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A Systematic Review of Disparities in Risk for Neglected Infections of Poverty in the United States

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Abstract

Purpose of Review This review aims to identify and characterize which neglected infections of poverty (NIPs) represent a public health risk in the United States (US) and describe the health disparities these NIPs represent within the US population. Another aim of this review is to describe public health surveillance for NIPs in the US, including potential gaps in surveillance, and suggest actions to mitigate the disparities represented by these infections.

Recent Findings Data are insufficient to reliably estimate prevalence, burden of disease, and provide optimal diagnostics and treatment for various NIPs in the US. Some of these infections have a long history in the US; others emerged more recently and are expected to increase with climate change. Virtually all NIPs represent racial and economic disparities.

Summary We provide an updated review of risk factors and suggest actions state, Tribal, local, and territorial public health jurisdictions can take now to respond to this uniquely American crisis.

Keywords Neglected infections of poverty · Health disparity · United States · Neglected parasitic infections · Autochthonous

Introduction

Neglected infections of poverty (NIPs) are caused by viruses, bacteria, fungi, and parasites for which United States (US) clinical and public health communities lack sufficient data to reliably estimate prevalence, burden of disease, and provide optimal diagnostic and treatment strategies [1]. NIPs disproportionately affect people living in poverty and underrepresented minority populations, tend to be concentrated in areas of high poverty, and perpetuate poverty in these areas because of their adverse impact on child development, pregnancy, and worker productivity [2]. Some of these infections have a long history in the US; others emerged more recently and are expected to increase with climate change. While the risks are unique for each due to different ecological, epidemiologic, and biological factors, virtually, all NIPs represent racial and economic disparities owing to risk factors common among low-income populations: substandard housing, occupational hazards, limited access to health care and public health services, and poorer nutrition and immunocompetence. According to the US Census Bureau, 2021 child poverty rates are highest among Hispanic (8.4%), Black (8.1%), and Asian (5.1%) children and lowest among non-Hispanic white (2.7%) children [3].

Collectively, the impact of NIPs on US population health is mediated through maternal, neonatal, and child morbidity and mortality; impairment of physical and cognitive development; decreased socioeconomic productivity and quality of life; and higher risks of severe disease and death for elder and immunocompromised populations [4–7, 8••, 9–12].

The aim of this review is to identify and characterize which NIPs represent a public health risk in the US and describe the health disparities these NIPs pose within the US population. Another aim of this review is to describe public health surveillance for NIPs in the US, including gaps, and suggest actions to mitigate the disparities represented by these infections.

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Methods

This study followed PRISMA guidelines for systematic reviews [13]. We conducted a literature search in April 2023 of five databases—Cochrane, Google Scholar, Scopus, Web of Science, and PubMed—using search terms focused on health disparities in tropical diseases in the US and a 10-year publication limit. Full details of search syntax per database are available upon request. One reviewer screened each record and conferred with a second reviewer if it was unclear whether inclusion criteria were satisfied. Articles met inclusion criteria if they (1) included US data or case reports, (2) focused on human cases or risk to human health, (3) described an NIP or group of NIPs, and (4) were peer-reviewed. Opinion-based articles, in vitro studies, and bibliometric analyses were excluded from this review. References of included articles were hand-searched, and additional relevant studies that met inclusion criteria were included.

Each included article was reviewed by one or both reviewers and summarized using a standardized article extraction form. This form collected descriptive information including the setting and population, the infection(s), bias or limitations, study design, outcome or hypothesis, and results of each study. Zotero (Corporation for Digital Scholarship) was used to manage references.

Results/Findings

Our search of Cochrane, Google Scholar, Scopus, Web of Science, and PubMed yielded 0, 53, 65, 67, and 32 results, respectively, with 47 duplicates. A total of 155 articles were identified that met our inclusion criteria; 111 (72%) of these were identified by hand-searching references. The full reference list is available upon request. Further details of our search process are described in Fig. 1.

Our findings suggest that a diverse group of NIPs impact US population health and pose disparities, often along racial, geographic, and socioeconomic lines. Vector-borne infections in the US include arboviruses, Chagas disease, and leishmaniasis; exposure to insect vectors is a proxy for poverty. The sexually transmitted infection trichomoniasis represents a stark health disparity for US Black women. A wide array of helminth infections, including several zoonoses, threaten US public health and disproportionately affect poor minority populations. The individual NIPs, their reported geographic ranges, populations most at risk, and national notifiability status are summarized in Table 1.

