19.0
(Eyasu et al., 2022)	Amhara	Hospital-Based	▪ Direct wet mount ▪ Modified formal-ether sedimentation ▪ Modifed Ziehl–Neelsen method	Systematic random	100	258	45	17.44
(Tadele et al., 2023)	SNNPR	Community-Based	▪ Kato Katz method	Simple random	95	1683	241	14.3
(Worku et al., 2023)	SNNPR	Institutional-Based	▪ Direct wet mount ▪ Formol-ether concentration ▪ Modifed Ziehl–Neelsen method	Simple random	–	300	68	22.67
(Duguma et al., 2023)	SNNPR	Facility-Based	▪ Direct wet mount	Systematic random	100	323	95	29.4
(Melese et al., 2023)	Amhara	Community-Based	▪ Direct wet mount ▪ Formol-ether concentration ▪ Double slide Kato-Katz technique	Simple random	100	400	130	32.5

Table 2
Prevalence of IPIs among preschool-aged children in Ethiopia.

Category	Pooled frequency (%)
Helminthes	**3791 (23.53)**
Ascaris lumbricoides	1653 (10.26)
Trichuris trichiura	829 (5.15)
Schistosoma mansoni	534 (3.32)
Hymenolepis nana	351 (2.18)
Hookworm	303 (1.88)
Enterobius vermicularis	49 (0.30)
Taenia species	44 (0.27)
Strongyloides stercoralis	28 (0.17)
Protozoan	**1217 (7.55)**
Giardia lamblia	620 (3.85)
Entamoeba histolytica/dispar/ moshkovskii	559 (3.47)
Cryptosporidium species	33 (0.20)
Entamoeba coli	5 (0.03)
Mixed infections	**232 (1.44)**
E. histolytica & G. lamblia	48 (0.30)
E. histolytica & H. nana	36 (0.22)
G. lamblia & H. nana	23 (0.14)
A. lumbricoides & H. nana	22 (0.14)
A. lumbricoides & Taenia spp.	20 (0.12)
A. lumbricoides & T. trichiura	19 (0.12)
A. lumbricoides & Hook worm	11 (0.07)
A. lumbricoides & E. vermicularis	5 (0.03)
H. nana & E. vermicularis	4 (0.03)
E. histolytica & A. lumbricoides	2 (0.01)
S. mansoni & E. vermicularis	2 (0.01)
Entamoeba & Cryptosporidium	2 (0.01)
E. histolytica/dispar & E. vermicularis	2 (0.01)
G. lamblia & Cryptosporidium spp.	2 (0.01)
Taenia spp. & H. nana	2 (0.01)
H. nana & S. mansoni	2 (0.01)
S. mansoni & G. lamblia	1 (0.006)
A. lumbricoides & S. stercoralis	1 (0.006)
E. histolytica & S. mansoni	1 (0.006)
I. belli & H.nana	1 (0.006)
E. histolytica/dispar, G. lamblia & Cryptosporidium spp	14 (0.10)
G. lamblia, E. histolytica/dispar & H. nana	8 (0.05)
T. trichiura, Taenia species & H. nana	4 (0.03)
Total	**5240 (32.52)**

3. Results

3.1. PRISMA flow chart description

A total of 938 articles were identified through the above-mentioned databases. After 320 duplicates were removed, another 230 studies were also excluded from the remaining articles after evaluating the title and/or abstract. In addition, 13 articles were also excluded after the full text assessment. Furthermore, a total of 343 articles were removed due to: review articles ($n = 35$); qualitative studies ($n = 85$); other diseases among pre-school children ($n = 93$); studies out-of-pre-school children ($n = 125$); and correspondence, proceedings and letters to the editor ($n = 5$). Finally, 32 of the articles met the eligibility criteria and were included in the systematic review and meta-analysis (Fig. 1).

3.2. Characteristics of the eligible studies

Table 2 presents the characteristics of the 32 eligible studies included in the meta-analysis. Studies were conducted between 2005 and 2023, and 31 of them were cross-sectional and 1 was a longitudinal study. Twenty and twelve studies have been conducted with less than and >384 sample sizes, respectively. The sample size of PSAC among eligible studies ranged between 158 and 2462. Based on the criteria, three regions, namely Amhara (15 articles), SNNPR (12 articles), Oromia (3 articles), and Somali and Tigray (1 article each), were involved. Regarding sampling method, seventeen, thirteen and two studies, respectively, applied simple, systematic, and convenient sampling methods. With regard to study settings, seventeen, six, five, and four studies were community, facility, hospital,

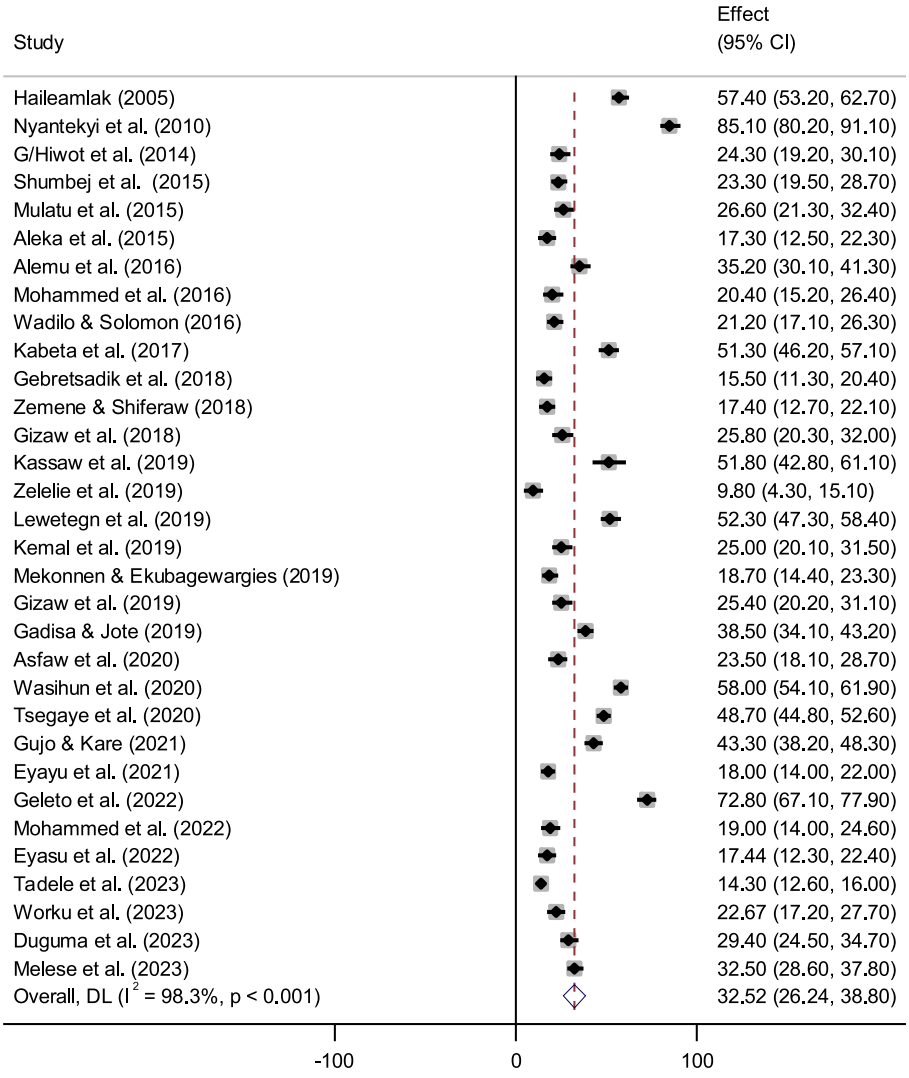

Fig. 2. Forest plot of the prevalence of IPI among preschool-aged children in Ethiopia.

and institutional-based studies, respectively. Nine, fourteen, and nine studies were carried out between 2005 and 2016, 2017 and 2020, as well as between 2021 and 2023, respectively. Fourteen, eleven, six, and one studies, respectively, used one, two, three, and four diagnosis methods (Table 1). The prevalence of IPI among eligible studies ranged from 14.3 to 85.1% (Table 1).

