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Chapter

Taenia solium Cysticercosis in Pigs and Human: A Review of Epidemiological Data in West Africa (1990–2019)

Rebecca Weka, Pam Luka, Ndudim Ogo and Paul Weka

Abstract

Taenia solium taeniasis/cysticercosis/neurocysticercosis is a neglected zoonotic disease endemic in sub-Saharan Africa, Latin-American and Asia and is an emerging public health and economic problem. The association between cysticercosis and epilepsy has been documented worldwide including West Africa. Poor sanitary conditions, traditional pig farming and poverty play an important role in perpetuation of *Taenia solium*. There has been limited research undertaken in *T. solium* in human and pigs in some West African countries, where prevalence of taeniasis was up 40%, human cysticercosis 10.3%, porcine cysticercosis 32.5–39.6% and epilepsy 28.0/1000–43.0/1000. The study identified porcine cysticercosis in 18 countries, human cysticercosis in 19 countries, taeniasis in 4 countries and epilepsy was reported in 25 countries. The aim of this study is to review scientific literature on the epidemiology of *T. solium* infections in pigs and humans in Western Africa and document data on the prevalence of epilepsy in the region. The objective is to document occurrence of disease in West Africa so as to offer options available for control. The study conducted literature search of online international databases of published resources for information on *T. solium* in Western Africa and Epilepsy from 1990 to 2018.

Keywords: *Taenia solium*, epilepsy, human, pigs, West Africa, literature search, epidemiology

1. Introduction

Parasitic zoonoses are becoming increasingly important in the spectrum of emerging and re-emergent diseases for both developed and developing countries, and are typically associated with poor marginalized countries in low-income countries. They are regarded as disease of the poorest among the poor [1–3]. *Taenia solium* is found in sub-Saharan Africa, Central Asia and Latin America where domestic pig husbandry is practiced, poverty, illiteracy and deficient sanitary infrastructures are common [1, 4, 5]. Similarly, the disease has been reported in urban areas where most of the infected pigs are transported and consumed. The incidence of the disease in humans is increasing and now is a re-emerging disease in some developed countries and in areas of non-endemicity, due to international

travel and immigration [6, 7]. Hence cysticercosis/neurocysticercosis/teaniosis complex caused by the larval stage of *T. solium* in both pigs and humans remains a significant cause of human morbidity and mortality in many parts of the world. It is seriously affecting pig production and also considered as a public health and economic problem in many developing countries affecting food security and negatively impacts the nutritional and economic well-being of the small holder farming community [8, 9].

2. Life cycle

2.1 Life cycle and pathogenesis

Taenia solium life cycle is sustained where free roaming pigs, have access to contaminated feces of tapeworm carriers. *T. solium* has a complex two host life cycle and is cyclically transmitted between pigs and man. Humans are the only definitive host and harbor the adult stages of these cestodes following ingestion of insufficiently cooked pork meat infested with cysticerci. Infection with the adult stage is relatively innocuous and carries mild clinical manifestations leading to taeniasis [1–11]. Pigs are the natural intermediate host, while human's acts as the accidental dead-end intermediate host and are both infected with *T. solium* by ingestion of embryonated eggs from feces of tapeworm carriers from contaminated soil, water, vegetation/foods to form cysticerci. Infection with the cysticerci leads to more severe symptoms including headache and neurocysticercosis when the pathology occurs in the CNS [11].

2.2 Epidemiology

Neurocysticercosis has been considered to be the most common parasitic infestation of the central nervous system and the single most common cause of preventable acquired epilepsy and mortality in developing countries [12–14], and a strong correlation was reported between the prevalence of epilepsy and seropositivity against *T. solium* cysticercosis [15]. The association between cysticercosis and epilepsy has been documented as a leading neurological condition worldwide including West Africa. Epilepsy is a frequent chronic neurologic disorder that affects approximately 70 million people of all ages worldwide [15] Studies of [10] in 2010 reported that the median prevalence of active epilepsy was 4.9/1000 (2.3–10.3) for developed countries, 12.7/1000 (3.5–45.5) and 5.9/1000 (3.4–10.2) in rural and urban studies in developing countries. Neurocysticercosis has been associated with 30% of adult onset epilepsy in endemic regions where 10–20% of the general population can have brain lesions consistent with neurocysticercosis on CT scans [16]. Neurocysticercosis creates a tremendous economic burden in endemic areas incurring significant costs due to diagnosis, treatment and disability [17]. Poor sanitary conditions, traditional pig farming, lack of awareness of the disease and poverty play an important role in the perpetuation of the *Taenia solium*/cysticercosis, and are present in West Africa [18]. Research in the region on *Taenia solium* cysticercosis and taeniasis in both human and pigs has been limited. Prevalence information of the disease in some countries within the region has been scanty leading to underestimation of the prevalence, epidemiology and clinical impacts of the disease which has made it difficult to make definitive recommendations on control strategies. Data on porcine and human cysticercosis are available from several countries. However, there is no recent information on *T. solium* taeniasis-cysticercosis complex in some countries including Guinea Bissau, Liberia, Ivory

