



# **Epidemiology of Porcine Cysticercosis in Eastern and Southern Africa: Systematic Review and Meta-Analysis**

# Yewubdar Gulelat<sup>1,2</sup>, Tadesse Eguale<sup>1</sup>, Nigatu Kebede<sup>1</sup>, Hailelule Aleme<sup>3</sup>, Eric M. Fèvre<sup>2,4\*</sup> and Elizabeth A. J. Cook<sup>2,4\*</sup>

<sup>1</sup> Aklilu Lemma Institute of Pathobiology, Addis Ababa University, Addis Ababa, Ethiopia, <sup>2</sup> International Livestock Research Institute, Nairobi, Kenya, <sup>3</sup> School of Public Health, Addis Ababa University, Addis Ababa, Ethiopia, <sup>4</sup> Institute of Infection, Veterinary, and Ecological Sciences, University of Liverpool, Liverpool, United Kingdom

#### **OPEN ACCESS**

#### Edited by:

Aleksandra Barac, University of Belgrade, Serbia

#### Reviewed by: Takafira Mduluza.

University of Zimbabwe, Zimbabwe Isaac Khozozo Phiri, University of Zambia, Zambia

#### \*Correspondence:

Eric M. Fèvre Eric.Fevre@liverpool.ac.uk Elizabeth A. J. Cook E.Cook@cgiar.org

#### Specialty section:

This article was submitted to Infectious Diseases - Surveillance, Prevention and Treatment, a section of the journal Frontiers in Public Health

Received: 15 December 2021 Accepted: 16 February 2022 Published: 16 March 2022

#### Citation:

Gulelat Y, Eguale T, Kebede N, Aleme H, Fèvre EM and Cook EAJ (2022) Epidemiology of Porcine Cysticercosis in Eastern and Southern Africa: Systematic Review and Meta-Analysis. Front. Public Health 10:836177. doi: 10.3389/fpubh.2022.836177

Taenia solium cysticercosis is the most common cause of acquired epilepsy in pig-raising and pork-consuming parts of Africa, Latin America, and Asia. This review aimed to systematically compile and synthesize data on the epidemiology of porcine cysticercosis in the Eastern and Southern Africa (ESA) region. Comprehensive searching strategies were employed to retrieve the studies published or reported between January 1,1997 and March 1, 2021, from Pub Med, Hinari, and Google Scholar databases and search platforms. The identified studies that met the inclusion criteria were then appraised for methodological quality. Finally, 44 studies obtained from nine countries were selected and included in this review. Relevant data were extracted using standardized templates for qualitative synthesis and meta-analysis. The overall pooled prevalence estimate of porcine cysticercosis in the ESA region was 17% (95% CI: 14-20%). The prevalence level between and within countries showed high variability. The pooled estimate showed high heterogeneity among the reports (the inverse variance index value  $(I^2)$  of 98.99%, p < 0.05). The meta-analysis sub-grouped by the type of diagnostic test showed the pooled prevalence estimate of 27% (95% CI: 9-50) by carcass dissection; 23% (95% CI: 14-33) by Antibody-based immunodiagnostic techniques; 23% (95% CI: 18-29) by antigen detecting (Ag)-ELISA, 12% (95% CI: 7-18) by meat inspection, and 9% (95% Cl: 7-11) by lingual examination. The meta-analysis sub-grouped by region showed a relatively higher pooled prevalence estimate for the Southern region 22% (95% CI: 15-30) compared to 13% (95% CI: 11-15) in the Eastern region. The highest country-based pooled prevalence was obtained from South Africa (33%, 95% CI: 20-48) and Zambia (22%, 95% CI: 16–29), whereas the lowest pooled prevalence was identified in Madagascar (5%, 95% Cl: 4-5) and Rwanda (7%, 95% Cl: 6-8). The lack of latrine, traditional pig husbandry practices, unprotected water sources, and increase in age were identified as significant risk factors for the occurrence of porcine cysticercosis in the pooled studies. The findings of this review will provide context-specific input to prioritize

1

the possible intervention programs for *T. solium* control in the ESA region. More sensitive and specific test-based prevalence estimates, detailed risk factor investigations, and financial losses analysis are needed to establish feasible control strategies.

**Systematic Review Registration:** http://www.crd.york.ac.uk/PROSPERO/, identifier: CRD42021238931.

Keywords: porcine cysticercosis, epidemiology, systematic review, meta-analysis, Eastern and Southern Africa

### INTRODUCTION

Taenia solium cysticercosis is officially recognized as a neglected tropical disease endemic in pig-raising and pork-consuming parts of Africa, Latin America, and Asia (1-4). The lifecycle of T. solium involves humans as both the definitive host and an accidental dead-end intermediate host, and pigs as the main intermediate host. Humans acquire the adult T. solium through the consumption of undercooked pork infected with cysticerci. Pigs become infected by ingesting tapeworm eggs passed in the stool of the tapeworm carriers during scavenging in the contaminated environment. In humans, accidental ingestion of the tapeworm eggs results in migration and development of the cysticerci in different tissues. The establishment of cysticerci in the brain leads to the development of neurocysticercosis (NCC) (5-8), which is a leading cause of acquired epilepsy in the endemic regions (2). The T. solium is ranked among the most important foodborne parasites globally (9). It is responsible for an estimated loss of approximately 2.8 million disability-adjusted life-years majorly due to neurocysticercosis (10).

Pig rearing is an important livelihood activity for many smallholder farmers in sub-Saharan Africa (SSA) (11). The T. solium has been reported in almost all countries in the SSA region apart from areas where pig keeping and consumption are not common due to cultural or religious reasons (12-17). Similarly, the traditional pig production and pork consumption have grown fast in the ESA region (15, 18), with the reported case of T. solium taeniosis and cysticercosis (TSTC) increasing through time (15, 19). Despite the reported significance of TSTC, it is neglected in most African countries and little effort has been exerted to control or eliminate this neglected zoonotic parasite (15). This led to the establishment of the regional network, the Cysticercosis Working Group for Eastern and Southern Africa (CWGESA), which aimed to improve human health and well-being, as well as the smallholder pig production through facilitating the regional cooperation and sharing of the knowledge and the limited resources (7, 19, 20).

As part of CWGESA, a regional action plan for combating TSCT in the ESA region called the analytical reviews of the existing information at both country and regional level as one focus area to address TSCT (20). Despite the increased

reports of TSCT, the compiled overview on its epidemiology at a regional level is still lacking. Hence, this review intends to answer the question, "What are the pooled prevalence, incidence, distribution, and risk factors of *T. solium* cysticercosis in pigs in Eastern and Southern Africa?". The *T. solium* cysticercosis was first indicated as emerging public health and agricultural problem in ESA in the international workshop on taeniasis and cysticercosis held in South Africa in 1997 (19). So, this review aimed to systematically compile and synthesize regional epidemiologic data from 1997 onwards to provide relevant information about the epidemiology of porcine cysticercosis.

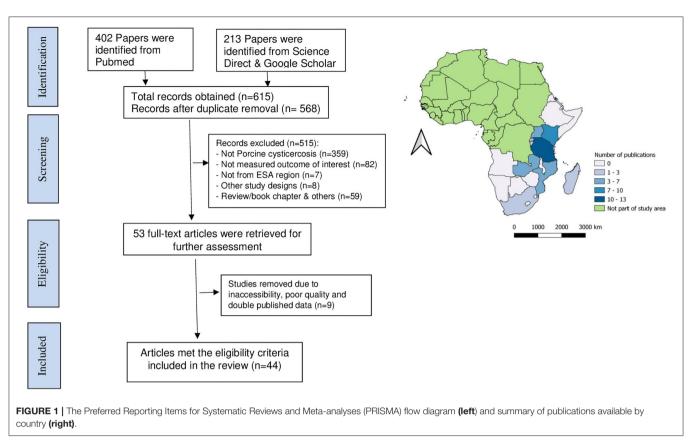
# METHODOLOGY

#### **Search Strategy**

A systematic review and meta-analysis were conducted following a pre-registered protocol on the International Prospective Register of Systematic Reviews (PROSPERO) database (CRD42021238931) and Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines (Supplementary Material 1) to identify relevant articles written in English language and published/reported between January 1, 1997 and March 1, 2021 on the prevalence, incidence, distribution, and risk factors of porcine cysticercosis in ESA. All countries within the ESA region were targeted to search for relevant information about the topic. The ESA was defined as the Eastern and Southern regions of Africa covered by the following countries/territories (Figure 1): Angola, Botswana, Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Lesotho, Madagascar, Malawi, Mauritius, Mayotte, Mozambique, Namibia, Réunion, Rwanda, Seychelles, Socotra, Somalia, Somaliland, South Africa, Swaziland, Tanzania, Uganda, Zambia, and Zimbabwe (21).

The search was applied using a three-step search strategy. An initial limited search in PubMed, Health Internetwork Access to Research Initiative (HINARI), and Google scholar was undertaken, followed by an analysis of the text words contained in the titles and abstracts, and of the index terms used to describe the article. A second extensive search was undertaken using identified keywords and index terms across all included databases and search platforms. During the search, the Boolean operators (AND/OR/NOT) were used to combine the mesh terms with the keywords. The mesh terms and keywords used for searching include: "porcine cysticercosis OR *Cysticercus cellulosae* OR *C. cellulosae* OR cysticerc<sup>\*</sup> OR pig tapeworm OR *Taenia solium* cysticercosis OR *T. solium* cysticercosis AND Angola OR Botswana OR Burundi OR Comoros OR Djibouti

Abbreviations: ELISA, Enzyme Linked Immuno Sorbent Assay; ESA, Eastern and Southern Africa; EITB, Enzyme linked Immunoelectro Transfer Blot; FAO, Food and Agricultural Organization; NCC, Neurocysticercosis; SSA, Sub-Sahara Africa; CWGESA, Cysticercosis Working Group for Eastern and Southern Africa; OIE, Office International de-Epizooties; TSTC, Taenia solium taeniosis and cysticercosis; WHO, World Health Organization.



OR Eritrea OR Ethiopia OR Kenya OR Lesotho OR Madagascar OR Malawi OR Mauritius OR Mayotte OR Mozambique OR Namibia OR Réunion OR Rwanda OR Seychelles OR Socotra OR Somalia OR Puntland OR Somaliland OR South Africa OR Swaziland OR Tanzania OR Uganda OR Zambia OR Zimbabwe<sup>\*</sup>. Then, the reference lists of studies included in the reviews were hand-searched for further eligible studies. The references from the search in each database were imported directly into EndNote citation manager X6.

# **Selection Criteria**

The predefined inclusion and exclusion criteria were used to screen the relevance of titles and abstracts for this review. The studies about *T. solium* cysticercosis were included in the review if they recruited pig as a study animal, employed a cross-sectional or cohort study designs, conducted within Eastern and Southern Africa region, reported porcine cysticercosis prevalence (number of infected pigs/ total number of pigs examined/tested) and/or incidence (number of infected pigs /pig-time), mentioned the diagnostic methods used, written in English, and published within a period between January 1,1997 and March 3,2021.

# **Study Selection**

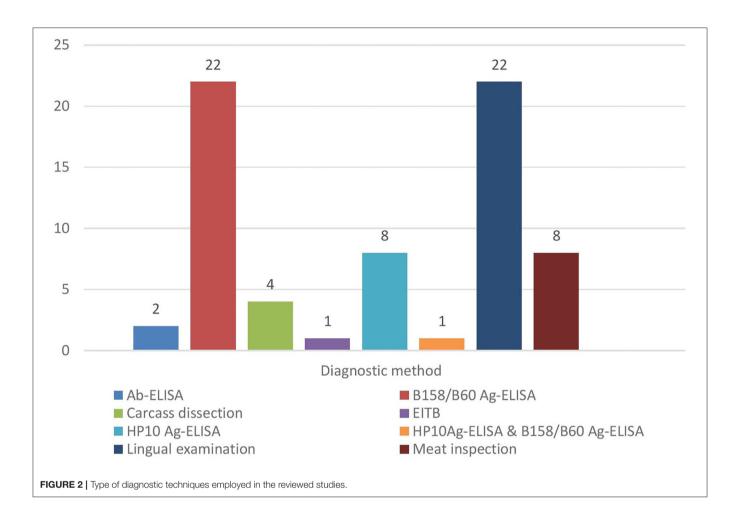
Following the search, all identified citations were collated and uploaded into EndNote citation manager X6 and duplicates were removed. The titles and abstracts were then screened against the inclusion criteria. Those studies meeting the eligibility criteria were retrieved in full. The full texts of selected studies were assessed in detail, and those that did not meet the inclusion criteria were excluded. Included studies underwent a process of critical appraisal. Any disagreements were resolved through discussion with the two primary reviewers and a third reviewer. The result of the search and summary of publications available by country is presented below (**Figure 1**).

# **Data Extraction**

Relevant data were extracted from the papers that included the review using a standardized data extraction template developed using a Microsoft Excel workbook. Double data extraction and entry were performed to ensure accuracy. The variables extracted from each article were: name of the journal, title of the article, first author, publication date, country, study location, study period, study design, sample size, diagnostic methods, number of subjects with positive test results, the degree of association between the outcome of interest with each predictor variable (Odds ratio and 95% confidence interval was extracted for each risk factor). The authors of the papers were contacted to request missing or additional data if required. Any disagreements were resolved through discussion and a third reviewer.

# Assessment of Methodological Quality

The selected studies were critically appraised by two independent reviewers using the standardized critical appraisal instruments: (1) the Newcastle Ottawa Quality Assessment Scale for cohort studies, and (2) the Newcastle Ottawa Quality Assessment Scale adapted for cross-sectional studies (22) were employed to guide the quality assessment of the included studies. Any disagreements were resolved through discussion and a third reviewer. Details on



the critical appraisal assessment result for the selected studies is provided in **Supplementary Material 5**.

# **Data Analysis**

The articles were, as much as possible, pooled in a statistical meta-analysis. and the pooled prevalence (%) of porcine cysticercosis and odds ratio of significant risk factors with their 95% confidence intervals (CI) were calculated. Ninetyfive percent of exact binomial CI was calculated for every prevalence. The studies were stratified based on the type of study design, diagnostic methods, country, and region, and a separate meta-analysis was conducted when sufficiently reported data were available (>2 studies). Forest plots were presented for proportions of individual studies, sub-group, and overall prevalence. Heterogeneity among the included studies was assessed using the I-squared test and Q statistic (P-value 0.1). The random-effect model was used for the meta-analysis. Sensitivity analyses were performed by assessing the influence of omitting a single study on the overall estimate. A funnel plot and the Egger's regression assumption were used to investigate publication bias. If statistical pooling is not possible, the findings are presented in the narrative form including tables and figures to appropriately aid in data presentation. The analysis of the data was conducted using the STATA statistical software package.

# RESULT

A total of 615 articles were obtained from all data sources. After the removal of duplicates (23), 568 article titles and abstracts were screened, and 515 records were excluded following predefined selection criteria (**Figure 1**). Then, 53 records were passed for full article reading, of which nine were excluded because two contained duplicate data, six were inaccessible, and the other did not pass the quality assessment. Finally, 44 full-text articles met the predefined inclusion criteria and passed the quality assessment for meta-analysis, and were included in the qualitative synthesis.

Out of the 27 countries/territories studied, the records that met the eligibility criteria were obtained from nine countries (**Figure 1**). Of these, most records were obtained from Tanzania (n = 13) and the others included data from Kenya (n = 9), Uganda (n = 4), Rwanda (n = 1), Burundi (n = 2), South Africa (n = 3), Zambia (n = 6), Mozambique (n = 5), and Madagascar (n = 2). From the 44 studies included in the review, 15 employed more than one diagnostic technique. Most studies included in the review used Ag-ELISA (B158/B60 Ag-ELISA and HP10 Ag-ELISA) (24) to ascertain cases of porcine cysticercosis, followed by lingual examination (22), meat inspection (8), carcass dissection (4), and antibody-based immunodiagnostic techniques [Enzyme-linked Immunoelectro Transfer Blot (EITB) and Ab-ELISA] (3) (Figure 2).

The available prevalence data identified through a review of cross-sectional studies are summarized in **Tables 1**, **2**. For each included study, authors, year of publication, the number of sampled pigs, and the prevalence of porcine cysticercosis based on immunological and parasitological diagnostic techniques along with 95% CI are reported.

This review identified high variability in the prevalence levels among and within countries ranging from 0 to 57% using different diagnostic techniques (**Figure 3**). Since few studies employed the gold standard techniques to ascertain cases of porcine cysticercosis, we included the studies if they clearly described the employed diagnostic technique. For all the studies, we computed prevalence by dividing the number of positive cases by the total number of pigs tested. Though we did not consider the sensitivity and specificity of used techniques in the prevalence estimation, we assessed the effect of diagnostic test parameter variation by undertaking a sub-group meta-analysis. Pondja et al. (44) in Mozambique reported the point prevalence (only the estimate from the first prevalence survey was included in **Table 1**) and the incidence rate (the mean incidence rate of 6.2 cases per 100 pig-months between 4 and 9 months of age, and 21.2 cases per 100 pig-months between 9 and 12 months of age) using B158/B60 Ag-ELISA. As this report was the only cohort study obtained, so far, it was only included in the qualitative synthesis.

