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Helminth diseases in migrants from Sub-Saharan Africa with particular reference to schistosomiasis and strongyloidiasis

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Abstract (German)

Seit dem Jahr 2015 ist das Thema Migration in Europa stark in den Fokus gerückt: Über eine Million Menschen migrierte in diesem Jahr nach Europa, darunter auch viele aus den Ländern Subsahara Afrikas. Für diese Menschen ist nicht nur der oftmals gefährliche Transit unter widrigen Umständen ein Gesundheitsrisiko, sondern auch die im Herkunftsland oder auf der Migrationsroute erworbenen (vernachlässigten) Tropenerkrankungen. Es besteht die Gefahr, dass diese vielen Ärzten in Europa wahrscheinlich nicht geläufigen Erkrankungen, zu spät erkannt werden und so zu Gesundheitsschäden führen können.

Diese Arbeit fokussiert sich auf Helminthosen, insbesondere auf die Schistosomiasis und die Strongyloidiasis. Im ersten Teil wurde anhand der Literatur der Jahre 2015 bis 2020 eine Übersicht über das Spektrum der Wurmerkrankungen bei Migranten aus Subsahara Afrika nach Europa gegeben. Hierzu wurden die medizinische Datenbanken Pubmed, Embase und Medline zu englisch- und deutschsprachiger Literatur zu diesem Thema durchsucht. Insgesamt 74 Artikel wurden in die Literaturübersicht eingeschlossen. Sie zeigen ein breites Spektrum an Wurmerkrankungen, wobei der Fokus der Forschung auf der Schistosomiasis liegt. Die Ergebnisse dieses Teils der Arbeit sind bereits veröffentlicht worden (siehe Publikationsliste).

Im zweiten Teil der Arbeit wurden anonymisierte Daten aus der Patientendatenbank der Abteilung für Infektions- und Tropenmedizin am LMU Klinikum München aus den Jahren 2016 bis 2020 ausgewertet. Hier fanden sich unter den Patienten aus Subsahara Afrika serologische Prävalenzen von 31.4% für die Schistosomiasis und 20% für die Strongyloidiasis. Die Stuhl- beziehungsweise Urinprävalenz für die Schistosomiasis betrug 12.5% beziehungsweise 5.8%; die Stuhlprävalenz für die Strongyloidiasis 2.8%. Besonders hohe Schistosomiasis-Prävalenzen fanden sich bei Migranten aus Eritrea, was erstaunlich ist, da Eritrea als Land mit niedriger Prävalenz gilt.

Sowohl die Forschung der letzten Jahre als auch die Auswertung der Datenbank stützen die Notwendigkeit der Implementierung eines Screeningprogramms für Helminthosen – insbesondere Schistosomiasis und Strongyloidiasis – für Migranten aus den betroffenen Regionen. Wünschenswert wäre ein möglichst niedrigschwelliges Angebot und die Nutzung einfacher, aber zuverlässiger Screeningmethoden. Eine Alternative wäre eine präsumtive Behandlung aller Migranten.

Abstract (English)

Since 2015, the issue of migration has come into focus in Europe: over a million people migrated to Europe this year, including many from Sub-Saharan African countries. For these people, not only the often-perilous transit under adverse circumstances poses a health risk, but also the (neglected) tropical diseases acquired in the country of origin or on the migration route. There is a risk that these diseases, which could be unknown to many medical practitioners in Europe, will be recognized too late and can therefore lead to health problems.

This work focuses on helminth infections, particularly schistosomiasis and strongyloidiasis. In the first part, an overview of the spectrum of helminth diseases in migrants from Sub-Saharan Africa to Europe is given based on the literature from 2015 to 2020. For this purpose, the medical databases Pubmed, Embase and Medline were searched for English and German literature on this topic. A total of 74 articles were included in the literature review. They show a wide spectrum of helminth diseases, with the focus of research being on schistosomiasis.

In the second part of the work, anonymized data from the patient database of the Division of Infectious Diseases and Tropical Medicine at the University Hospital LMU Munich from 2016 to 2020 was evaluated. Serological prevalences of 31.4% for schistosomiasis and 20% for strongyloidiasis were found among patients from Sub-Saharan Africa. The stool and urine prevalence for schistosomiasis was 12.5% and 5.8%, respectively; the stool prevalence for strongyloidiasis 2.8%. A Particularly high schistosomiasis prevalence was found among migrants from Eritrea, which is surprising since Eritrea is considered a country with low prevalence.

Both, recent research, and the evaluation of the database support the need to implement a screening program for helminth diseases - especially schistosomiasis and strongyloidiasis - for migrants from affected regions. Low-threshold screening offers and simple, but reliable screening methods, would be desirable. Alternatively, a presumptive treatment of all migrants could be an option.

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List of abbreviations

A. lumbricoides ..... *Ascaris lumbricoides*
AU ..... *antibody units*
CAA ..... *circulating anodic antigen*
CCA ..... *circulating cathodic antigen*
CDC ..... *Centers of Disease Control*
CT ..... *computed tomography*
D. dendriticum ..... *Dicrocoelium dendriticum*
DNA ..... *deoxyribonucleic acid*
E. granulosus ..... *Echinococcus granulosus*
E. vermicularis ..... *Enterobius vermicularis*
ELISA ..... *enzyme-linked immunosorbent assay*
EU ..... *European Union*
F. hepatica ..... *Fasciola hepatica*
FECT ..... *formalin-ether concentration technique*
H. nana ..... *Hymenolepis nana*
HBV ..... *hepatitis B virus*
HIV ..... *human immunodeficiency virus*
ICT ..... *immunochromatography*
IFAT ..... *immunofluorescence test*
Ig ..... *immunoglobulin*
IQR ..... *inter-quartile range*
L. loa ..... *Loa loa*
LIPS ..... *luciferase immunoprecipitation system*
M. perstans ..... *Mansonella perstans*
MRI ..... *magnetic resonance imaging*
NTD ..... *neglected tropical diseases*
O. volvulus ..... *Onchocerca volvulus*
PCR ..... *polymerase chain reaction*
POC ..... *point-of-care*
qPCR ..... *quantitative polymerase chain reaction*
S. fülleborni ..... *Strongyloides fülleborni*
S. haematobium ..... *Schistosoma haematobium*
S. japonicum ..... *Schistosoma japonicum*
S. mansoni ..... *Schistosoma mansoni*
S. mekongi ..... *Schistosoma mekongi*
S. ratti ..... *Strongyloides ratti*
S. stercoralis ..... *Strongyloides stercoralis*
SAF ..... *sodium acetate-acetic acid-formalin*
SD ..... *Standard deviation*
spp ..... *species pluralis*