coast and Sierra-Leone [19] as shown in **Tables 1** and **2**. The aim of this study is to review scientific and gray literature and to identify the empirical data on *T. solium* taeniasis/human/porcine cysticercosis/neurocysticercosis/epilepsy in West Africa and the risk factors responsible for the epidemiology of *T. solium* cysticercosis in order to understand the differences in exposure to the parasite in endemic areas around the world. This will give an update and compile the current knowledge on *T. solium* in Western Africa, including risk factors for infections in pigs and humans

Author	Country/location	Diagnosis	Total	Prevalence	Type of study
[20]	Benin, Southern Benin	Meat inspection	118.073	0.06–0.69%	Abattoir
[21]	Burkina Faso, Ouagadougou	Meat inspection	62,311	0.22 (*n* = 139)	Abattoir
[22]	Burkina Faso	B158/B60 Ag-ELISA	336	32.5–39.6%	Cross sectional
[58]	Burkina Faso	Meat inspection	117,026	0.57% (*n* = 673)	Abattoir
[59]	Ghana, Kumasi	Ante mortem/post mortem	4121	2.31% (*n* = 95)	Cross sectional
[60]	Ghana, Upper East Region	Post mortem	60	11.70%	Cross sectional
[61]	Nigeria, Bodija, Ibadan, Oyo State	Meat inspection	593	1.01% (*n* = 6)	Abattoir
[62]	Nigeria, Michika, Adamawa State,	Post mortem	247	3.2% (*n* = 8)	Cross sectional
[65]	Nigeria, Nasarawa and Gonin Gora,Chikun, Kaduna	Post mortem	43	9.3% (*n* = 4)	Cross sectional
[63]	Nigeria, Jalingo, Taraba State	Post mortem	323	4.95% (*n* = 16)	Cross sectional
[23]	Nigeria, Zuru, Kebbi State	Lingual, post mortem	4208	5.85% (*n* = 205) 14.4% (*n* = 118)	Cross sectional
[64]	Nigeria, Bodija, Ibadan,	Post mortem	250	4.4% (*n* = 11)	Cross sectional
[24]	Nigeria, Ibi Taraba State	Antemortem/post mortem	4380	6.25% (*n* = 274)	Cross sectional
[25]	Nigeria, Nsukka Enugu State	Lingual/post mortem	2358	20% (*n* = 483)	Cross sectional
[26]	Nigeria, Enugu State Udenu, Igbo-Eze South Nsukka Enugu State	Post mortem	379	2.4% (*n* = 9)	Cross sectional
[66]	Nigeria, Jos	Antibody ELISA	115	46% (*n* = 29)	Cross sectional
[67]	Gambia, Western region	Lingual, Ag-ELISA	1705	4.8%	Cross sectional
[67]	Senegal	Lingual, Ag-ELISA	1705	6.4–13.2%	Cross sectional

Table 1.
Selected studies of porcine cysticercosis in West Africa 1980–2019.

Author	Country/location	Diagnosis	Total	Epilepsy (*n*)	Neurocysticercosis	Cysticercosis	Taeniasis
[27]	Benin	Capture recapture/Neurlogist	3134	20.1/1000 (*n* = 66) GP	ND	ND	ND
[28]	Benin	Capture recapture/Neurlogist	11,668	12.7/1000 (148) GP	ND	ND	ND
[29]	Benin, Savolou	Ab-ELISA, skull/muscle X-ray and pathol. of cysts	1443	1.5 (22/1443), 17/186 GP	4.0% (*n* = 57)	1% (*n* = 14 skin nodules)	ND
[29]	Benin, Vekky	Ab-ELISA, skull/muscle X-ray and pathol. of cysts	319	GP	3.5% (319)	ND	ND
[29]	Benin	Ab-ELISA, skull/muscle X-ray and pathol. of cysts	2625	GP	1.6% (*n* = 41)	ND	ND
[30]	Benin	AB,ELISA/(EITB)	2625	41/1.3% (35) GP	ND	ND	ND
[31]	Benin	Questionnaire,clinical/neurologist	13,046	8.05/1000 (*n* = 105), GP	ND	ND	ND
[32]	Burkina Faso	B158/B60 AG-ELISA	3609	GP	ND	0–11.5% (*n* = 120)	ND
[33]	Burkina Faso	Ag B158/B60 ELISA	1729/1719	GP	ND	3·8% (*n* = 65) CC 2.7% (*n* = 47) (2.7%)	ND
[34]	Burkina Faso´ a	B158/B60 Ag-ELISA	763	GP	ND	6.29% (*n* = 48)	ND
[35]	Burkina Faso	B158/B60 Ag-ELISA questionnaire/neurologist	3696	3.9% (*n* = 145), GP		3.4% (*n* = 129)	ND
[36]	Burkina Faso	AgELISA/CT scan/neurologist	888	4.4$(39) epi, VLVL	29% (20/68)	ND	ND
[37]	Burkina Faso	Ag-ELISA, physician	888	4.5% (39) of 70 VL	5/39 epileptics (12.8%), 3.4% (28/814)	ND	ND
[34]	Burkina Faso	Questionnaire neurologist	4768	669 (14.0%), VL	0.6% (29)	ND	ND
[38]	Burkina-Faso		16,627	10.6 per 1000, CB	ND	ND	ND
[39]	Ghana Bunkpuru	Kato-Katz technique	494		ND	ND	13.15% (*n* = 65)

