Review of parasitic zoonotic infections in Egypt

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Zoonoses are diseases and infections that are transmitted in nature between vertebrates and humans. Zoonoses consist of an interaction among at least three species: one pathogen and two hosts – animals and humans. This review aimed at shedding in depth light on zoonotic parasitic diseases in Egypt, with special reference to their relative incidence between humans, reservoir animals, sources of human infection and control policies. According to the available literature, many parasitic zoonoses are endemic in Egypt. In rural areas, intestinal parasitic zoonoses are widespread and are the leading cause of diarrhea, particularly among children. Some parasitic zoonoses are mainly found in certain areas in Egypt, for example, cutaneous leishmaniasis and zoonotic babesiosis in Sinai. Other locations in Egypt have a history of certain parasitic zoonoses, such as visceral leishmaniasis in the El Agamy area in Alexandria. Fortunately, control programs have led to a dramatic decrease in the prevalence of other zoonoses, such as intestinal schistosomiasis and fascioliasis in the country. In Egypt, animal reservoirs of parasitic zoonoses have been identified. These include rodents, stray dogs, and cats as well as domestic and farm animals and birds. Many vectors have also been revealed, typically mosquitoes and ticks, which pose real threats for disease transmission. Strict control strategies are needed to upgrade and complement current efforts at eradicating parasitic zoonoses in Egypt.

Keywords:
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Introduction

Zoonotic diseases are diseases that may be transmitted between animals and humans. It is a Latin name meaning ZOON=Animal and Noson=Disease. An estimated 60–70% of infectious diseases in humans globally are zoonotic, and great percentages originate from wildlife [1]. Approximately 25% of the world's population may be suffering from parasitic diseases. These infections are classically predominant in underdeveloped agricultural and rural areas of tropical and subtropical regions, causing reduced worker efficiency and a waste of economic resources. As many as 400 million people of the Middle East and the North Africa region including Egypt may be affected due to environmental, social, educational, and economic factors [2,3]. In general, the consequences of such zoonoses are amplified because they lead to morbidity in both immunocompromised and immunocompetent patients [4].

Intestinal parasites are common in school-age children because of overcrowding and behavioral patterns that contribute to the extent of parasitic infection. High incidence rates of parasitic infection among children have been documented, with levels reaching up to 48% [5,6].

The medical and financial impacts of parasitic zoonoses have been studied by many scientists in Egypt. The hazards of zoonoses are significant due to the proximal vicinity of cattle and other domestic animals to households, specifically in rural parts, and, similarly, pets and stray animals, especially canines and felines, are predominant all over the country [3,7]. Numerous surveys of parasitic infections accomplished in rural areas of Egypt conveyed high infection rates of solitary and numerous gastrointestinal parasitic infections, with levels reaching up to 85% [8,9]. Indeed, both domestic and wild animals and birds are well-documented reservoir hosts in Egypt. This is predominately noted because of the vast unpopulated desert areas where wild rats, felines and canines live and replicate. An epidemiological study of wild rodents described an infection rate of parasites of 54% (93/172), including 28% cestodes, 7% nematodes, 8% *Acanthocephala*, and 41% protozoa [3]. In addition, a cross-sectional study revealed that the overall incidence of helminths in domestic rodents in Dakahlia was 53%,

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and a total of 24 species of helminths were recognized [3,10,11].

Arthropod-borne zoonotic parasites are found in Egypt; the role of arthropods as vectors for some parasitic infections is well documented, like the sandfly vector of leishmaniasis, or like ticks, the vectors of *Babesia* spp. infection. In addition, non-blood-sucking arthropods play a significant role in the mechanical spread of human parasites such as the American cockroach (*Periplaneta americana*) and the house fly *Musca domestica* var. vicina [12]. Nevertheless, apparently due to lack of vectors and other environmental elements, numerous severe parasitic diseases such as Kala-azar and sleeping sickness are not endemic in Egypt, in contrast to tropical Africa. However, several zoonotic parasitic infections are present in Egypt, such as soil-transmitted nematode infections, hydatidosis, filarial infections, schistosomiasis, fascioliasis and leishmaniasis [3]. For example, a cross-sectional study was planned to investigate the incidence, control policies and public health importance of the gastrointestinal parasites of sheep from the Nile Delta, Egypt, and showed the existence of parasites in more than 60% of the cases [13].