SSA ..... *Sub-Saharan Africa*
subsp. ..... *subspecies*
T. saginata ..... *Taenia saginata*
T. solium ..... *Taenia solium*
T. trichiura ..... *Trichuris trichiura*
VFR ..... *visiting friends and relatives*
W. bancrofti ..... *Wuchereria bancrofti*
WB ..... *western blot*

1. Introduction

No other event shaped the year 2015 in Europe as much as the so-called “migrant crisis”: Over a million people from different parts of the world sought asylum in European countries. This development continues to this day and the issue of migration remains a topic of political and social debates (1-4).

Although people from Syria, Afghanistan and Iraq made up most of the asylum seekers during the “migrant crisis”, there was also a great proportion of people arriving from Sub-Saharan Africa (SSA). Migration from SSA peaked in 2016 with around 210,000 people applying for asylum in the European Union (EU, including the United Kingdom), with Nigeria, Eritrea and Somalia as the top countries of origin. In 2019, the number of asylum seekers from SSA was still almost 130,000 (see **figure 1**)(4, 5).

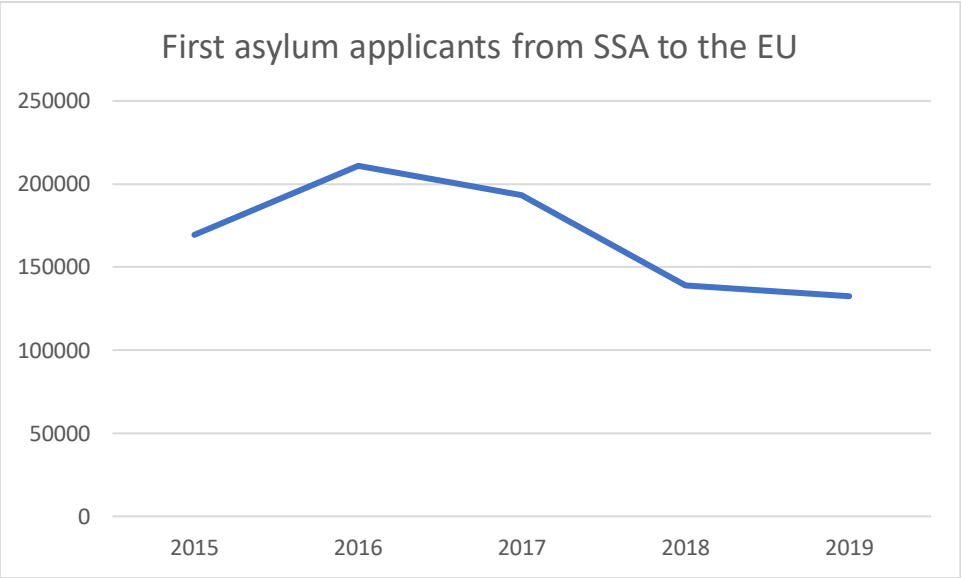

Figure 1: Development of the number of first-time asylum applicants from SSA to the EU (including United Kingdom). Data from (5).

The reasons why people from SSA make their way to Europe are various. Besides political and ethnic conflicts in the home countries, persecution and human rights violations, there are also economic reasons or simply a “nomadic lifestyle”, a thirst for adventure or curiosity. In the future, natural disasters due to climate change could also be a driver of migration. In addition to the “irregular” migration to Europe, which has shaped the image of the “migrant crisis”, there is also legal migration for reasons of family reunification, education or work (4, 6-9). Because the reasons for leaving the home country are diverse and the legal status of the people migrating is not always known or explicitly mentioned in some studies, the generic term “migrant” will be used throughout this work and will also include asylum seekers and refugees – if not stated otherwise.

Especially irregular migration poses a health risk, because of the often long, perilous transit and the unsanitary conditions in overcrowded refugee camps. But also the lack of access to (preventive) health care and poor hygienic conditions in the home country make migrants vulnerable for diseases: Infectious diseases, but also chronic conditions, psychological and social problems make up a large part of the health problems of migrants (4, 10-13).

In addition, SSA is endemic to many neglected tropical diseases (NTD), including helminthiases (14). Treating migrants from SSA, medical practitioners in Europe could be confronted with diseases with which they have no experience. This increases the risk of false or delayed diagnosis, which can be particularly dangerous in the case of two helminth diseases: schistosomiasis and strongyloidiasis. Both diseases often stay asymptomatic for a long time or cause only non-specific symptoms, but they can lead to long-term complications and can even be life-threatening (4, 15, 16).

1.1 Schistosomiasis

1.1.1 Epidemiology

Schistosomiasis is a disease caused by trematodes of the genus *Schistosoma*. The number of people in need of a therapy in 2021 was estimated at over 250 million, 90% of whom lived in Africa. Deaths from this disease are estimate at around 11,800 annually although, according to the World Health Organization (WHO), these figures may represent an underestimate (17).

There are five *Schistosoma* species that are responsible for the majority of infections in humans, with *Schistosoma (S.) haematobium* and *Schistosoma (S.) mansoni* playing the most important role on the African continent (see **figure 2**); therefore the focus of this work lies on these two species (15).