Arboviruses

Chikungunya

Chikungunya virus (CHIKV) is a mosquito-borne alphavirus spread by *Aedes* spp. mosquitoes. Rheumatologic disease is a notable clinical feature of this virus and can be severe, particularly in older adults [33]. Most cases of CHIKV in the US occur among persons who have traveled to endemic areas or areas with current virus activity. However, the vectors are found in the US and infected, returning travelers provide an opportunity for virus introduction. This is evident through local transmission events that have occurred sporadically in limited geographic areas of the US, with the first occurrence of local transmission occurring in South Florida in 2014 [34].

Zika Virus

Zika virus is a flavivirus that presents unique prevention and control challenges as it is transmitted by *Aedes* spp. mosquitoes as well as through congenital and sexual transmission. Although most Zika infections result in asymptomatic or mild illness, fetal microcephaly and pregnancy loss can occur in patients who become infected while pregnant [35, 36]. In March 2015, the first cases of Zika virus were identified in the Americas in Brazil; by March 2016, Zika had spread to over 30 other countries and territories in the Americas [5]. Zika rapidly spread throughout Puerto Rico resulting in hundreds of cases [37–39]. Zika virus cases also increased in the contiguous US during this time primarily due to travel-related exposures [40] prompting public health officials to recommend pregnant women consider postponing travel to areas with Zika activity. Zika testing guidance was also released to health care providers including the recommendation to test asymptomatic pregnant patients with possible exposure to Zika [41]. Also, in 2016, the first sexually transmitted cases were reported [42, 43], and local transmission in the contiguous US was first identified in Florida [44].

Dengue

Dengue is a mosquito-borne illness caused by one of four related viruses and spread by *Aedes* spp. mosquitoes. Dengue is not endemic in the US, but sporadic, local outbreaks have occurred in Hawaii, Texas, and Florida [45, 46] and travel-related cases have occurred along the US-Mexico border including during a dengue outbreak in northern Mexico [47].