According to the WHO, an obvious modernization in drinking water sources and sanitation amenities has occurred in Egypt, with over 90% of the population having access to healthier drinking water sources. Furthermore, the wellbeing of people has improved significantly compared with the regional average; consequently, along with prevention and control efforts, infections such as schistosomiasis and fascioliasis have decreased among humans and animals in the country [3].

Zoonotic parasites can be categorized into four classes: direct zoonotic, metazoonotic, cyclozoonotic, and saprozoonotic. Direct zoonotic parasites infect humans directly from animals and include *Entamoeba histolytica*, *Cryptosporidium parvum*, *Toxoplasma gondii*, and *Sarcoptes scabiei*. Metazoonotic parasites comprise *Fasciola* spp. and *Schistosoma* spp., and these require a molluscan/invertebrate intermediate host to infect humans. In contrast, cyclozoonotic parasites have vertebrate intermediate hosts and include *Echinococcus granulosus*, *Taenia saginata*, and *Taenia solium*. However, saprozoonotic parasites can infect humans from soil or water, such as *Ancylostoma caninum* and *Strongyloides stercoralis* [3,14]. Bearing in mind the dynamic alterations in the Egyptian health, ecological, and veterinary sections, which readily affect reservoirs of parasitic infections and linked zoonoses, this review aimed to cover such infections and deliver an updated insight on zoonotic parasites in the country.

Zoonotic protozoan infections in Egypt

Intestinal zoonotic protozoal infections

Gastrointestinal protozoa are one of the main health problems with a high predominance all over the world. This prevalence depends on several factors including environmental, social, and economic ones. All in all, a high incidence of intestinal parasites is often correlated with several health problems in a given society. This is predominately seen in low-income nations where gastrointestinal parasites in children are linked to inhibition of normal growth, low intellectual progression, and vitamin deficiency by malabsorption, chronic diarrhea, and dysentery [15,16]. Definitely, in Egypt, parasites are the major cause of diarrhea, with the prevalence reaching over 60% [17–19].

The majority of parasitic gastrointestinal problems in Egypt was caused by protozoa (57.6%); whereas helminthes were found only in 9.9% of cases [20]. Further studies in the Delta region revealed that up to 67.1% of chronic diarrheic patients had parasitic infections; involving mixed infections in 12.9% of total chronic diarrhea patients. It is noteworthy that both immunosuppressed and immunocompetent patients showed a high prevalence of intestinal protozoa disease in Egypt [4,21].

In Egypt, *E. histolytica* was reported to have a prevalence that ranged from 0 to 57% in diarrheic patients, with greater infection rates in poor regions and Upper Egypt [4,21,22]. As for probable reservoir animals, amebiasis has been described in both wild and domestic animals [11].

Giardiasis produced by *Giardia intestinalis* is a major international diarrheal disease. It is a predominately common intestinal parasite in Egypt, particularly among children. *G. intestinalis* infection rates of 10–34.6% have been stated. Prevalence rates of 11 and 15.4% among children were reported, whereas, among chronic diarrhea patients, the prevalence reached up to 27.3% [3,6,23]. In contrast to former reports abroad declaring that assemblage B is the most frequent genotype of *G. intestinalis* (80%) [24], it was later reported that the greatest prevalent genotype in Egypt was assemblage A [25]. Other assemblages, C and E, have also been noted [26]. Concerning reservoir animals in Egypt for *Giardia* spp., cysts were revealed in stool samples of 2% of homeless cats [27] and 8% of wild rats [10]. Furthermore, fish have been incriminated as a potential reservoir for *G. intestinalis*, as the parasite has been found in fish, with a prevalence of 3.3% [28].