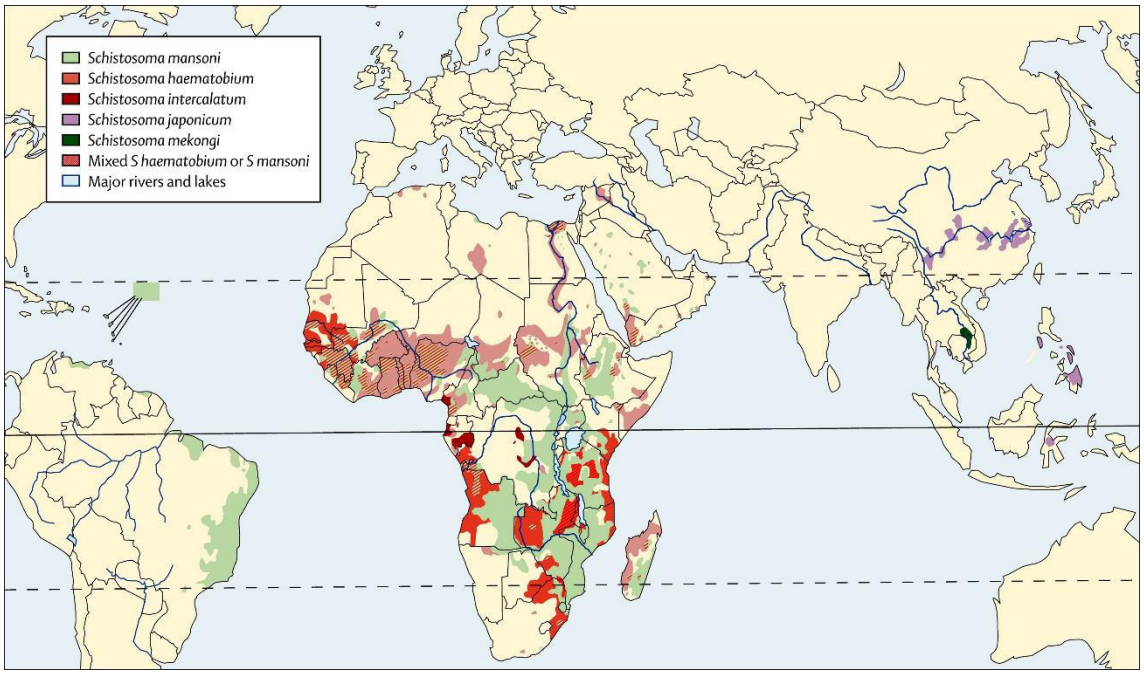

Figure 2: Global distribution of schistosomiasis. Adapted from Gryseels B, Polman K, Clerinx J, Kestens L. Human schistosomiasis. Lancet 2006; 368: 1106–18[1]

1.1.2 Life cycle

The life cycle of schistosomes is divided into a phase of sexual reproduction in humans and a phase of asexual reproduction in freshwater snails (see **figure 3**).

[1] Reprinted from The Lancet, 383, Colley DG, Bustinduy AL, Secor WE, King CH, Human schistosomiasis, 2253–64, Copyright (2014), with permission from Elsevier.

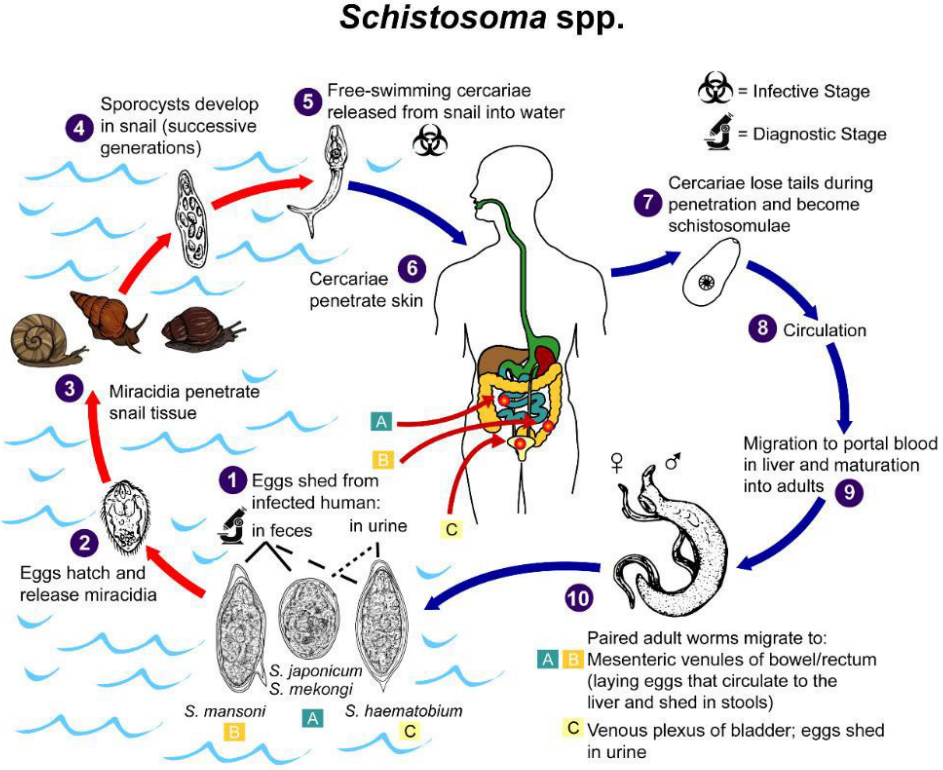

Figure 3: Schistosoma life cycle with a phase of asexual reproduction in water and a phase of sexual reproduction in humans. Schistosoma (S.) japonicum and Schistosoma (S.) mekongi, which are also depicted here, only occur in Asia (CDC/ Alexander J. da Silva, PhD; Melanie Moser).

Humans become infected with the parasite through contact with contaminated fresh water, for example when doing household chores, during leisure time or when working in and around a freshwater body. The larval forms of the pathogen, the cercariae, penetrate the human skin. They lose their tail and migrate as schistosomulae via tissue, lymphatic system and venules to the pulmonary circulation before they finally arrive in the hepatic portal vein system. Here, the schistosomulae develop into male and female adult worms. They mate and migrate to the mesenteric (*S. mansoni*) or the vesical plexus (*S. haematobium*), where the females lay eggs every day for several years. The eggs finally break through the wall of the intestinal, urinary or genital tract. Part of the eggs remain in the tissue and induce an inflammatory reaction, another part is excreted in stool or urine. This process of egg excretion is dependent on the hosts immune system. The lifespan of a fluke is estimated to be on average between 3 and 5 years, but much longer-lived specimens have been described with a lifespan of almost 40 years. It takes about 5 to 7 weeks for the schistosomulae to grow into adult, egg-producing flukes (15, 18, 19).