3.3. Causative agents of IPIs among PSAC

The prevalence of IPIs among Ethiopian PSAC was assessed in 32 eligible studies conducted from 2005 to 2023. Helminthes, and protozoan, were the most prevalent IPI among PSAC in Ethiopia, with a pooled prevalence of 23.53%, and 7.55%, respectively. The remaining 1.44%, was pooled prevalence of mixed IPI among PSAC in Ethiopia. 10.26%, 5.15%, 3.85%, 3.47%, 3.32%, 2.18% and 1.88% were, respectively, the pooled prevalences of *A. lumbricoides*, *T. trichiura*, *G. lamblia*, *E. histolytica/dispar/moshkovskii*, *S. mansoni*, *H. nana* and hookworm (Table 2).

3.4. Prevalence of IPI

In the current systematic review and meta-analysis, a total of 14,994 study participants, of whom 4878 had IPIs, emanated from thirty-two eligible primary studies to determine the pooled prevalence of IPIs using a random-effects model. The pooled national prevalence of IPIs among PSAC was 32.52% (95% CI: 26.24, 38.80), with high significant heterogeneity ($I^2 = 98.3, p < 0.001$) (Fig. 2 and Table 3).

3.5. Subgroup analysis

With evidence of substantial heterogeneity in Fig. 2, a subgroup analysis based on sample size, regions, study design, sampling method, study settings, and year of publication was performed to measure its influence on the pooled prevalence of IPIs among PSAC. In this subgroup analysis, the highest pooled prevalence of IPIs was in sample sizes >384 (39.47%, 95% CI: 27.73, 51.20), followed by <384 sample sizes (28.32%, 95% CI: 21.11, 35.53), with high heterogeneity in both groups (Table 3 and Fig. 3). The highest pooled prevalence of IPI among PSAC was reported from the Tigray region at 58.00% (95% CI: 54.10, 61.90), followed by Oromia at 40.10% (95% CI: 21.88, 58.33), SNNPR at 38.48% (95% CI: 25.88, 51.08), and Somali at 25.00% (95% CI: 19.30, 30.70), whereas a low prevalence of IPI among PSAC was observed in the Amhara region at 24.86% (95% CI: 19.34, 30.38) (Table 3 and Fig. 4), and there was no heterogeneity in the Tigray and Somali regions. The highest pooled prevalence estimates of IPI were recorded in cross-sectional studies, with a pooled prevalence estimate of 32.76% (95% CI: 26.31, 39.21) compared to the longitudinal study at 25.00% (95% CI: 19.30, 30.70), with no heterogeneity (Table 3 and Fig. 5). The prevalence estimate of IPI was higher in the studies using the simple random sampling method, with a pooled prevalence estimate of 39.61% (95% CI: 29.19, 50.03), than in the studies using the systematic random sampling method (25.18%; 95% CI: 19.22, 31.14) and the convenient sampling method (20.25%; 95% CI: 16.78, 23.73), without heterogeneity (Table 3 and Fig. 6). The highest pooled prevalence of IPI among study settings was reported from community-based studies at 42.33% (95% CI: 31.93, 52.74), followed by facility studies at 25.78% (95% CI: 16.69, 34.87), institutional studies at 19.30% (95% CI: 16.97, 21.63), and hospital-based study settings at 17.78% (95% CI: 15.66, 19.91) (Table 3 and Fig. 7), and there was no heterogeneity in both institutional and hospital-based study settings. The highest pooled prevalence estimate in the study period was recorded between 2005 and 2016 with a pooled prevalence estimate of 34.53% (95% CI: 20.13, 48.92), followed by the study period from 2017 to 2020 with a pooled prevalence estimate of 32.93% (95% CI: 24.04, 41.83), and in the next

Table 3
Subgroup analysis of the prevalence of IPIs among preschool-aged children.

Variables	Characteristics	Included Studies	Sample Size	Prevalence% (95% CI)	I^2, P–Value
Sample size	<384	20	5494	28.32 (95% CI: 21.11, 35.53)	97.4, $P < 0.001$
	>384	12	9500	39.47 (95% CI: 27.73, 51.20)	99.0, $P < 0.001$
Region	Oromia	3	1859	40.10 (95% CI: 21.88, 58.33)	97.6, $P < 0.001$
	SNNPR	12	7995	38.48 (95% CI: 25.88, 51.08)	99.1, $P < 0.001$
	Amhara	15	4294	24.86 (95% CI: 19.34, 30.38)	94.2, $P < 0.001$
	Somali	1	236	25.00 (95% CI: 19.30, 30.70)	0.0, *P*–
	Tigray	1	610	58.00 (95% CI: 54.10, 61.90)	0.0, *P*–
Study design	Cross-sectional	31	14,758	32.76 (95% CI: 26.31, 39.21)	98.4, $P < 0.001$
	Longitudinal	1	236	25.00 (95% CI: 19.30, 30.70)	0.0, *P*–
Sampling method	Simple random	17	10,710	39.61 (95% CI: 29.19, 50.03)	99.0, $P < 0.001$
	Systematic random	13	3640	25.18 (95% CI: 19.22, 31.14)	94.5, $P < 0.001$
	Convenient	2	644	20.25 (95% CI: 16.78, 23.73)	0.0, $P = 0.539$
Study settings	Community	17	10,735	42.33 (95% CI: 31.93, 52.74)	98.9, $P < 0.001$
	Facility	6	1669	25.78 (95% CI: 16.69, 34.87)	94.1, $P < 0.001$
	Hospital	5	1437	17.78 (95% CI: 15.66, 19.91)	0.0, $P = 0.530$
	Institutional	4	1153	19.30 (95% CI: 16.97, 21.63)	0.0, $P = 0.558$
Publication year	2005–2016	9	3644	34.53 (95% CI: 20.13, 48.92)	98.6, $P < 0.001$
	2017–2020	14	3377	32.93 (95% CI: 24.04, 41.83)	97.7, $P < 0.001$
	2021–2023	9	7973	29.88 (95% CI: 18.85, 40.90)	98.5, $P < 0.001$
	Overall	32	14,994	32.52 (95% CI: 26.24, 38.80)	98.3, $P < 0.001$