**Figures 3**, **4** demonstrate the high variation in prevalence range between countries as well as within countries. The distribution of porcine cysticercosis in the ESA region is provided in **Figure 3**, where each color represents the average prevalence range classified into 0–10%; 10–20%, 20–30%, and 30–40%. From 27 countries/territories of the ESA region, no article was

TABLE 1 | Prevalence of porcine cysticercosis based on immunological diagnostic techniques.

| Reference               | YOP  | Country      | Sample size | Prevalence of PCC and 95% CI                                |                              |  |
|-------------------------|------|--------------|-------------|---|------------------------------|--|
|                         |      |              |             | Ag-ELISA  | Ab-assay                     |  |
| Akoko et al. (25)       | 2019 | Kenya        | 700         | 8.7ª (6.7–11.1)   |                              |  |
| Braae et al. (26)       | 2014 | Tanzania     | 822         | 15.5 <sup>a</sup> (13.1–8.1)                                |                              |  |
| Chembensofu et al. (27) | 2017 | Zambia       | 68          | 52.9 <sup>a</sup> (40.4–65.2)                               |                              |  |
| Chilundo et al. (28)    | 2017 | Mozambique   | 262         | 12.6 <sup>a</sup> (8.8–17.2)                                |                              |  |
| Dorny et al. (29)       | 2004 | Zambia       | 868         | 57.1 <sup>a</sup> (53.8–60.5)                               | 24.9 <sup>c</sup> (22-27.9)  |  |
| Eshitera et al. (30)    | 2012 | Kenya        | 232         | 32.8 <sup>b</sup> (26.8–39.2)                               |                              |  |
| Fèvre et al. (31)       | 2017 | Kenya        | 91          | 17.6 <sup>b</sup> (10.4–27)                                 |                              |  |
| Kabululu et al. (24)    | 2020 | Tanzania     | 350         | 19.4 <sup>a</sup> (15.4–24)                                 |                              |  |
| Kabululu et al. (32)    | 2015 | Tanzania     | 482         | 11.4 <sup>a</sup> (8.7–14.6)                                |                              |  |
| Kagira et al. (33)      | 2010 | Kenya        | 284         | 3.9 <sup>a</sup> (1.9–6.8)                                  |                              |  |
| Komba et al. (34)       | 2013 | Tanzania     | 600         | 18.9 <sup>a</sup> (27.6–35.2)                               |                              |  |
| Krecek et al. (35)      | 2008 | South Africa | 261         | 54.8 <sup>a</sup> (48.5–60.9) 40.6 <sup>b</sup> (34.6–46.8) | 33.3 <sup>d</sup> (27.6–39.4 |  |
| Krecek et al. (36)      | 2012 | South Africa | 256         | 41ª (34.9–47.3) 54 <sup>b</sup> (47.6–60.1)                 |                              |  |
| Kungu et al. (37)       | 2017 | Uganda       | 1,185       | 12.2 <sup>e</sup> (10.3-14.1)                               |                              |  |
| Thomas (38)             | 2013 | Kenya        | 93          | 17.2 <sup>b</sup> (10.2–26.4)                               |                              |  |
| Maganira et al. (39)    | 2019 | Tanzania     | 447         | 17.2 <sup>a</sup> (13.8–21.1)                               |                              |  |
| Matos et al. (40)       | 2011 | Mozambique   | 132         |   | 12.1°(7.1–18.9)              |  |
| Nguhiu et al. (41)      | 2017 | Kenya        | 276         | 4.3 <sup>a</sup> (2.3–7.5)                                  |                              |  |
| Nsadha et al. (42)      | 2014 | Uganda       | 378         | 25.7 <sup>a</sup> (21.3–30.4)                               |                              |  |
| Phiri et al. (43)       | 2002 | Zambia       | 249         | 13.7 <sup>a</sup> (9.6–18.6)                                |                              |  |
| Pondja et al. (14)      | 2010 | Mozambique   | 661         | 34.9 <sup>a</sup> (31.3–38.7)                               |                              |  |
| Pondja et al. (44)      | 2015 | Mozambique   | 108         | 5.6 <sup>a</sup> (2.1-11.7)                                 |                              |  |
| Shongwe et al. (45)     | 2020 | South Africa | 126         | 7ª (3.3–13.1)   |                              |  |
| Porphyre et al. (46)    | 2015 | Madagascar   | 175         | 10.9 <sup>a</sup> (6.7–16.4)                                |                              |  |
| Shonyelaet al. (47)     | 2017 | Tanzania     | 330         | 33.3ª(28.3–38.7)  |                              |  |
| Sikasunge et al. (48)   | 2007 | Zambia       | 800         | 37.6 <sup>a</sup> (34.3–41.1)                               |                              |  |
| Sikasunge et al. (49)   | 2008 | Zambia       | 1,691       | 23.3ª(21.3–25.4)  |                              |  |
| Thomas et al. (17)      | 2016 | Kenya        | 343         | 49.9 <sup>b</sup> (44.4–55.3)                               |                              |  |
| Waiswa et al. (13)      | 2009 | Uganda       | 480         | 8.5 <sup>a</sup> (6.2-11.4)                                 |                              |  |
| Wardrop et al. (50)     | 2015 | Kenya        | 93          | 17.2 <sup>b</sup> (10.2–26.4)                               |                              |  |

YOP, Year of publication; PCC, porcine cysticercosis; CI, Confidence Interval; Ag-ELISA, Antigen based ELISA; Ab-assay, Antibody-based immunodiagnostic techniques; a, Results obtained from B158/B60 Ag-ELISA; b, Results obtained from HP10 Ag-ELISA; c, Results obtained from Ab-ELISA; d, Results obtained from EITB; e, Results obtained from HP10Ag-ELISA & B158/B60 Ag-ELISA.

TABLE 2 Prevalence of porcine cysticercosis based on Lingual examination, meat inspection, and carcass dissection methods.

| References               | YOP  | Country      | Sample size                            | Prevalence of PCC and 95% CI |                  |                  |  |
|--------------------------|------|--------------|--|------------------------------|------------------|------------------|--|
|                          |      |              |  | LE                           | МІ               | CD               |  |
| Boa et al. (51)          | 2006 | Tanzania     | 1,832                                  | 9.5 (8.2–10.9)               |                  |                  |  |
| Chembensofu et al. (27)  | 2017 | Zambia       | 68                                     | 5.9 (4.1–6.5)                |                  | 55.9 (43.3–67.9) |  |
| Dorny et al. (29)        | 2004 | Zambia       | 868                                    | 13.2 (11.1–15.7)             | 13.9 (11.7–16.4) |                  |  |
| Eshitera et al. (30)     | 2012 | Kenya        | 392                                    | 5.6 (3.6-8.4)                |                  |                  |  |
| Kabululu et al. (24)     | 2020 | Tanzania     | 350                                    |                              |                  | 8.3 (5.6–11.7)   |  |
| Kabululu et al. (52)     | 2020 | Tanzania     | 282                                    |                              |                  | 9.2 (6.1–13.2)   |  |
| Komba et al. (34)        | 2013 | Tanzania     | 600                                    | 8.8 (6.7–11.7)               |                  |                  |  |
| Krecek et al. (35)       | 2008 | South Africa | 261                                    | 11.9 (8.2–16.4)              |                  |                  |  |
| Thomas (38)              | 2013 | Kenya        | 93                                     | 9.2 (4.5-17.6)               |                  |                  |  |
| Minani et al. (53)       | 2021 | Burundi      | 496                                    | 15.5 (12.4–19)               |                  |                  |  |
| Mkupasi et al. (54)      | 2011 | Tanzania     | 731                                    |                              | 5.9 (4.3–7.8)    |                  |  |
| Mushonga et al. (55)     | 2018 | Rwanda       | 984 <sup>LE</sup> /1,720 <sup>MI</sup> | 3.86 (2.7-5.2)               | 9.2 (7.9–10.7)   |                  |  |
| Mutua et al. (56)        | 2007 | Kenya        | 505                                    | 6.5 (4.5–9.1)                |                  |                  |  |
| Newell et al. (57)       | 1997 | Burundi      | 81                                     |                              | 16 (8.8–25.9)    |                  |  |
| Ngowi et al. (23)        | 2010 | Tanzania     | 784                                    | 7.3 (5.5–9.3)                |                  |                  |  |
| Ngowi et al. (58)        | 2004 | Tanzania     | 770                                    | 17.4 (14.8–20.3)             |                  |                  |  |
| Ngowi et al. (59)        | 2004 | Tanzania     | 70                                     | 0 (0–0.5)                    |                  |                  |  |
| Phiri et al. (43)        | 2002 | Zambia       | 1,316 <sup>FB</sup>                    | 10.9 (9.2–12.7)              | 20.6 (18.4–22.9) |                  |  |
| Phiri et al. (43)        | 2002 | Zambia       | 249                                    | 6.4 (3.7–10.2)               |                  |                  |  |
| Phiri et al. (60)        | 2006 | Zambia       | 65                                     | 7.7 (2.5–17)                 | 18.5 (9.9–30)    | 47.7(35.1–60.5)  |  |
| Pondja et al. (14)       | 2010 | Mozambique   | 661                                    | 12.7 (10.3–15.5)             |                  |                  |  |
| Porphyre et al. (61)     | 2015 | Madagascar   | 68,432 <sup>FB</sup>                   |                              | 4.7 (4.5-4.8)    |                  |  |
| Shonyelaet al. (47)      | 2017 | Tanzania     | 698                                    | 6.3 (4.6-8.4)                |                  |                  |  |
| Sikasunge et al. (48)    | 2007 | Zambia       | 800                                    | 18.8 (16.1–21.6)             |                  |                  |  |
| Sikasunge et al. (49)    | 2008 | Zambia       | 1,691                                  | 10.8 (9.4–12.4)              |                  |                  |  |
| Thomas et al. (17)       | 2016 | Kenya        | 343                                    | 5.5 (3.4-8.5)                |                  |                  |  |
| Yohana et al. (62)       | 2013 | Tanzania     | 308                                    | 7.5 (4.8–11)                 |                  |                  |  |
| Zirintunda and Ekou (63) | 2015 | Uganda       | 178                                    |                              | 18 (12.6–24.4)   |                  |  |

YOP, Year of publication; PCC, porcine cysticercosis; CI, Confidence Interval; LE, Lingual examination; MI, Meat inspection; CD, Carcass dissection; FB, facility-based study.

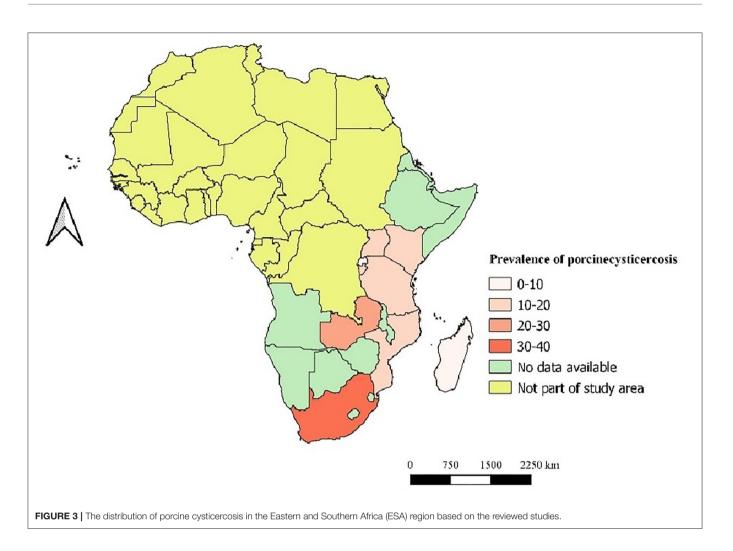
obtained from 18 countries/territories. At the regional level, South Africa is the country with the highest average prevalence range (30–40%), whereas Rwanda and Madagascar reported lower average prevalence (0–10%). Zambia reported the highest point prevalence (57%), whereas the lowest point prevalence (0%) was reported from Tanzania. Similarly, high prevalence variation was observed within-country reports which are evident with a wide 95% confidence interval in South Africa and Zambia, and the presence of outlier values in Tanzania, Mozambique, and Kenya (**Figure 4**).

The overall pooled prevalence estimate of porcine cysticercosis in the ESA region was 17% (95%CI: 14–20%) (**Figure 5**). The sensitivity analysis was performed to examine the influence of a single study on the overall estimate and omitting a single study in the analysis did not show a significant impact on the overall estimates (**Supplementary Material 2**). The calculated Cochran Chi-square value (Q statistic) (P < 0.001) and the inverse variance index value ( $I^2$ ) of 98.99% indicate a high degree of heterogeneity among the reports (**Figure 5**). Moreover, the funnel plot analysis showed the

significant effect of small studies (p < 0.005) and the presence of publication bias (**Supplementary Material 3**).

Since the overall prevalence estimate showed high variation among the reports, a subgroup analysis was performed based on the country, the types of diagnostic technique, and the region (Eastern and Southern). The results of the sub-group analysis are presented in a forest plot in **Figure 6** and **Supplementary Material 4**.

The meta-analysis sub-grouped by the diagnostic test showed the pooled prevalence estimate of 27% (95% CI: 9–50) for studies employing carcass dissection, 23% (95% CI:14–33) for studies that used Antibody-based immunodiagnostic techniques, 23% (95% CI: 18–29) for those employing Ag-ELISA, 12% (95% CI: 7–18) using meat inspection, and 9% (95% CI: 7–11) by lingual examination. The meta-analysis sub-grouped by region showed a relative difference in the pooled prevalence estimate, which is higher for the Southern region with 22% (95% CI: 15– 30) compared to 13% (95% CI: 11–15) for the Eastern region. The sub-grouped prevalence based on country estimated the highest pooled prevalence from South Africa (33%, 95% CI:



20–48) and Zambia (22%, 95% CI: 16–29). Burundi, Uganda, and Mozambique reported a 15% pooled prevalence (within 95% CI range of 6–26%), followed by Kenya at 13% (95% CI: 7–21) and Tanzania at 12% (95% CI: 9–16). Madagascar (5%, 95% CI: 4– 5) and Rwanda (7%, 95% CI: 6–8) reported the lowest pooled prevalence (**Supplementary Material 4**). The high I<sup>2</sup> values (> 97%) for each of the subgroup analyses indicate a high degree of heterogeneity between studies applying a similar methodology, within and among countries, and sub-regions.

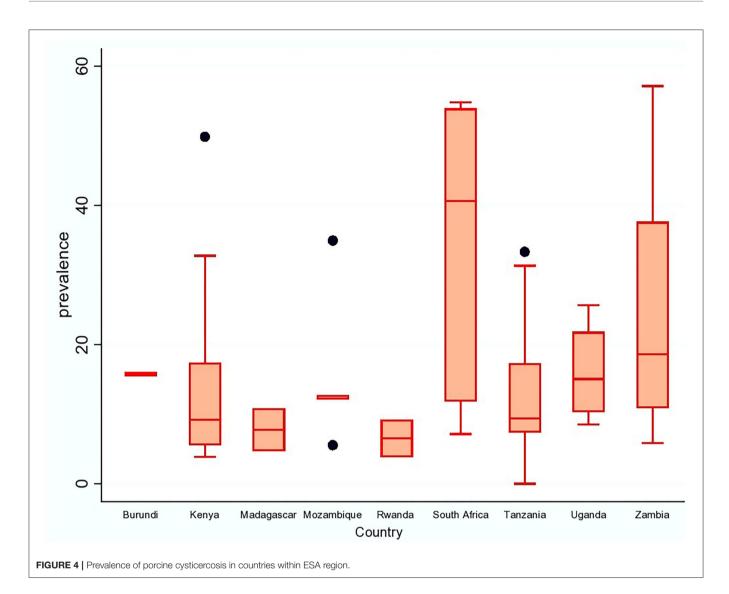
Thirteen articles out of the 44 selected studies reported statistically significant risk factors for the occurrence of porcine cysticercosis. To be significantly associated with porcine cysticercosis in ESA, the identified risk factors were as follows: lack of latrine at household level (n = 6); keeping free-range pigs (n = 5); semi-confined pig management (n = 2); home-slaughter (n = 2); unprotected water source (water obtained from rivers, streams, wells, lakes, ponds, and so on) (n = 3), and older age of pigs (n = 3). The pooled OR of 2.4 was recorded for keeping free-range pigs with low heterogeneity ( $I^2 = 55.7\%$ , p = 0.06), an OR of 2 was recorded for lack of latrine at household level with no heterogeneity ( $I^2 = 0\%$ , p = 0.72), showing homogeneity among reports. The  $I^2$  values for old

age and semi-confined pig management system showed higher heterogeneity I<sup>2</sup> >72.9 (p < 0.05). The summary of the pooled OR between the studied variables and porcine cysticercosis is shown in **Figure 7**.

### DISCUSSION

The present study aimed to review 24 years of published literature on the epidemiology of porcine cysticercosis in the ESA region. Out of 27 countries/territories studied, records that met the eligibility criteria were obtained from only nine countries. However, the absence of data for some countries does not exclude the possibility that this parasite is present there. The distribution of TSTC in SSA was reported as not well-documented and under-reported (15, 38).

The overall pooled prevalence of porcine cysticercosis based on the included studies was 17% (95% CI: 14–20%). Despite the poor diagnostic accuracy of tests used in most of the included studies, the presumptive investigation of the primary studies suggests the presence of *T. solium* in the region. Africa is one of the regions conducive for maintaining the full cycle of *T. solium* because of the favorable conditions and other factors



associated with poverty (23). The seroprevalence of *T.solium* taeniasis and human cysticercosis in Africa have been estimated to be 0-17.25% and 0.68-34.5%, respectively (16).

This review identified high variability in the prevalence of porcine cysticercosis between and within countries ranging from 0 to 57%. In country-based sub-group analysis of the ESA region, the highest pooled prevalence (33%, 95% CI: 20-48) was obtained from South Africa. Based on the data obtained from Food and Agriculture Organization Corporate Statistical Database (FAOSTAT), the country is among the top countries in ESA in terms of the number of pigs between 1997 and 2019 (64). Though the traditional free-range system is only practiced in poor areas of South Africa, the prevalence of TSTC is reported as the highest from SSA (35). Zambia is identified with the highest point prevalence of porcine cysticercosis (57%), and the second one in terms of pooled prevalence (22%), which is comparable with a report by Shonyela et al. (24.32%) (65). In Zambia, open defecation has been reported as a public health problem (37, 66), particularly in rural areas, where the prevalence of open defecation is reported to be 17% (67).

The subgroup prevalence for Burundi, Uganda, and Mozambique was 15% (within 95% CI range of 6%-26%), followed by Kenya at 13% (95% CI: 7-21) and Tanzania 12% (95% CI: 9-16) (Supplementary Material 4). According to FAOSTAT data (64), Uganda is among the countries that have the largest pig population in Africa, most of which are raised under the traditional husbandry system (42). The country has also the highest per capita consumption of pork in SSA (63). Mozambique is among the countries with the highest prevalence of open defecation at 40%, compared to countries included in this review (67). The pooled prevalence for Kenya and Tanzania were comparable to each other but lower than that reported by Shonyela et al., at 22% (65). The lowest pooled prevalence was recorded in Madagascar (5%) and Rwanda (7%). Madagascar is one of the WHO selected countries for piloting T. solium control (68).