Author	Country/location	Diagnosis	Total	Epilepsy (*n*)	Neurocysticercosis	Cysticercosis	Taeniasis
[40]	GhanaKintampo	Questionnairesclinicians/western blot	586,607	10.1/1000	ND	0.01	ND
[41]	Senegal	Direct fecal examination		ND	ND	ND	2/43* 4.65
[42]		Fecal egg count		ND	ND	ND	4/43** 9.30
[42]		Worm expulsion/amorphological identification	ND	ND	ND	ND	1/43***2.33
[43]	Nigeria ebonyi/ benue state	Questionnaire	2500 and 6000	(*n* = 52) 20.8/1000 and (28) 4.7/1000, PB	ND	ND	ND
[44]	Nigeria Agu-Abor/ Enugu	Questionnaire, medical	8228	0.6%/1000 (*n* = 49)	ND	ND	ND
[48]	Nigeria Kaduna	Ab-ELISA	300			14.3% (*n* = 43)	ND
[45]	Nigeria Abuja	An 8000 B-Scan Scanmate				Ocular cysticercosis	
[70]	Nigeria Ukpo,Dunukofia Anambra state,	Door to door Questionnaire, neurologist	6800	4.3/1000 (*n* = 29)	ND	ND	ND
[46]	Nigeria Odeda, Ogun State,	Sodium acetate acetic acid formalin concentration method (SAF-Ether)	428		ND		40% (*n* = 175)
[25]	Nigeria Nsukka Enugu State,	Stool microscopy	1525		ND	ND	8·6% (*n* = 131)
[47]	Nigeria Jos	Ab-ELISA	125		ND	9.6% (*n* = 12)	ND
[48]	Nigeria Nasarawa	Copro Ag ELISA, questionnaire	10				30 (*n* = 3)
[49]	Nigeria Ile-Ife	Surgeon/histopathological, biopsy				Cysticercosis of breast	ND

Author	Country/location	Diagnosis	Total	Epilepsy (*n*)	Neurocysticercosis	Cysticercosis	Taeniasis
[50]	Nigeria, Edo State,	Surgeon, histopathological				Cysticercosis in the anterior chamber	ND
[51]	Nigeria	Questionnaire	18,951	5.3/1000 101, CB			ND
[71]	Nigeria Osun	Surgery, Occular Ultrasound				Intraocular cysticercosis	ND
[42]	Senegal Soutou	(Ag-ELISA) and (EITB),CT scan	403		7.69 (*n* = 31)/7.69 (*n* = 31)	23.3 (10/43)	ND
[52]	Senegal Pikine, Dakar	Questionnaire, physician, electroencephalography	4500	(*n* = 64) 14.2/1000	ND	ND	ND
[53]	Senegal		7682	8.3/per 1000	ND	ND	ND
[41]	Liberia		4436	(123) 28.0per 1000			
[54]	Liberia		2733	43.0 per 1000, CB	ND	ND	ND
[55]	Mauritania	Neurologist	236	34.7% (*n* = 82), HB			
[56]	Togo, Tone		9155 for epi and 1343 for cyst (*n* = 5264) 2.4%	18.6%/1000, GB	ND	38/1000	ND
[57]	Togo, the Kozah district of North Togo		5264	(*n* = 88) 16/1000	ND	23.3% (*n* = 123)	ND

2/43 4.65, foot note =direct microscopy.*
*4/43** 9.30, foot note = Ritchie formol ether method.*
*1/43*** 2.33,foot note= Worm expulsion.*

Table 2.
Selected prevalence of human cysticersosis and epilepsy in west African countries.

cysticercosis (HCC) from endemic communities. The objective of the study will be to review and document data on the prevalence of human cysticercosis/neurocysticercosis in the region with emphasis on epilepsy.