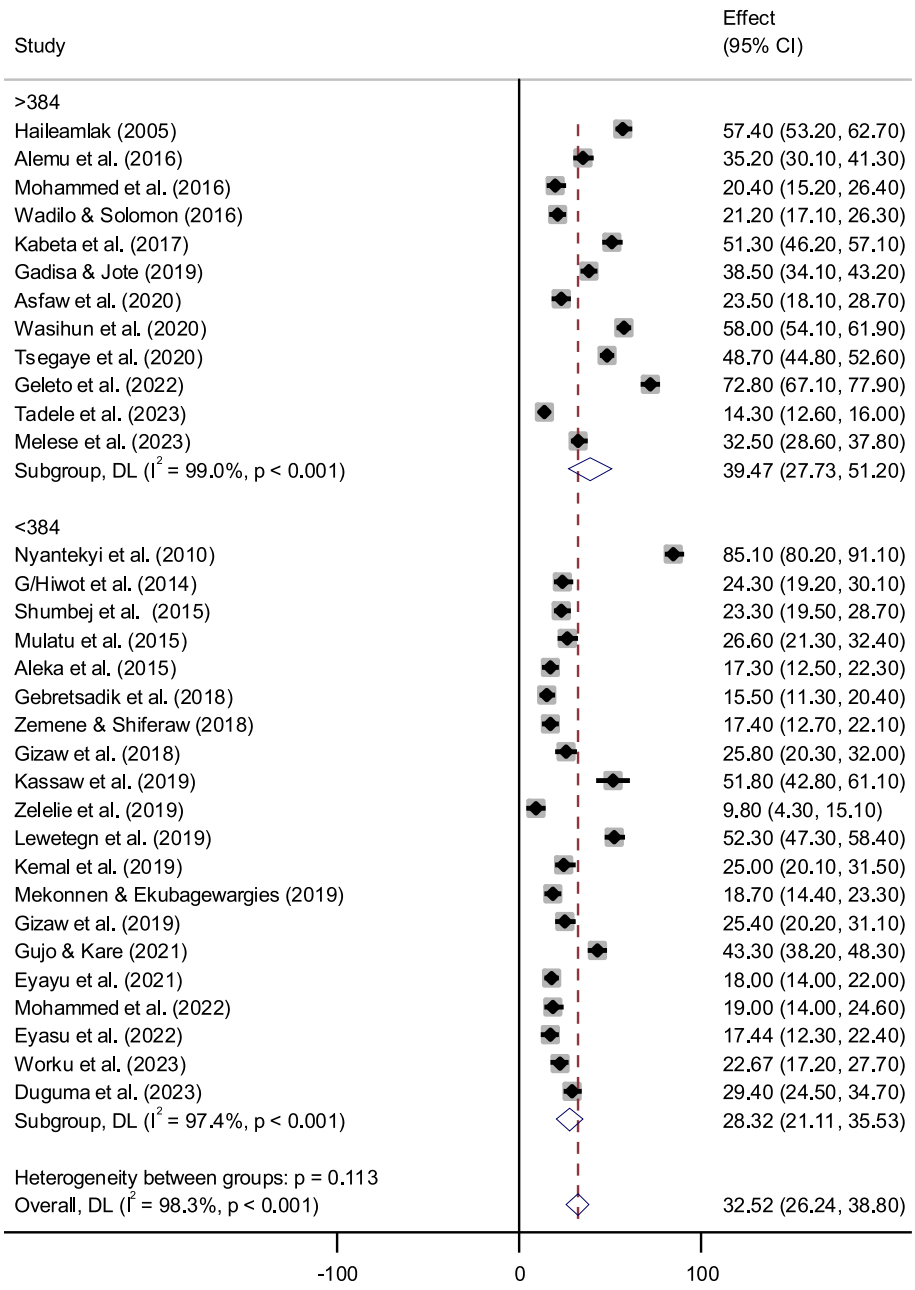

Fig. 3. Subgroup analysis by sample size on the pooled prevalence of IPI among preschool-aged children in Ethiopia.

three years (2021−2023) at 29.88% (95% CI: 18.85, 40.90), with substantial heterogeneity in all study periods (Table 3 and Fig. 8).

3.6. Heterogeneity and publication bias

Within the included studies, heterogeneity and publication bias were identified. High levels of heterogeneity were present in the included studies ($I^2 = 98.3\%$, $P < 0.001$). The funnel plot (Fig. 9) revealed an asymmetrical distribution, which might be due to the detected heterogeneity or simply by chance. Begg's rank test and Egger's regression intercept test were used to test whether the funnel-plot asymmetry was greater than what had been expected by chance. Using the findings of the tests by Egger (Fig. 10) and Begg (Fig. 11), it was determined that there was no substantial publication bias ($P > 0.05$), indicating the funnel plot asymmetry might be observed by chance.