A subgroup analysis by region revealed a relatively higher pooled prevalence in the Southern region at 22% (95% CI: 15– 30), compared to 13% (95% CI: 11–15) in the Eastern region. The high variation on the pooled and sub-group prevalence

| Chembersofu et al., 2017       0.08 (0.24, 0.44)       1.35         Shoryela et al., 2017       0.08 (0.24, 0.44)       1.51         Shoryela et al., 2017       0.08 (0.24, 0.46)       1.51         Shoryela et al., 2017       0.08 (0.24, 0.46)       1.51         Shoryela et al., 2020       0.07 (0.36, 0.08)       1.51         Shorye et al., 2010       0.07 (0.36, 0.08)       1.51         Yehna et al., 2013       0.07 (0.26, 0.04)       1.51         Yehna et al., 2013       0.07 (0.26, 0.11)       1.58         Xoke et al., 2019       0.08 (0.04, 0.11)       1.50         Korbulut et al., 2013       0.09 (0.07, 0.11)       1.51         Korbulut et al., 2020b       0.09 (0.07, 0.11)       1.59         Makonga et al., 2013       0.09 (0.07, 0.11)       1.50         Kabulut et al., 2002       0.01 (0.09, 0.12)       1.52         Privi et al., 2005       0.11 (0.09, 0.12)       1.52         Privi et al., 2015       0.11 (0.09, 0.13)       1.52         Privi et al., 2017       0.13 (0.09, 0.77)       1.48         Mabourget et al., 2017       0.13 (0.09, 0.77)       1.48         Mabourget et al., 2017       0.11 (0.09, 0.13)       1.52         Privi et al., 2017       0.11 (0.09, 0.17)       1.4  | Study                            | ES (95% CI)         | %<br>Weight |
|--|----------------------------------|---------------------|-------------|
| Weshongs et al., 2018         0.04 (0.03, 0.05)         1.51           Yguhu et al., 2017         0.06 (0.02, 0.07)         1.48           Yguhu et al., 2017         0.06 (0.02, 0.07)         1.48           Pondja et al., 2017         0.06 (0.02, 0.07)         1.48           Pondja et al., 2017         0.06 (0.02, 0.07)         1.49           Pondja et al., 2017         0.06 (0.02, 0.07)         1.49           Pondja et al., 2017         0.06 (0.02, 0.03)         1.49           Shonyow et al., 2007         0.06 (0.02, 0.03)         1.51           Witta et al., 2007         0.07 (0.05, 0.00)         1.59           Shonyow et al., 2003         0.07 (0.05, 0.00)         1.59           Witta et al., 2006         0.08 (0.00, 0.13)         1.49           Witta et al., 2008         0.06 (0.00, 0.13)         1.49           Waiswa et al., 2008         0.06 (0.06, 0.13)         1.49           Waiswa et al., 2018         0.06 (0.08, 0.11)         1.59           Shonyow et al., 2018         0.06 (0.08, 0.13)         1.49           Waiswa et al., 2018         0.06 (0.08, 0.13)         1.49           Waiswa et al., 2018         0.06 (0.08, 0.11)         1.59           Shonyow et al., 2015         0.11 (0.09, 0.13)         1.59   | Ngowi et al., 2004b              | 0.00 (0.00, 0.05)   | 1.36        |
| Ngubuic et al., 2017         0.04 (0.02, 0.07)         1.48           Prophyse et al., 2016         0.06 (0.05, 0.05)         1.53           Thormas et al., 2017         0.06 (0.04, 0.06)         1.41           Shorpal et al., 2017         0.06 (0.04, 0.06)         1.41           Shorpal et al., 2017         0.06 (0.04, 0.06)         1.51           Shorpal et al., 2017         0.06 (0.04, 0.06)         1.51           Shorpal et al., 2017         0.07 (0.05, 0.06)         1.57           Shorpal et al., 2010         0.07 (0.05, 0.06)         1.57           Shorpal et al., 2010         0.07 (0.05, 0.06)         1.51           Shorpal et al., 2010         0.07 (0.05, 0.06)         1.51           Shorpal et al., 2018         0.07 (0.05, 0.06)         1.51           Shorpal et al., 2019         0.07 (0.05, 0.11)         1.51           Kabulub et al., 2018         0.06 (0.07, 0.11)         1.51           Kabulub et al., 2018         0.06 (0.07, 0.11)         1.52           Bas et al., 2018         0.06 (0.08, 0.11)         1.52           Shorpal et al., 2018         0.06 (0.08, 0.11)         1.52           Shorpal et al., 2017         0.06 (0.08, 0.11)         1.52           Shorpal et al., 2018         0.06 (0.08, 0.11)         1.52     <   | Mushonga et al., 2018            |                     |             |
| Dephyse et al., 2015         0.05 (0.05, 0.05)         1.53           Pondja et al., 2017         0.06 (0.03, 0.06)         1.49           Pondja et al., 2017         0.06 (0.02, 0.13)         1.41           Demberson et al., 2017         0.06 (0.02, 0.13)         1.41           Shonyale at al., 2017         0.06 (0.02, 0.13)         1.41           Shonyale at al., 2017         0.06 (0.02, 0.13)         1.51           Shonyale at al., 2017         0.06 (0.04, 0.08)         1.51           Shonyale at al., 2017         0.06 (0.04, 0.08)         1.51           Shonyale at al., 2013         0.07 (0.05, 0.11)         1.48           Shonyale at al., 2013         0.07 (0.05, 0.11)         1.49           Shonyale at al., 2013         0.07 (0.05, 0.11)         1.49           Washonya at al., 2013         0.06 (0.07, 0.11)         1.51           Shonyale at al., 2013         0.06 (0.07, 0.11)         1.51           Kashonya at al., 2013         0.06 (0.07, 0.11)         1.52           Shonyale at al., 2013         0.06 (0.08, 0.13)         1.48           Shonyale at al., 2018         0.11 (0.07, 0.16)         1.45           Shonyale at al., 2018         0.11 (0.07, 0.16)         1.45           Shonyale at al., 2017         0.12 (0.07, 0.16) <t< td=""><td></td><td></td><td></td></t<>  |                                  |                     |             |
| Thermas et al., 2016         0.06 (0.02, 0.12)         1.41           Sahlera et al., 2012         0.07         0.08 (0.02, 0.12)         1.41           Waipagi et al., 2017         0.08 (0.04, 0.08)         1.51           Shoryela et al., 2017         0.08 (0.04, 0.08)         1.51           Shoryela et al., 2007         0.06 (0.04, 0.08)         1.51           Shoryela et al., 2007         0.07 (0.03, 0.03)         1.41           Shoryela et al., 2007         0.07 (0.03, 0.03)         1.41           Chana et al., 2008         0.07 (0.03, 0.01)         1.41           Chana et al., 2013         0.07 (0.06, 0.01)         1.41           Shoryee at al., 2013         0.08 (0.06, 0.12)         1.49           Vaiswa et al., 2019         0.08 (0.06, 0.12)         1.49           Vaiswa et al., 2018         0.09 (0.06, 0.13)         1.48           Mushorga et al., 2018         0.09 (0.08, 0.11)         1.52           Shoryee at al., 2018         0.09 (0.08, 0.11)         1.52           Shoryee at al., 2018         0.09 (0.08, 0.11)         1.52           Shoryee at al., 2016         0.09 (0.08, 0.11)         1.52           Shoryee at al., 2017         0.11 (0.09, 0.13)         1.49           Shoryee at al., 2017         0.11 (0.09, 0.15)   |                                  |                     |             |
| Pendja et al., 2015 Eshitera et al., 2017 Compared at al., 2017 Eshitera et al., 2017 Compared at al., 2018 Compared al., 2018 Compared at al., 2017 Compared at al., 2018 Compa   |                                  |                     |             |
| Eshiera et al., 2012<br>Dempéndiu et al., 2017<br>Mupasi et al., 2017<br>Mupasi et al., 2017<br>Mutus et al., 2007<br>Mutus et al., 2010<br>Yohan et al., 2013<br>Prinri et al., 2008<br>Muschenga et al., 2018<br>Muschenga et al., 2018<br>Shasaunge et al., 2008<br>Mutus et al., 2015<br>Prinri et al., 2008<br>Mutus et al., 2017<br>Mutus et al., 2018<br>Base et al., 2018<br>Muschenga et al., 2008<br>Muschenga et al., 2008<br>Muschenga et al., 2018<br>Muschenga et al., 2018<br>Muschenga et al., 2008<br>Muschenga et al., 2008<br>Muschenga et al., 2017<br>Porphyre et al., 2017<br>Muschenga et al., 2018<br>Muschenga et al., 2018<br>Muschenga et al., 2018<br>Muschenga et al., 2017<br>Porphyre et al., 2018<br>Muschenga et al., 2017<br>Porphyre et al., 2017<br>Porphyre et al., 2018<br>Muschenga et al., 2017<br>Porphyre et al., 2017<br>Porphyre et al., 2018<br>Muschenga et al., 2017<br>Porphyre et al., 2017<br>Porphyre et al., 2018<br>Porphyre et al., 2017<br>Porphyre et al., 2018<br>Porphyre et al., 2019<br>Porphyre et al., 2018<br>Porphyre et al., 2018<br>Porphyre et al., 2019<br>Porphyre et al., 2017<br>Porphyre et al., 2018<br>Porphyre et al., 2017<br>Porphyre et al., 2018<br>Porp   |                                  |                     |             |
| Chembersofu et al., 2017       0.08 (0.24, 0.44)       1.35         Shoryela et al., 2017       0.08 (0.24, 0.44)       1.51         Shoryela et al., 2017       0.08 (0.24, 0.46)       1.51         Shoryela et al., 2017       0.08 (0.24, 0.46)       1.51         Shoryela et al., 2020       0.07 (0.36, 0.08)       1.51         Shorye et al., 2010       0.07 (0.36, 0.08)       1.51         Yehna et al., 2013       0.07 (0.26, 0.04)       1.51         Yehna et al., 2013       0.07 (0.26, 0.11)       1.58         Xoke et al., 2019       0.08 (0.04, 0.11)       1.50         Korbulut et al., 2013       0.09 (0.07, 0.11)       1.51         Korbulut et al., 2020b       0.09 (0.07, 0.11)       1.59         Makonga et al., 2013       0.09 (0.07, 0.11)       1.50         Kabulut et al., 2002       0.01 (0.09, 0.12)       1.52         Privi et al., 2005       0.11 (0.09, 0.12)       1.52         Privi et al., 2015       0.11 (0.09, 0.13)       1.52         Privi et al., 2017       0.13 (0.09, 0.77)       1.48         Mabourget et al., 2017       0.13 (0.09, 0.77)       1.48         Mabourget et al., 2017       0.11 (0.09, 0.13)       1.52         Privi et al., 2017       0.11 (0.09, 0.17)       1.4  |                                  |                     |             |
| Shoriyela et al., 2017       0.06 (0.04, 0.05) (0.05) (0.07)         Mutua et al., 2007       0.07 (0.05, 0.09)       1.50         Shorayee at al., 2020       0.07 (0.05, 0.09)       1.50         Shorayee at al., 2013       0.07 (0.05, 0.01)       1.41         Phiri et al., 2008       0.07 (0.05, 0.01)       1.48         Yohan et al., 2013       0.07 (0.05, 0.12)       1.49         Yohan et al., 2009       0.08 (0.03, 0.12)       1.49         Yohan et al., 2019       0.09 (0.06, 0.11)       1.51         Gomba et al., 2013       0.09 (0.06, 0.11)       1.51         Shorayee at J., 2018       0.09 (0.06, 0.11)       1.52         Shorayee at J., 2018       0.09 (0.06, 0.11)       1.52         Shaaunge et J., 2008       0.11 (0.09, 0.12)       1.52         Porphyre et al., 2015       0.11 (0.09, 0.12)       1.52         Shaaunge et J., 2007       0.11 (0.09, 0.13)       1.52         Shabulu et Al., 2017       0.12 (0.07, 0.19)       1.43         Shuaung et J., 2017       0.12 (0.07, 0.19)       1.43         Porhyre et Al., 2017       0.12 (0.07, 0.19)       1.43         Shuaung et J., 2017       0.13 (0.10, 0.15)       1.51         Porhyre et Al., 2017       0.13 (0.10, 0.15)       1.51 <td></td> <td></td> <td></td>  |                                  |                     |             |
| Phiri et al., 2002       0.06 (0.04, 0.10)       1.47         Witua et al., 2020       0.07 (0.05, 0.09)       1.50         Shongwe et al., 2010       0.07 (0.05, 0.09)       1.50         Cohana et al., 2013       0.08 (0.03, 0.13)       1.43         Kongwe et al., 2020a       0.08 (0.06, 0.12)       1.49         Maiswa et al., 2019       0.09 (0.07, 0.11)       1.50         Ackco et al., 2013       0.09 (0.07, 0.11)       1.50         Ackco et al., 2013       0.09 (0.07, 0.11)       1.50         Abcko et al., 2016       0.09 (0.07, 0.11)       1.50         Mushonga et al., 2016       0.09 (0.07, 0.11)       1.52         Space tal., 2016       0.09 (0.07, 0.13)       1.52         Space tal., 2016       0.09 (0.07, 0.13)       1.52         Stasunge et al., 2015       0.11 (0.09, 0.13)       1.52         Prinri et al., 2002a       0.11 (0.09, 0.13)       1.52         Abuluid et al., 2015       0.11 (0.09, 0.13)       1.52         Stasunge et al., 2017       0.13 (0.10, 0.17)       1.51         Prinri et al., 2016       0.11 (0.09, 0.15)       1.50         Abuluid et al., 2017       0.13 (0.10, 0.15)       1.51         Prinri et al., 2004       0.13 (0.10, 0.15)       1.51   | Mkupasi et al., 2011             |                     |             |
| Mutua et al., 2007         0.07 (0.05, 0.05)         1.50           Shongwe et al., 2010         0.07 (0.03, 0.04)         1.51           Optimite tal., 2016         0.07 (0.05, 0.05)         1.51           Shongwe et al., 2013         0.07 (0.05, 0.05)         1.51           Shubilui et al., 2020         0.08 (0.06, 0.09)         1.51           Shubilui et al., 2020         0.08 (0.06, 0.12)         1.43           Shubilui et al., 2013         0.09 (0.07, 0.11)         1.50           Shabului et al., 2018         0.09 (0.08, 0.11)         1.52           Shabului et al., 2018         0.09 (0.08, 0.11)         1.52           Shabului et al., 2016         0.11 (0.07, 0.13)         1.48           Wushong at al., 2016         0.11 (0.07, 0.13)         1.48           Shabului et al., 2016         0.11 (0.07, 0.13)         1.42           Shabului et al., 2017         0.11 (0.07, 0.13)         1.42           Shabului et al., 2017         0.12 (0.08, 0.17)         1.48           Matos et al., 2017         0.12 (0.08, 0.17)         1.48           Shabului et al., 2017         0.13 (0.09, 0.17)         1.48           Pandja et al., 2017         0.13 (0.09, 0.17)         1.48           Shabului et al., 2017         0.13 (0.10, 0.15)         1.51 <td></td> <td></td> <td></td>   |                                  |                     |             |
| Shongwe et al., 2020       0.07 (0.03, 0.13)       1.43         Yoowi et al., 2013       0.07 (0.06, 0.09)       1.51         Yini et al., 2003       0.08 (0.03, 0.17)       1.48         Kabululu et al., 2010a       0.08 (0.03, 0.17)       1.48         Kabululu et al., 2010a       0.08 (0.07, 0.11)       1.49         Acko et al., 2013       0.09 (0.07, 0.11)       1.50         Kabululu et al., 2016       0.09 (0.08, 0.11)       1.52         San et al., 2016       0.11 (0.09, 0.13)       1.48         Mushonga et al., 2015       0.11 (0.09, 0.13)       1.52         San et al., 2015       0.11 (0.09, 0.13)       1.52         Schululu et al., 2017       0.12 (0.07, 0.19)       1.43         Vatos et al., 2014       0.12 (0.07, 0.19)       1.43         Vatos et al., 2015       0.11 (0.09, 0.13)       1.52         Yatos et al., 2017       0.12 (0.07, 0.19)       1.43         Vatos et al., 2017       0.13 (0.06, 0.17)       1.48         Yatos et al., 2017       0.13 (0.06, 0.17)       1.48   |                                  |                     |             |
| Ngowie tal., 2010         0.07 (0.06, 0.09)         1.51           Phirie tal., 2003         0.07 (0.06, 0.09)         1.51           Phirie tal., 2004         0.08 (0.03, 0.17)         1.35           Kabuluk at al., 2013         0.08 (0.06, 0.12)         1.48           Valawa et al., 2013         0.09 (0.06, 0.12)         1.49           Walswa et al., 2013         0.09 (0.06, 0.13)         1.51           Kabuluk et al., 2020b         0.09 (0.06, 0.13)         1.48           Walswa et al., 2018         0.09 (0.06, 0.13)         1.48           Boa et al., 2018         0.09 (0.06, 0.13)         1.49           Skasunge et al., 2015         0.11 (0.07, 0.16)         1.45           Frinr et al., 2015         0.11 (0.07, 0.16)         1.45           Kabuluk et al., 2017         0.11 (0.07, 0.16)         1.45           Matos et al., 2017         0.12 (0.07, 0.16)         1.48           Matos et al., 2017         0.13 (0.10, 0.15)         1.51           Denny et al., 2017         0.13 (0.10, 0.15)         1.51           Denny et al., 2017         0.13 (0.10, 0.16)         1.51           Denny et al., 2017         0.13 (0.10, 0.16)         1.51           Denny et al., 2017         0.13 (0.10, 0.16)         1.51 <td< td=""><td></td><td></td><td></td></td<>   |                                  |                     |             |
| Chana et al., 2013       0.07 (0.05, 0.11)       1.48         Phini et al., 2020a       0.08 (0.03, 0.17)       1.35         Kabululu et al., 2020a       0.09 (0.06, 0.12)       1.40         Waiswa et al., 2019       0.09 (0.06, 0.11)       1.50         Kack et al., 2019       0.09 (0.06, 0.11)       1.50         Kack et al., 2018       0.09 (0.06, 0.11)       1.52         Boa et al., 2008       0.11 (0.09, 0.12)       1.52         Phini et al., 2013       0.11 (0.09, 0.12)       1.52         Skasunge et al., 2008       0.11 (0.09, 0.12)       1.52         Porphyre et al., 2015       0.11 (0.09, 0.13)       1.52         Koceke t al., 2008       0.11 (0.09, 0.15)       1.52         Koceke t al., 2007       0.11 (0.09, 0.15)       1.52         Koceke t al., 2017       0.12 (0.07, 0.19)       1.48         Matos et al., 2017       0.13 (0.10, 0.15)       1.51         Pondig et al., 2017       0.13 (0.10, 0.15)       1.51         Porny et al., 2014       0.13 (0.10, 0.15)       1.51         Matos et al., 2017       0.13 (0.10, 0.15)       1.51         Porny et al., 2014       0.13 (0.10, 0.15)       1.51         Matos et al., 2015       0.17 (0.10, 0.26)       1.40   |                                  |                     |             |
| Phini et al., 2006 Kabululu et al., 2017 Maiswa et al., 2019 Maiswa et al., 2019 Maiswa et al., 2019 Koko et al., 2013 Kobululu et al., 2013 Kobululu et al., 2016 Maiswa et al., 2018 Mushonga et al., 2015 Print et al., 2020 Mushonga et al., 2017 Mushonga et al., 2017 Mushonga et al., 2017 Print et al., 2024 Mushonga et al., 2017 Mushonga et al., 2017 Print et al., 2024 Mushonga et al., 2017 Print et al., 2024 Mushonga et al., 2017 Print et al., 2024 Mushonga et al., 2017 Mushonga et al., 2017 Print et al., 2024 Mushonga et al., 2017 Mushonga et al., 2017 Mushonga et al., 2017 Mushonga et al., 2017 Print et al., 2024 Mushonga et al., 2017 Mushonga et al   |                                  |                     |             |
| Waiswa et al., 2009       0.09 (0.06, 0.11)       1.50         Korbo et al., 2013       0.09 (0.07, 0.11)       1.51         Komba et al., 2013       0.09 (0.07, 0.11)       1.50         Mushenga et al., 2018       0.09 (0.08, 0.11)       1.52         Boa et al., 2006       0.09 (0.08, 0.11)       1.52         Thomas, 2013       0.10 (0.05, 0.18)       1.49         Skasunge et al., 2006       0.11 (0.09, 0.15)       1.52         Phin et al., 2002a       0.11 (0.09, 0.15)       1.50         Kabululu et al., 2015       0.11 (0.09, 0.15)       1.50         Kreek et al., 2001       0.12 (0.08, 0.16)       1.48         Kungu et al., 2017       0.12 (0.09, 0.17)       1.48         Porny et al., 2017       0.13 (0.09, 0.17)       1.48         Porny et al., 2017       0.13 (0.09, 0.17)       1.48         Porny et al., 2014       0.14 (0.10, 0.16)       1.51         Phin et al., 20102       0.14 (0.10, 0.16)       1.51         Print et al., 2014       0.14 (0.10, 0.26)       1.40         Print et al., 2015       0.17 (0.10, 0.26)       1.40         Print et al., 2014       0.16 (0.13, 0.24)       1.40         Madrop et al., 2015       0.17 (0.10, 0.26)       1.40 <t< td=""><td></td><td></td><td>1.35</td></t<>  |                                  |                     | 1.35        |