When the eggs reach fresh water through human excretion, they hatch and release miracidia, which infect the intermediate hosts: freshwater snails. Each *Schistosoma* species is adapted to a different snail species: *S. mansoni* infects snails of the species *Biomphalaria*, while *S. haematobium* infects the species *Bulinus*. In the snails, the miracidia develop into mother sporocysts, which in turn form germ cells from which daughter sporocysts develop. These mature into cercariae, leave their intermediate host and can infect humans (or in the case of *S. mansoni* also other mammals). This asexual phase of the *Schistosoma* life cycle takes about 4 to 6 weeks (15, 18).

Breaking this life cycle, for example by avoiding the contamination of freshwater with sewage, eliminating snails as the intermediate hosts or keeping people away from contaminated freshwater, are approaches to the prevention of the infection (15, 18).

1.1.3 Pathogenesis and morbidity

The first sign of an infection with schistosomes can be dermatitis, which is caused by the penetration of the cercariae into the skin, but is likely to go undetected in endemic regions (20). Schistosomiasis can present as an acute disease – also known as Katayama's syndrome – and a chronic disease, the former mainly occurring in people who have not had any contact with the pathogen, such as travelers from non-endemic countries. People from endemic areas are likely to be immunologically sensitized due to early exposure to the pathogen in the womb or during childhood. The clinical picture of acute schistosomiasis therefore hardly plays a role for migrants from SSA (15).

Katayama's syndrome occurs around 14 to 84 days after initial infection. This delayed onset of the disease, sometimes long after the initial infection, can make diagnosis difficult. The disease begins suddenly with non-specific symptoms such as fever, fatigue, myalgia, urticaria and an unproductive cough. Lung infiltrates may be visible in X-ray. Later, abdominal symptoms may appear. Eosinophilia is common. Most of the time, patients recover spontaneously, but some can develop long-term symptoms with dyspnea, hepatomegaly, diarrhea, diffuse abdominal pain and a generalized rash. Symptoms of acute schistosomiasis may also be altogether absent (21).

Chronic schistosomiasis – the more relevant clinical picture in migrant medicine – results from the granulomatous immune reaction to *Schistosoma* eggs enclosed in the tissue. It is characterized by lymphocytes, eosinophils or activated macrophages. Depending on the species, it manifests either as an intestinal and/or hepatosplenic form (*S. mansoni*) or as urogenital schistosomiasis (*S. haematobium*). Granulomatous inflammation can occur in other tissues – albeit less often – which leads for example to neurological or pulmonal manifestations (15, 22).

In intestinal schistosomiasis, the granulomatous immune response to the parasite’s eggs in the intestinal mucosa leads to the formation of pseudopolyps, microulcerations and superficial bleeding. This can manifest itself with abdominal pain, diarrhea, loss of appetite and bloody stools (15, 20).

The hepatosplenic form begins with the formation of granulomas in the liver sinusoids, which causes hepatomegaly. This clinical picture is mainly found in infected children, less often in adults. Mild, diffuse fibrosis can be seen in ultrasound. Over the years, the inflammation leads to an excess deposition of collagen and other components of the extracellular matrix, which then results in periportal fibrosis ("Symmer’s pipe-stem fibrosis") and occlusion of the hepatic vessels. The consequences are portal hypertension, splenomegaly, the development of portocaval shunts and esophageal varices. Life-threatening upper gastrointestinal bleeding can occur. In ultrasound, typical fibrotic streaks and a dilatation of the portal veins become visible. This fibrotization process takes about 5 to 15 years and can persist even if the infection can no longer be detected parasitologically (20, 22).

In the urogenital form of schistosomiasis, the inflammatory processes are triggered by eggs trapped in the bladder wall or in the ureters. Ulcerations and pseudopolyposis of the urinary

bladder and ureter walls can be found. So called “sandy patches” can be found in cystoscopy, which are associated with neovascularization and a friable mucosa that tends to bleed. Symptoms are hematuria, dysuria, pollakiuria and proteinuria. Over time, fibrotization and calcification of the bladder and ureters can occur. This can result in hydroureter and hydronephrosis, which in the long term can lead to a loss of kidney function. There is also an association between chronic urogenital schistosomiasis and squamous cell carcinoma of the bladder (15, 20, 23).

Infection with *S. haematobium* can also lead to genital schistosomiasis. In women, the granulomas cause ulcerations on the vulva, vagina, cervix, ovaries and fallopian tubes. Pathognomic for an infection in the lower genital area are "sandy patches". Female genital schistosomiasis causes pain, is associated with stress incontinence, infertility and the risk of abortion and ectopic pregnancies. There is also evidence that genital schistosomiasis promotes transmission of the human immunodeficiency virus (HIV). In men, the genital form manifests with hematospermia, dyspareunia and oligospermia; orchitis and prostatitis can occur (15, 24).

In addition to the symptoms described, the persistent inflammatory process and bleeding in schistosomiasis causes other symptoms, such as anemia. It can impair the physical and cognitive development of children (15).

It should be noted that despite the manifold manifestations, chronic schistosomiasis can be asymptomatic over a long period of time (25-27).

1.1.4 Diagnosis

Schistosomiasis can be detected using various methods. The tests are based on the direct detection of the pathogen, its deoxyribonucleic acid (DNA), antibodies or antigens. All of them have certain advantages, but also limitations (28). In the following, the diagnostic methods of chronic schistosomiasis are presented, with an emphasis on those used in non-endemic settings.