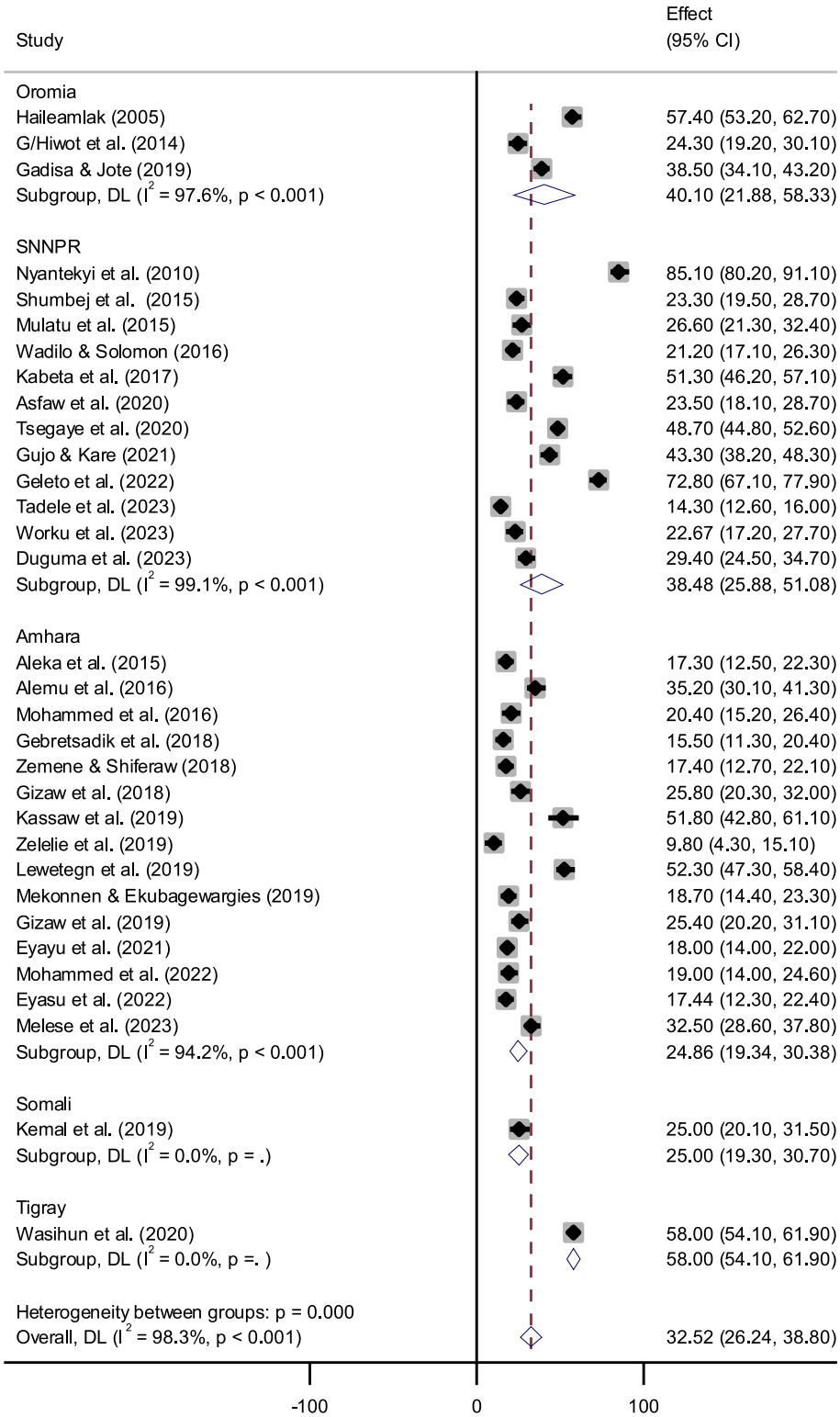

Fig. 4. Subgroup analysis by region on the pooled prevalence of IPI among preschool-aged children in Ethiopia.

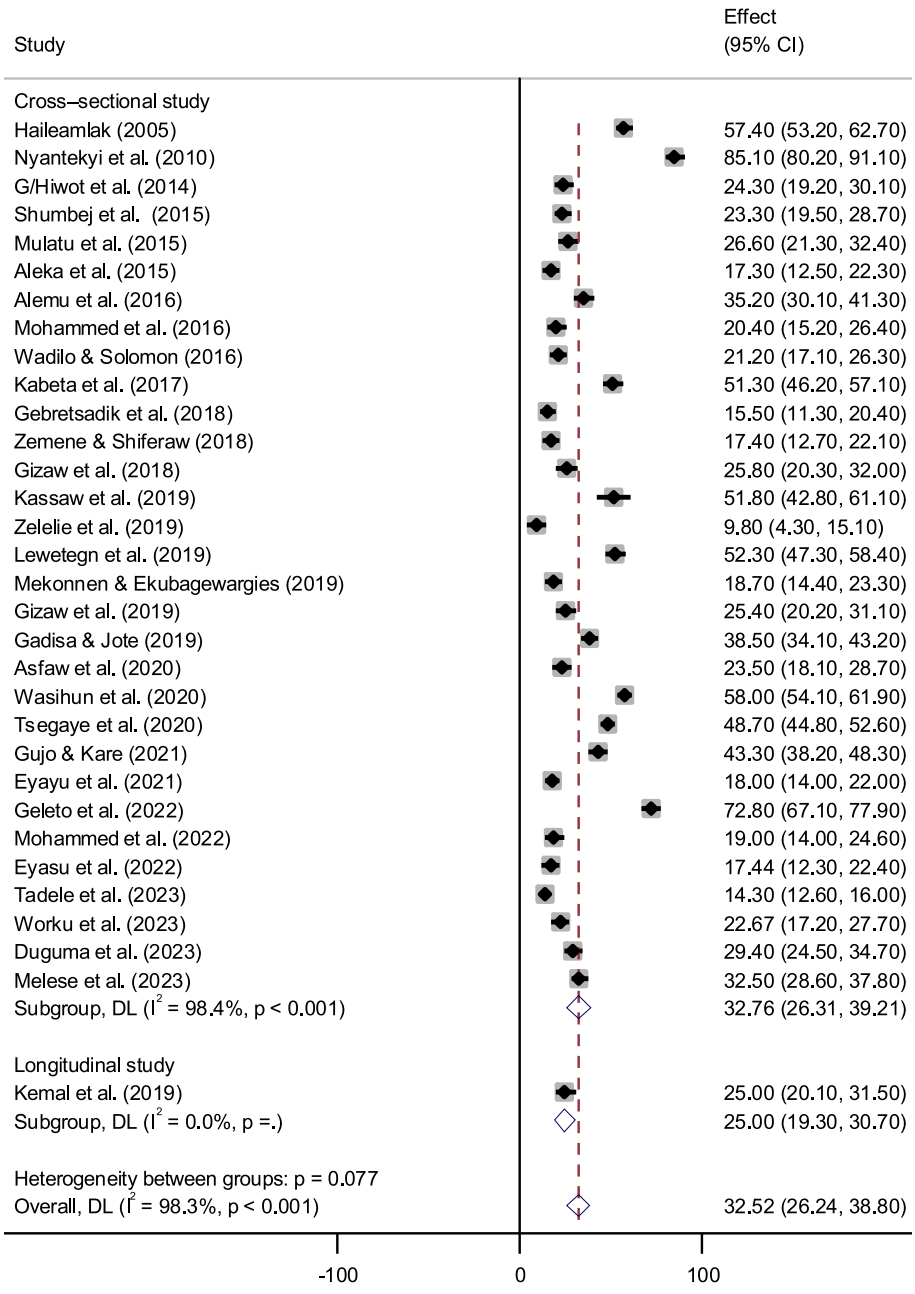

Fig. 5. Subgroup analysis by study design on the pooled prevalence of IPI among preschool-aged children in Ethiopia.

3.7. Sensitivity analysis

Sensitivity analysis was conducted to investigate the heterogeneity of those studies by systematically removing one study in order to determine whether each study's findings affected the overall prevalence of IPIs. However, during the sensitivity analysis, six studies (Haileamlak, Nyantekyi et al., Wasihun et al., Tsegaye et al., Geleto et al., and Tadele et al.) had relatively determinant effects on the overall magnitude of IPIs among PSAC in Ethiopia. 27.98 (27.18–28.79), 27.59 (26.78–28.39), 27.54 (26.73–28.36), 27.95 (27.14–28.76), 27.83 (27.03–28.64), and 32.85 (31.95–33.74) were the estimates after removing each study one at a time, namely, Haileamlak, Nyantekyi et al., Wasihun et al., Tsegaye et al., Geleto et al., and Tadele et al., respectively. After totally removing those six studies, the estimate becomes 25.92 (24.92–26.92) (Fig. 12).