| Akcko et al., 2019       0.09 (0.07, 0.11)       1.51         Komba et al., 2013       0.09 (0.07, 0.11)       1.59         Kabululu et al., 2020b       0.09 (0.08, 0.11)       1.52         Boa et al., 2018       0.09 (0.08, 0.11)       1.52         Boa et al., 2013       0.09 (0.08, 0.11)       1.52         Boa et al., 2016       0.11 (0.09, 0.12)       1.52         Perphyre et al., 2015       0.11 (0.09, 0.12)       1.52         Print et al., 2002a       0.11 (0.06, 0.13)       1.52         Kabululu et al., 2017       0.12 (0.07, 0.16)       1.45         Pondja et al., 2017       0.12 (0.07, 0.16)       1.45         Pondja et al., 2017       0.13 (0.09, 0.17)       1.48         Pondja et al., 2017       0.13 (0.09, 0.17)       1.48         Domy et al., 2004       0.13 (0.10, 0.16)       1.51         Domy et al., 2014       0.13 (0.10, 0.16)       1.51         Minani et al., 2017       0.16 (0.09, 0.26)       1.38         Mackard et al., 2017       0.16 (0.09, 0.26)       1.40         Minani et al., 2017       0.13 (0.10, 0.16)       1.51         Domy et al., 2014       0.17 (0.10, 0.26)       1.40         Mackard et al., 2015       0.17 (0.10, 0.26)       1.40   |                                  |                     |             |
| Komba et al., 2013       0.09 (0.07, 0.11)       1.50         Kabululu et al., 2018       0.09 (0.08, 0.11)       1.52         Bas et al., 2008       0.10 (0.05, 0.18)       1.40         Porphyre et al., 2015       0.11 (0.07, 0.16)       1.45         Porphyre et al., 2017       0.11 (0.09, 0.12)       1.52         Kabululu et al., 2017       0.11 (0.09, 0.15)       1.52         Kabululu et al., 2017       0.12 (0.07, 0.19)       1.43         Kabululu et al., 2017       0.12 (0.07, 0.19)       1.43         Kabululu et al., 2017       0.12 (0.07, 0.19)       1.43         Porphyre et al., 2010       0.13 (0.08, 0.16)       1.48         Matos et al., 2017       0.12 (0.07, 0.19)       1.43         Chuidon et al., 2017       0.13 (0.08, 0.17)       1.48         Domy et al., 2010       0.13 (0.08, 0.17)       1.48         Domy et al., 2014       0.13 (0.09, 0.17)       1.49         Domy et al., 2014       0.16 (0.10, 0.15)       1.51         Maran et al., 2017       0.13 (0.09, 0.17)       1.48         Nadrog et al., 2016       1.40       1.51         Maran et al., 2017       0.16 (0.12, 0.19)       1.50         Nadrog et al., 2015       0.17 (0.10, 0.26)       1.40  |                                  |                     |             |
| Kabululu et al., 2020b       0.09 (0.08, 0.13)       1.48         Mushonga et al., 2018       0.09 (0.08, 0.11)       1.52         Boa et al., 2008       0.10 (0.05, 0.18)       1.40         Sikasunge et al., 2015       0.11 (0.07, 0.16)       1.45         Porphyre et al., 2015       0.11 (0.09, 0.12)       1.52         Kabululu et al., 2015       0.11 (0.09, 0.13)       1.52         Kabulu et al., 2017       0.12 (0.07, 0.16)       1.48         Kungu et al., 2017       0.12 (0.07, 0.19)       1.43         Kungu et al., 2017       0.13 (0.09, 0.17)       1.48         Porny et al., 2010       0.13 (0.09, 0.17)       1.48         Porny et al., 2014       0.13 (0.09, 0.17)       1.48         Porny et al., 2017       0.13 (0.10, 0.15)       1.51         Phint et al., 2004       0.13 (0.10, 0.15)       1.51         Porny et al., 2014       0.13 (0.10, 0.16)       1.47         Porny et al., 2014       0.13 (0.10, 0.16)       1.51         Wardrop et al., 2014       0.16 (0.09, 0.22)       1.38         Wardrop et al., 2015       0.17 (0.10, 0.26)       1.40         Nardrop et al., 2019       0.17 (0.10, 0.26)       1.40         Maganira et al., 2017       0.18 (0.10, 0.27)       1.39     <   |                                  |                     |             |
| Mushenga et al., 2018       0.09 (0.88, 0.11)       1.52         Boa et al., 2008       0.09 (0.88, 0.11)       1.52         Fhomas, 2013       0.10 (0.05, 0.18)       1.40         Sikasunge et al., 2008       0.11 (0.09, 0.12)       1.52         Porphyre et al., 2015       0.11 (0.09, 0.13)       1.52         Kabululu et al., 2017       0.11 (0.09, 0.15)       1.50         Kreeck et al., 2017       0.12 (0.07, 0.16)       1.48         Pondja et al., 2017       0.12 (0.07, 0.16)       1.48         Child cold et al., 2017       0.13 (0.09, 0.17)       1.48         Pondja et al., 2010       0.13 (0.10, 0.15)       1.51         Demy et al., 2014       0.13 (0.10, 0.15)       1.51         Minario et al., 2012       0.14 (0.10, 0.10)       1.51         Minario et al., 2014       0.16 (0.12, 0.10)       1.61         Minario et al., 2015       0.17 (0.10, 0.20)       1.40         Thomas, 2013       0.17 (0.10, 0.20)       1.40         Maganira et al., 2015       0.17 (0.10, 0.20)       1.40         Minario et al., 2017       0.18 (0.10, 0.27)       1.39         Nordrop et al., 2015       0.17 (0.14, 0.22)       1.51         Phiri et al., 2016       0.17 (0.14, 0.22)       1.51   |                                  |                     |             |
| Baa et al., 2006<br>Thomas, 2013<br>Shasunge et al., 2015<br>Print et al., 2015<br>Kreeck et al., 2015<br>Kreeck et al., 2017<br>Chilundo et al., 2014<br>Chilundo et al., 2014<br>Chilundo et al., 2014<br>Chilundo et al., 2015<br>Chilundo et al., 2015<br>Chilundo et al., 2019<br>Chilundo et al., 2014<br>Chilundo et al., 2017<br>Chilundo et al., 2018<br>Chilundo et al., 2019<br>Chilundo et al., 2014<br>Chilundo et al., 2017<br>Chilundo et al., 2014<br>Chilundo et al., 2017<br>Chilundo et al., 2014<br>Chilundo et al., 2017<br>Chilundo et al., 2014<br>Chilundo et al., 2014<br>Chilundo et al., 2017<br>Chilundo et al., 2014<br>Chilundo et al., 2017<br>Chilundo et al., 2014<br>Chilundo et al., 2014<br>Chilundo et al., 2017<br>Chilundo et al., 2014<br>Chilundo et al., 2017<br>Chilundo et al., 2014<br>Chilundo et al., 2017<br>Chilundo et al., 2018<br>Chilundo et al., 2017<br>Chilundo et al., 2017<br>Chilundo et al., 201   |                                  |                     |             |
| Kabululu et al., 2020a       0.19 (0.15, 0.24)       1.49         Phiri et al., 2002b       0.21 (0.18, 0.23)       1.52         Sikasunge et al., 2008       0.25 (0.22, 0.28)       1.51         Dorny et al., 2014       0.26 (0.21, 0.30)       1.49         Komba et al., 2013       0.26 (0.21, 0.30)       1.49         Eshitera et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2017       0.33 (0.28, 0.39)       1.48         Pondja et al., 2017       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2016       0.41 (0.35, 0.47)       1.48         Chembensofu et al., 2017       0.53 (0.440, 0.65)       1.35         Krecek et al., 2012d       0.54 (0.48, 0.60)       1.48         Krecek et al., 2012d       0.55 (0.49, 0.61)       1.48         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Dorny et al., 2004       0.57 (0.54, 0.60)   | Boa et al., 2006                 | 0.09 (0.08, 0.11)   |             |
| Kabululu et al., 2020a       0.19 (0.15, 0.24)       1.49         Phiri et al., 2002b       0.21 (0.18, 0.23)       1.52         Sikasunge et al., 2008       0.25 (0.22, 0.28)       1.51         Dorny et al., 2014       0.26 (0.21, 0.30)       1.49         Komba et al., 2013       0.26 (0.21, 0.30)       1.49         Eshitera et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2017       0.33 (0.28, 0.39)       1.48         Pondja et al., 2017       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2016       0.41 (0.35, 0.47)       1.48         Chembensofu et al., 2017       0.53 (0.440, 0.65)       1.35         Krecek et al., 2012d       0.54 (0.48, 0.60)       1.48         Krecek et al., 2012d       0.55 (0.49, 0.61)       1.48         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Dorny et al., 2004       0.57 (0.54, 0.60)   | Thomas, 2013                     | 0.10 (0.05, 0.18)   |             |
| Kabululu et al., 2020a       0.19 (0.15, 0.24)       1.49         Phiri et al., 2002b       0.21 (0.18, 0.23)       1.52         Sikasunge et al., 2008       0.25 (0.22, 0.28)       1.51         Dorny et al., 2014       0.26 (0.21, 0.30)       1.49         Komba et al., 2013       0.26 (0.21, 0.30)       1.49         Eshitera et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2017       0.33 (0.28, 0.39)       1.48         Pondja et al., 2017       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2016       0.41 (0.35, 0.47)       1.48         Chembensofu et al., 2017       0.53 (0.440, 0.65)       1.35         Krecek et al., 2012d       0.54 (0.48, 0.60)       1.48         Krecek et al., 2012d       0.55 (0.49, 0.61)       1.48         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Dorny et al., 2004       0.57 (0.54, 0.60)   | Sikasunge et al., 2008           | 0.11 (0.09, 0.12)   |             |
| Kabululu et al., 2020a       0.19 (0.15, 0.24)       1.49         Phiri et al., 2002b       0.21 (0.18, 0.23)       1.52         Sikasunge et al., 2008       0.25 (0.22, 0.28)       1.51         Dorny et al., 2014       0.26 (0.21, 0.30)       1.49         Komba et al., 2013       0.26 (0.21, 0.30)       1.49         Eshitera et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2017       0.33 (0.28, 0.39)       1.48         Pondja et al., 2017       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2016       0.41 (0.35, 0.47)       1.48         Chembensofu et al., 2017       0.53 (0.440, 0.65)       1.35         Krecek et al., 2012d       0.54 (0.48, 0.60)       1.48         Krecek et al., 2012d       0.55 (0.49, 0.61)       1.48         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Dorny et al., 2004       0.57 (0.54, 0.60)   | Porphyre et al., 2015            | 0.11 (0.07, 0.16)   |             |
| Kabululu et al., 2020a       0.19 (0.15, 0.24)       1.49         Phiri et al., 2002b       0.21 (0.18, 0.23)       1.52         Sikasunge et al., 2008       0.25 (0.22, 0.28)       1.51         Dorny et al., 2014       0.26 (0.21, 0.30)       1.49         Komba et al., 2013       0.26 (0.21, 0.30)       1.49         Eshitera et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2017       0.33 (0.28, 0.39)       1.48         Pondja et al., 2017       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2016       0.41 (0.35, 0.47)       1.48         Chembensofu et al., 2017       0.53 (0.440, 0.65)       1.35         Krecek et al., 2012d       0.54 (0.48, 0.60)       1.48         Krecek et al., 2012d       0.55 (0.49, 0.61)       1.48         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Dorny et al., 2004       0.57 (0.54, 0.60)   | Phiri et al., 2002a              | 0.11 (0.09, 0.13)   |             |
| Kabululu et al., 2020a       0.19 (0.15, 0.24)       1.49         Phiri et al., 2002b       0.21 (0.18, 0.23)       1.52         Sikasunge et al., 2008       0.25 (0.22, 0.28)       1.51         Dorny et al., 2014       0.26 (0.21, 0.30)       1.49         Komba et al., 2013       0.26 (0.21, 0.30)       1.49         Eshitera et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2017       0.33 (0.28, 0.39)       1.48         Pondja et al., 2017       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2016       0.41 (0.35, 0.47)       1.48         Chembensofu et al., 2017       0.53 (0.440, 0.65)       1.35         Krecek et al., 2012d       0.54 (0.48, 0.60)       1.48         Krecek et al., 2012d       0.55 (0.49, 0.61)       1.48         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Dorny et al., 2004       0.57 (0.54, 0.60)   | Kabululu et al., 2015            | 0.11 (0.09, 0.15)   |             |
| Kabululu et al., 2020a       0.19 (0.15, 0.24)       1.49         Phiri et al., 2002b       0.21 (0.18, 0.23)       1.52         Sikasunge et al., 2008       0.25 (0.22, 0.28)       1.51         Dorny et al., 2014       0.26 (0.21, 0.30)       1.49         Komba et al., 2013       0.26 (0.21, 0.30)       1.49         Eshitera et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2017       0.33 (0.28, 0.39)       1.48         Pondja et al., 2017       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2016       0.41 (0.35, 0.47)       1.48         Chembensofu et al., 2017       0.53 (0.440, 0.65)       1.35         Krecek et al., 2012d       0.54 (0.48, 0.60)       1.48         Krecek et al., 2012d       0.55 (0.49, 0.61)       1.48         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Dorny et al., 2004       0.57 (0.54, 0.60)   | Matos et al. 2011                | 0.12 (0.03, 0.10)   |             |
| Kabululu et al., 2020a       0.19 (0.15, 0.24)       1.49         Phiri et al., 2002b       0.21 (0.18, 0.23)       1.52         Sikasunge et al., 2008       0.25 (0.22, 0.28)       1.51         Dorny et al., 2014       0.26 (0.21, 0.30)       1.49         Komba et al., 2013       0.26 (0.21, 0.30)       1.49         Eshitera et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2017       0.33 (0.28, 0.39)       1.48         Pondja et al., 2017       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2016       0.41 (0.35, 0.47)       1.48         Chembensofu et al., 2017       0.53 (0.440, 0.65)       1.35         Krecek et al., 2012d       0.54 (0.48, 0.60)       1.48         Krecek et al., 2012d       0.55 (0.49, 0.61)       1.48         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Dorny et al., 2004       0.57 (0.54, 0.60)   | Kungu et al., 2017               | 0.12 (0.10, 0.14)   |             |
| Kabululu et al., 2020a       0.19 (0.15, 0.24)       1.49         Phiri et al., 202b       0.21 (0.18, 0.23)       1.52         Sikasunge et al., 2004       0.25 (0.22, 0.28)       1.51         Nsadha et al., 2014       0.26 (0.21, 0.30)       1.49         Komba et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2008e       0.33 (0.28, 0.39)       1.48         Shonyela et al., 2017       0.33 (0.28, 0.39)       1.49         Pondja et al., 2010       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2016       0.48 (0.35, 0.60)       1.35         Chembensofu et al., 2017       0.55 (0.49, 0.65)       1.49         Krecek et al., 2012d       0.55 (0.49, 0.61)       1.48         Krecek et al., 2017       0.56 (0.43, 0.68)       1.35         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.48         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)  | Chilundo et al., 2017            | 0.13 (0.09, 0.17)   |             |
| Kabululu et al., 2020a       0.19 (0.15, 0.24)       1.49         Phiri et al., 202b       0.21 (0.18, 0.23)       1.52         Sikasunge et al., 2004       0.25 (0.22, 0.28)       1.51         Nsadha et al., 2014       0.26 (0.21, 0.30)       1.49         Komba et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2008e       0.33 (0.28, 0.39)       1.48         Shonyela et al., 2017       0.33 (0.28, 0.39)       1.49         Pondja et al., 2010       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2016       0.48 (0.35, 0.60)       1.35         Chembensofu et al., 2017       0.55 (0.49, 0.65)       1.49         Krecek et al., 2012d       0.55 (0.49, 0.61)       1.48         Krecek et al., 2017       0.56 (0.43, 0.68)       1.35         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.48         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)  | Pondja et al., 2010              | 0.13 (0.10, 0.15)   |             |
| Kabululu et al., 2020a       0.19 (0.15, 0.24)       1.49         Phiri et al., 202b       0.21 (0.18, 0.23)       1.52         Sikasunge et al., 2004       0.25 (0.22, 0.28)       1.51         Nsadha et al., 2014       0.26 (0.21, 0.30)       1.49         Komba et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2008e       0.33 (0.28, 0.39)       1.48         Shonyela et al., 2017       0.33 (0.28, 0.39)       1.49         Pondja et al., 2010       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2016       0.48 (0.35, 0.60)       1.35         Chembensofu et al., 2017       0.55 (0.49, 0.65)       1.49         Krecek et al., 2012d       0.55 (0.49, 0.61)       1.48         Krecek et al., 2017       0.56 (0.43, 0.68)       1.35         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.48         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)  | Dorny et al., 2004               | 0.13 (0.11, 0.16)   |             |
| Kabululu et al., 2020a       0.19 (0.15, 0.24)       1.49         Phiri et al., 202b       0.21 (0.18, 0.23)       1.52         Sikasunge et al., 2004       0.25 (0.22, 0.28)       1.51         Nsadha et al., 2014       0.26 (0.21, 0.30)       1.49         Komba et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2008e       0.33 (0.28, 0.39)       1.48         Shonyela et al., 2017       0.33 (0.28, 0.39)       1.49         Pondja et al., 2010       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2016       0.48 (0.35, 0.60)       1.35         Chembensofu et al., 2017       0.55 (0.49, 0.65)       1.49         Krecek et al., 2012d       0.55 (0.49, 0.61)       1.48         Krecek et al., 2017       0.56 (0.43, 0.68)       1.35         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.48         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)  | Phiri et al., 2002d              | 0.14 (0.10, 0.19)   |             |
| Kabululu et al., 2020a       0.19 (0.15, 0.24)       1.49         Phiri et al., 202b       0.21 (0.18, 0.23)       1.52         Sikasunge et al., 2004       0.25 (0.22, 0.28)       1.51         Nsadha et al., 2014       0.26 (0.21, 0.30)       1.49         Komba et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2008e       0.33 (0.28, 0.39)       1.48         Shonyela et al., 2017       0.33 (0.28, 0.39)       1.49         Pondja et al., 2010       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2016       0.48 (0.35, 0.60)       1.35         Chembensofu et al., 2017       0.55 (0.49, 0.65)       1.49         Krecek et al., 2012d       0.55 (0.49, 0.61)       1.48         Krecek et al., 2017       0.56 (0.43, 0.68)       1.35         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.48         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)  | Brass et al. 2014                | 0.14 (0.12, 0.16)   |             |