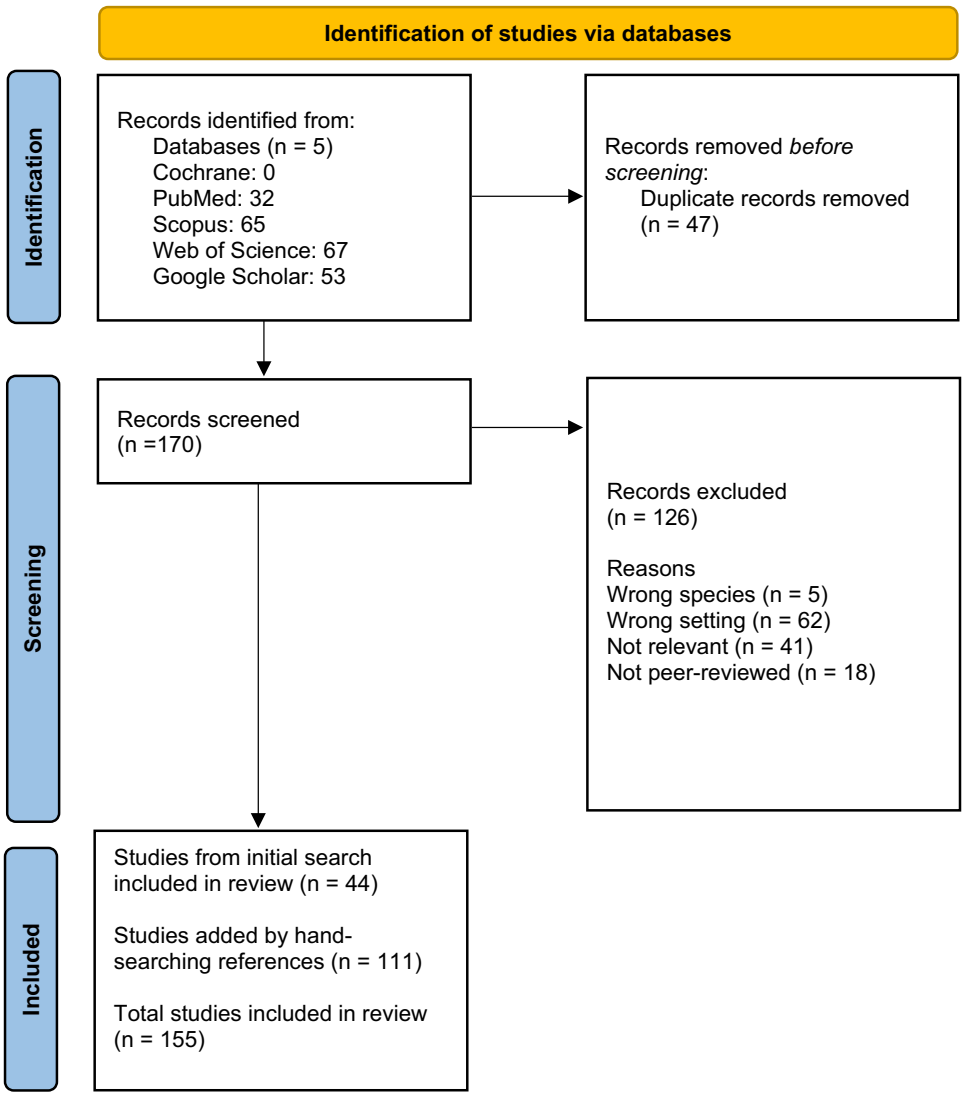

Fig. 1 Results of systematic search. This figure depicts the results of a systematic search of 5 online databases including total number of excluded and included records and reasons for exclusion. Adapted from: Page et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews [13]

As the mosquito vector is the same for CHIKV, dengue, and Zika virus, areas where this vector is sustained in the US are at highest risk for introduction from infected travelers and local transmission. These areas primarily include southern Florida, Texas, and Hawaii. In the US territories, no cases of Zika or CHIKV have been identified since 2019; however, dengue cases are common. Clustering of cases within households has been demonstrated in previous outbreaks [46, 48]. Preventing mosquito bites and removing mosquito breeding sites are essential to limiting transmission. Contact with mosquitoes is increased for populations living in substandard housing lacking air conditioning and screens and urbanized, overcrowded areas, where breeding sites can be abundant [5, 49, 50].

Chagas Disease

Chagas disease (CD) is caused by the protozoan parasite *Trypanosoma cruzi* and is transmitted to animals and people via the triatomine insect vector. While endemic in parts of Latin America, autochthonous CD cases have also been reported in the US [15, 35, 36, 51•, 52, 53] and there is concern that CD could become more prevalent due to expansion of the vector's range from climate change and human encroachment upon the vector's habitat [54•]. Transmission through blood transfusions and organ transplantation as well as congenital transmission prompted efforts to screen blood donors in the US for CD [55] and advocate for CD screening in women of reproductive age [54•]. Dilated cardiomyopathy is an important

Table 1 Neglected infections of poverty in the United States

Infection	US geographic range	Populations at risk	Nationally notifiable[a]
Arboviruses			
Chikungunya virus disease	Local transmission has occurred in FL, TX, PR, and VI	People traveling to or living in endemic areas or areas in the US where local transmission has previously occurred; people without window screens or air conditioning; people experiencing homelessness	As of 2015
Dengue	Local outbreaks have occurred in HI, FL, and TX Common in the US territories: AS, PR, and VI and freely associated states: FSM, RMI, and Palau	People traveling to or living in endemic areas or areas in the US where local transmission has previously occurred; people without window screens or air conditioning; people experiencing homelessness	Dengue virus infections as of 2010 Dengue, dengue-like illness, and severe dengue as of 2015
Zika virus	Local transmission has previously occurred in FL and TX (2016–2017) No confirmed Zika virus cases have been reported in US territories since 2019	People traveling to or living in an area with a risk of Zika and who have not already been infected, neonates born to people with Zika infection, people who have sex with someone with Zika infection, people without window screens or air conditioning, people experiencing homelessness	Zika virus infection, congenital as of 2016 Zika virus infection, non-congenital as of 2016 Zika virus disease and Zika virus infection; Zika virus disease, congenital; and Zika virus disease, non-congenital as of 2016
Protozoa			
Leishmaniasis	South central US Autochthonous US cases reported from: TX and OK	Travelers, immigrants, and military personnel returning from endemic areas; Hispanic females; residents of south central and northeastern TX and southeastern OK	No
Trichomoniasis	Throughout US	Black females, including those ≥ 45 years	No
Chagas disease	Most prevalent across southern half of US [14] Autochthonous US cases reported from: AR, AZ, CA, LA, MS, and TX [15, 16]	Immigrants and migrants from Latin America, transplant and blood transfusion recipients, and persons living in substandard housing or experiencing homelessness in areas where the vector is present	No
Helminths			
Ascariasis	Historically prevalent throughout Appalachia and the southern US: KY, TN, NC, GA, LA, and SC [17] Autochthonous US cases reported from: ME and LA [18, 19]	People living in poverty; people in contact with pigs	No
Hookworm	Historically prevalent throughout Appalachia and the southern US: KY, TN, NC, GA, LA, and SC [17] Historically endemic in FL, TX, NC, TN, KY, WV, VA, GA, SC, AR, MS, AL, and LA [20] Autochthonous US cases reported from: AL [10]	People living in poverty; people in contact with contaminated soil	No

Table 1 (continued)