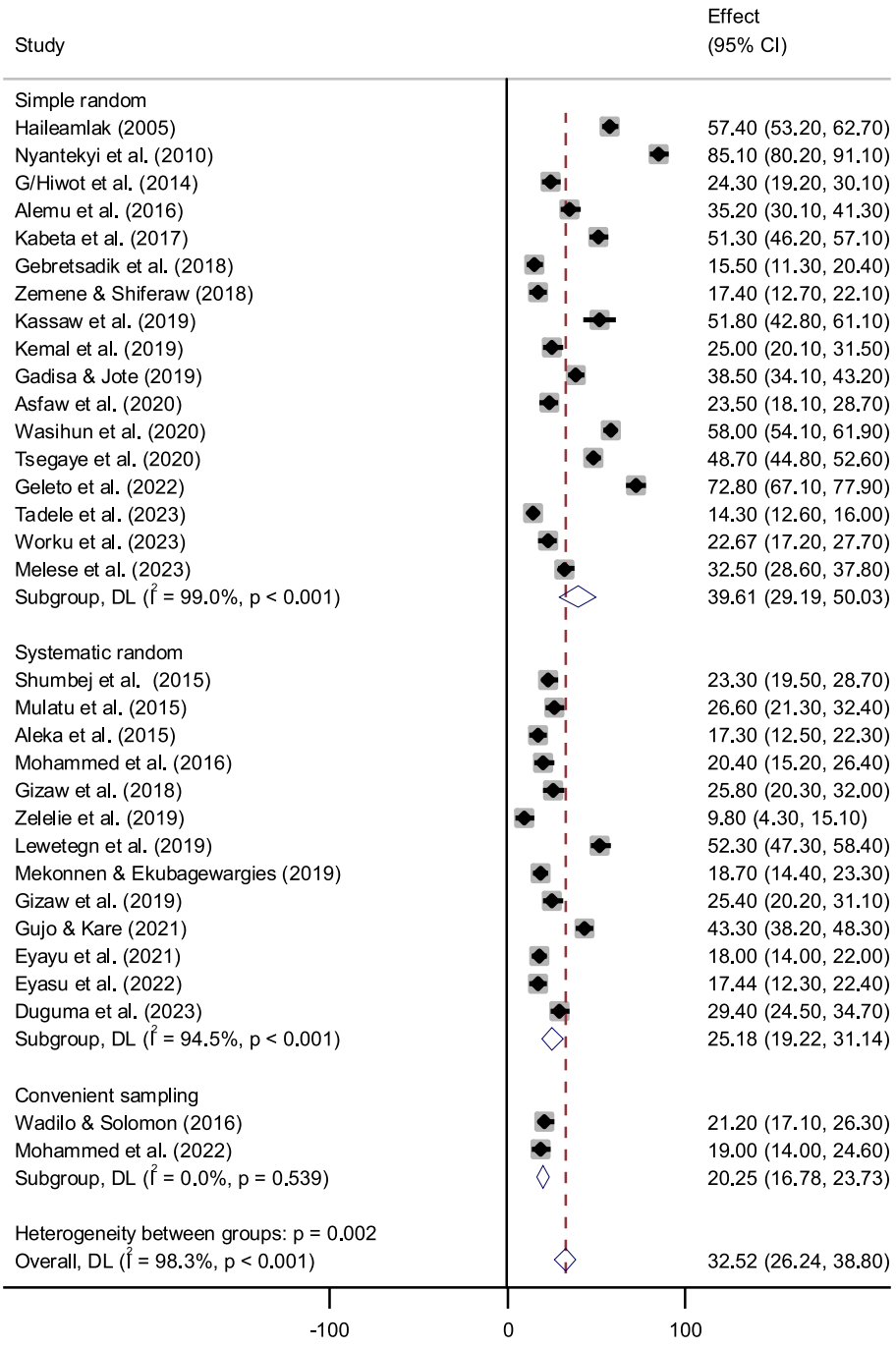

Fig. 6. Subgroup analysis by sampling method on the pooled prevalence of IPI among preschool-aged children in Ethiopia.

3.8. Factors associated with IPIs among under five children

In this meta-analysis, several potential risk factors associated with IPIs among PSAC in Ethiopia were reviewed. Of them, eating raw fruits and vegetables (OR = 3.21; 95% CI: 1.11, 5.31), large family size (OR = 2.51; 95% CI: 1.23, 3.80), rarely fresh child meal (OR = 5.81; 95% CI: 2.82, 8.79), irregular child's nail trimming (OR = 2.63; 95% CI: 1.71, 3.56), no formal family education (OR = 13.46; 95% CI: −9.11, 36.03), unclear playing ground/geophage habit of children (OR = 2.75; 95% CI: 1.59, 3.91), lack of handwashing before meal (OR = 2.65; 95% CI: 1.58, 3.72), lack of caregiver handwashing habit after toilet use (OR = 4.25; 95% CI: 0.46, 8.03), lack of health professional visit (OR = 2.74; 95% CI: 1.45, 4.04), lack of shoe wearing (OR = 2.42; 95% CI: 1.57, 3.28), absence of latrine