In Egypt, infection with *Cryptosporidium* spp. is one of the growing reasons for diarrhea, with infection rates up to 49% between both inpatient and outpatient clinic attendants [3,18,29]. More specifically, it was demonstrated that infection with *C. parvum* protozoan was the most common in immunosuppressed patients, with an infection rate of 60.2% [25]. Cryptosporidiosis, including *C. hominis* and *C. bovis*, is a well-documented zoonotic disease, and has been described in farmers and their domestic animals [3], with a prevalence rate of 32.2% in ruminants [29]. Calves drinking from canals or underground water were at a higher risk of infection than calves drinking tap water [29]. Oocysts have been identified in the fecal samples of neonatal calves (30.2%) and neonatal lambs (30%). Different genotypes have been identified in animals with a high incidence of zoonotic C. parvum subtype families (IIa and IId) in Egypt [29]. In animals, *C. parvum* appears to be the dominant species with infection rates of up to 82.8% [29,30] in Egypt. There have been reports recording the existence of additional *Cryptosporidium* spp. in Egyptian domestic animals: *C. ryanae* (11.8%), *C. bovis* (4.1%), and *C. andersoni* (6.9%) [30]. In addition, *Cryptosporidium* spp. was detected in wild rats, with a prevalence of 22.7% (*C. parvum*) and 20.3% (*C. muris*) [3].

Sarcocystis spp. is a zoonotic parasite of livestock animals. Moreover, *S. cruzi*, *S. hirsute*, and *S. hominis* have canids, felids, and humans as definitive hosts, correspondingly, and can affect bovines as intermediate hosts creating muscle cysts [3,31]. This parasite is endemic in Egypt; cysts were repeatedly identified in cattle and buffalo during meat inspection. Furthermore, *Sarcocystis* spp. infection in stray cats was reported at a rate of 1% [32]. Thus, stray cats may, consequently, be potential reservoirs in Egypt, too.

Blastocystis hominis has been revealed in Egypt with a prevalence rate of 22.4% in asymptomatic patients, compared with 12.1% in patients with diarrhea and in immunosuppressed children [4]. Its zoonotic potential is not largely explored, but an infection rate of 3% was reported among stray dogs in Egypt [7]. This suggests a possibility that *B. hominis* may be a zoonotic infection in the country.

In Egypt, numerous additional zoonotic intestinal protozoa have been reported [33] with variable infection rates, such as *Iodamoeba butschlii* (16%), *Isospora hominis* (7.7%), *Endolimax nana* (6.9%), *Entamoeba hartmani* (5.9%), *Dientamoeba fragilis* (5.1%), *Chilomastix mesnili* (5.1%), *Trichomonas hominis* (4.2%), Microsporidia spores (3.2%), *Enteromonas hominis* (1.9%), and *Embadomonas intestinalis* (1.3%).

Blood and tissue zoonotic protozoal infections

Leishmaniasis is a vector-transmitted parasitic infection with a worldwide distribution. Infection with *Leishmania* spp. has a wide range of clinical manifestations, ranging from skin infections to lethal visceral disease. The Sinai Peninsula in the northeast part of Egypt, a sporadically inhabited locality, has seen occasional cases of zoonotic cutaneous leishmaniasis. The vectors of *Leishmania* spp. such as *Phlepotomus papatasii* and *P. sergenti* sandflies have been identified in endemic regions [34]. Previous studies on the etiologic factor of cutaneous leishmaniasis have steadily recognized *Leishmania major* and *L. tropica* as the primary and secondary causes, correspondingly. Wild-caught rodents were identified as reservoir hosts of *Leishmania* spp. infection in endemic areas. *Gerbillus pyramidum floweri* have been documented to be naturally infected with *L. major* and *L. tropica* in North Sinai [35]. Additional rodent species, *Rattus norvegicus*, was classified as a reservoir host of *Leishmania* infection in nonendemic regions of Qualyobia [36].