1.1.4.1 Microscopy

The direct microscopic diagnosis of *Schistosoma* eggs in stool or urine is traditionally considered the diagnostic gold standard. To diagnose *S. mansoni* infections, stool samples are examined under a microscope. A widely used method – especially in endemic countries – is the Kato-Katz technique, in which the stool is pressed through a mesh fabric, filled into a specific template, and colored, before it is examined under the microscope. In other methods the stool is further processed, for example in the formalin-ether concentration technique (FECT), which includes the homogenization of stool in formalin, filtration, addition of ether, and centrifugation. Finally, the sediment layer is examined under a microscope. In the FLOTAC technique, stool is homogenized in formalin, filtered and a flotation solution is added, which causes the eggs to float on the surface (28, 29).

The infection with *S. haematobium* can be detected by microscopic examination of urine. Since the maximum egg excretion is between 10 am and 2 pm, the urine collection should cover this period. The urine sample can be examined under the microscope either after sedimentation or centrifugation; alternatively, the urine is passed through filters that hold back the eggs (23).

Schistosoma eggs can also be detected in tissue biopsies, for example in rectal biopsies or in biopsies of the liver, bladder, cervix, vagina, perineum and skin (18).

Due to their characteristic appearance, the eggs are easy to identify under the microscope. The eggs of the two species differ in the position of their spine, which is lateral in *S. mansoni*-eggs and terminal in *S. haematobium*-eggs (see **figure 4**) (28).

Figure 4: Left: egg of S. mansoni with the characteristic lateral spine (CDC); right: egg of S. haematobium with terminal spine (CDC/ Dr. D.S. Martin)

It should be noted that the eggs can be detected earliest about two months after infection, as the worm needs about this time to produce eggs (23).

Microscopic techniques have a specificity of 100%, but sensitivity tends to be low and variable (30). Bärenbold and colleagues for example, estimated a sensitivity of around 50 to 90% for the Kato-Katz technique (depending on the intensity of infection and the number of samples) using a model. It must be said however, that this model was applied on data from studies in settings with medium and high transmission (31). Sensitivity can be lower when egg-shedding is reduced, which is the case in long-lasting infections, in HIV infected, in older people (egg excretion peaks between the age of 12 to 15 years) or when parasite burden is low which often is the case for migrants in non-endemic settings (18, 19, 30, 32, 33). Beltrame et al. for example, determined a sensitivity of 45% for microscopy (one urine sample and three stool samples) according to a composite reference standard, when testing migrants from African countries (29).

Furthermore, the success of microscopy is dependent on skilled laboratory personnel. The examination of a larger number of samples per patient can increase sensitivity, however, particularly in screening situations, it can be difficult to obtain more than one sample as it requires certain patient compliance (30, 32).

1.1.4.2 Detection of antibodies

Most serological techniques detect immunoglobulin (Ig) G, IgM or IgE against soluble egg antigens or worm antigens in the patient's serum. Enzyme-linked immunosorbent assays (ELISA), immunofluorescence tests (IFAT), indirect hemagglutination assays (IHA) or immunoblots are used, amongst others. There are also rapid diagnostic tests based on immunochromatography (ICT). Antibodies against schistosomes are formed around 4 to 8 weeks after infection and may be detected even before eggs are excreted. Antibodies against cercariae and schistosomulae can also be detected, which can be used to diagnose the infection at an earlier stage. However, this is less relevant for migrants, as the infections often occurred some time ago (23, 29, 33, 34).

Laboratories mostly use *S. mansoni* antigens for serological tests, which, through cross-reactions, also indicate infections with other schistosome species (although some tests are less sensitive for *S. haematobium* infections). Most tests cannot distinguish the *Schistosoma* species

responsible for the infection. The differentiation of the species is possible to a certain extent by means of immunoblot (29, 34-36).

Serological tests are more sensitive than microscopy. In a study by Beltrame et al. for example a serological test using ELISA on migrants showed a sensitivity of 82% using microscopy as a gold standard. The sensitivity of the Western blot (WB) and the ICT test was even higher (WB: 92%; ICT: 94%). Specificity on the other hand was lower (84% for ELISA, 72% for WB, and 62% for ICT) (29).

Serological examinations have the disadvantage that they do not differentiate between an active and a past infection, since antibodies persist for a long time even after therapy or cure. There is also the possibility of cross-reaction, for example with the trematode *Fasciola (F.) hepatica.* Furthermore, some of the techniques require expensive equipment, appropriate facilities and technical expertise (28, 32, 36).

1.1.4.3 Detection of DNA

Schistosomal DNA can be detected using polymerase chain reaction (PCR) techniques in stool, urine, serum or other body fluids such as sperm or vaginal secretions. While the specificity is almost 100% in many studies, the sensitivity varies. It ranges between that of microscopy but can also be much higher. Sensitivity can suffer if the stool, of which only a small amount can be used in the assay, does not contain any DNA from the parasite. PCR can also be inhibited by compounds within the stool sample (28, 32).

Besides the conventional PCR there are also other techniques like the real-time PCR which is quantitative (qPCR), can detect lower DNA-concentrations and is less labor-intensive. PCR-ELISA combines the nucleic acid amplification technique with serology. The loop-mediated isothermal amplification (LAMP) is a simpler and less expensive amplification method than the PCR. It is also more rapid and the results can be evaluated with the naked eye, which makes it a promising technique for countries which lesser resources. For detection of DNA mostly in-house tests are used, so they can differ from laboratory to laboratory (32, 37, 38).

In a meta-analysis, Li and colleagues found an overall sensitivity for the DNA amplification techniques of 89.8% and a specificity of 87.7% for human samples (stool, urine and serum). Although it has to be said that only studies from endemic countries were included (39).

It should be noted that PCR analysis can also remain positive for a while after the therapy, which could be due to the fact that the degenerating eggs enclosed in the tissue continue to release genetic material. However, in the study by Guegan and colleagues, the PCR reached negative values more quickly after the therapy compared to serology (40).

1.1.4.4 Detection of antigens

The most important antigens used for diagnosis are the circulating cathodic antigen (CCA) and the circulating anodic antigen (CAA). The antigens are released by adult worms through regular regurgitation of undigested components from the parasite's intestines (41).

The CCA currently plays a greater role in the diagnosis of schistosomiasis since a point-of-care (POC) test is commercially available. The POC-CCA test can be used to detect the antigen in urine, but it is more reliable in the detection *of S. mansoni* infections compared to infections with *S. haematobium* (28, 38).