2.3 Methods

A systematic literature search was done on studies carried out on cysticercosis in humans and pigs, seroprevalence of cysticercosis in humans and pigs, neurocysticercosis/taeniasis, risk factors for transmission of cysticercosis and epilepsy in West Africa published between 1980 and 2019. This search focused on the articles in which data was obtained using the following techniques and protocols: (1) enzyme-linked immunoelectrotransfer blot (EITB), (2) enzyme-linked immunosorbent assay (B158/B60 Ag-ELISA or HP10 Ag-ELISA), (3) copro-antigen ELISA and real-time polymerase chain reaction assay (copro-PCR). Language restriction was applied, the considered languages were English and French. The selected databases for this study were: PubMed (http://www.ncbi.nlm.nih.gov/pubmed/), Google scholar and others. The search was performed from May 22 to August 22, 2019.

2.4 Literature search

The following data were included in this study (1) peer-reviewed studies of *T. solium* taeniasis/cysticercosis/neurocysticercosis, porcine cysticercosis and epilepsy in West Africa. (2) "Gray literature" on *T. solium* taeniasis/cysticercosis, neurocysticercosis presence in West Africa which consisted of informally published written materials including reports. We performed a literature search using PubMed (http://www.ncbi.nlm.nih.gov/pubmed/) with date restriction from January 1, 1980 to January 5, 2019 using the following search term: (solium OR Tapeworm OR Taeniasis OR Taeni* OR Taeniosis OR Neurocysticercosis OR Cysticerc* OR epilepsy) AND West Africa (Benin OR Burkina Faso OR Ivory Coast OR Cape Verde OR Gambia OR Ghana OR Guinea OR Guinea Bissau OR Liberia OR Libya OR Malawi OR Mali OR Mauritania OR Niger OR Nigeria OR Senegal OR Sierra Leone OR Togo). We also searched other databases such as Google Scholar (http://scholar.google.com), Cab Direct (http://www.cab direct.org) and African Journals Online (http://www.ajol.info) using the following keywords: "*Taenia solium*," "porcine cysticercosis," "neurocysticercosis," "human cysticercosis" and "taeniasis" Epilepsy, West Africa.

2.5 Data extraction and collection

Presence of *T. solium* in this study was defined as a documented case of disease related to the tapeworm, whether it was diagnosed and documented as human cysticercosis, neurocysticercosis, porcine cysticercosis, taeniasis or epilepsy. Initially, we reviewed all titles and abstracts, if accessible, and excluded studies outside West Africa, and studies with no specified diagnostic technique, studies written in languages other than English and French, and studies not having full paper, that is, abstracts only experimental studies were also excluded.

2.6 Study selection

Figure 1 describes the review process and the number of articles selected at each stage of the review. From an initial number of 550 articles, only 121 were eventually used. The search selected by removal of duplicate studies from the title selection and studies performed before 1980. Secondly, another set of articles were excluded due to: (1) parasites other than *T. solium*; (2) studies performed in non-west African