L. donovani producing visceral leishmaniasis has been reported in Egypt, mostly at the Mediterranean coast in Alexandria Governorate; where 27 cases were discovered from 1982 to 1985 through active and passive case detection. Of them, 22 cases were revealed in El Agamy, a resort town of 50 000 inhabitants situated 15 km west of the city of Alexandria. An additional case of infantile visceral leishmaniasis was recognized in an adult farmer in Banha city. Likewise, infrequent cases were reported among hypersplenic patients in Dakahlia Governorate. No new cases have been discovered since these sporadic cases. In contrast, the preceding history of visceral leishmaniasis indicates an ongoing possibility for such infections in Egypt. Dogs are a chief reservoir host for visceral leishmaniasis, including in El Agamy, Alexandria, where *L. infantum* was detected in stray dogs [37]. An epidemiological study in Giza confirmed that antibody to *Leishmania* spp. was detected in five of 50 (10%) dogs examined for *Leishmania* causing visceral leishmaniasis [38].

Toxoplasmosis trigged by *T. gondii* infection is a rising global health concern, with up to one-third of the world's population assessed to be infected with the parasite [39]. Many authors revealed high rates of seroprevalence of *T. gondii* in Egypt. For example, among 260 asymptomatic blood donors, 155 (59.6%) were anti-*Toxoplasma* immunoglobulin (Ig)G positive, as detected by enzyme-linked immunesorbent assay (ELISA) [40].

Toxoplasmosis causes a diversity of effects, particularly in pregnant women facing a possible risk of fetomaternal transmission leading to abortion, premature birth, and other congenital deformities of the newborn. The hazard of fetomaternal transmission of *Toxoplasma* spp. has been documented with antibody prevalence of 51.5% of pregnant women, as revealed by ELISA. Seropositivity to specific anti-*Toxoplasma* IgG antibodies was 57.9, 58.1, and 44.7% in serum samples from haphazardly collected samples, full-term pregnant women, and women who had suffered a miscarriage, respectively [41]. However, the seropositivity rates to specific anti- *Toxoplasma* IgM for the same groups were 10.5, 6.5, and 23.7%, respectively. Moreover, another study had previously described that 10 of 42 meningoencephalitis patients (26%) had *Toxoplasma* IgG antibodies in cerebrospinal fluid samples, evaluated by immunofluorescent antibody assay [42]. High infection rates of *T. gondii* infection among cats and other animals have been reported. The incidence of *T. gondii* varied between 9% and up to 95.5% among Egyptian cats by modified agglutination test, which implies a high risk of *T. gondii* human disease [43]. In domestic animals, high levels of antibodies have been demonstrated. Immunofluorescent antibody was revealed in the serum of slaughtered animals at a prevalence of 48.8%. Anti-*Toxoplasma* antibodies were reported using a modified agglutination test in 59.5% of domestic turkeys, 47.2% of chickens, and 50% of ducks, in addition to 10.8% of cattle, as demonstrated by ELISA [44].

Concerning other uncommon blood and tissue zoonoses in Egypt, zoonotic *Babesia* infections were reported in Sinai, where rodents are *Babesia microti* reservoirs, particularly the mice of *Acomys* spp., whereas *Ixodes ricinus* ticks have been detected to be the vectors [45,46]. *Neospora caninum* is a predominant animal protozoan parasite with a global distribution. It is not identified to produce human infection; however, antibodies to *N. caninum* were recognized in 7.9% of pregnant women in a study in Egypt, whereas the detection rate was 20.4% in cattle and 1.9% in rabbits [41]. In another rare incidence, a case of zoonotic infection of *Trypanosoma evansi* was described [47].