While the sensitivity of the POC-CCA test in high and moderate endemic settings was satisfactory with sensitivities between 67 and 99.1%, in the non-endemic setting it was below that of microscopy, ELISA, WB, and ICT. POC-CCA tests often give false positive values, for example in the case of pregnancy, hematuria or urinary tract infections. Combined with serology, however, like in a small study by Chernet et al. on asymptomatic Eritrean migrants, a sensitivity of 100% could be achieved (29, 38, 42).

In a study by Tamarozzi et al. an up-converting reporter particle technology lateral flow assay detecting CAA (UCP-LF CAA) showed promising sensitivity (86.9%) in diagnosing schistosomiasis in migrants, however, this test is not yet commercially available (30).

1.1.5 Therapy

The drug of choice for treating schistosomiasis is praziquantel. The manufacturer recommends a one-day therapy against *S. mansoni* and *S. haematobium* with 40 mg / kg body weight of praziquantel; the current German guidelines recommend a three-day therapy with this dosage. Praziquantel has a good safety profile. The side effects of the therapy are usually minor and include dizziness, drowsiness, fever, gastrointestinal complaints, and urticarial skin reactions. Praziquantel can also be used in pregnant and breastfeeding women (15, 27, 36, 43).

Praziquantel kills the worm by paralyzing it and damaging its tegument. The mechanism of action of praziquantel is not completely known. The drug only works on adult flukes, it does not kill immature stages of the parasite. These can develop into adults even after therapy, which can lead to a persistence of infection. This is especially a problem in regions with constant reinfection. There is no clear evidence of praziquantel resistance, but it can be induced experimentally (15, 44).

1.2 Strongyloidiasis

1.2.1 Epidemiology

Strongyloidiasis is usually caused by an infection with the nematode *Strongyloides (S.) stercoralis*, in rare cases also by *Strongyloides (S.) fülleborni subsp. fülleborni* (whose final hosts are monkeys) and *S. fülleborni subsp. kellyi*. *S. stercoralis* is widespread in tropical and sub-tropical regions of the world, but transmission can also occur in temperate climates. Humans are usually infected in areas with poor hygiene, remote or rural areas, or in institutional settings. Socially weak, marginalized groups are particularly affected. It is estimated that 30 to 100 million people are infected with *S. stercoralis* each year; an analysis by Buonfrate et al. even assumes 613,9 million infected people worldwide, with Southeast Asia, Africa and the West-Pacific regions accounting for over 75% of the global infections (45-47).

1.2.2 Life cycle

The lifecycle of *S. stercoralis* consists of an internal and external sexual cycle (**see figure 5**). The host gets infected by walking barefoot on contaminated soil. The filariform larvae penetrate the skin and migrate to the lungs through the venous circulation. Subsequently, the larvae are expectorated and swallowed. The larvae grow into adults in the small intestine. The female worms parthenogenetically produce eggs that hatch as rhabditiform larvae and are excreted in the feces (16, 48).

The excreted larvae develop into free-living worms that reproduce sexually in the soil (external sexual cycle). The resulting rhabditiform larvae then develop into the infectious filariform larvae that can survive in the ground for many weeks (16, 48).

A special feature of *S. stercoralis* is the ability of autoinfection during an internal lifecycle: This takes place either when filariform larvae are not excreted in the stool but penetrate the intestine or perianal skin or when the filariform larvae remain in the bronchial epithelium and multiply there. Due to this mechanism the worm can persist for a long time without the need of an external source of infection. Sometimes infections are detected decades after the initial exposure; in one case report the disease was diagnosed 75 years after initial infection (16, 48).

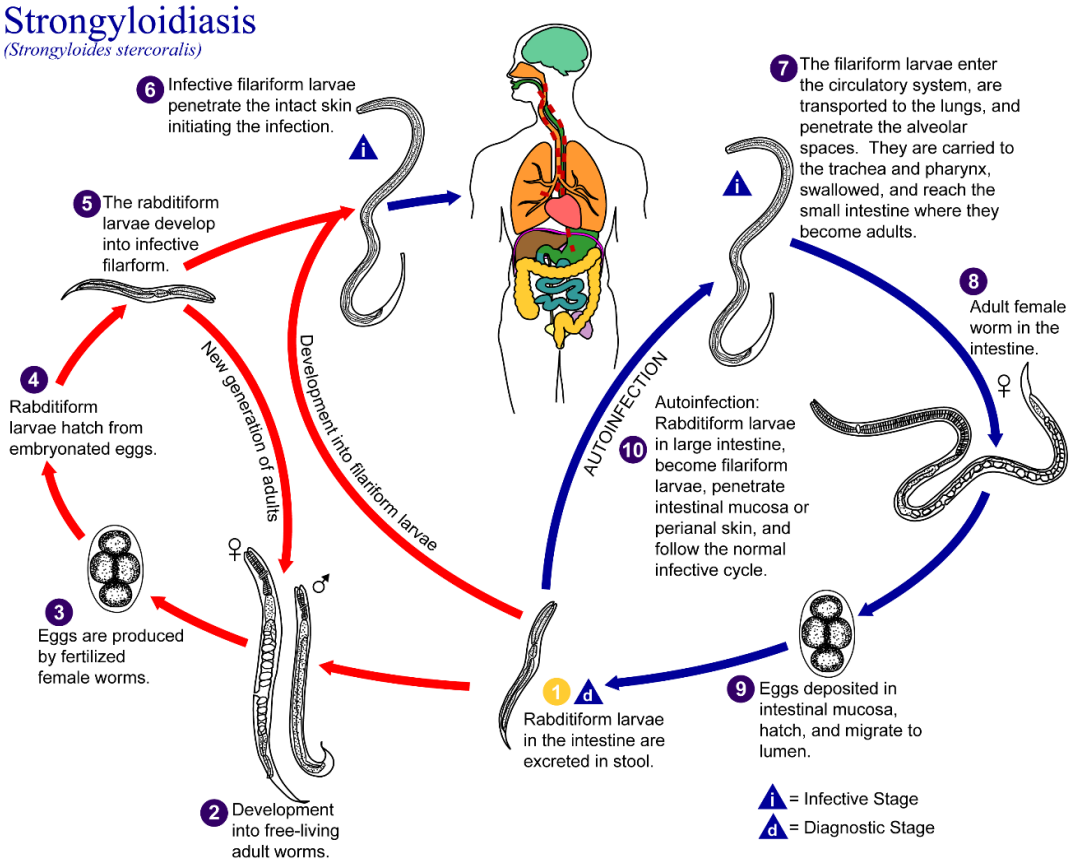

Figure 5: Lifecycle of S. stercoralis (CDC/ Alexander J. da Silva, PhD; Melanie Moser)