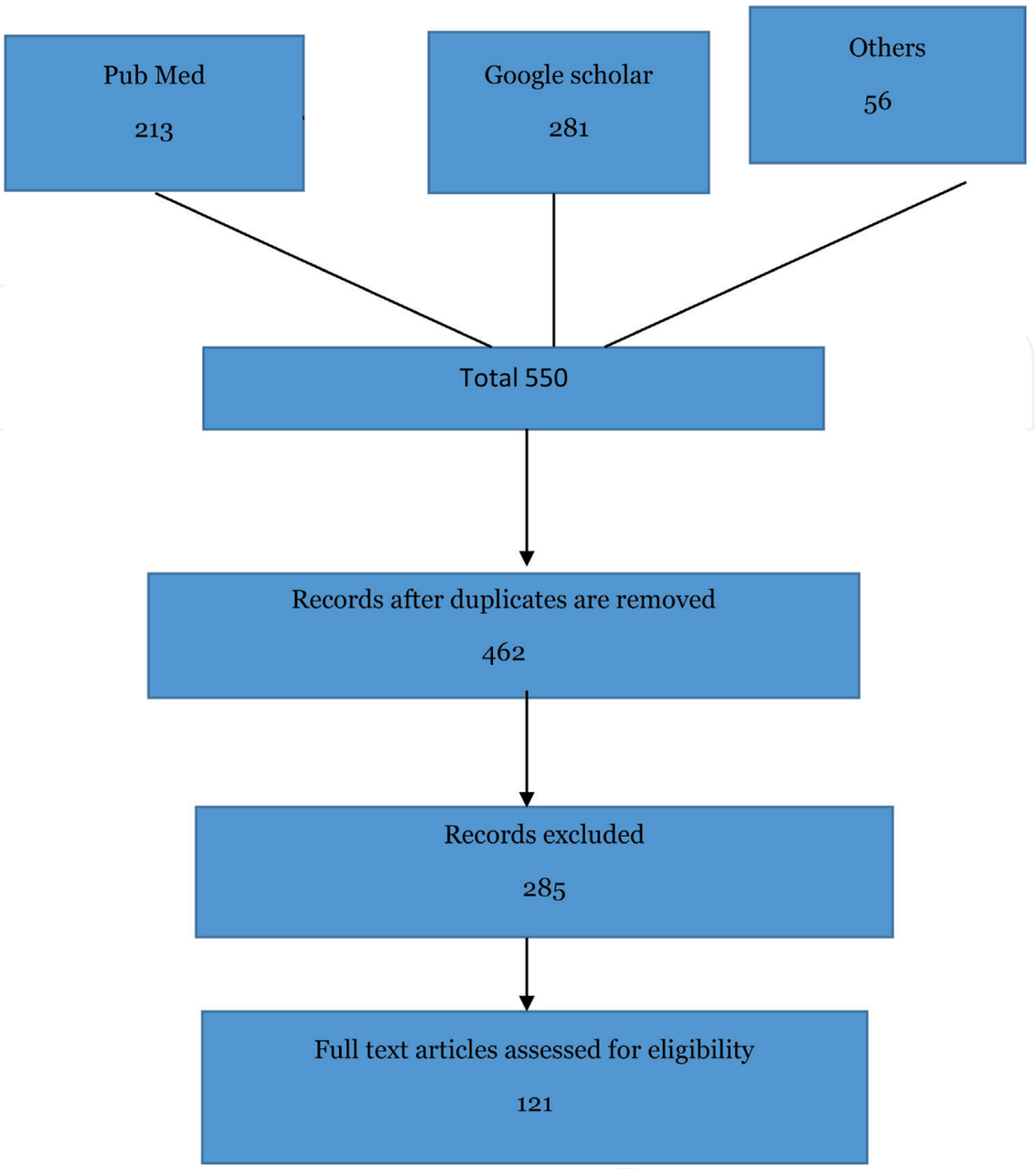


Figure 1.
Flow diagram.

countries; (3) articles written in languages other than French and English; (4) studies not presenting original data and/or the techniques and protocols performed on their studies and (5) studies not related to *T. solium* epidemiology and epilepsy in West African countries. Finally, when full texts were read, the following were selected. Community-based studies, case reports, HCC prevalence reports available, HCC diagnosis using the EITB and Ag ELISA, porcine cysticercosis using carcass inspection and Ab and Ag ELISA, Taeniasis studies based on Copro-Ag ELISA and stool microscopy, and epilepsy studies based on questionnaire, medical or non-medical sources.

3. Results

The search identified 66 studies that reported the prevalence of *T. solium* taeniasis/cysticercosis/neurocysticercosis and epilepsy in West Africa from 1980 to 2019.The study identified porcine cysticercosis in 18 countries, human cysticercosis in 19 countries, taeniasis in 4 countries and epilepsy was reported in 25 countries

(**Tables 1** and **2**). **Figure 1** shows the flow chart of the selection of literature for the informed prevalence estimations of studies included in this review; 8 from Benin (1PC/7HCC/PWE), 11 from Burkina Faso (3PC/8HCC/PWE), 1 from Gambia (PC), 4 from Ghana (2PC/1EP/1TE), 2 from Liberia (PWE), 1 from Mali (PWE), 1 from Mauritania (PWE), 24 from Nigeria (PC10/HCC/PWE14), 3 from Senegal (1PC/2PWEI) and 4 from Togo (4 PWE).

3.1 Porcine cysticercosis in West Africa

One epidemiological studies from Benin [20] used carcass inspection to determine the prevalence of porcine inspection and obtained a prevalence of 0.06–0.69% among a total of 118,073, slaughtered pigs. Two studies from Burkina Faso used carcass inspection to determine the prevalence of porcine cysticercosis and obtained a prevalence of 0.22–0.57% in a total of 179,337 pigs [21, 58]. One study used B158/B60 Ag-ELISA to determine the prevalence of active cysticercosis in pigs and obtained a seroprevalence of 32.5–39.6% among 336 pigs [22]. Two studies from Ghana determined the prevalence of porcine cysticercosis by carcass inspection and obtained the prevalence of 2.31–11.70% [59, 60], among a total of 4181 pigs. A total of 10 studies in Nigeria determined the prevalence of porcine cysticercosis by carcass inspection and obtained a prevalence of 1–20% [23–26, 61–65] among a total population of 12,781 pigs. While one study determined the seroprevalence of porcine cysticercosis and obtained a seroprevalence of 46% IgG antibodies among 115 pigs [66]. A study in Senegal determined the prevalence of porcine cysticercosis by lingual inspection and obtained a prevalence of 0.1–1.0%, while Ag-ELISA gave a seroprevalence of 4.8% [67]. All the data are presented in **Table 1**.