Infection	US geographic range	Populations at risk	Nationally notifiable[a]
Strongyloidiasis	Historically prevalent throughout Appalachia and the southern US: KY, TN, LA, WV, and PR [17, 21] High-risk modeled for: Appalachia, central TX, southeast, south, east, and northeast and west coasts [22•] Autochthonous US cases reported from: AL, TX, and KY [10, 23••, 24]	People living in poverty, especially in rural areas; solid organ transplant recipients; immigrants; migrants; refugees; health care workers and institutionalized people; people working in occupations that put them in contact with soil; children that go barefoot in low-income communities with poor sanitation; and immunosuppressed	No Strongyloidiasis 2023 Case Definition[b]
Toxocariasis	Autochthonous US cases reported from: AR, NY, and NJ [25–27]	People living in poverty, Black people, Hispanic people, male sex, residents of the south, children especially those with pica, and people with lower levels of education	No
Taeniasis/cysticercosis	Autochthonous US cases reported from: CA, NY, and OR [7]	Hispanic people, travelers, immigrants, and refugees from endemic areas	No
Schistosomiasis	Not endemic to US	Immigrants, refugees from endemic areas, and travelers	No
Fungi			
Chromoblastomycosis and eumycetoma	Remote or rural settings Autochthonous US cases reported from: GA [28]	People living in poverty; people with agricultural and landscaping occupations; people with environmental trauma/exposure to plants, animals, agricultural tools, car crashes, bricks, shoes, falls, and natural disasters	No
Bacteria			
Nocardiosis and actinomycetoma	Remote or rural settings US cases reported from: VA, MA, TX, and FL [29–32]	People living in poverty and immunosuppressed	No

This table summarizes individual NIPs identified in this review, their reported US geographic ranges, populations most at risk, and national notifiability status. [a]Centers for Disease Control and Prevention. National Notifiable Diseases Surveillance System (NNDSS). Condition Search Results. https://ndc.services.cdc.gov/search-results/. Accessed 6/11/2023. [b]Council of State and Territorial Epidemiologists. Standardized Surveillance Case Definition for Strongyloidiasis (Current or Past). CSTE Position Statement, PS 22-ID-09. https://cdn.ymaws.com/www.cste.org/resource/resmgr/ps/ps2022/22-ID-09_Strongyloidiasis.pdf. Accessed 6/12/2023. *FL*, Florida; *TX*, Texas; *PR*, Puerto Rico; *VI*, Virgin Islands; *HI*, Hawaii; *AS*, American Samoa; *FSM*, the Federated States of Micronesia; *RMI*, the Republic of the Marshall Islands; *Palau*, the Republic of Palau; *OK*, Oklahoma; *LA*, Louisiana; *AZ*, Arizona; *CA*, California; *KY*, Kentucky; *TN*, Tennessee; *NC*, North Carolina; *GA*, Georgia; *SC*, South Carolina; *ME*, Maine; *WV*, West Virginia; *AR*, Arkansas; *MS*, Mississippi; *AL*, Alabama; *NY*, New York; *NJ*, New Jersey; *MA*, Massachusetts.

and costly clinical feature that often goes undiagnosed as CD and can lead to poor long-term outcomes, including unexpected death [56].

Immigrants to the US from endemic areas of Latin America are at highest risk for infection and can face barriers to appropriate care once in the US [57•]. The disease burden of CD in the US has been estimated at approximately 238,091 cases to over 300,000 cases with California, Texas, Florida, and New York having the highest number of cases due to immigrant populations in these states [6, 58]. Substandard housing is a risk for exposure to the vector. Outdoor activity and exposure to other animals might also increase the risk of CD exposure [59]. Seroprevalence studies in dogs from Texas where the vector is widespread suggest increased risk for human exposure to *T. cruzi* [60].

Chromoblastomycosis, Mycetoma, and Nocardiosis

Mycetoma is a chronic, destructive bacterial or fungal infection of the skin and subcutaneous tissue and can lead to significant disability and mortality [61]. Poverty and rural residence are risk factors but there are no prevalence data for the US [62]. The disease is most rigorously studied and reported from Mexico, India, and Sudan; emergence of new geographical loci includes the US and the Americas, where bacterial forms appear to dominate [61]. Cases of nocardial mycetoma and nocardiosis (caused by bacteria in the *Nocardia* genus) have been reported from eastern Virginia [29], Massachusetts [30], Texas [31], and Florida [32]; 500–1,000 cases are reported annually in the US [63], with most but not all associated with preexisting immunocompromising conditions [64]. The clinical spectrum of nocardiosis ranges from localized skin and soft tissue infections to life-threatening pulmonary, CNS, and/or disseminated infections [32]. Antibiotic resistance in *Nocardia* spp. isolates from the US has been reported and is highly variable by agent and by species [31, 63, 64].