Zoonotic trematodal infections in Egypt

In Egypt, animal and human fascioliasis is an endemic disease produced by *Fasciola* spp. It has been reported in almost all governorates, particularly the Nile Delta and Alexandria [48–50]. Fascioliasis is considered hyperendemic in the Delta region [51], with a frequency of 4.8% of outpatients examined in that study. However, fascioliasis spreads even as far west as the desert oases [52]. Over the last three eras, cases of human fascioliasis have been reported. For example, a prevalence of 5.2–19.0% (mean=12.8%) was documented in the Nile Delta villages [51]. Afterwards, human infections have begun a fading drift in Egypt [48–50,53]. However, more recently, it was stated that it may be re-emerging in upper Egypt [54].

Donkeys' and camels' infection with *Fasciola gigantica* has been recorded in Egypt, in addition to that of grass-grazing domestic and farm animals. Fascioliasis was recognized to be endemic in sheep [55], particularly in the Nile Delta, as identified by abattoir surveys (20.6%) and by the microscopic revealing of *Fasciola* spp. in fecal samples (12.7%) [56].

Heterophyiasis is an intestinal fluke infection that is endemic in Egypt, particularly in brackish and fresh water fish in northern areas, where the parasites are indigenous in the lakes and neighboring regions. The peak rate of infection was found in fishermen (33.8%) and native inhabitants in northern Egypt (13.3%) [57,58]. The overall prevalence of heterophyid infection of fish was documented to be 32% (the mean of 22% in brackish water fish and 42% in fresh water fish) [58]. Moreover, the prevalence of heterophyid metacercaria in fresh water fish was recognized to be 95.4% in Ismailia [41]. Several heterophyids have been recognized from fish in Egypt. Adult heterophyids from *Heterophyes heterophyes*, *Heterophyes aequalis*, *Pygidiopsis genata*, *Haplorchis yokogawai*, *Prohemostomum vivax*, *Phagicola ascolonga*, and *Stictodora tridactyla* were recorded from encysted metacercaria-fed puppies. Moreover, the prevalence of *Heterophyes heterophyes* was 3% among stray cats in Kafr Elsheikh in the northern area of the Delta [27,59].

Schistosomiasis is the third leading endemic parasitic disease in the world. It was stated that more than 200 million persons in 74 countries are infected and that 120 million have symptoms of the disease. In 2011, 42 countries in Africa, including Egypt, were considered endemic for this infection. Farmers and peasants are especially unprotected to *Schistosoma* spp. infection, given the nature of the mode of infection by cercarial penetration of the skin [9,60,61]. However, such infection in Egypt is decreasing in general; *Schistosoma hematobium* rates declined from 60 to 70% in 1925 to 5% in 1996, and *S. mansoni* rates decreased from 32% in 1932 to 12% in 1996 [60]. In recent years, control programs are applied, and the prevalence of infection with *Schistosoma* spp. has declined, particularly with the continuous and reliable praziquantel treatment.

Subsequently, lower infection rates ranging between about 1 and 5% have been recorded for *S. mansoni* in Egypt [9,11,20]. In Egypt, the incidence and species dissemination of schistosomiasis vary classically in Upper verses Lower Egypt. A study executed in nine governorates reported that *S. mansoni* was uncommon in Upper Egypt, excluding Fayoum, with an incidence rate of 4.3%. Yet, the incidence of *S. mansoni* in five governorates in Lower Egypt, where it is endemic, had an average of 36.4%. The prevalence of *S. haematobium* in four governorates in Upper Egypt, where it is also endemic, was revealed to have an average of 7.8%. This species is rare in the Delta areas [62].

Conflicts and human and animal migrations are key social factors in prevention, control, or eradication of zoonotic parasitic infections in Egypt, while local political motivation, reinforced global and intersectoral cooperative efforts for surveillance, mass drug administration, and vaccination are vital for eradication [63,64]. However, a novel report revealed rather active *S. mansoni* transmission status in certain districts in Lower Egypt, using the urine-circulating cathodic antigen and Kato technique [65]. In this report, of 35 regions surveyed in five governorates, *S. mansoni* infection was documented in 19 (54.3%) districts using Kato technique, and in 31 (88.6%) districts by the urine test. Male individuals and higher age groups had significantly higher urine antigen prevalence rates. On the basis of these discoveries, authorities of the Ministry of Health and Population implemented a new eradication strategy by readapting thresholds for mass treatment with praziquantel and targeting all transmission regions [3,65,66].