3.2 Human cysticercosis, taeniasis and epilepsy in West Africa

Sero-epidemiological studies from 16 countries were selected for the West African region, 3 studies [29] from Benin used Ab-ELISA, skull/muscle X-ray and pathology of cysts and a study used both Ab-ELISA and EITB [30]. The total number of individuals sampled for serological testing in this region was 4387. Prevalence of circulating antibodies ranged from 1 to 4%. Detailed description of each study is given in **Table 2**. The total number of individuals examined for epilepsy survey in the region was 27,848, excluding 1443 individuals that were involved in the serological study by [29]. Three studies used door-to-door method of survey in estimating the prevalence of epilepsy [27, 30, 31]. Two of the authors used capture/recapture method. They used questionnaires/neurologist to diagnose epileptics [27, 30, 31] and according to definition by the ILAE 1989, and PAANS [68, 69]. The prevalence of epilepsy in the country ranged from 8.08/1000 to 20.1/1000. A study [29] linked the 1.5% seroprevalence epilepsy to the prevalence of human cysticercosis. A 0–29% human cysticercosis seroprevalence in Burkina Faso was obtained from six studies using Ag-ELISA [32–34, 36, 37] and the prevalence of epilepsy in the region ranged from 4.5 to 14% per 1000. The total individuals sampled for seroprevalence studies were 13,413. Three of the studies associated the prevalence of epilepsy to cysticercosis [36, 37]. Two studies [34, 38] estimated the prevalence of epilepsy only, with a total individuals sample size of 29,315 excluding studies that associated the prevalence of epilepsy with cysticercosis.

Human taeniasis from Ghana was obtained from a study performing the Katao Khazt method and obtained a prevalence of 13.3% in a total sample size of 44 individuals [39]. Human cysticercosis in Ghana was obtained from a study by western blot and obtained a prevalence of 0.01% and the same study estimated the prevalence of epilepsy as 10.1/1000 in a total population size of 586,607 [40].

Human cysticercosis from Nigeria was obtained from two studies [47, 48] by using Ab ELISA with prevalence of cysticercosis ranging from 9.6 to 14.3% in a total of 425 individuals. There were five studies selected for epilepsy [43, 44, 51, 70] with prevalence ranging from 4.3/1000 to 20.8/1000 in a total of 64,979 individuals for the epilepsy study. Five studies in the region were case report of cysticercosis [45, 49, 50, 71] involving the ocular and breast cysticercosis. Human taeniasis was obtained from two studies by stool microscopy [25, 46] with a prevalence ranging from 8.6 to 40% among a total of 1953 individuals in the region. Human cysticercosis in Senegal was obtained from one study performing antigen and antibody ELISA [42]. The total number of individuals in the study were 403, and prevalence of both antigen and antibody was 7.6%.The prevalence of epilepsy in the country was obtained from two selected studies [52, 53] and the prevalence of epilepsy ranged from 8.3/1000 to 14.2/1000 in a total of 12,182 individuals. Prevalence of epilepsy from Liberia was obtained from two studies [41, 54] and the prevalence of epilepsy across the region ranged from 28.0/1000 to 43.0/1000 among a total of 7169. Prevalence of epilepsy from Mauritania was obtained in one study [55] with a prevalence of 34.7/1000 in a total of 236 individuals. Human cysticercosis was obtained from two sero-epidemiological studies from Togo by antibody ELISA and gave a prevalence of 23.3 [57] and cysticercosis 38/1000 [56] among a total of 14,419 individuals. The two studies also estimated the prevalence of epilepsy and obtained 16/1000 and 18.6/1000 [56, 57] among a total of 6607. A detailed description of each study is given in **Table 2**.