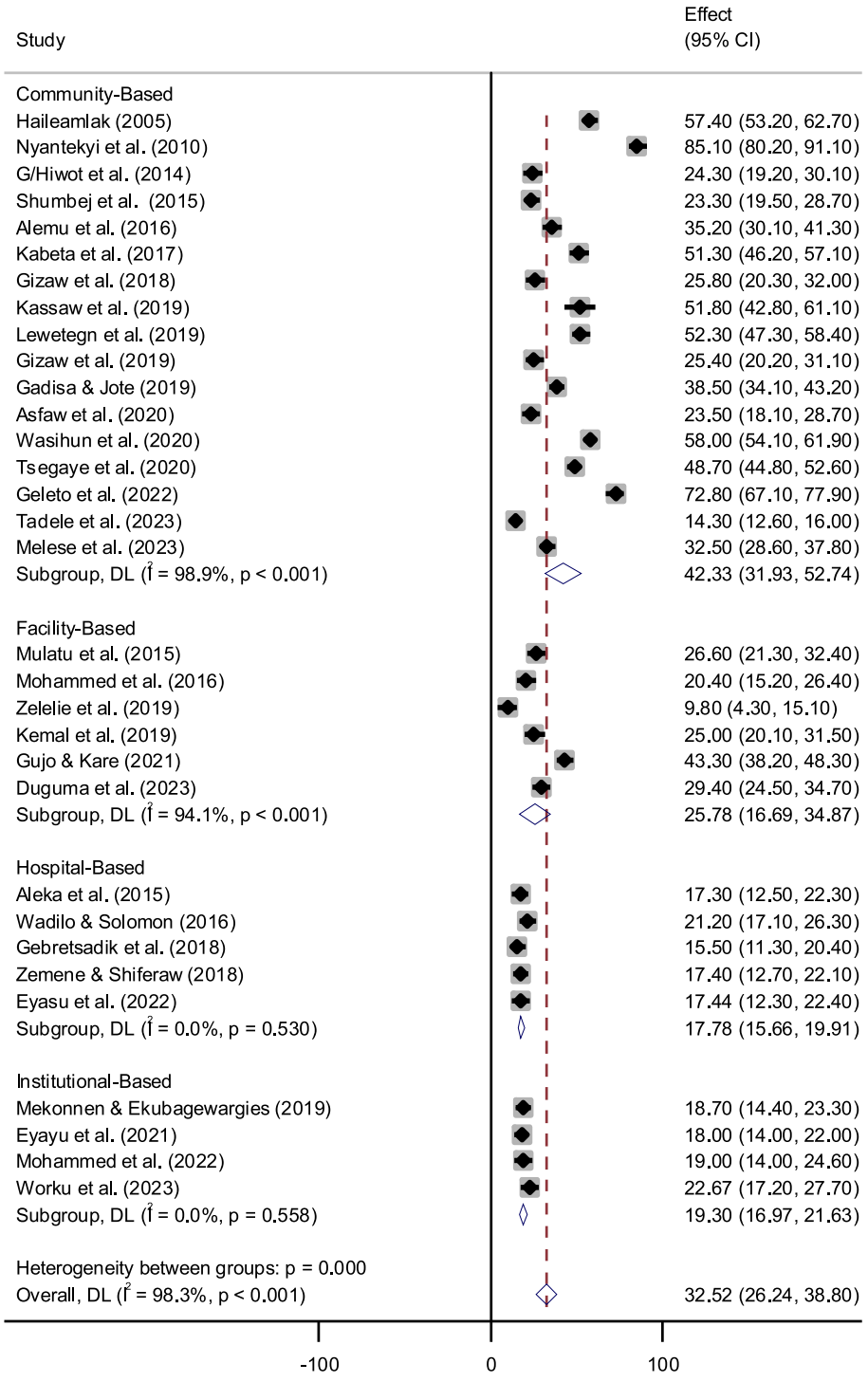

Fig. 7. Subgroup analysis by study settings on the pooled prevalence of IPI among preschool-aged children in Ethiopia.

(OR = 2. 83; 95% CI: 1.24, 4.41), and unprotected drinking water (OR = 4.80; 95% CI: 2.07, 7.52) were factors associated with IPIs among under five children (Table 4).

4. Discussion

Intestinal parasitic infections (IPIs) pose a serious public health threat across the globe, particularly in children in developing

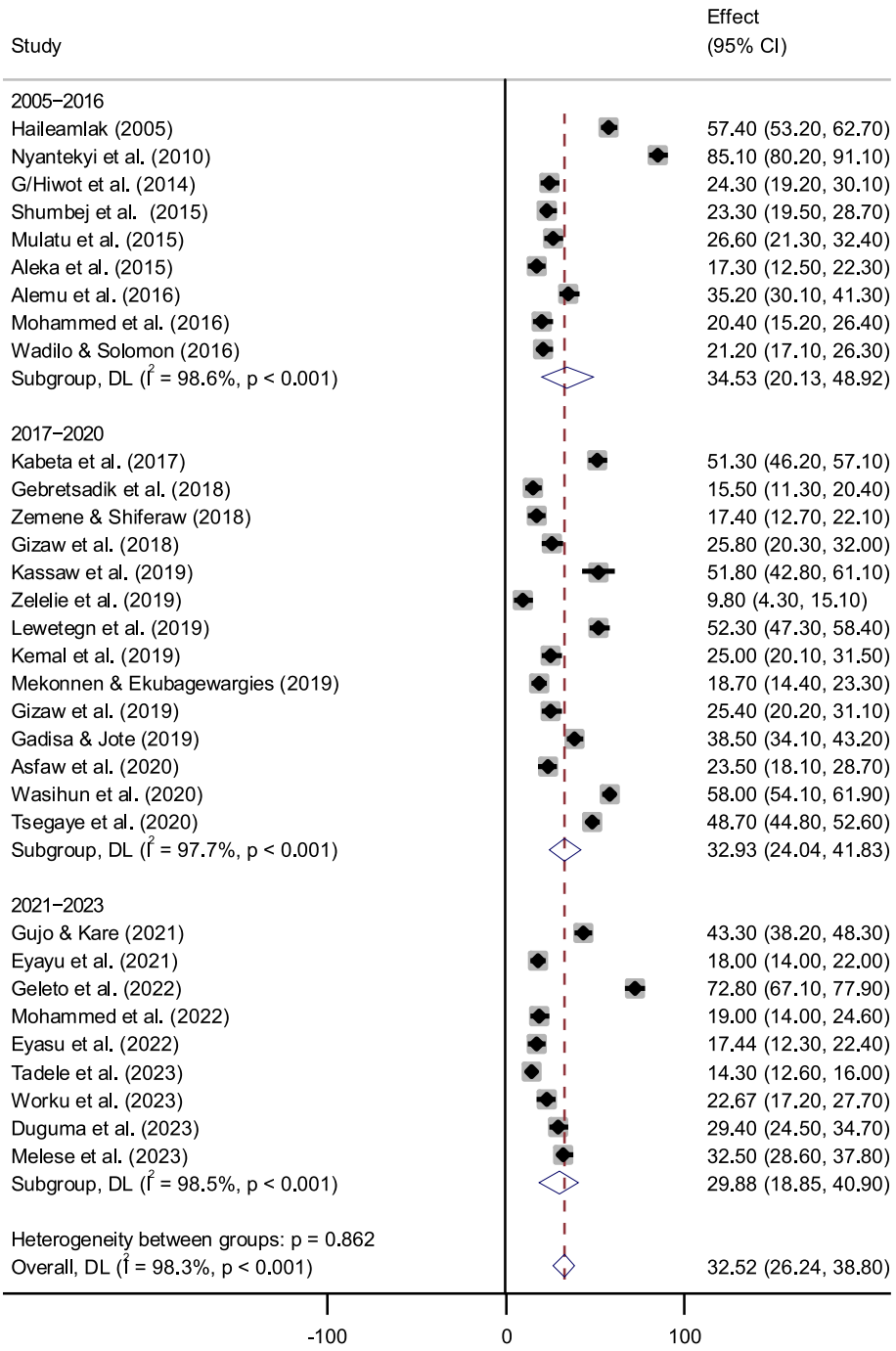

Fig. 8. Subgroup analysis by publication year on the pooled prevalence of IPI among preschool-aged children in Ethiopia.

countries like Ethiopia. The current study was designed to assess the success of the national ongoing control and preventive measures and complement national efforts towards the control of IPIs by providing useful epidemiological data that will aid its control and elimination. The study provides information on IPIs, its magnitude at the national and regional levels, its distribution across regions, types, periods, and settings, and finally, its determinant factors. Moreover, it provides information that will serve as a guide for targeted and cost-effective control by focusing their efforts in highly endemic areas. Several studies have been available from different regions of Ethiopia on IPIs among PSAC, while the information on IPIs remains unorganized and scattered. Therefore, organizing and locating information has the potential to inform and develop a comprehensive approach to control IPIs and target highly endemic areas with greater urgency.