It is noteworthy that the zoonotic potential of schistosomiasis in Egypt was emphasized before, as *S. mansoni* and *S. haematobium* were detected as a natural double infection in the Nile rat, *Arvicanthis niloticus*, from a human endemic region in Egypt [67].

Zoonotic cestodal infections in Egypt

Intestinal zoonotic cestode infections

Taeniasis due to infection with *T. saginata* is more in Egypt than due to infection with *T. solium*, as the intermediate host of the latter is pig, and pork in not broadly consumed for religious reasons. However, few studies are reported about taenisais in Egypt. For example, an infection rate of human *T. saginata* infection of 1.1% was reported [11]. Another study was carried out at an abattoir, on meat samples from 6 434 039 slaughtered animals, between 1994 and 1997; the infection rate was 0.2% in domestic cattle, 7.3% in imported cattle, 0.1% in buffaloes and 0.1% in pigs, with an overall incidence of cysticerci (*Cysticercus bovis* and *cysticercus cellulosae*) of 0.7% [68]. Although human cysticercosis due to consumption of *T. solium* egg is not a health problem in Egypt, it has a harmful effect on intermediate host animals and remains a potential zoonosis source. It was demonstrated that 20% of the studied cattle were infected with *cysticercus bovis*, and 12% of pigs were infected by *cysticercus cellulosae*, among slaughtered animals in El-Minia in Upper Egypt [69].

Hymenolepis nana infection remains a common intestinal cestode disease, particularly among children in Egypt, whereas *H. diminuta* is an unusual zoonotic parasite. Earlier studies of *H. nana* infections in children specified a high prevalence of 16% [70]. In another report on outpatients of a hospital in Dakahlia, the reported rate of *H. nana* in stool samples was 3.9% [11]. In Menoufia, among 2292 farmers, the rate of reported *H. nana* eggs in stool samples was 3% [9]. It was demonstrated that *H. nana* infected up to 16% of children registered in their report at Fayoum University Hospital [71]. As for reports on *H. diminuta* infections, a lower rate of 1.4% was detected [11]. Rodents are considered the chief reservoirs of *H. diminuta* infections, with an infection rate of 23.8% in Egypt [10]. More recently, an infection rate of 1.5% was found among dog populations in Egypt [7].

Concerning *Dipylidium caninum*, it was reported that it had not been described as a zoonotic infection among humans in Egypt [33]. Yet, it was reported to be at 5% in stray cats [27].

Larval zoonotic cestode infections

Cystic echinococcosis or hydatidosis due to consumption of the egg of *E. granulosus* is predominant in the Middle East and Arabic North Africa, and is endemic in Egypt [3,72]. In a retrospective study [72] on human cystic echinococcosis in Egypt between 1997 and 1999, using 492 353 patient records, 133 (0.03%) new human cystic echinococcosis cases were reported. Another study on seropositivity levels of echinococcosis stated a rate of 5% in patients with acute and chronic hepatic diseases in Assiut and Aswan [73].

As for the incidence of *E. granulosus* in the chief final hosts in Egypt, a rate of 5% was documented among street dogs, particularly in rural areas [33]. In intermediate hosts, the overall five-year hydatidosis incidence from August 2000 to August 2005 was 2.5, 0.3, and 0.7% in camels, sheep and goats, and pigs, correspondently. However, a higher level of hydatidosis mainly in camels was confirmed, reaching up to 7.7% [74]. Six genotypes of the *E. granulosus* complex are found in Africa. In Egypt, the sheep strain (G1) was reported in sheep, goats, cattle, camels, and humans, and the camel strain (G6) in camels, sheep, cattle, and humans. All in all, the G6 genotype had a higher prevalence in humans and animals in the country [75].