Chromoblastomycosis (CBM) is a fungal infection most diagnosed in impoverished and marginalized people who live in remote and rural areas [65]. Between 1915 and 2018, 24 US cases were reported, most around the 1950s and most occurring in the south or southeast, with some limited cases in the northeast [28, 65]. Risk factors include traumatic injuries with soil contamination, agricultural activities, landscaping, and post-hurricane settings [28, 66]. CBM and mycetoma are considered occupational diseases associated with social stigma and severe socioeconomic consequences [61, 65].

Helminths

Ascariasis

Ascaris spp. are parasitic nematodes that can cause infection in humans and pigs [18]. *A. lumbricoides* is generally thought of as a human parasite and *A. suum* as a pig parasite, though they can cross-infect and there is debate as to whether they are the same species [67]. Ascariasis persists in commercial swine in the US posing a risk of zoonotic transmission [67]. Infection with *Ascaris* spp., ascariasis, is not nationally notifiable and is to our knowledge only reportable in Texas (as of 2016); the same is true for hookworm (below). Fourteen cases of ascariasis were identified in persons who had contact with pigs in Maine during 2010–2013 [18]. An 8-year-old child was diagnosed with ascariasis complicated by Löffler syndrome, a pneumonitis resulting from migration of *Ascaris* larvae through the lungs, after contact with pigs on a southern Louisiana farm [19]. While recently reported cases are zoonotic, *Ascaris* is predominantly a soil-transmitted helminth (STH) that causes infection when eggs from other infected humans are ingested. However, the current prevalence of soil-transmitted ascariasis in the US is unknown.

Hookworm

Another STH, human hookworm infection caused by *Necator americanus* was prevalent in about 40% of the US south population when the Rockefeller Sanitary Commission for the Eradication of Hookworm Disease (1909–1914) fielded its philanthropic public health project across 11 states: Virginia, North Carolina, Georgia, South Carolina, Tennessee, Arkansas, Mississippi, Alabama, Louisiana, Kentucky, and Texas [20]. Between 2010 and 2013, 100 hookworm infections were identified in newly resettled refugees in Texas and conferred a significantly increased odds of latent tuberculosis infection [68]. Poor, Black residents of Lowndes County, Alabama without a travel history recently tested positive for *N. americanus* by stool, highlighting the persistence of the parasite in areas of high poverty in the US [10].

Strongyloidiasis

Strongyloides stercoralis is another STH, though, like hookworm, is predominantly transmitted via skin penetration by infective larvae. *S. stercoralis* is the most neglected of the STH; the diagnostic methods used in historical STH surveys were insensitive to this species and it was often excluded or underestimated [17]. *S. stercoralis* is also unique among STH in its ability to persist and replicate in the human host lifelong, during which the infection is asymptomatic unless

and until the host becomes immunocompromised; in that event, the infection becomes acutely life-threatening by dissemination and hyperinfection [9, 21]. These complications of latent strongyloidiasis have a high mortality rate approaching 90%; complicated strongyloidiasis is preventable and often due to negligence, lack of awareness, and failure by health care providers to recognize the need for parasite screening before prescribing corticosteroids [8••, 21, 23••]. Disseminated strongyloidiasis is relatively common in populations at high risk for infection and is often misdiagnosed as gram-negative septicemia or acute respiratory distress syndrome [21]. Deaths from strongyloidiasis have been reported in a majority of states, with most deaths among persons born in the US [69].

A recent study by one of the authors detected 16.5% seroprevalence in a sample of predominantly poor Mexican American central Texas residents, many of whom had not traveled [23••]. Others found 7.3% of stool samples positive for *S. stercoralis* from a sample of poor Black residents in rural Alabama [10]. While the extent of autochthonous transmission is unknown, strongyloidiasis also represents a significant health threat among immigrant populations in the US, albeit underrecognized [70•]. Strongyloidiasis was among the most common infections identified in a review of a decade of outpatient tropical medicine in Houston, TX [71]. There is recent evidence of ongoing transmission in rural Kentucky [24]. The author's modeling study predicts suitable habitat for *S. stercoralis* in at least ten states beyond the southeastern US where it has been recorded; based on climate and poverty data, the likely distribution of the parasite includes states in the south, east and northeast, and west coasts [22•]. We recommend strongyloidiasis should be reportable in at least the states with historical and predicted endemic risk. Strongyloidiasis is not nationally notifiable nor is it currently reportable in any state; however, the Council of State and Territorial Epidemiologists voted to establish a standardized surveillance case definition for strongyloidiasis in 2022 [72].