| Kabululu et al., 2020a       0.19 (0.15, 0.24)       1.49         Phiri et al., 2002b       0.21 (0.18, 0.23)       1.52         Dorny et al., 2004       0.23 (0.21, 0.25)       1.52         Nsadha et al., 2014       0.25 (0.22, 0.28)       1.51         Komba et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2008e       0.33 (0.28, 0.39)       1.48         Shonyela et al., 2017       0.33 (0.28, 0.39)       1.49         Pondja et al., 2017       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2007       0.38 (0.34, 0.41)       1.51         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2017       0.48 (0.35, 0.60)       1.35         Phiri et al., 2016       0.44 (0.35, 0.47)       1.48         Chembensofu et al., 2017       0.55 (0.49, 0.61)       1.49         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Krecek et al., 2017       0.56 (0.43, 0.68)       1.35         Krecek et al., 2017       0.56 (0.43, 0.68)       1.48         Krecek et al., 2017       0.56 (0.43, 0.68)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1  | Minani et al. 2021               | 0.16 (0.12, 0.19)   |             |
| Kabululu et al., 2020a       0.19 (0.15, 0.24)       1.49         Phiri et al., 202b       0.21 (0.18, 0.23)       1.52         Sikasunge et al., 2004       0.25 (0.22, 0.28)       1.51         Nsadha et al., 2014       0.26 (0.21, 0.30)       1.49         Komba et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2008e       0.33 (0.28, 0.39)       1.48         Shonyela et al., 2017       0.33 (0.28, 0.39)       1.49         Pondja et al., 2010       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2016       0.48 (0.35, 0.60)       1.35         Chembensofu et al., 2017       0.55 (0.49, 0.65)       1.49         Krecek et al., 2012d       0.55 (0.49, 0.61)       1.48         Krecek et al., 2017       0.56 (0.43, 0.68)       1.35         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.48         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)  | Newell et al., 1997              | 0.16 (0.09, 0.26)   |             |
| Kabululu et al., 2020a       0.19 (0.15, 0.24)       1.49         Phiri et al., 202b       0.21 (0.18, 0.23)       1.52         Sikasunge et al., 2004       0.25 (0.22, 0.28)       1.51         Nsadha et al., 2014       0.26 (0.21, 0.30)       1.49         Komba et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2008e       0.33 (0.28, 0.39)       1.48         Shonyela et al., 2017       0.33 (0.28, 0.39)       1.49         Pondja et al., 2010       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2016       0.48 (0.35, 0.60)       1.35         Chembensofu et al., 2017       0.55 (0.49, 0.65)       1.49         Krecek et al., 2012d       0.55 (0.49, 0.61)       1.48         Krecek et al., 2017       0.56 (0.43, 0.68)       1.35         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.48         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)  | Wardrop et al., 2015             | 0.17 (0.10, 0.26)   |             |
| Kabululu et al., 2020a       0.19 (0.15, 0.24)       1.49         Phiri et al., 202b       0.21 (0.18, 0.23)       1.52         Sikasunge et al., 2004       0.25 (0.22, 0.28)       1.51         Nsadha et al., 2014       0.26 (0.21, 0.30)       1.49         Komba et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2008e       0.33 (0.28, 0.39)       1.48         Shonyela et al., 2017       0.33 (0.28, 0.39)       1.49         Pondja et al., 2010       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2016       0.48 (0.35, 0.60)       1.35         Chembensofu et al., 2017       0.55 (0.49, 0.65)       1.49         Krecek et al., 2012d       0.55 (0.49, 0.61)       1.48         Krecek et al., 2017       0.56 (0.43, 0.68)       1.35         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.48         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)  | Thomas, 2013                     | 0.17 (0.10, 0.26)   | 1.40        |
| Kabululu et al., 2020a       0.19 (0.15, 0.24)       1.49         Phiri et al., 202b       0.21 (0.18, 0.23)       1.52         Sikasunge et al., 2004       0.25 (0.22, 0.28)       1.51         Nsadha et al., 2014       0.26 (0.21, 0.30)       1.49         Komba et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2008e       0.33 (0.28, 0.39)       1.48         Shonyela et al., 2017       0.33 (0.28, 0.39)       1.49         Pondja et al., 2010       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2016       0.48 (0.35, 0.60)       1.35         Chembensofu et al., 2017       0.55 (0.49, 0.65)       1.49         Krecek et al., 2012d       0.55 (0.49, 0.61)       1.48         Krecek et al., 2017       0.56 (0.43, 0.68)       1.35         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.48         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)  | Maganira et al., 2019            | 0.17 (0.14, 0.21)   |             |
| Kabululu et al., 2020a       0.19 (0.15, 0.24)       1.49         Phiri et al., 202b       0.21 (0.18, 0.23)       1.52         Sikasunge et al., 2004       0.25 (0.22, 0.28)       1.51         Nsadha et al., 2014       0.26 (0.21, 0.30)       1.49         Komba et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2008e       0.33 (0.28, 0.39)       1.48         Shonyela et al., 2017       0.33 (0.28, 0.39)       1.49         Pondja et al., 2010       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2016       0.48 (0.35, 0.60)       1.35         Chembensofu et al., 2017       0.55 (0.49, 0.65)       1.49         Krecek et al., 2012d       0.55 (0.49, 0.61)       1.48         Krecek et al., 2017       0.56 (0.43, 0.68)       1.35         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.48         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)  | Ngowi et al., 2004a              | 0.17 (0.15, 0.20)   |             |
| Kabululu et al., 2020a       0.19 (0.15, 0.24)       1.49         Phiri et al., 202b       0.21 (0.18, 0.23)       1.52         Sikasunge et al., 2004       0.25 (0.22, 0.28)       1.51         Nsadha et al., 2014       0.26 (0.21, 0.30)       1.49         Komba et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2008e       0.33 (0.28, 0.39)       1.48         Shonyela et al., 2017       0.33 (0.28, 0.39)       1.49         Pondja et al., 2010       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2016       0.48 (0.35, 0.60)       1.35         Chembensofu et al., 2017       0.55 (0.49, 0.65)       1.49         Krecek et al., 2012d       0.55 (0.49, 0.61)       1.48         Krecek et al., 2017       0.56 (0.43, 0.68)       1.35         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.48         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)  | -evre et al., 2017               | • 0.18 (0.10, 0.27) |             |
| Kabululu et al., 2020a       0.19 (0.15, 0.24)       1.49         Phiri et al., 202b       0.21 (0.18, 0.23)       1.52         Sikasunge et al., 2004       0.25 (0.22, 0.28)       1.51         Nsadha et al., 2014       0.26 (0.21, 0.30)       1.49         Komba et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2008e       0.33 (0.28, 0.39)       1.48         Shonyela et al., 2017       0.33 (0.28, 0.39)       1.49         Pondja et al., 2010       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2016       0.48 (0.35, 0.60)       1.35         Chembensofu et al., 2017       0.55 (0.49, 0.65)       1.49         Krecek et al., 2012d       0.55 (0.49, 0.61)       1.48         Krecek et al., 2017       0.56 (0.43, 0.68)       1.35         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.48         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)  | Phiri et al. 2006                |                     |             |
| Kabululu et al., 2020a       0.19 (0.15, 0.24)       1.49         Phiri et al., 2002b       0.21 (0.18, 0.23)       1.52         Sikasunge et al., 2008       0.25 (0.22, 0.28)       1.51         Dorny et al., 2014       0.26 (0.21, 0.30)       1.49         Komba et al., 2013       0.26 (0.21, 0.30)       1.49         Eshitera et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2017       0.33 (0.28, 0.39)       1.48         Pondja et al., 2017       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2016       0.41 (0.35, 0.47)       1.48         Chembensofu et al., 2017       0.53 (0.440, 0.65)       1.35         Krecek et al., 2012d       0.54 (0.48, 0.60)       1.48         Krecek et al., 2012d       0.55 (0.49, 0.61)       1.48         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Dorny et al., 2004       0.57 (0.54, 0.60)   | Sikasunge et al., 2007           | 0.19 (0.16, 0.22)   |             |
| Sikasunge et al., 2008       0.23 (0.21, 0.25)       1.52         Dorny et al., 2004       0.25 (0.22, 0.28)       1.51         Nsadha et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2008e       0.33 (0.28, 0.39)       1.48         Shonyela et al., 2017       0.33 (0.28, 0.39)       1.48         Pondja et al., 2010       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2007       0.38 (0.34, 0.41)       1.51         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2012c       0.50 (0.44, 0.55)       1.49         Phiri et al., 2016       0.50 (0.44, 0.55)       1.49         Chembensofu et al., 2017       0.50 (0.44, 0.55)       1.49         Krecek et al., 2008a       0.50 (0.44, 0.55)       1.49         Chembensofu et al., 2017       0.53 (0.40, 0.61)       1.48         Krecek et al., 2008a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Dorny et al., 2004       0.57 (0.54, 0.80)       1.51  |                                  |                     |             |
| Dorny et al., 2004       0.25 (0.22, 0.28)       1.51         Nsadha et al., 2014       0.26 (0.21, 0.30)       1.49         Komba et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2008e       0.33 (0.28, 0.39)       1.48         Shonyela et al., 2017       0.33 (0.28, 0.39)       1.49         Pondja et al., 2010       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2007       0.38 (0.34, 0.41)       1.51         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2016       0.48 (0.35, 0.60)       1.35         Chembensofu et al., 2017       0.53 (0.40, 0.65)       1.49         Krecek et al., 2012d       0.55 (0.49, 0.61)       1.48         Krecek et al., 2017       0.53 (0.40, 0.65)       1.49         Chembensofu et al., 2017       0.55 (0.49, 0.61)       1.48         Krecek et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Dorny et al., 2004       0.57 (0.54, 0.60)       1.51  | Phiri et al., 2002b              |                     | 1.52        |
| Nsadha et al., 2014       0.26 (0.21, 0.30)       1.49         Komba et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.28, 0.39)       1.47         Krecek et al., 2008e       0.33 (0.28, 0.39)       1.48         Shonyela et al., 2017       0.33 (0.28, 0.39)       1.49         Pondja et al., 2010       0.33 (0.28, 0.39)       1.49         Sikasunge et al., 2007       0.33 (0.28, 0.39)       1.49         Krecek et al., 2008b       0.38 (0.34, 0.41)       1.51         Krecek et al., 2012c       0.41 (0.35, 0.47)       1.48         Phiri et al., 2006       0.41 (0.35, 0.60)       1.35         Chembensofu et al., 2017       0.50 (0.44, 0.55)       1.49         Krecek et al., 2008a       0.55 (0.49, 0.61)       1.48         Krecek et al., 2007a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Dorny et al., 2004       0.57 (0.54, 0.60)       1.51  |                                  |                     |             |
| Komba et al., 2013       0.31 (0.28, 0.35)       1.50         Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2008e       0.33 (0.28, 0.39)       1.48         Shonyela et al., 2017       0.33 (0.28, 0.39)       1.48         Pondja et al., 2010       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2007       0.38 (0.34, 0.41)       1.51         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Phiri et al., 2012c       0.41 (0.35, 0.47)       1.48         Phiri et al., 2016       0.50 (0.44, 0.55)       1.49         Chembensofu et al., 2012d       0.55 (0.49, 0.60)       1.35         Krecek et al., 2008a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Dorny et al., 2004       0.57 (0.54, 0.80)       1.35   |                                  |                     |             |
| Eshitera et al., 2012       0.33 (0.27, 0.39)       1.47         Krecek et al., 2008e       0.33 (0.27, 0.39)       1.48         Shonyela et al., 2017       0.33 (0.28, 0.39)       1.48         Pondja et al., 2010       0.35 (0.31, 0.39)       1.49         Sikasunge et al., 2007       0.38 (0.34, 0.41)       1.51         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2012c       0.41 (0.35, 0.47)       1.48         Phiri et al., 2006       0.41 (0.35, 0.60)       1.35         Chembensofu et al., 2017       0.50 (0.44, 0.55)       1.49         Krecek et al., 2012d       0.54 (0.48, 0.60)       1.48         Krecek et al., 2012d       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Dorny et al., 2004       0.57 (0.54, 0.80)       1.35   |                                  |                     |             |
| Krecek et al., 2008e       0.33 (0.28, 0.39)       1.48         Shonyela et al., 2017       0.33 (0.28, 0.39)       1.49         Pondja et al., 2010       0.33 (0.28, 0.39)       1.49         Sikasunge et al., 2007       0.38 (0.34, 0.41)       1.51         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2012c       0.41 (0.35, 0.47)       1.48         Phiri et al., 2006       0.41 (0.35, 0.60)       1.35         Chembensofu et al., 2017       0.50 (0.44, 0.55)       1.49         Krecek et al., 2012d       0.53 (0.48, 0.80)       1.48         Krecek et al., 2018       0.41 (0.35, 0.47)       1.48         Chembensofu et al., 2017       1.49       1.49         Krecek et al., 2008a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Dorny et al., 2004       0.57 (0.54, 0.60)       1.51  |                                  |                     |             |
| Shonyela et al., 2017       0.33 (0.28, 0.39)       1.49         Pondja et al., 2010       0.35 (0.31, 0.39)       1.51         Sikasunge et al., 2007       0.38 (0.34, 0.41)       1.51         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2012c       0.41 (0.35, 0.47)       1.48         Phiri et al., 2006       0.50 (0.44, 0.55)       1.49         Chembensofu et al., 2017       0.53 (0.40, 0.85)       1.35         Krecek et al., 2012d       0.53 (0.40, 0.85)       1.48         Chembensofu et al., 2017       0.55 (0.49, 0.80)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.48         Ohry et al., 2004       0.57 (0.54, 0.80)       1.51   |                                  |                     |             |
| Sikasunge et al., 2007       0.38 (0.34, 0.41)       1.51         Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2012c       0.41 (0.35, 0.47)       1.48         Phiri et al., 2006       0.41 (0.35, 0.47)       1.48         Chembensofu et al., 2017       0.48 (0.35, 0.60)       1.35         Chembensofu et al., 2012d       0.53 (0.44, 0.55)       1.49         Krecek et al., 2012d       0.53 (0.44, 0.65)       1.35         Krecek et al., 2012d       0.53 (0.40, 0.65)       1.48         Krecek et al., 2008a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Dorny et al., 2004       0.57 (0.54, 0.60)       1.35   |                                  |                     |             |
| Krecek et al., 2008b       0.41 (0.35, 0.47)       1.48         Krecek et al., 2012c       0.41 (0.35, 0.47)       1.48         Phiri et al., 2006       0.41 (0.35, 0.47)       1.48         Phiri et al., 2006       0.48 (0.35, 0.60)       1.35         Chembensolu et al., 2017       0.53 (0.40, 0.65)       1.35         Krecek et al., 2012d       0.53 (0.40, 0.65)       1.48         Chembensolu et al., 2017       0.53 (0.40, 0.65)       1.35         Chembensolu et al., 2017       0.55 (0.49, 0.61)       1.48         Chembensolu et al., 2017       0.55 (0.49, 0.61)       1.48         Dorny et al., 2004       0.57 (0.54, 0.80)       1.51  | Pondja et al., 2010              | 0.35(0.31, 0.39)    | 1.51        |
| Krecek et al., 2012c       0.41 (0.35, 0.47)       1.48         Phiri et al., 2006       0.48 (0.35, 0.60)       1.35         Chembensofu et al., 2017       0.50 (0.44, 0.55)       1.49         Chembensofu et al., 2012d       0.53 (0.40, 0.65)       1.35         Krecek et al., 2012d       0.54 (0.48, 0.60)       1.48         Chembensofu et al., 2017       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2018a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Dorny et al., 2004       0.57 (0.54, 0.60)       1.51  | Sikasunge et al., 2007           | 0.38 (0.34, 0.41)   |             |
| Phiri et al., 2006       0.48 (0.35, 0.60)       1.35         Chomas et al., 2018       0.50 (0.44, 0.55)       1.49         Chembensofu et al., 2017       0.53 (0.40, 0.65)       1.35         Krecek et al., 2012d       0.53 (0.40, 0.65)       1.48         Krecek et al., 2008a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.48, 0.60)       1.49         Chembensofu et al., 2008a       0.55 (0.49, 0.61)       1.48         Ochembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Dorny et al., 2004       0.57 (0.54, 0.60)       1.35   |                                  |                     |             |
| Thomas et al., 2016       0.50 (0.44, 0.55)       1.49         Chembensofu et al., 2017       0.53 (0.40, 0.65)       1.35         Krecek et al., 2012d       0.54 (0.48, 0.80)       1.48         Krecek et al., 2008a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Dorny et al., 2004       0.57 (0.54, 0.60)       1.51   |                                  |                     |             |
| Chembensofu et al., 2017       0.53 (0.40, 0.65)       1.35         Krecek et al., 2012d       0.54 (0.48, 0.60)       1.48         Krecek et al., 2008a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Dorny et al., 2004       0.57 (0.54, 0.60)       1.51  |                                  |                     |             |
| Krecek et al., 2012d       0.54 (0.48, 0.60)       1.48         Krecek et al., 2008a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Dorny et al., 2004       0.57 (0.54, 0.60)       1.51  |                                  |                     |             |
| Krecek et al., 2008a       0.55 (0.49, 0.61)       1.48         Chembensofu et al., 2017       0.56 (0.43, 0.68)       1.35         Dorny et al., 2004       0.57 (0.54, 0.60)       1.51  |                                  |                     |             |
| Chembensofu et al., 2017         0.56 (0.43, 0.68)         1.35           Dorny et al., 2004         0.57 (0.54, 0.60)         1.51  |                                  |                     |             |
|  |                                  | 0.56 (0.43, 0.68)   | 1.35        |
|  |                                  |                     |             |
| $\mathbf{O}_{11} = \mathbf{O}_{11} = \mathbf{O}$ | Overall (l^2 = 98.99%, p = 0.00) | 0.17 (0.14, 0.20)   | 100.00      |