3.3 Risk factors for human cysticercosis in West Africa

Out of the selected articles reviewed, 16 identified risk factors associated with the prevalence of *Taenia solium* cysticercosis, taeniasis, epilepsy and porcine cysticercosis. Lack of proper meat inspection, clandestine slaughtering of pigs and illegal sales of meat leading to poor sanitary control were all risk factors that were associated with an increased prevalence of cysticercosis in Benin Republic [30] as it will promote sale of infected pork carcass to unsuspecting consumers (since condemnation cannot be carried out) and predispose them to infection by these parasites (taeniasis) which increases transmission of infection in the community while increase age, stigma and lack of medical facilities were associated with increase prevalence of epilepsy, people with epilepsy may hide their true identity due to fear of marginalization and may not get proper health care [31]. In Burkina Faso, being a male, pig farming including percentage of soil in sand, residing in poor homes, lack of latrine. Males may have poor hygiene compared with females as they are likely to eat improperly washed fruits or vegetables after purchase and may eat food from food vendors prepared outside the home who might be carriers of the adult tapeworm. The authors also thought the acidic nature of the gastrointestinal tract might have made the eggs tolerate slightly more acidic soil. The higher soil (sandy) percentage might have favored spread of taenid eggs unto vegetation and water by wind. Carabin et al. [32] and living in communities with higher percentage of traditional pig husbandry [32, 36] were risk factors associated with the seroprevalence of cysticercosis [32]. Other factors include pig ownership, preparation method of pork by mothers, access to latrine [33] and pork consumption, pork consumption is associated with cysticercosis either by self-infection or through ingestion of contaminated food and water [32, 37]. Interestingly, previous consumption of pork, being a paid worker or trader as against farmer and housewives was also associated with the seroprevalence of cysticercosis [22, 37]. It was also observed that free roaming pigs in the rainy season and knowledge of porcine

cysticercosis was associated with an increase prevalence of porcine cysticercosis. Free roaming pigs get exposed to infected human feces deposited in the bush or open field thereby increasing the chance of infection and spread of porcine cysticercosis. Being a residence with more than one individual having epilepsy was associated with higher prevalence of active cysticercosis. Refs. [34, 36] observed that NCC and epilepsy were observed in older people compared with people with epilepsy without NCC. In addition, NCC was associated with epilepsy in communities where pig husbandry is practised and higher prevalence of NCC was observed in people with epilepsy. In Ghana, pork consumption and consumption of measly pork and pork soups lightly cooked were risk factors for taeniasis [39], while hypertension and exposure to *Taenia solium* infection were risk factors responsible for adult onset of epilepsy [40]. In Nigeria, pork preparation method and history of epilepsy was associated with seroprevalence of cysticercosis. Heat generated from boiling or frying is likely to kill the metacestode compared with heat from roasting or barbecuing [48]. Others include type and availability of toilets, open defecation, lack of personal hygiene after toilet use, pork consumption and traditional system of pig management [47]. One of the risk factors for epilepsy was history of febrile convulsions [70], purchasing home slaughtered pigs, lack of toilet facilities [64], sourcing pig from the northern part of the country and local breed of pigs [26]. It was observed in Senegal that the risk factor for seropositivity to cysticercosis was older age group and lack of latrine [42].

4. Discussion

Majority of studies on epilepsy use various combination of screening questionnaires, clinical confirmation by neurologists, general practitioners or medical students to identify cases of epilepsy with screening questionnaires developed by World Health Organization (WHO) [72] and Limoges Institute of Epidemiology and Tropical Neurology IENT questionnaire [69]. Epileptic seizures, which are the most common presentation of neurocysticercosis, have been documented in developing countries, which is three to six times higher than those in developed countries [68]. Causes of epilepsy are highly variable across different regions of sub-Saharan Africa and depend on geographical, climatic, political, social and hygienic conditions [73]. The main and most important causes of epilepsy seem to be very similar throughout sub-Saharan Africa showing that hypertension [40]. A genetic predisposition, a past history of febrile convulsions, perinatal neurological disorders, head injuries, cerebrovascular accidents and infections of the central nervous system account for most cases of epilepsy [73] Other presumed causes include witch craft/spiritual [43, 74], brain tumor [75], blood transmission and birth trauma due to self-delivery. Also included are protozoon and helminthic infections, including admission to hospital with malaria, exposure to *T. canis*, *T. gondii*, *O. volvulus* and *T. solium* [40] of which *Taenia solium* has received attention in sub-Saharan Africa over the past few years. Neurocysticercosis is a common cause of epilepsy in pig breeding area [76], however the wide variation in the frequency of epilepsy in the continent could be due to different definitions and type of epilepsy including the population studied and type of sample [44]. Some studies in the region showed the association between epilepsy and cysticercosis using different diagnostic criteria both for epilepsy and cysticercosis. These include three studies in Burkina Faso, of which some researchers [34] showed a seropositivity between cysticercal antigens and active epilepsy with a prevalence odds ratio (POR) of 2.40 (95%). A second study [36] showed 68 of the subjects