Toxocariasis

Toxocara spp. are roundworms of cats, dogs, and other domestic and wild animals; humans become infected when they accidentally ingest eggs which animal hosts excrete into the human environment at high rates [73]. Like other NIPs, this common zoonosis exhibits striking disparities in prevalence across races, with reported seroprevalence in the US Black population of 21.2% compared to 12% in the US white population [12]. In a study of US-born New York City (NYC) residents, overall seroprevalence was 8.5% with wide variation by borough, with the lowest (3.5%) in Manhattan. Mexican Americans had the highest seroprevalence (32.2%), over three times that of African Americans (10.4%) and over five times that of whites (7.5%) and individuals of undefined ethnicity (7.4%). The same study demonstrated significantly diminished lung function in seropositive participants, which further supports associations between toxocariasis and asthma [25]. Another study detected the highest contamination of playgrounds by *Toxocara* eggs in the Bronx, which has the lowest median income of all NYC boroughs and the lowest contamination rate in Manhattan, which has the highest median income [74••].

Toxocariasis, which clinically manifests as covert [11], ocular (OT, which can lead to blindness), or visceral toxocariasis (VT, which can be fatal), primarily impacts children because of their play habits and poor hygiene and is found disproportionately among Black children [12]. Toxocariasis is also associated with cognitive dysfunction in adults [75]. Like other NIPs, toxocariasis is completely preventable, can be devasting, and is not under surveillance in the US. Toxocariasis exemplifies the critical need for a One Health approach to prevention and control, involving a closer collaboration between veterinary and public health professionals and an integrated lens to public health [73, 76, 77].

Taeniasis and Cysticercosis

Taeniasis is a patent tapeworm infection occurring when humans ingest cysticeri from a pig. Cysticercosis occurs only after ingestion of eggs from a person with taeniasis, making taeniasis the source of autochthonous transmission of cysticercosis. The complete transmission cycle can be maintained in focal areas of the US. Despite its relevance to cysticercosis, there are few prevalence data on taeniasis [7]. Cysticercosis is underreported even in jurisdictions where it is reportable; very few surveillance programs have been implemented [78]. Up to 2% of US emergency department visits for seizures are caused by cysticercosis; the infection is increasingly recognized as a cause of severe and preventable neurologic disease in the US [7]. Studies of disease burden in Oregon and California found higher incidence in people who identified as Hispanic and that 5.4–18% of hospitalized patients were US-born [7].

Symptomatic human cysticercosis almost invariably presents as neurocysticercosis; this form of the disease consumes significant health resources and causes significant mortality, disproportionately among the Hispanic (particularly males aged 20–44) population, for which the risk for hospitalization has been estimated at 35 times that of the white population [7, 78, 79]. All regions of the US are impacted by cysticercosis-related hospitalizations; some argue that cysticercosis should be nationally notifiable [78].

Schistosomiasis

Schistosomiasis, infection with blood flukes, is dependent on exposure to freshwater containing snails that maintain the parasite's life cycle; transmission does not occur in the US. The infection enters the US through immigration and travel. Tourists often present with severe acute disease that many US clinicians are not trained to diagnose [80]. Of the more than 8,000 people estimated to be living in the US with schistosomiasis, most are African refugees [71]. Routine screening of all at-risk individuals is necessary to prevent morbidity from complications of chronic schistosomiasis, such as bladder cancer and pulmonary hypertension [71].

Leishmaniasis

Leishmaniasis is a protozoan zoonosis transmitted by the bite of the *Lutzomyia* sandfly. More than 24 different *Leishmania* species cause three main clinical subtypes: visceral, cutaneous (CLM), and mucocutaneous [81]. CLM is a disfiguring disease process, and there is no FDA-approved drug to treat it in the US [82]. Leishmaniasis is typically limited to foreign travelers, immigrants, and military personnel in the US; however, *L. mexicana* is endemic to Texas with a known mammalian reservoir, the Texas wood rat. The habitat of the Texas wood rat has shifted toward northeast Texas and southeast Oklahoma; a recent case series reported 9 locally transmitted cases of CLM in north Texas around Dallas-Fort Worth [82, 83]. A total of 33 autochthonous cases of CLM have been reported in the US, mostly in south central Texas, including two from southeastern Oklahoma as well as one case of a 2-year-old child with no travel history in Houston [82, 83].

Findings of sandfly surveys establish the presence of suitable *Lutzomyia* spp. vectors in the vicinity of Texas and Oklahoma cases, though trapping yield was low [83]. Sandfly control is extremely difficult because they travel considerable distances from breeding areas to feed [84]. There is an apparent trend of diagnosing human CLM with increasing frequency in the US as well as increasingly northeastward; 13 cases were reported from 2000–2007, whereas 29 cases (primarily in south central Texas) had been reported between 1903 and 1996 [83]. Risk factors in US cases include domestic fowl, rabbits, and debris harborage to rodents around residence [83]. Ecological niche modeling predicts that the range of the sandfly vector and rodent reservoir of *L. mexicana* will continue a northward expansion spurred by climate change [83].