1.2.3 Pathogenesis and morbidity

An infection with *S. stercoralis* is usually clinically mild or asymptomatic in immunocompetent people. When the larvae penetrate the host's skin, characteristic skin reactions can occur. At the point of entry, serpentine or urticarial tracts may be visible; severe itching may occur that lasts for days. Furthermore, in the acute stage, irritation of the trachea or a dry cough can occur. A Loeffler-like syndrome with fever, dyspnea, wheezing, pulmonary infiltrates to be seen in chest X-ray and increased eosinophils are less frequently reported. When the worms finally reach the intestine, gastrointestinal symptoms such as diarrhea, constipation, abdominal pain and anorexia may appear (16).

If symptomatic, chronic strongyloidiasis manifests with constipation or vomiting. Repeated mild pneumonitis with fever or restrictive lung disease can also be signs of chronic infection. The larvae can visibly migrate intradermally at a rate of 5 to 15 cm per hour ("larva currens"), which can lead to very itchy red tracts, mainly in the perianal region and on the thighs (16, 49).

In immunocompetent individuals, the immune system can control infection with *S. stercoralis*. The infection becomes problematic when the host's immune status changes. This can lead to hyperinfection syndrome, and the helminth can disseminate. One of the strongest risk factors for developing hyperinfection syndrome is taking corticosteroids. Even short-term therapies and low doses (around 20 mg / day) are enough to trigger hyperinfection syndrome. Further risk factors are co-infection with the human T-lymphotropic virus 1 (HTLV-1), use of immunosuppressants, organ transplants, alcoholism or haemato-oncological diseases, amongst others (16, 49, 50).

In hyperinfection syndrome larvae of *S. stercoralis* proliferate in an uncontrolled manner. This manifests itself in an exacerbation of gastrointestinal and pulmonary symptoms. Larvae can be found in abundance in the patient's stool and sputum. Hyperinfection syndrome may show with fever, hemoptysis and wheezing, pulmonary infiltrates may be seen on chest X-ray, which represent a combination of edema, hemorrhage and pneumonitis. Paralytic ileus and gastrointestinal hemorrhage may also occur. Hyponatremia due to syndrome of inappropriate antidiuretic hormone secretion was also observed (16, 49).

During the uncontrolled proliferation, the larvae of *S. stercoralis* can migrate from the lungs or gastrointestinal tract into other organs, such as the liver, the heart, the kidneys, the lymphatic and central nervous systems. Since the larvae take the intestinal flora with them during migration, bacterial infection such as gram-negative meningitis or sepsis may occur. The clinical symptoms depend on the organ involved. If left untreated, the case fatality rate from hyperinfection syndrome can be up to 100%. If treated adequately it can be reduced to around 47% (16, 49, 50).

1.2.4 Diagnosis

Strongyloidiasis can be diagnosed by examining stool samples or duodenal juice under a microscope for the presence of larvae. It is also possible to cultivate the pathogens, for example on an agar plate. Alternatively, the DNA of the nematode can be detected in stool by PCR. As an indirect method, antibodies can be detected in the blood (35).

1.2.4.1 Microscopy

Stool microscopy is considered the gold standard for diagnosing *S. stercoralis* infection. After the larvae have penetrated the host's skin, it takes a prepatent period of about 3 to 4 weeks before larvae can be detected in the stool (16).

The sensitivity of the stool examination is particularly low in case of chronic infections with a low worm burden and only intermittent excretion of larvae. A meta-analysis by Campo Polanco et al. indicated a sensitivity of only 21% for stool microscopy in such cases. The sensitivity can be increased by repeated stool examinations and various concentration methods. This includes, for example, the FECT, which had a sensitivity of 48% in the meta-analysis, or the Baermann technique with a sensitivity of 72%. In the latter, stool is mixed with activated charcoal and lukewarm water, incubated and filtered. The agar plate culture achieved the greatest sensitivity

in this meta-analysis with 89%. It can take, however, up to around 7 days to deliver results. The specificity was 100% in each of these tests (51-54).

In addition to examining stool, *S. stercoralis* infection can be detected in duodenal aspirate or biopsies and, especially in case of hyperinfection syndrome, in other body fluids, like sputum or broncho-alveolar lavage (50, 55).

1.2.4.2 Detection of antibodies

The serological tests for strongyloidiasis detect antibodies (mostly IgG) using ELISA, IFAT or luciferase immunoprecipitation system (LIPS). Various antigens are used to develop the test, such as antigens from *S. stercoralis* larvae, from the heterologous species *Strongyloides (S.) ratti* or recombinant antigens, which could improve the diagnosis through an even higher specificity (51, 56).

In a study by Bisoffi et al. in which the diagnostic accuracy of 5 serological tests was compared, sensitivities between 70.7 and 94.6% and specificities between 87.3 and 99.6% were achieved. The highest sensitivity was reached with a test based on IFAT, the highest specificity was achieved with a test based on LIPS, which was using a recombinant antigen ("NIE"). To measure accuracy, the researchers used a composite reference standard based on a combination of different tests (57).

As already mentioned, the disadvantage of serological tests is that they are unable to differentiate between a current and a treated or past infection. There is also the possibility of cross-reactions with other nematodes. In addition, none of the available tests has been evaluated for the detection of acute or early infection with *S. stercoralis* (56, 58).