Recently, the role of Norway rat as a potential *E. granulosus* reservoir in Cairo, Egypt, was studied [76]. Both rats and humans living in related regions were covered in that study. The results demonstrated the following overall seroprevalence rates of cystic hydatidosis in examined rats and persons: 36 and 11.9%, respectively. Cysts were recognized as *E. granulosus* hydatid cysts (G6 strain). According to the authors, this emphasizes the possible role of Norway rat in the epidemiological cycle of *E. granulosus,* particularly in urban and suburban locations.

Zoonotic nematodal infections in Egypt

Zoonotic intestinal nematode infections

Capillaria spp. has been an evolving imported zoonotic infection in Egypt [77], especially in Upper Egypt governorates for the past few decades. Dissimilarly, a low prevalence of *Capillaria* spp. infection was described in the Nile Delta (1%) [20,78]. Fish-eating birds are the essential host for this parasite, and man is infected accidentally [79]. Stray cats are assumed to be likely reservoir hosts, as *Capillaria* spp. was identified in them with a prevalence of 3% [27].

Previously, infection rates with *Ascaris lumbricoides* in Egypt were reasonably high, but, more recently, reports detected lower rates: under 2% [11,20]. In Egypt, dogs are thought to be reservoir hosts of *A. lumbricoides* as environmental polluters, mounting the risk of infection in humans [80].

Anisakis simplex is not native in Egypt, and, in one study directed to fish trapped in the Red Sea, it was reported with a rate of 2.2% from the orange-spotted trevally, *Carangoides bayad* (Carangidae) fish [81].

Eosinophilic enteritis caused by *A. caninum* was once recognized in Egypt. The prevalence of IgG antibodies to this nematode in patients with vague acute or recurrent abdominal pain was found to be 11.6% [82].

Other species of nematodes have been described in dogs that may be potential reservoirs, such as *Trichostrongylus* spp. (2.6%), *S. stercoralis* (1.5%), *Enterobius vermicularis* (1.1%), and *Trichuris trichiura* (0.7%) [80]. As for *Trichostrongylus*, it is a well-known parasite of farm animals, and it was the most prevalent intestinal nematode detected in sheep in Dakahlia [83].

Extraintestinal and larval zoonotic nematode infections

In Egypt, a high prevalence of human toxocariasis denoted by anti-*Toxocara* antibodies has been verified by several investigators [84,85].

Seroprevalence of IgG antibodies was 7.7% in the general community [85], 6.2% among suspected children, and 18% in adults [84]. The reservoirs of *T. canis* infection are dogs, denoting a direct infection risk to humans [86]. A report in Egypt recorded that 56% of dogs were infected with *T. canis,* and 8% were infected with *T. leonina*. In addition, *T. cati* and *T. leonina* have been found in stray cats at a prevalence of 9 and 5%, correspondently [80]. More recently *T. canis* was detected at a much lower rate of about 5% in different dog populations in Egypt: stray, military, and domiciled [7].

Human trichinellosis due to *Trichinella spiralis* is not predominant in Islamic nations like Egypt due to religious beliefs and food behaviors. Few studies of *T. spiralis* infection in fresh and handled pork in Egypt are accessible [87,88]. As for its zoonotic potential, *T. spiralis* infection was reported in 13.3% of rodents gathered from and around slaughterhouses in Alexandria [89].