One study explored trends and risk factors for leishmaniasis among hospitalized women of reproductive age in the US, finding an overall low prevalence of 1.57 cases per million during 2002–2017 and highest risk among women who were 35–49 years old, Hispanic, on Medicare, and who were inpatients at a large teaching hospital in the northeast [81]. A cross-sectional multicenter observational study of US cases from 2007 through 2017 identified 69 CLM cases, 41 (59%) of which were endemic [85]. These findings suggest that CLM is more frequently acquired endemically than via travel; the authors argue that leishmaniasis should be nationally notifiable, especially considering that climate models predict the number of US residents exposed to *L. mexicana* will double by 2080 [85].

Trichomoniasis

Infection with the protozoan parasite *Trichomonas vaginalis* (TV) is common, preventable, curable, and associated with significant reproductive and perinatal morbidity as well as increased risk of HIV acquisition and transmission [86, 87, 88••, 89]. TV is the most prevalent non-viral sexually transmitted infection in the US and likely globally yet has received much less consideration than other parasitic and sexually transmitted infections; this neglect is largely attributable to a poor understanding of the public health impact of trichomoniasis and its frequently asymptomatic presentation [4, 90, 91]. The prevalence of TV in the 2013–2014 non-institutionalized US population, ages 18–59, was 0.5% in a sample of 1,942 men and 1.8% in a sample of 2,115 women [87, 88••]. Among the same population aged 14–59 years in 2013–2016, TV prevalence was 2.1% among females, 0.5% among males, and highest at 9.6% among non-Hispanic Black females [92]. Another study found 11.3% prevalence among 77,740 women and 6.1% prevalence among 12,604 men in Alabama [93]. The number of estimated incident and prevalent TV infections among 15–59-year-olds in 2018 was 6.9 million and 2.6 million, respectively; although estimated prevalence is higher among women, estimated incidence is similar in men and women [91].

Risk factors for TV identified in US populations include female sex [87, 88••, 91, 93] increased age, particularly 45 years of age and older [4, 87, 89, 90, 93, 94•]; non-Hispanic Black race/ethnicity [87, 88••, 93]; poverty below the federal poverty level [87, 88••]; and active smoking [88••]. Additional risk factors include incarceration, intravenous drug use, commercial sex work, and the presence of bacterial vaginosis [90]. One cross-sectional study assessed the relationship between drug use in the past 6 months, sexual risk behaviors, and TV infection in a sample of majority Black and female adults aged 18–64 in Baltimore, Maryland and hypothesized that age- and drug-related immune decline may contribute to increased susceptibility for TV in adults aged 45 years and older [95].

Trichomoniasis is not reportable in any state nor is it nationally notifiable; the true incidence of infection is not well established but an estimated 1.1–6.9 million persons become infected annually [4, 91]. TV is linked to an

estimated 2–6% of new HIV infections annually among US women [4]. Among adults aged 18–39 years, a significant racial disparity was observed in *Chlamydia trachomatis* infection, genital human papillomavirus infection, herpes simplex virus type 2 serostatus, and TV infection, for which the disparity was greatest [87]. Among US women, TV infection is most prevalent among Black women with rates ranging from 13–51%, ten times higher than among white women [90]. While rates of TV infection in US males are lower than in females, TV is also fairly prevalent among men, particularly Black men, and it is important to also screen and treat men for infection [96, 97]. TV infection can also increase risk of cervical and prostate cancers [94•]. The burden of TV infection in the US adult Black population is high, disproportionate, and warrants a proportionate public health response focused on eliminating this health disparity [87].

Conclusions

Of all US residents, the poorest populations living in the US south are most impacted by parasitic infections [82]. Low-income, most often minority populations, are most susceptible to vector-borne NIPs (leishmaniasis, Chagas disease, and arboviruses) due to substandard housing lacking window screens and/or air conditioning, homelessness, and outdoor occupational risks. Travelers and immigrants are at risk of acquiring infections in endemic areas, but the risk of transmission within the US is substantial for all but schistosomiasis.

The findings of this review are subject to limitations. First, the number of articles identified by searching references far exceeded the number of articles identified on initial search of databases. This is likely because our search terms did not include names of infections or species; however, this decision was intentional to preclude biasing which infections would be characterized as neglected in the US context. Yet, the lack of coverage of infections generally thought of as neglected and disparities affecting US public health (e.g., trichuriasis, the other common STH; echinococcosis among Native American populations; and toxoplasmosis, for which the highest seroprevalence in the US is among Black people [82]) may indicate a lack of sensitivity in our search strategy.