FIGURE 5 | Forest plot showing the studies reporting porcine cysticercosis in the ESA region. The box shows the weight and estimate of the study; the length of the horizontal lines indicates the 95% CI; the vertical broken red line indicates the pooled estimate; the diamond-shaped box at the bottom represents the 95% CI; the solid line indicates the point of null assumption.

|  | nce of porcine | -,                                     | -           |  |              |  | %    |
|--|----------------|--|-------------|--|--------------|--|------|
| Study  |                | ES (95% CI)                            | %<br>Weight | Study  |              | ES (95% CI)                            | Welg |
| Lingual examination  | 1 1            |  |             | Eastern                                      | 1            |  |      |
| Ngowi et al., 2004b  |                | 0.00 (0.00, 0.05)                      | 1.36        | Ngowi et al., 2004b                          | · · · ·      | 0.00 (0.00, 0.05)                      | 1.36 |
| Mushonga et al., 2018  |                | 0.04 (0.03, 0.05)                      | 1.51        | Mushonga et al., 2018                        |              | 0.04 (0.03, 0.05)                      | 1.51 |
| Thomas et al., 2016  |                | 0.08 (0.03, 0.09)                      | 1.40        | Kagira et al., 2010                          |              | 0.04 (0.02, 0.07)                      | 1.48 |
| Eshitera et al., 2012  |                | 0.06 (0.04, 0.08)                      | 1.49        | Nguhlu et al., 2017                          |              | 0.04 (0.02, 0.07)                      | 1.48 |
| Chembensofu et al., 2017   |                | 0.08 (0.02, 0.14)                      | 1.35        | Thomas et al., 2016                          | -            | 0.06 (0.03, 0.09)                      | 1.49 |
| Shonyela et al., 2017<br>Phiri et al., 2002c                                 |                | 0.08 (0.05, 0.08)                      | 1.51        | Eshitera et al., 2012                        |              | 0.06 (0.04, 0.08)                      | 1.49 |
|  |                | 0.06 (0.04, 0.10)                      | 1.47        | Mkupasi et al., 2011                         |              | 0.06 (0.04, 0.08)                      | 1.51 |
| Mutue et al., 2007   |                | 0.07 (0.05, 0.09)                      | 1.50        | Shonyela et al., 2017                        |              | 0.06 (0.05, 0.08)                      | 1.51 |
| Ngowl et al., 2010   |                | 0.07 (0.06, 0.09)                      | 1.51        | Mutua et al., 2007                           |              | 0.07 (0.05, 0.08)                      | 1.50 |
| Yohana et al., 2013  |                | 0.07 (0.05, 0.11)                      | 1.48        |  |              |  |      |
| Phiri et al., 2006<br>Komba et al., 2013                                     |                | 0.08 (0.03, 0.17)<br>0.09 (0.07, 0.11) | 1.35        | Ngowi et al., 2010                           |              | 0.07 (0.06, 0.09)                      | 1.51 |
| Komba et al., 2013<br>Boa et al., 2006                                       |                | 0.09 (0.08, 0.11)                      | 1.62        | Yohana et al., 2013                          |              | 0.07 (0.05, 0.11)                      | 1.48 |
| Thomas, 2013   |                | 0.10 (0.05, 0.18)                      | 1.62        | Kabululu et al., 2020a                       |              | 0.08 (0.06, 0.12)                      | 1.49 |
| Sikasungo et al., 2008   |                | 0.11 (0.08, 0.12)                      | 1.52        | Walswa et al., 2009                          |              | 0.09 (0.06, 0.11)                      | 1.50 |
| Phiri et al., 2002a  |                | 0.11 (0.09, 0.13)                      | 1.62        | Akoko et al., 2019                           |              | 0.09 (0.07, 0.11)                      | 1.51 |
| Krecek et al., 2002a   | 12             | 0.12 (0.08, 0.16)                      | 1.48        | Komba et al., 2013                           |              | 0.09 (0.07, 0.11)                      | 1.50 |
| Pondia et al., 2010  | 1 =            | 0.13 (0.10, 0.15)                      | 1.51        | Kabululu et al., 2020b                       |              | 0.09 (0.06, 0.13)                      | 1.48 |
| Domy et al., 2004  |                | 0.13 (0.11, 0.16)                      | 1.61        | Mushonga at al., 2018                        | ****         | 0.09 (0.08, 0.11)                      | 1.52 |
| Minani et al., 2004  |                | 0.16 (0.12, 0.19)                      | 1.50        | Bos et al., 2006                             | 1 -          | 0.09 (0.08, 0.11)                      | 1.52 |
| Ngowi et al., 2021   |                | 0.17 (0.15, 0.20)                      | 1.50        | Thomas, 2013                                 |              | 0.10 (0.05, 0.18)                      | 1.40 |
| Sikasunge et al., 2007   |                | 0.19 (0.16, 0.22)                      | 1.61        | Sikasunge et al., 2008                       |              | 0.11 (0.09, 0.12)                      | 1.40 |
| Subtotal (I^2 = 91.72%, p = 0.00)  | 0              | 0.09 (0.07, 0.11)                      | 32.49       |  |              | 0.11 (0.09, 0.12)                      | 1.50 |
|  |                | ,                                      |             | Kabululu et al., 2015                        |              | 0.11 (0.09, 0.15)                      |      |
| Ag-ELISA   |                |  |             | Kungu et al., 2017                           |              | 0.12 (0.10, 0.14)                      | 1.51 |
| Kegine et al., 2010  | In 1           | 0.04 (0.02, 0.07)                      | 1.48        | Braae et al., 2014                           |              | 0.15 (0.13, 0.18)                      | 1.51 |
| Nguhlu et al., 2017  |                | 0.04 (0.02, 0.07)                      | 1.48        | Minani et al., 2021                          |              | 0.16 (0.12, 0.19)                      | 1.50 |
| Pondja et al., 2015  | - · ·          | 0.06 (0.02, 0.12)                      | 1.41        | Newell et al., 1997                          |              | 0.16 (0.09, 0.26)                      | 1.38 |
| Shongwe et al., 2020   |                | 0.07 (0.03, 0.13)                      | 1.43        | Wardrop et al., 2015                         |              | 0.17 (0.10, 0.26)                      | 1.40 |
| Walawa et al., 2009  |                | 0.08 (0.08, 0.11)                      | 1.50        | Thomas, 2013                                 |              | 0.17 (0.10, 0.26)                      | 1.40 |
| Akoko et al., 2019   |                | 0.09 (0.07, 0.11)                      | 1.61        | Maganira et al., 2019                        |              | 0.17 (0.14, 0.21)                      | 1.50 |
| Porphyre et al., 2015  | and the set    | 0.11 (0.07, 0.16)                      | 1.45        | Ngowi et al., 2004a                          |              | 0.17 (0.15, 0.20)                      | 1.51 |
| Kabululu et el., 2015  |                | 0.11 (0.09, 0.15)                      | 1.50        | Fèvre et al., 2017                           |              | 0.18 (0.10, 0.27)                      | 1.39 |
| Kungu et al., 2017   |                | 0.12 (0.10, 0.14)                      | 1.51        | Zirintunda and Ekou, 2015                    | I I          | 0.18 (0.13, 0.24)                      | 1.46 |
| Chilundo et al., 2017  | -              | 0.13 (0.09, 0.17)                      | 1.48        | Sikasunge et al., 2007                       | -            | 0.19 (0.16, 0.22)                      | 1.51 |
| Phiri et al., 2002d  |                | 0.14 (0.10, 0.19)                      | 1.47        |  |              |  |      |
| Braae et al., 2014   |                | 0.15 (0.13, 0.18)                      | 1.51        | Kabululu et al., 2020a                       |              | 0.19 (0.15, 0.24)                      | 1.49 |
| Wardrop et al., 2015   |                | 0.17 (0.10, 0.26)                      | 1.40        | Sikasunge et al., 2008                       |              | 0.23 (0.21, 0.25)                      | 1.52 |
| Thomas, 2013   |                | 0.17 (0.10, 0.28)                      | 1.40        | Nsadha et al., 2014                          |              | 0.26 (0.21, 0.30)                      | 1.49 |
| Maganira et al., 2019  |                | 0.17 (0.14, 0.21)                      | 1.50        | Komba et al., 2013                           |              | 0.31 (0.28, 0.35)                      | 1.50 |
| Fèvre et al., 2017   |                | 0.18 (0.10, 0.27)                      | 1.39        | Eshitera et al., 2012                        |              | 0.33 (0.27, 0.39)                      | 1.47 |
| Kabululu et el., 2020a   | -              | 0.19 (0.15, 0.24)                      | 1.49        | Shonyela et al., 2017                        |              | 0.33 (0.28, 0.39)                      | 1.49 |
| Sikasunge et el., 2006   |                | 0.23 (0.21, 0.25)                      | 1.52        | Sikasunge et al., 2007                       |              | 0.38 (0.34, 0.41)                      | 1.51 |
| Nsadha et al., 2014  | · · · · ·      | 0.26 (0.21, 0.30)                      | 1.49        | Thomas et al., 2016                          |              | 0.50 (0.44, 0.55)                      | 1.49 |
| Komba et al., 2013   |                | 0.31 (0.28, 0.35)                      | 1.50        | Subtotal (1^2 = 97.37%, p = 0.00)            |              | 0.13 (0.11, 0.16)                      | 59.2 |
| Echitera et al., 2012  |                | 0.33 (0.27, 0.39)                      | 1.47        |  |              | 0.10 (0.11, 0.10)                      | 00.2 |
| Shonyela et al., 2017  |                | 0.33 (0.28, 0.39)                      | 1.49        | Southern                                     |              |  |      |
| Pondja et al., 2010  |                | 0.35 (0.31, 0.39)                      | 1.51        |  |              |  |      |
| Sikasungo et al., 2007   |                | 0.38 (0.34, 0.41)                      | 1.51        | Porphyre et al., 2015                        |              | 0.05 (0.05, 0.05)                      | 1.53 |
| Krecek et al., 2008b   |                | 0.41 (0.35, 0.47)                      | 1.48        | Pondja et al., 2015                          |              | 0.06 (0.02, 0.12)                      | 1.41 |
| Krecek et al., 2012c   |                | 0.41 (0.35, 0.47)                      | 1.48        | Chembensofu et al., 2017                     |              | 0.06 (0.02, 0.14)                      | 1.35 |
| Thomas et al., 2018  |                | 0.50 (0.44, 0.55)                      | 1.49        | Phiri et al., 2002c                          |              | 0.06 (0.04, 0.10)                      | 1.47 |
| Chembensofu et al., 2017<br>Kracek at al., 2012d                             |                | 0.53 (0.40, 0.65)                      | 1.35        | Shongwe et al., 2020                         | <b>IIIII</b> | 0.07 (0.03, 0.13)                      | 1.43 |
| Krecek et al., 2012d<br>Krecek et al., 2008a                                 |                | 0.54 (0.48, 0.80)                      | 1.48        | Phiri et al., 2006                           |              | 0.08 (0.03, 0.17)                      | 1.35 |
|  |                | 0.55 (0.49, 0.61)<br>0.57 (0.54, 0.60) | 1.46        | Porphyre et al., 2015                        |              | 0.11 (0.07, 0.16)                      | 1.45 |
| Domy et al., 2004<br>Subtotal (I^2 = 98.27%, p = 0.00)                       |                | 0.67 (0.64, 0.60)<br>0.23 (0.18, 0.29) | 45.65       | Phiri et al., 2002e                          |              | 0.11 (0.09, 0.13)                      | 1.52 |
| Subtotal (I*2 = 98.27%, p = 0.00)  | P              | 0.23 (0.18, 0.29)                      | 45.65       | Krecek et al., 2008                          | 13           | 0.12 (0.08, 0.16)                      | 1.48 |
| Meat inspection  |                |  |             |  |              |  |      |
| Meat Inspection<br>Porphyre et al., 2015                                     | - :            | 0.05 (0.05, 0.05)                      | 1.53        | Matos et al., 2011                           |              | 0.12 (0.07, 0.19)<br>0.13 (0.09, 0.17) | 1.43 |
| Porphyre et al., 2015<br>Mkupasi et al., 2011                                |                | 0.05 (0.05, 0.05)<br>0.06 (0.04, 0.08) | 1.53        | Chilundo et al., 2017                        |              |  |      |
| Mkupaal et al., 2011<br>Mushonga et al., 2018                                |                | 0.08 (0.04, 0.08)<br>0.09 (0.08, 0.11) | 1.51        | Pondja et al., 2010                          | 15           | 0.13 (0.10, 0.15)                      | 1.51 |
| Domy et al., 2004  |                | 0.14 (0.12, 0.16)                      | 1.51        | Dorny et al., 2004                           |              | 0.13 (0.11, 0.16)                      | 1.51 |
| Newell et al., 1997  |                | 0.14 (0.12, 0.16)<br>0.16 (0.09, 0.26) | 1.51        | Phiri et al., 2002d                          |              | 0.14 (0.10, 0.19)                      | 1.47 |
| Zirintunda and Ekou, 2015  |                | 0.18 (0.13, 0.24)                      | 1.46        | Dorny et al., 2004                           |              | 0.14 (0.12, 0.16)                      | 1.51 |
| Phiri et al., 2006   |                | 0.18 (0.10, 0.24)                      | 1.35        | Phiri et al., 2006                           |              | 0.18 (0.10, 0.30)                      | 1.35 |
| Phiri et al., 2002b  | -              | 0.21 (0.18, 0.23)                      | 1.52        | Phiri et al., 2002b                          |              | 0.21 (0.18, 0.23)                      | 1.52 |
| Subtotel (1^2 = 98.66%, p = 0.00)  | 0              | 0.12 (0.07, 0.18)                      | 11.76       | Dorny et al., 2004                           |              | 0.25 (0.22, 0.28)                      | 1.61 |
|  |                |  |             | Krecek et al., 2008e                         |              | 0.33 (0.28, 0.39)                      | 1.48 |
| Carcase dissection   |                |  |             | Pondia et al., 2010                          |              | 0.35 (0.31, 0.39)                      | 1.61 |
| Kabululu et al., 2020a   |                | 0.08 (0.06, 0.12)                      | 1.49        | Kracak et al., 2008b                         |              | 0.35 (0.31, 0.39)                      | 1.61 |
| Kabululu et al., 2020b   |                | 0.09 (0.06, 0.13)                      | 1.48        |  |              |  |      |
| Phiri et al., 2008   |                | 0.46 (0.35, 0.60)                      | 1.35        | Krecek et al., 2012c                         |              | 0.41 (0.35, 0.47)                      | 1.48 |
| Chembensofu et al., 2017   |                | 0.56 (0.43, 0.68)                      | 1.35        | Phiri et al., 2006                           |              | 0.48 (0.35, 0.60)                      | 1.35 |
| Subtotal (I^2 = 97.34%, p = 0.00)  |                | 0.27 (0.09, 0.50)                      | 5.67        | Chembensofu et al., 2017                     |              | 0.53 (0.40, 0.65)                      | 1.35 |
|  |                |  |             | Krecek et al., 2012d                         |              | 0.54 (0.48, 0.60)                      | 1.48 |
| Ab based immunodiagnostic  |                |  |             | Krecek et al., 2008a                         |              | 0.55 (0.49, 0.61)                      | 1.48 |
| Matos et al., 2011   | -              | 0.12 (0.07, 0.19)                      | 1.43        | Chembensofu et al., 2017                     |              | 0.56 (0.43, 0.68)                      | 1.35 |
| Domy et al., 2004  |                | 0.25 (0.22, 0.28)                      | 1.51        | Domy et al., 2004                            |              | 0.57 (0.54, 0.60)                      | 1.51 |
| Krecek et al., 2008e   |                | 0.33 (0.28, 0.39)                      | 1.48        | Subtotal (I^2 = 99.36%, p = 0.00)            |              | 0.22 (0.15, 0.30)                      | 40.7 |
| Subtotal (I^2 = .%, p = .)   | $\diamond$     | 0.23 (0.14, 0.33)                      | 4.42        |  |              | 5.22 (0.10, 0.00)                      | -0.1 |
|  |                |  |             | Heterogeneity between groups: p = 0.015      |              |  |      |
| Heterogeneity between groups: p = 0.000<br>Overall (I^2 = 98.99%, p = 0.00); | 4              | 0.17 (0.14, 0.20)                      | 100.00      | Overall (1 <sup>2</sup> = 98.99%, p = 0.00); | •            | 0.17 (0.14, 0.20)                      | 100. |
|  |                | 1 1                                    |             |  |              | !                                      |      |
|  | Proportion     | .a i<br>I                              |             |  | Proportion   | . 1                                    |      |
|  |                |  |             |  | . isperaon   |  |      |
|  |                |  |             |  |              |  |      |