confirmed with epilepsy by CT scan and 20 were diagnosed with definitive NCC (for a proportion of 45.5–46.9% in two of the study villages). The third study [37] showed that 39 of 70 positive were confirmed with epilepsy for a lifetime prevalence of 4.5% and epilepsy was associated with cysticercosis by Ag-ELISA (POR = 3.1, 95% BCI = 1.0; 8.3). All three studies confirmed epilepsy by ILAE definition/physician. In Senegal, a study [42] showed that one of 10 CT-scan positives individual by Ag-ELISA and EITB was reported to have epileptic seizures, and cerebral CT-scans showed that 23.3% of the seropositive were affected by neurocysticercosis. In Togo, a previous study [57] showed that cysticercosis (confirmed by ELISA, anatomopathological examination, cranial or muscle X-ray) caused 29.5% epilepsy in sufferers. A study by [40] in five Health and Demographic Surveillance System centeres in Kintampo Ghana and four other countries (Kenya, South Africa, Uganda and Tanzania) showed that epilepsy was significantly associated with exposure to *T. solium* (odds ratios 7·03, P = 0·002), in adults epilepsy confirmed by questionnaire/clinician and cysticercosis was confirmed by detection antibody by Western Blot, while active convulsive epilepsy in the study was defined as two or more unprovoked convulsive seizures (occurring at least 24 h apart, with at least one seizure in the preceding 12 months).

The stigmatization and marginalization of epilepsy is also enormous *n* many African countries, epileptic patients are cast out because it is considered a contagious or shameful disease [28, 43, 69, 77]. Those affected go through social seclusion and people will not marry PWE unless both parties have epilepsy. For example, consanguineous marriage is forbidden by culture in South East Nigeria [43], and may potentially force them to intermarry thereby promoting genetic transmission of epilepsy [43, 44]. Other beliefs include that inheriting properties from PWE will get one infected but if a medicine man performs burial rites for the dead person and takes away their properties and burn it then it stops. Burial of PWE far away from home prevents people from getting epilepsy. Eating, sleeping together or wearing same clothes with PWE is said to be a source of infection [43, 44]. Eating of pork by someone with epilepsy promotes cysticercosis and corroborates with a study that found a significant link between cysticercosis occurrence and epilepsy [78]. In West Africa, *T. solium* cysticercosis in pigs and man has been reported and reports have shown the prevalence's of porcine cysticercosis across the west African countries varies from 0.05 to 46% for both carcass inspection and serological studies and prevalence of taeniid eggs were found to be between 8.6 and 40% based on stool microscopy while copro-antigen ELISA gave a prevalence of 30% [65] as shown in **Tables 1** and **2**. Difference in severity of infection caused by *T. solium* could also explain the differences in prevalence of epilepsy. In addition, the extent of the presence of other environmental factors such as use of bad hygiene practices, close contact of humans and pigs and consumption of inadequately cooked pork affects the differences in prevalence of epilepsy [31] including free roaming pigs [43]. Abattoirs and approved slabs are the only approved places for slaughter and inspection of pork meat for consumption, however most carcasses are sold uninspected hence, lack of inspection and large scale clandestine slaughter of pigs promote spread of cysticercosis [32, 34]. The poor knowledge of *T. solium*, poor hand washing practices, not treating drinking water and handling of raw pork with bare hands promote spread of cysticercosis [65]. Reports in the region indicate that home slaughter conditions were normally substandard because they are makeshift and not constructed to actually meet the requirements of ideal slaughter premises [48]. There was also strong association between knowledge of cysticercosis and occupation and could be attributed to the fact that people in certain occupations are considered to be more knowledgeable about the disease than others [48].

5. Conclusions

The high prevalence of porcine and human cysticercosis and epilepsy in the region indicates that there is a need to get more updated prevalence data of cysticercosis in rural areas where epilepsy is suspected to be more prevalent, compared to urban regions due to parasitic infection. Studies determining the association between epilepsy and cysticercosis should be carried out in countries where it has not been done. The conditions necessary for the parasite to thrive and be transmitted in the region is present in West Africa. Interventions studies including Health education has only been done recently in Burkina Faso, such intervention measures should be carried out in other parts of the region so as to enlighten the populace on the menace caused by the parasite and how it could be prevented.

6. Limitations

The present study has some limitations as the criteria for inclusion and exclusion of articles might have increased or reduced the number of studies used in the region and not all risk factor s and causes of epilepsy were discussed. The study did not determine the prevalence of epilepsy and both porcine and human cysticercosis, in the region as the aim of the study was to show data on studies done by other researchers in the region.

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Conflict of interest

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Acronyms and abbreviations

PWE	people with epilepsy
HCC	human cysticercosis
Ag-ELISA	antigen ELISA
Ab-ELISA	antibody ELISA
ND	not done
GP	general population
VL	villagers
CR	cross sectional survey
CT	computed tomography
HB	hospital based

T. canis	*Toxoca canis*
T. gondii	*Toxoplasma gondii*
O. volvulus	*Onchocerca volvulus*
PC	porcine cysticercosis
TE	taeniasis
BCI	Bayesian hierarchical logistic regression credible intervals

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