Second, estimates of disease burden in the US population have limited reliability. Precise data on true prevalence and incidence of most of the NIPs in the US are limited, partly driven by inadequate funding to the CDC and state and local health agencies to conduct active surveillance studies [82]. The NIPs thrive in six recognized focal points of US poverty: Appalachia, Native American tribal lands, northeastern inner cities, the southern cotton belt, the Mississippi Delta, and the borderland with Mexico [84]. Prevalence estimates are generally considered to be underestimated due to potential underreporting from a lack of clinical awareness and suspicion, inadequate or nonexistent surveillance programs, and limited access to health care for vulnerable populations [4, 7, 9, 16, 23••, 33, 39, 46, 54•, 70•, 77, 81, 87, 94•, 98–104, 105•].

Of all the NIPs identified in this review, only infections with arboviruses are notifiable at the national level, meaning that public health jurisdictions may voluntarily report cases to the CDC (Table 1). A motif among articles reviewed is the lack of sufficient data to estimate prevalence, incidence, and disease burden and to identify risk factors with high certainty; yet, there is consensus among authors that these are important public health problems meriting those answers. In reference to the myriad gaps in our understanding of the epidemiology of cysticercosis in the US, yet applicable to all NIPs, Cantey et al. opine that these data must be complete and improved; "otherwise, we will continue to be dependent on data collected in the few areas of the country that have taken an active interest in this parasitic infection of neglected people [7]."

Ultimately, the NIPs and the conditions that promote them stem from a lack of prioritization by US policymakers; yet, control of NIPs is both a highly cost-effective mechanism for helping to address poverty and consistent with the American values of equity and equality [2]. US public health and clinical institutions also have a role to play in implementing surveillance, prevention, and control measures for these diverse infections. The neglect for these infections by public policy makers, public health, and health care institutions in the US context represents neglect of poor people living in the US.

We suggest, as have others, that educating US frontline health care providers on NIPs should be prioritized. Tropical medicine curricula should be standard, not merely elective, in US undergraduate medical education. Significant investment would be required and is warranted to expand access to tropical medicine clinics in high-prevalence areas (Gulf Coast, Appalachia, and urban areas of poverty) and to develop and implement comprehensive, systematic national screening and surveillance [71]. As a framework for national screening and surveillance, public health leaders should leverage existing health data exchange systems (e.g., electronic health records) to promote interoperability and national coverage. An integrated, multidisciplinary approach is required to address outstanding gaps in knowledge about basic NIP epidemiology, prevention, and control. For this reason, adopting a One Health approach as well as leveraging partnerships with researchers and public health practitioners is critical to embracing the complex socioeconomic and disease ecology factors at root of these disparities.

In the absence of and as a prerequisite to a coordinated national response, there are actions state, Tribal, local, and territorial (STLT) health agencies can take now to respond to this crisis of public health disparity and injustice:

1) Adapt and employ surveys like the Community Assessment for Public Health Emergency Response (CASPER) [106] to characterize local risk for NIPs and make a plan for addressing findings. While the CASPER method was developed in the context of emergency response, surveys in this vein can be adapted for implementation as a risk factors assessment for individual NIPs or groups of NIPs within a jurisdiction. Data from CASPERs could then be analyzed together with public health surveillance and vector monitoring to assess the prevalence of risk factors for NIPs, guiding public health priority setting and strategy [106]
2) Consider whether to conduct surveillance for any NIPs and whether they should be reportable in your jurisdiction and to which public health partners those data should be disseminated, including CDC. Individual jurisdictions can decide to mandate reporting for a condition irrespective of national policy; the Council of State and Territorial Epidemiologists in partnership with the CDC annually revises standardized surveillance case definitions and the list of nationally notifiable conditions, which provide streamlined guidance for adoption by STLT agencies
3) Identify communities with substandard housing and failing sanitation and work with community members and local, state, and federal granting agencies to sustainably address those environmental hazards
4) Seek and share best practices from experienced partners, including international, and adopt and advocate a human rights policy framework to eliminate the root causes of NIPs

The paradox of poverty and NIPs amidst great wealth and ingenuity can be overcome when policymakers at every level prioritize the health and rights of all Americans.

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Data availability Full results of systematic search are available upon request.

Declarations

Competing interests The authors declare no competing interests.

Ethical Approval This article does not contain any studies with human or animal subjects performed by any of the authors.

Conflict of Interest The authors declare no competing interests.

Disclaimer The contents of this review are solely the responsibility of the authors and do not necessarily represent the official views of the organization(s) with which they are affiliated.

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