It was demonstrated that about 50 million people in Egypt and sub-Saharan Africa had bancroftian filariasis due to infection with *Wuchereria Bancrofti.* In a longitudinal report of bancroftian filariasis in the Nile Delta of Egypt, microfilaremia and filarial antigenemia rates among 1,853 subjects more than nine years of age was 7.7 and 11.2%, correspondently, while the one-year frequency was 1.8 and 3.1%, respectively [90]. Subsequently, by examining night blood films, a high incidence of 38% was documented among asymptomatic patients with *W. bancrofti* [91]. Concerning the common Egyptian vectors, *W. bancrofti* DNA was found in 31.9% of *Culex pipiens* mosquitos gathered from an Egyptian village with low filariasis prevalence [92]. Furthermore, high rates of microfilaria were reported in mosquito vectors collected from households with significant risk factors for microfilaria spread [90,92]. In animals, *W. bancrofti* microfilaria was reported in a stray cat from Assiut in Upper Egypt [93].

Human dirofilariosis, caused by *Dirofilaria repens*, is an evolving zoonosis, and dogs are the main hosts. Three cases of human infection with *D. repens*, one pulmonary and two subcutaneous, were detected in Assiut, Upper Egypt. This was the first report of human pulmonary dirofilariosis in Africa [94]. Concerning the role of cats in the transmission of *D. immitis*, a seroprevalence rate of 3.4% was discovered in stray cats in Cairo [43]. Furthermore, a case of subcutaneous nodule in the upper eyelid was reported in Egypt due to *D. conjunctivae* [95].

Zoonotic arthropod infestations in Egypt

The worldwide mite *S. scabiei* (*Acari: Sarcoptidae*) is a compulsory ectoparasite that infests the skin of a broad range of mammalian hosts, causing sarcoptic mange in companion animals, livestock, and wildlife, as well as scabies in humans [96].

In Egypt, scabies has been detected in humans [97], wild games [98] and farm animals [99], and zoonotic bird and rat mites (*Ornithoyssus*) have been recognized to produce dermatitis in poultry farm laborers [100]. Rat ectoparasites that may infest humans have also been reported, comprising *Xenopsylla cheopis*, *Hyalomma dromedarii* (nymph), *Echinolaelaps echidninus*, and *Hemolaelaps glassgowi* [101]. In addition to zoonotic mites, stray dogs and cats are documented to be reservoirs for uncommon zoonotic arthropods such as *Linguatula serrate* [27].

Prevention and control strategies

There is a lack of information on several parasitic zoonoses control in Egypt, and, overall, there is a crucial need to magnify these surveillance strengths for most of the parasitic zoonoses. Tools exist to control, or in some cases, eradicate such main parasitic zoonoses in Egypt. For the soil-transmitted nematode infections, coverage with anthelmintics, particularly in school-aged children, needs to expand [102]. Mass drug administration programs with albendazole or mebendazole should be increased in the high-burden regions such as Egypt, although, because of post-treatment reinfection, there is no proof that the major soil-transmitted nematode infections will be eradicated in the near future. Mass drug administration has now ceased in Egypt due to an overall incidence of less than 1% [103], while, as reported above, schistosomiasis has been almost eradicated. Through mass drug administration with praziquantel, huge improvements have been made in the control of schistosomiasis in Egypt, with the near eradication of *S. haematobium*-produced bladder cancer, although recurrence is a distinct possibility, and *S. mansoni* infection remains endemic in the northern part of Egypt [83].

Two zoonotic helminth infections, echinococcosis and fascioliasis, are still predominant, and there are chances to exert enhanced control for them by animal treatment and, more downstream, animal vaccination to avoid transmission to humans. Special highlighting for aimed interventions is required. A global or regional strategy emphasizing Egypt for control and eradication, particularly for soil-transmitted nematode infections, filarial infections, schistosomiasis and fascioliasis, would support overall disease control in the region [64,103].

Conclusion

Zoonotic parasitic diseases remain an important health issue in Egypt. Some protozoa and helminthes are prevalent all over the country, while others have more specific geographical distribution. Animal reservoirs are varied, including domestic animals, pets, and stray and wild animals. Control measures have managed to help curb many of these zoonoses; however, additional strategies are needed to decrease their transmission country wide. Continual focused cooperation between health, veterinary, and agricultural authorities are needed to achieve high prevention and control of zoonotic parasitic infections in Egypt.

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