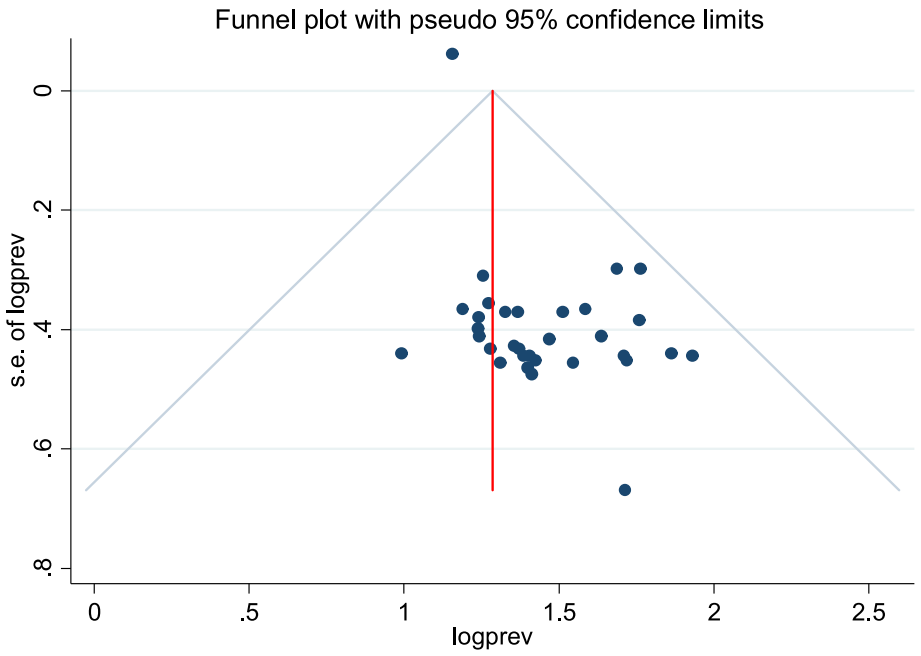

Fig. 9. Funnel plot representing evidence of publication bias,

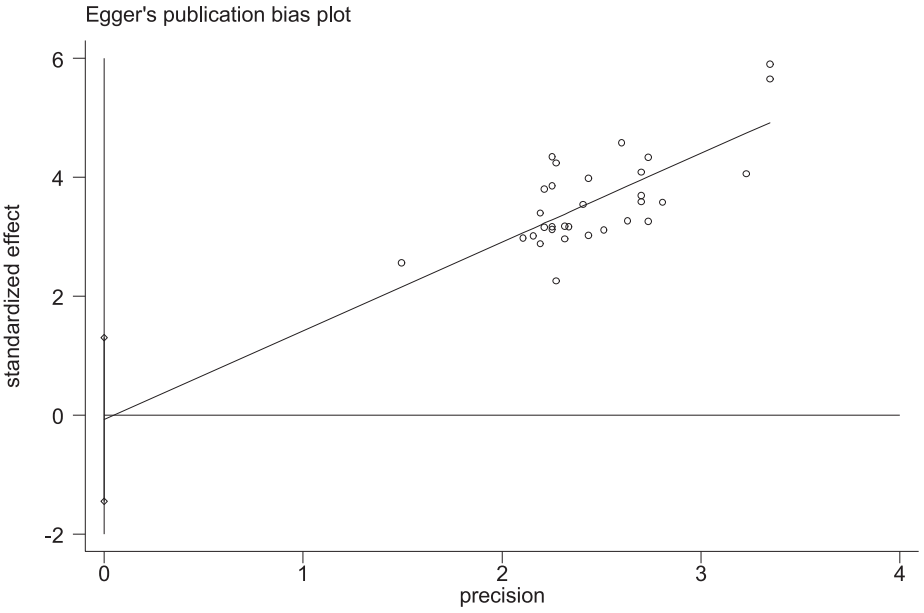

Fig. 10. Egger's test indicated the existence of publication bias among the included studies.

The total national prevalence of IPI among PSAC was 32.52%. This is comparable to findings conducted in Uganda (Ojja et al., 2018), Brazil (Lander et al., 2012), Mozambique (Ferreira et al., 2020), where the prevalence rates are 26.5%, 30.0%, 31.6%, respectively. However, the result of this study was higher than the previous reports conducted in Iran (9.8%) (Mahmoudvand et al., 2020), Nigeria (13.7%) (Achi et al., 2017), Tanzania (15.1%) (Vargas et al., 2004), and Zambia (19.6%) (Mwale and Siziya, 2015). Moreover, the magnitude was lower than studies conducted elsewhere in Colombia (37.0%) (Pazmiño et al., 2022), Iran (38.19%) (Daryani et al., 2017), Iraq (39.5%) (Al-Kahfaji, 2014), Ghana (44.08%) (Abaka-Yawson et al., 2020), India (47.2%) (Deka et al., 2022), Ethiopia (48.1%) (Asfaw and Giotom, 2000), Rwanda (48.8%) (Butera et al., 2019), Egypt (51.8%) (Hegazy et al., 2014), Pakistan (52.8%) (Mehraj et al., 2008), and Cameroon (66.82%) (Asa et al., 2022). This variation could be caused by variations in geographic location, survey times, study subject characteristics, diagnostic methodology, sample sizes, the usage of various

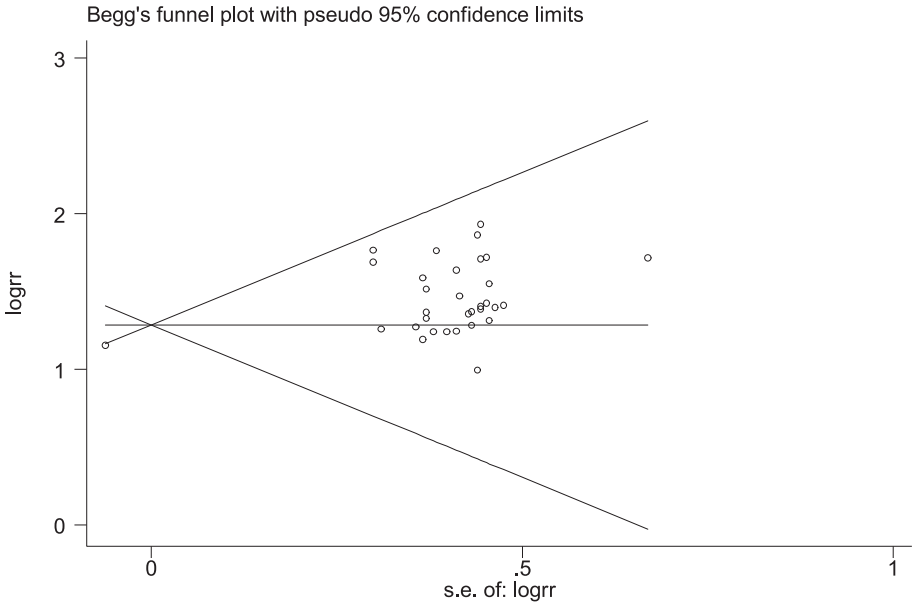

Fig. 11. Begg's test indicated the existence of publication bias among the included studies.