FIGURE 6 | Forest plot showing subgroup analysis of prevalence reports grouped by the diagnostic technique (left) and region (right).

estimate might be the result of a combination of more than one element capable of affecting the presence of porcine cysticercosis, such as individual host characteristics (e.g., differences in gender, age, and breed), the existence of variation in the exposure to risk factors among and within countries (pig production system, geographical situation, etc.), the environmental conditions or socio-cultural practices enhancing or disfavoring egg dispersal, and survival (16, 69).

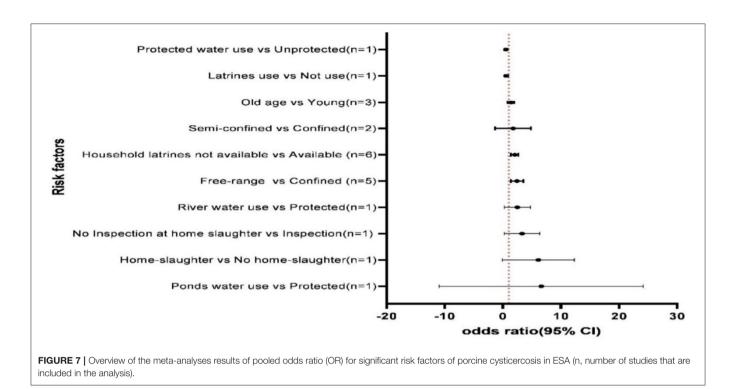
The other source of variation might be the inclusion of studies that employed diagnostic techniques with a huge disparity in sensitivity and specificity. A meta-analysis sub-grouped by the diagnostic test estimated the prevalence of 27% (95% CI: 9– 50) by carcass dissection, 23% (95% CI: 14–33) by Antibodybased immunodiagnostic techniques, 23% (95% CI: 18–29) by Ag-ELISA, 12% (95% CI: 7–18) by meat inspection, and 9% (95% CI: 7–11) by lingual examination.

Full carcass dissection is a gold standard technique to diagnose porcine cysticercosis (29, 70–72). However, it is not feasible in daily practice because it is extremely laborious, requires trained staff to conduct the procedure, and is expensive as the entire carcass must be sliced in more or less 0.5 cm

cuts (72). The prevalence upon carcass dissection in this review is higher than studies in Cameroon (19.6%) and Peru (16.8%) (73).

The lingual examination and meat inspection are reported to be highly specific but poorly sensitive at 7–21% (29, 60, 74) and 22–66% (29, 46, 60), respectively, and likely to lead to underestimation of true prevalence, particularly in light infection. Despite the lower sensitivity of lingual examination, it is widely used for the rapid assessment of porcine cysticercosis in poor endemic areas (17, 23). Meat inspection is used all over the world to ensure the fitness of meat for human consumption, but official guidelines and practices to diagnose porcine cysticercosis vary widely across the countries (70). Some reports highlighted that the prevalence estimation based on meat inspection might be biased because of the pre-screening tradition by traders/butchers during purchasing of pigs; hence, positive pigs are likely not presented for formal slaughter (17, 50, 59).

Most studies included in the review used Ag-ELISA (B158/B60 Ag-ELISA and HP10 Ag-ELISA) to ascertain cases of porcine cysticercosis. Despite the ability of Ag-ELISA for detecting the presence of viable cyst (50), the technique is genus-specific and



likely results in overestimation in areas where *Taenia* species (*T. solium, T. hydatigena, T. asiatica*) co-exist (29, 72, 75). Hence, all reports of the prevalence of porcine cysticercosis using Ag-ELISA should be interpreted with care and the results may be more indicative of exposure to *Taenia* spp. broadly. Besides, the result obtained using B158/B60 Ag-ELISA and HP10 Ag-ELISA have not been compared, which could lead to different results given their difference in their diagnostic performance (16).

The sensitivity of HP10 and B158/B60 Ag-ELISAs has been reported to be 44.4-89.5% and 63.3-95.7% (46, 74, 76), while the specificity of the assays has been determined to be 45-100% and 84.4-95% (24, 46, 74, 76), respectively. The prevalence based on Ag-ELISA in the subgroup analysis (23%, 95% CI:18-29) is lower than the report from Burkina Faso, 32.5-48.2% (77), and the Democratic Republic of Congo, 38.4-41.2% (78). The sub-group prevalence of Antibody-based immunodiagnostic techniques in this review (23%, 95% CI: 14-33) was also found lower than 46% in Nigeria (79). The Ab-based immunodiagnostic techniques detect circulating antibodies (Ab) and indicate exposure to the parasite, but not necessarily an active infection (71). However, at the population level, they give a useful indication of areas, where the life cycle of the parasite is ongoing (15, 71). Despite the limitations of the diagnostic tests, we consider the results to indicate the presence and trends of porcine cysticercosis in ESA, and that this information will be useful for targeted research and controlled efforts in the future.

The overall pooled and subgroup prevalence analysis in this review showed high heterogeneity between studies ( $I^2 > 97\%$ ). The presence of publication bias (p < 0.05), which was detected using the funnel plot analysis might be associated with the restriction of the language use, the use of the limited searching

platform, the large gap in time frames of data collection (24 years), the would-be biases by the publishers (the lower interest in the publication of manuscripts with statistically non-significant or unfavorable findings), and the authors (research is likely conducted where *T. solium* is a problem and not in other regions).

Thirteen articles out of the 44 selected cross-sectional studies reported statistically significant risk factors for the occurrence of porcine cysticercosis, including lack of latrine at the household level, keeping free-range pigs, semi-confined pig management, home-slaughter, unprotected water source, and old age. The pooled OR of 2.4 was recorded for keeping free-range pigs, and the pooled OR of two was recorded for lack of latrine at household level with insignificant heterogeneity among reports. In SSA, an increased risk of cysticercosis in pigs has been reported to be significantly associated with allowing pigs to roam freely (8, 12, 14, 33, 48), outdoor defecation or lack of latrines at household (30, 48, 56, 80), poor sanitary conditions (15, 81, 82), and age of pigs (4, 15).

Pig rearing is an important livelihood activity in SSA (11), and 60–90% of total pigs in the region are raised under traditional semi-intensive and free-range systems (15). Similarly, about 80% of pigs kept in ESA are raised under the traditional free-ranging system (83). Unhygienic sanitary conditions including limited use or the absence of latrines are prevalent in most rural areas of Africa. According to WHO and UNICEF reports, the overall prevalence of open defecation in SSA was 25% (67), and only 25.7% (23.1–28.6%) of the population in the region has access to improved sanitation (84). In these conditions, tapeworm carriers can disseminate the parasite eggs in their environment and is likely to influence the prevalence of porcine or human cysticercosis (4, 15).

# CONCLUSION

The data presented in this review described the epidemiology of porcine cysticercosis in the ESA region. The review demonstrated the variability in the reports of porcine cysticercosis. The overall pooled prevalence estimate of porcine cysticercosis in the ESA region based on the included studies was 17%. The evidence concerning porcine cysticercosis in the ESA region provided by the few prevalence studies conducted, so far, showed the magnitude of porcine cysticercosis in pig raising and consumption in parts of the ESA region, providing the impetus for further research, as well as calling for urgent control measures to be implemented in countries where there is enough evidence concerning the presence of porcine cysticercosis. The risk factors which could probably have influenced the transmission and distribution of porcine cysticercosis in the area were: the presence of latrine at the household level, pig management system, water source, and older pig age. The findings will guide in defining priority areas for intervention and control of T. solium in the ESA region, but accurate prevalence estimates using more sensitive and specific tests, detailed risk factor analysis incorporating climatic and environmental factors, as well as data on the epidemiology of human cysticercosis and taeniasis, are needed to develop effective control strategies. Epidemiological studies should be promoted in the form of health partnerships and programs implemented within the context of the CWGESA to ensure that comparative results are obtained across the region.

### DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

#### REFERENCES

- 1. WHO/FAO/OIE. WHO/FAO/OIE Guidelines for the surveillance, prevention, and control of taeniosis/cysticercosis. (2005).
- 2. Ndimubanzi PC, Carabin H, Budke CM, Nguyen H, Qian YJ, Rainwater E, et al. A systematic review of the frequency of neurocyticercosis with a focus on people with epilepsy. *PLOS Negl Trop Dis.* (2010). 4:e870. doi: 10.1371/journal.pntd.0000870
- 3. WHO. Working to overcome the global impact of neglected tropical diseases: First WHO report on neglected tropical diseases First WHO report on neglected tropical diseases, Geneva: World Health Organization. (2010).
- Kungu JM. MMD Michael Ocaido and Francis Ejobi Status of Taenia solium cysticercosis and predisposing factors in developing countries involved in pig farming. *Int J One Health.* (2015) 1:6–13. doi: 10.14202/IJOH.2015.6-13
- Schantz PM, Cruz M, Sarti E, Pawlowski Z. Potential eradicability of taeniasis and cysticercosis bulletin of PAHO. *Bull Pan Am Health Organ.* (1993) 27:397–403.
- García HH, Gonzalez AE, Evans CA, Gilman RH. Taenia solium cysticercosis. Lancet. (2003). 362:547–56. doi: 10.1016/S0140-6736(03)14117-7
- Gabriël S, Dorny P, Mwape KE, Trevisan C, Braae UC, Magnussen P, et al. Control of Taenia solium taeniasis/cysticercosis: the best way forward for sub-Saharan Africa? *Acta Tropica*. (2017) 165:252–60. doi: 10.1016/j.actatropica.2016.04.010
- 8. Dermauw V, Carabin H, Ganaba R, Cissé A, Tarnagda Z, Gabriël S, et al. Factors associated with the 18-month cumulative incidence of seroconversion

### **AUTHOR CONTRIBUTIONS**

YG conceived the idea, developed the review protocol, involved in the critical appraisal of included studies, extracted and analyzed the data, and produced the first draft of the manuscript. HA was involved in the critical appraisal of included studies, extracted, and analyzed the data. TE, NK, EC, and EF were involved in the writing of the manuscript. All authors edited manuscript drafts, provided feedback, and read and approved the final manuscript.

### FUNDING

This work was part-funded by the Global Challenges Research Fund (GCRF) One Health Regional Network for the Horn of Africa (HORN) Project, from UK Research and Innovation (UKRI) and Biotechnology and Biological Sciences Research Council (BBSRC) (project number BB/P027954/1). Support was also received from the CGIAR Research Program on Agriculture for Nutrition and Health (A4NH), led by the International Food Policy Research Institute (IFPRI). We acknowledge the CGIAR Fund Donors (https://www.cgiar.org/funders/) and the Organization for Women in Science for the Developing World (fund reservation number: 3240303489). The funders had no role in the decision to publish or the preparation of this manuscript. Open access publication fees are supported by the University of Liverpool institutional access fund.

### SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh. 2022.836177/full#supplementary-material

of active infection with taenia solium cysticercosis: a cohort study among residents of 60 villages in burkina faso. *Am J Trop Med.* (2018). 99:1018–27. doi: 10.4269/ajtmh.18-0294

- 9. WHOandFAO. *Multicriteria-based ranking for risk management of food-borne parasites: report of a Joint FAO/WHO expert meeting.* Rome, Italy: World Health Organization and Food and Agriculture Organization of the United Nations (2014).
- Torgerson PR, Devleesschauwer B, Praet N, Speybroeck N, Willingham AL, Kasuga F, et al. World Health Organization Estimates of the Global and Regional Disease Burden of 11 Foodborne Parasitic Diseases, 2010: A Data Synthesis. *PLoS Medicine*. (2015). 12:e1001920. doi: 10.1371/journal.pmed.1001920
- 11. Levy M. Challenges and Opportunities of Small-Holder Pig Production and Marketing in Western Kenya [PhD]. Canada: University of Guelph. (2014).
- Zoli A, Shey-Njila O, Assana E, Nguekam JP, Dorny P, Brandt J, et al. Regional status, epidemiology and impact of taenia solium cysticercosis in Western and Central Africa. Acta Tropica. (2003). 87:35–42. doi: 10.1016/S0001-706X(03)00053-6
- Waiswa C, Fèvre EM, Nsadha Z, Sikasunge CS, Willingham AL. Porcine cysticercosis in Southeast Uganda: seroprevalence in Kamuli and Kaliro districts. J Parasitol Res. (2009) (2009):375493. doi: 10.1155/2009/375493
- Pondja A, Neves L, Mlangwa J, Afonso S, Fafetine J, Willingham 3rd AL, et al. Prevalence and risk factors of porcine cysticercosis in Angónia District, Mozambique. *PLOS Negl Trop Dis.* (2010). 4:e594. doi: 10.1371/journal.pntd.0000594

- Assana E, Lightowlers MW, Zoli AP, Geerts S. Taenia solium taeniosis/cysticercosis in Africa: risk factors, epidemiology and prospects for control using vaccination. *Vet Parasitol.* (2013) 195:14–23. doi: 10.1016/j.vetpar.2012.12.022
- Coral-Almeida M, Gabriël S, Abatih EN, Praet N, Benitez W, Dorny P. Taenia solium Human Cysticercosis: A Systematic Review of Sero-epidemiological Data from Endemic Zones around the World. *PLOS Negl Trop Dis.* (2015). 9:e0003919. doi: 10.1371/journal.pntd.0003919
- Thomas LF, Harrison LJ, Toye P, de Glanville WA, Cook EA, Wamae CN, et al. Prevalence of Taenia solium cysticercosis in pigs entering the food chain in western Kenya. *Tropical Animal Health Production*. (2016). 48:233– 8. doi: 10.1007/s11250-015-0949-6
- Mafojane NA, Appleton CC, Krecek RC, Michael LM, Willingham 3rd AL. The current status of neurocysticercosis in Eastern and Southern Africa. *Acta Tropica*. (2003). 87:25–33. doi: 10.1016/S0001-706X(03)00052-4
- Mukaratirwa S, Kassuku AA, Willingham AL, Murrell 3rd KD. Background to the international action planning workshop on Taenia solium cysticercosis/taeniosis with special focus on Eastern and Southern Africa. *Acta Tropica*. (2003). 87:3–5. doi: 10.1016/S0001-706X(03)00050-0
- CWGESA. Regional action plan for combating Taenia solium cysticercosis/taeniosis in Eastern and Southern Africa. Acta Tropica. (2003). 87:183–6. doi: 10.1016/S0001-706X(03)00117-7
- Dermauw V, Dorny P, Braae UC, Devleesschauwer B, Robertson LJ, Saratsis A, et al. Epidemiology of Taenia saginata taeniosis/cysticercosis: a systematic review of the distribution in southern and eastern Africa. *Parasites Vectors*. (2018) 11:578. doi: 10.1186/s13071-018-3163-3
- 22. Pietro Amedeo Modesti GR, Cappuccio FP, Agyemang C, Remuzzi G, Rap S, Perruolo E, Parati G, ESH Working Group on CV Risk in Low Resource Settings. Panethnic differences in blood pressure in europe: a systematic review and meta-analysis. *PloS ONE.* (2016) 11. doi: 10.1371/journal.pone.0147601
- Ngowi HA, Kassuku AA, Carabin H, Mlangwa JE, Mlozi MR, Mbilinyi BP, et al. Spatial clustering of porcine cysticercosis in Mbulu district, northern Tanzania. *PLOS Negl Trop Dis.* (2010) 4:e652. doi: 10.1371/journal.pntd.0000652
- Kabululu ML, Johansen MV, Mlangwa JED, Mkupasi EM, Braae UC, Trevisan C, et al. Performance of Ag-ELISA in the diagnosis of Taenia solium cysticercosis in naturally infected pigs in Tanzania. *Parasites Vectors*. (2020) 13:534. doi: 10.1186/s13071-020-04416-4
- Akoko JM, MacLeod E, Thomas LF, Alarcon P, Kang'ethe E, Kivali V, et al. Detection of circulating antigens for Taenia spp. in pigs slaughtered for consumption in Nairobi and surroundings, Kenya. *Parasite Epidemiology Control.* (2019) 4:e00093. doi: 10.1016/j.parepi.2019.e00093
- Braae UC, Magnussen P, Lekule F, Harrison W, Johansen MV. Temporal fluctuations in the sero-prevalence of Taenia solium cysticercosis in pigs in Mbeya Region, Tanzania. *Parasites Vectors*. (2014) 7:574. doi: 10.1186/s13071-014-0574-7
- Chembensofu M, Mwape KE, Van Damme I, Hobbs E, Phiri IK, Masuku M, et al. Re-visiting the detection of porcine cysticercosis based on full carcass dissections of naturally Taenia solium infected pigs. *Parasites Vectors*. (2017) 10:572. doi: 10.1186/s13071-017-2520-y
- Chilundo AG, Mukaratirwa S, Pondja A, Afonso S, Miambo R, Johansen MV. Prevalence and risk factors of endo- and ectoparasitic infections in smallholder pigs in Angónia district, Mozambique. *Vet Parasitol, Regional Studies Reports.* (2017) 7:1–8. doi: 10.1016/j.vprsr.2016.11.008
- Dorny P, Phiri IK, Vercruysse J, Gabriel S, Willingham 3rd AL, Brandt J, et al. A Bayesian approach for estimating values for prevalence and diagnostic test characteristics of porcine cysticercosis. *Int J Parasitol.* (2004). 34:569– 76. doi: 10.1016/j.ijpara.2003.11.014
- Eshitera EE, Githigia SM, Kitala P, Thomas LF, Fèvre EM, Harrison LJ, et al. Prevalence of porcine cysticercosis and associated risk factors in Homa Bay District, Kenya. *BMC Vet Res.* (2012) 8:234. doi: 10.1186/1746-6148-8-234
- 31. Fèvre EM, de Glanville WA, Thomas LF, Cook EAJ, Kariuki S, Wamae CN. An integrated study of human and animal infectious disease in the Lake Victoria crescent small-holder crop-livestock production system, Kenya. BMC Infectious Diseases. (2017) 17:457. doi: 10.1186/s12879-017-2559-6
- Kabululu ML, Ngowi HA, Kimera SI, Lekule FP, Kimbi EC, Johansen MV. Risk factors for prevalence of pig parasitoses in Mbeya Region,