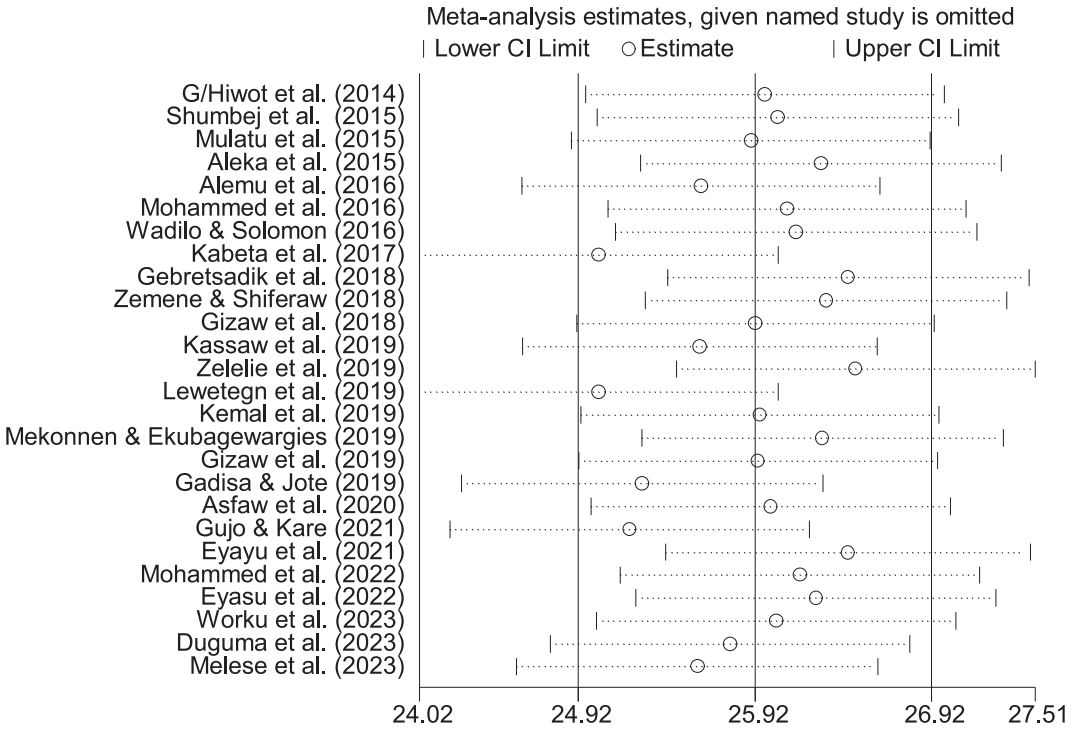

Fig. 12. Sensitivity analysis result of the included studies that assessed the impact of each study on the overall magnitude of scabies.

preventative and control strategies, and socioeconomic status.

It has been shown that countries with different geographical and climatic characteristics have different parasites that are mostly responsible for intestinal infections. In the present study, *A. lumbricoides* was the most prevalent IPI among PSAC, with a pooled prevalence of 10.26%. This is consistent with the findings of a similar study conducted in Nigeria (Achi et al., 2017), Ghana (Abaka-Yawson et al., 2020), India (Deka et al., 2022), Rwanda (Butera et al., 2019), South Africa (Sacolo-Gwebu et al., 2019), and Ethiopia (Girma and Aemiro, 2022). The current combined study found a high prevalence of *A. lumbricoides*, which could be because children catch germs when they contact contaminated objects, surfaces, or soil, increasing the risk of hand contamination with disease-causing

Table 4
Factors associated with IPIs prevalence among preschool-aged children in Ethiopia.

Variables	Number of articles	Pooled odds ratio (95% CI)	I-squared (%)	I^2 p-value
Fruits and vegetables	4	3.21 (1.11, 5.31)	75.0	0.007
Family size	2	2.51 (1.23, 3.80)	0	0.760
Child meal	2	5.81 (2.82, 8.79)	54.2	0.140
Child's nail trimming	6	2.63 (1.71, 3.56)	0	0.804
Family education	2	13.46 (−9.11, 36.03)	0	0.344
Playing ground and geophage	4	2.75 (1.59, 3.91)	0	0.817
Handwashing before meal	4	2.65 (1.58, 3.72)	0	0.594
Caregiver handwashing habit after toilet	2	4.25 (0.46, 8.03)	0	0.355
Health professional	2	2.74 (1.45, 4.04)	0	0.535
Shoes wearing	3	2.42 (1.57, 3.28)	3.3	0.355
Latrine	3	2.83 (1.24, 4.41)	0	0.910
Drinking water	3	4.80 (2.07, 7. 52)	0	0.693

infections. Further the durability of *Ascaris* eggs under varying environmental conditions, the high fertility, and the sticky nature of the *Ascaris* egg shell, which facilitates its attachment to human hands, fruits, and vegetables.

In the present study, the prevalence of IPIs over time showed slight decreasing trends from 34.53% to 32.93% and 29.88% in 2005–2016, from 2017 to 2020, and in the next three years (2021–2023). This slight decline in prevalence may probably be due to socioeconomic development, improvements in sanitation, and large-scale deworming programs. Despite many initiatives and efforts to introduce mass deworming programs and improve water quality and sanitation, IPIs are still prevalent, and the decrease in trend is less than that of other countries (Ethiopia 34.53% in 2005–2016 *vs.* Nepal 20.4% in 2011–2015 (Kunwar et al., 2016) and Brazil 23.8% in 2010–2011 (de Oliveira Serra et al., 2015)). The reason for the high levels of intestinal parasite infections (IPIs) in the country could be linked to the insufficient funding and support needed to implement effective strategies that have been proven to reduce the spread of infection—measures including the provision of clean water, personal hygiene and sanitation facilities, education campaigns to raise awareness, as well as regular deworming. Another factor could be the limited engagement displayed by political representatives, alongside attitudes and features of the local environment, potentially aiding in the persistence of the IPI issue.

Long-term intestinal parasite control requires public health interventions such as providing clean water, community health education, observing food hygiene, and maintaining functional sanitation infrastructure. In the current study, PSAC who ate raw fruits and vegetables were 3.21 times more likely to be infected with IPI than those who did not eat dirty fruits and vegetables. This is comparable with the findings of Mahmoudvand et al (Mahmoudvand et al., 2020) This could be due to the contamination of fruits and vegetables with the infective stages of IPIs, which children under the age of five easily consume. Furthermore, intestinal parasitic infection is a global health burden in underdeveloped nations, owing to fecal contamination of water and food as well as climatic, environmental, and sociocultural variables.

5. Limitations of the study

The current study has certain limitations. The present systematic review and meta-analysis included the different times of studies (2005–2023) that could affect the prevalence and the heterogeneity between studies. The different IPI diagnostic methods used in the various studies had an impact on the overall magnitude. It was also challenging to generalize the results due to a lack of information and data from other regions of Ethiopia.

6. Conclusion and recommendations

The overall magnitude of IPIs among PSAC is relatively high in comparison to other population groups. Such a high magnitude could have a substantial impact on the health, physical, and mental development of PSAC in Ethiopia. In the present study, *A. lumbricoides* and *T. trichiura* were the most dominant species of intestinal helminths, whereas *G. lamblia* was the dominant intestinal protozoa among PSAC in Ethiopia. The prevalence trend of IPIs among preschool-aged Ethiopian children showed a significant decrease from 2005 to 2023. Further extensive research on the nature, dynamics, and risk factors of IPIs among different regions of Ethiopia is suggested to develop evidence-based IPI control and preventive measures suitable for PSAC.

Ethics approval and consent to participate

Formal consent or ethics approval was not required for this review.

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CRediT authorship contribution statement

Abayeneh Girma: Conceptualization, Formal analysis, Investigation, Software, Supervision, Validation, Visualization, Writing – review & editing, Data curation. **Amere Genet:** Data curation, Methodology, Project administration, Resources, Validation, Visualization, Writing – original draft.

Declaration of competing interest

The authors declare that they have no competing interests.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.parepi.2024.e00368.

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