Tanzania. Vet Parasitol. (2015) 212:460-4. doi: 10.1016/j.vetpar.2015. 08.006

- Kagira JM, Maingi N, Kanyari PW, Githigia SM, Ng'ang'a JC, Gachohi JM. Seroprevalence of Cysticercus cellulosae and associated risk factors in free-range pigs in Kenya. J Helminthol. (2010) 84:398–403. doi: 10.1017/S0022149X10000076
- 34. Komba EV, Kimbi EC, Ngowi HA, Kimera SI, Mlangwa JE, Lekule FP, et al. Prevalence of porcine cysticercosis and associated risk factors in smallholder pig production systems in Mbeya region, southern highlands of Tanzania. *Vet Parasitol.* (2013) 198:284–91. doi: 10.1016/j.vetpar.2013.09.020
- Krecek RC, Michael LM, Schantz PM, Ntanjana L, Smith MF, Dorny P, et al. Prevalence of Taenia solium cysticercosis in swine from a community-based study in 21 villages of the Eastern Cape Province, South Africa. *Vet Parasitol.* (2008) 154:38–47. doi: 10.1016/j.vetpar.2008.03.005
- Krecek RC, Mohammed H, Michael LM, Schantz PM, Ntanjana L, Morey L, et al. Risk factors of porcine cysticercosis in the Eastern Cape Province, South Africa. *PLoS ONE*. (2012) 7:e37718. doi: 10.1371/journal.pone.0037718
- Bulaya C, Mwape KE, Michelo C, Sikasunge CS, Makungu C, Gabriel S, et al. Preliminary evaluation of Community-Led Total Sanitation for the control of Taenia solium cysticercosis in Katete District of Zambia. *Vet Parasitol.* (2015) 207:241–8. doi: 10.1016/j.vetpar.2014.12.030
- Thomas L. Epidemiology of Taenia solium Cysticercosis in western Kenya [PhD Thesis]. England: University of Edinburgh. (2013).
- Maganira JD, Mwang'onde BJ, Kidima W, Mwita CJ, Höglund J. Seroprevalence of circulating taeniid antigens in pigs and associated risk factors in Kongwa district, Tanzania. *Parasite Epidemiol Control.* (2019) 7:e00123. doi: 10.1016/j.parepi.2019.e00123
- Matos C, Sitoe C, Afonso S, Banze J, Baptista J, Dias G, et al. A pilot study of common health problems in smallholder pigs in Angónia and Boane districts, Mozambique. J S Afr Vet Assoc. (2011) 82:166–9. doi: 10.4102/jsava.v82i3.55
- NguhiuP LK. Kelvin Kinyuaand Paul Matonge. Seroprevalence of Porcine Cysticercosis and Associated Risk Factors in Pigs Slaughtered in Abattoirs in Thika, Kiambu County, Kenya. J Life Sci. (2017) 11:321–6. doi: 10.17265/1934-7391/2017.07.002
- Nsadha Z, Thomas LF, Févre EM, Nasinyama G, Ojok L, Waiswa C. Prevalence of porcine cysticercosis in the Lake Kyoga Basin, Uganda. *BMC Vet Res.* (2014) 10:239. doi: 10.1186/s12917-014-0239-y
- Phiri IK, Dorny P, Gabriel S, Willingham AL, 3rd, Speybroeck N, Vercruysse J. The prevalence of porcine cysticercosis in Eastern and Southern provinces of Zambia. *Vet Parasitol.* (2002) 108:31-9. doi: 10.1016/S0304-4017(02) 00165-6
- Pondja A, Neves L, Mlangwa J, Afonso S, Fafetine J, Willingham 3rd AL, et al. Incidence of porcine cysticercosis in Angónia District, Mozambique. *Prev Vet Med.* (2015) 118:493–7. doi: 10.1016/j.prevetmed.2015.01.001
- 45. Shongwe NA, Byaruhanga C, Dorny P, Dermauw V, Qekwana DN. Knowledge, practices and seroprevalence of Taenia species in smallholder farms in Gauteng, South Africa. *PloS ONE*. (2020) 15:e0244055. doi: 10.1371/journal.pone.0244055
- 46. Porphyre V, Betson M, Rabezanahary H, Mboussou Y, Zafindraibe NJ, Rasamoelina-Andriamanivo H, et al. Taenia solium porcine cysticercosis in Madagascar: comparison of immuno-diagnostic techniques and estimation of the prevalence in pork carcasses traded in Antananarivo city. *Vet Parasitol.* (2015) 219:77–83. doi: 10.1016/j.vetpar.2015.08.027
- Shonyela SM, Mkupasi EM, Sikalizyo SC, Kabemba EM, Ngowi HA, Phiri I. An epidemiological survey of porcine cysticercosis in Nyasa District, Ruvuma Region, Tanzania. *Parasite Epidemiology Control.* (2017) 2:35– 41. doi: 10.1016/j.parepi.2017.09.002
- Sikasunge CS, Phiri IK, Phiri AM, Dorny P, Siziya S, Willingham AL, 3rd. Risk factors associated with porcine cysticercosis in selected districts of Eastern and Southern provinces of Zambia. *Vet Parasitol.* (2007) 143:59– 66. doi: 10.1016/j.vetpar.2006.07.023
- Sikasunge CS, Phiri IK, Phiri AM, Siziya S, Dorny P, Willingham 3rd AL. Prevalence of Taenia solium porcine cysticercosis in the Eastern, Southern and Western provinces of Zambia. Vet J. (2008) 176:240– 4. doi: 10.1016/j.tvjl.2007.02.030
- 50. Wardrop NA, Thomas LF, Atkinson PM, de Glanville WA, Cook EA, Wamae CN, et al. The Influence of Socio-economic, Behavioural and Environmental Factors on Taenia spp. Transmission in Western Kenya: Evidence from a

Cross-Sectional Survey in Humans and Pigs. *PLOS Negl Trop Dis.* (2015) 9: e0004223. doi: 10.1371/journal.pntd.0004223

- Boa ME, Mahundi EA, Kassuku AA, Willingham 3rd AL, Kyvsgaard NC. Epidemiological survey of swine cysticercosis using ante-mortem and postmortem examination tests in the southern highlands of Tanzania. *Vet Parasitol.* (2006). 139:249–55. doi: 10.1016/j.vetpar.2006.02.012
- Kabululu ML, Ngowi HA, Mlangwa JED, Mkupasi EM, Braae UC, Trevisan C, et al. Endemicity of Taenia solium cysticercosis in pigs from Mbeya Rural and Mbozi districts, Tanzania. *BMC Vet Res.* (2020) 16:325. doi: 10.1186/s12917-020-02543-9
- Minani S, Dorny P, Trevisan C. Prevalence and risk assessment of porcine cysticercosis in Ngozi province, Burundi. Vet Parasitol: Regional Studies and Reports. (2021) 23:100514. doi: 10.1016/j.vprsr.2020.100514
- Mkupasi EM, Ngowi HA, Nonga HE. Prevalence of extra-intestinal porcine helminth infections and assessment of sanitary conditions of pig slaughter slabs in Dar es Salaam city, Tanzania. Tropical animal health and production. (2011) 43:417–23. doi: 10.1007/s11250-010-9708-x
- 55. Mushonga B, Habarugira G, Birori A, Kandiwa E, Samkange A, Bhebhe E. An epidemiological survey of the magnitude and local perceptions of porcine cysticercosis by two methods in Nyaruguru district, Rwanda. *Vet Parasitol*, regional studies and reports. (2018) 14:18–24. doi: 10.1016/j.vprsr.2018.07.010
- Mutua FK RT, Arimi SM, Kitala PM, Githigia SM, Willingham AL, Njeruh FM. Palpable lingual cysts, a possible indicator of porcine cysticercosis, in Teso District, Western Kenya. J Swine Health and Production. (2007) 15:206–12.
- Newell E, Vyungimana F, Geerts S, Van Kerckhoven I, Tsang VC, Engels D. Prevalence of cysticercosis in epileptics and members of their families in Burundi. *Trans R Soc Trop Med Hyg.* (1997) 91:389– 91. doi: 10.1016/S0035-9203(97)90251-0
- Ngowi HA, Kassuku AA, Maeda GEM, Boa ME, Carabin H, Willingham AL. Risk factors for the prevalence of porcine cysticercosis in Mbulu District, Tanzania. Vet Parasitol. (2004) 120:275–83. doi: 10.1016/j.vetpar.2004.01.015
- Ngowi HA, Kassuku AA, Maeda GE, Boa ME, Willingham AL. A slaughter slab survey for extra-intestinal porcine helminth infections in northern Tanzania. *Trop Anim Health Prod.* (2004) 36:335-40. doi: 10.1023/B:TROP.0000026663.07862.2a
- Phiri IK, Dorny P, Gabriel S, Willingham 3rd AL, Sikasunge C, Siziya S, et al. Assessment of routine inspection methods for porcine cysticercosis in Zambian village pigs. J Helminthology. (2006) 80:69–72. doi: 10.1079/JOH2005314
- Porphyre V, Rasamoelina-Andriamanivo H, Rakotoarimanana A, Rasamoelina O, Bernard C, Jambou R, et al. Spatio-temporal prevalence of porcine cysticercosis in Madagascar based on meat inspection. *Parasites Vectors*. (2015) 8:3914. doi: 10.1186/s13071-015-0975-2
- Yohana C, Mwita CJ, Nkwengulila G. The prevalence of porcine cysticercosis and risk factors for taeniasis in iringa rural district. J Anim Vet Adv. (2013) 5:251–5. doi: 10.19026/ijava.5.5606
- Zirintunda G, Ekou J. Occurrence of porcine cysticercosis in free-ranging pigs delivered to slaughter points in Arapai, Soroti district, Uganda. J Vet Res. 2015:82:888. doi: 10.4102/ojvr.v82i1.888
- 64. FAO. Live Animals. Food and Agriculture Organization of the United Nations Statistical Databases]. (2021) Available online at: http://www.fao.org/faostat/ en/#home (accessed on April, 21, 2021).
- Shonyela SM. GYaCW. Current status of prevalence, possible control and risk factors associated with porcine cysticercosis from endemic countries in africa. *World J Vac.* (2018) 8:53–80. doi: 10.4236/wjv.2018.83006
- 66. Thys S, Mwape KE, Lefèvre P, Dorny P, Marcotty T, Phiri AM, et al. Why latrines are not used: communities' perceptions and practices regarding latrines in a Taenia solium endemic rural area in Eastern Zambia. *PLOS Negl Trop Dis.* (2015) 9: e0003570. doi: 10.1371/journal.pntd.0003570
- 67. WHOandUNICEF. *Progress on sanitation and drinking water*. Geneva: World Health Organization and UNICEF 2014, (2014).
- Ramiandrasoa NS, Ravoniarimbinina P, Solofoniaina AR, Andrianjafy Rakotomanga IP, Andrianarisoa SH, Molia S, et al. Impact of a 3-year mass drug administration pilot project for taeniasis control in Madagascar. *PLOS Negl Trop Dis.* (2020) 14:e0008653. doi: 10.1371/journal.pntd.0008653
- González ML. Epidemiology of taeniosis and cysticercosis in Europe. Bellaterra Universitat Autonoma De Barcelona. (2018).
- 70. Boa ME, Kassuku AA, Willingham 3rd AL, Keyyu JD, Phiri IK, Nansen P. Distribution and density of cysticerci of Taenia solium by muscle groups and

organs in naturally infected local finished pigs in Tanzania. *Vet Parasitol.* (2002) 106:155–64. doi: 10.1016/S0304-4017(02)00037-7

- Dorny P. Jef Brandt, Andre' Zoli, Geerts S. Immunodiagnostic tools for human and porcine cysticercosis. Acta tropica. (2003) 87:79–86. doi: 10.1016/S0001-706X(03)00058-5
- Samorek-Pieróg Małgorzata JK. Tomasz Cencek. Identification and control of sources of Taenia solium infection –the attempts to eradicate the parasite. J Vet Res. (2018) 62:27–34. doi: 10.2478/jvetres-2018-0004
- Lightowlers MW AE, Jayashi CM, Gauci CG, Donadeu M. Sensitivity of partial carcass dissection for assessment of porcine cysticercosis at necropsy. *Int J Parasitol.* (2015) 45. doi: 10.1016/j.ijpara.2015.08.004
- 74. Krecek R.C LMM, P.M. Schantz, L. Ntanjana, M.F. Smith, P. Dorny, L.J.S. Harrison, F. Grimm, N. Praeth, A.L. Willingham III. Corrigendum to Prevalence of Taenia solium cysticercosis in swine from a community-based study in 21 villages of the Eastern Cape Province, South Africa. *Vet Parasitol.* (2011) 183:198–200. doi: 10.1016/j.vetpar.2011.09.033
- Dinh Ng-Nguyen MASaRJT. A systematic review of taeniasis, cysticercosis and trichinellosis in Vietnam. *Parasites Vectors*. (2017) 10. doi: 10.1186/s13071-017-2085-9
- 76. Sciutto E, GarcôÂa MHG, de Aluja AS, Villalobos ANM, Rodarte LF, Parkhouse M, et al. Diagnosis of porcine cysticercosis: a comparative study of serological tests for detection of circulating antibody and viable parasites. *Vet Parasitol.* (1998) 78:185–94. doi: 10.1016/S0304-4017(98)00129-0
- 77. Ganaba R, Praet N, Carabin H, Millogo A, Tarnagda Z, Dorny P, et al. Factors associated with the prevalence of circulating antigens to porcine cysticercosis in three villages of Burkina Faso. *PLOS Negl Trop Dis.* (2011) 5: e927. doi: 10.1371/journal.pntd.0000927
- Praet N KK, Kabwe C, Maketa V, Lukanu P, Lutumba P, Polman K, et al. Taenia solium cysticercosis in the democratic Republic of Congo: How does pork trade affect the transmission of the parasite? *PLOS Negl Trop Dis.* (2010) 4. doi: 10.1371/journal.pntd.0000817
- Rebecca Paul Weka JK, Cogan T, Eisler M, Eric R. Morgan overview of taenia solium cysticercosis in West Africa. Acta tropica. (2019) 190:329– 38. doi: 10.1016/j.actatropica.2018.12.012
- Kagira JM, Kanyari PW. Occurrence of risk factors for zoonoses in Kisumu City, Kenya: a questionnaire survey. *East Afr J Public Health*. (2010) 7:1– 4. doi: 10.4314/eajph.v7i1.64668
- Mwape KE, Phiri IK, Praet N, Speybroeck N, Muma JB, Dorny P, et al. The incidence of human cysticercosis in a rural community of Eastern Zambia. *PLOS Negl Trop Dis.* (2013) 7: e2142.. doi: 10.1371/journal.pntd.0002142
- Mwape KE, Phiri IK, Praet N, Dorny P, Muma JB, Zulu G, et al. Study and ranking of determinants of Taenia solium infections by classification tree models. The American journal of tropical medicine and hygiene. (2015) 92:56–63. doi: 10.4269/ajtmh.13-0593
- Lekule FP, Kyvsgaard NC. Improving pig husbandry in tropical resource-poor communities and its potential to reduce risk of porcine cysticercosis. *Acta Tropica*. (2003) 87:111–7. doi: 10.1016/S0001-706X(03)00026-3
- Roche R BR, Cumming O. A long way to go estimates of combined water, sanitation and hygiene coverage for 25 sub-Saharan African countries. *PLoS ONE*. (2017) 12. doi: 10.1371/journal.pone.0173702

**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

**Publisher's Note:** All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Copyright © 2022 Gulelat, Eguale, Kebede, Aleme, Fèvre and Cook. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.