1.2.4.3 Detection of DNA

There is the possibility of detecting *S. stercoralis* DNA in stool samples using PCR. In a systematic review article and metanalysis, however, Buonfrate et al. showed that the PCR was very specific (93 to 95% depending on the reference test), but sensitivity was unsatisfactory (56 to 71%). Thus, according to the authors, PCR is not suitable as a universal screening test, but it could be useful as a confirmatory test. A possible reason for the poor sensitivity is the irregular excretion of larvae in the stool in chronically ill patients – the same problem that reduces the sensitivity of stool microscopy. The examination of several stool samples could lead to better sensitivities (59).

1.2.5 Therapy

The treatment of choice for chronic strongyloidiasis is ivermectin. Thiabendazole is similarly effective, but ivermectin is better tolerated and more widely available. It must be mentioned that most studies on the effectiveness of ivermectin were based on the examination of stool samples, which are known to have a low sensitivity and thus could overestimate the effectiveness. In a study based on serology, the drug was found to be less effective (51).

Ivermectin works by binding to glutamate-gated chloride ion channels and hyperpolarizing the nerve cells, which ultimately kills the parasite. Because it cannot cross the blood-brain barrier, the effects do not occur in humans (16).

The American Centers of Disease Control (CDC) recommend ivermectin at a dose of 200µg / kg for 1 to 2 subsequent days for the treatment of chronic strongyloidiasis. Other experts recommend taking two doses 2 weeks apart to accommodate the 3 to 4 week duration of autoinfection cycle and also because the effectivity of ivermectin on extra-intestinal stages of development of the parasite remains uncertain. However, in a randomized-clinical trial by Buonfrate et al. single-dose ivermectin was not inferior to multiple-dose ivermectin regarding efficacy. The single dose was also better tolerated (16, 55, 60).

Generally, ivermectin is a well-tolerated drug. Side effects such as temporary hypereosinophilia, liver dysfunction, nausea, vomiting, diarrhea and neurological side effects such as asthenia, somnolence and tremor were observed. Serious skin reactions such as Stevens-Johnson's syndrome occur very rarely (16, 61).

Treatment with ivermectin can cause dangerous side effects in people co-infected with *Loa (L.) loa*. An increased incidence of encephalopathies was observed in *S. stercoralis* - *L. loa* co-infected patients receiving ivermectin. Patients from West or Central Africa should therefore be screened for *L. loa* prior to therapy (16).

Treatment of hyperinfection syndrome consists of ivermectin, antibiotics against gram-negative bacteria, supportive measures and – if possible – a reduction in immunosuppression. In contrast to chronic infection, many more larvae are excreted in hyperinfection syndrome, so that the stool examination can be used to monitor therapeutic success. Daily ivermectin therapy should be continued until 2 weeks after the last positive stool sample. When ivermectin can't be applied orally, for example in cases of paralytic ileus, malabsorption or vomiting, subcutaneous administration can be an alternative. It should be taken however into account that the parenteral formulation is only available in form of veterinary preparation and there are no recommendation concerning the dose or schedule of application (16, 62).

2. Aim of this thesis

With the influx of migrants from SSA, it can be assumed that physicians in Europe will increasingly be confronted with tropical diseases with which they only have little experience. It is to be feared that many patients remain undiagnosed or are treated incorrectly.

This work aims to provide an overview of the current data on helminth diseases and their prevalence in migrants from SSA to Europe – with a focus on schistosomiasis and strongyloidiasis. Published data will be complemented by data on migrant health gathered at the Division of Infectious Diseases and Tropical Medicine at the University Hospital LMU Munich.

This work is divided into two parts:

1. An overview of the recent literature on helminth diseases in migrants from SSA to Europe from 2015 to 2020 (see section 3). This literature review has already been published (Grzegorek K, Kroidl I, Prazeres da Costa C, Rothe C. Spectrum of Helminth Infections in Migrants from Sub-Saharan Africa to Europe: A Literature Review. Am J Trop Med Hyg. 2023; 108:1096-1104)

2. A retrospective analysis of anonymized data from the patient database at the Division of Infectious Diseases and Tropical Medicine of the LMU University Hospital Munich (see section 4)

3. Literature review on helminth diseases in migrants from SSA to Europe

3.1 Methods

For the literature review on helminth diseases in migrants from SSA to Europe the databases Medline, Embase and Pubmed were screened. The following search terms and a combination of them were used: Emigration and immigration/exp, refugees/exp, “asylum seeker*”, immigrants and emigrants/exp, migrants and transients/exp, “unaccompanied minor*”, migra*, emigra*, immigra*, refugee*, Europe/exp, helminthiasis/exp, „tropical disease*“, „neglected disease*“, helminth*, worm*, echinococcosis, “hydatid disease“, fasciol*, paragonim*, filariasis, onchocerciasis, “river blindness”, “Wuchereria bancrofti”, loiasis, “Loa loa”, hookworm*, “Necator americanus”, “Ancylostoma duodenale”, “Ascaris lumbricoides”, “Trichuris trichiura”, “soil-transmitted helminths”, geohelminths, schistosomiasis, bilharzia, taeniasis, cysticercosis, strongyloidiasis (4).

Literature on human infections published in English and German between January 1, 2015 and December 31, 2020 was taken into consideration (4).

The review was limited to original research and case reports. Literature reviews, cost-effectiveness-analyses, studies focusing on treatment (for example to explore its efficacy) and conference abstracts were excluded. The data included had to be attributable to migrants from SSA; data from travelers, people visiting their friends and relatives (VFR) or adopted children was not taken into consideration (4).

The definition of the region SSA is not always consistent. While the European Commission and the World Bank for example include Sudan to SSA, it is considered North Africa for the United Nations Statistics Division (63-65). If countries of origin were explicitly mentioned in the articles, migrants from Sudan were also included in this review.

3.2 Results

The search yielded 778 entries. After removing duplicate entries and applying the exclusion criteria, 74 articles were obtained for the literature review (**figure 6**; short summary of each article see **table A 1 in the annex**). In the following sections, the prevalence of the helminthiases found in migrants from SSA are presented, as well as a selection of results from some of the reviewed studies and case reports (4).

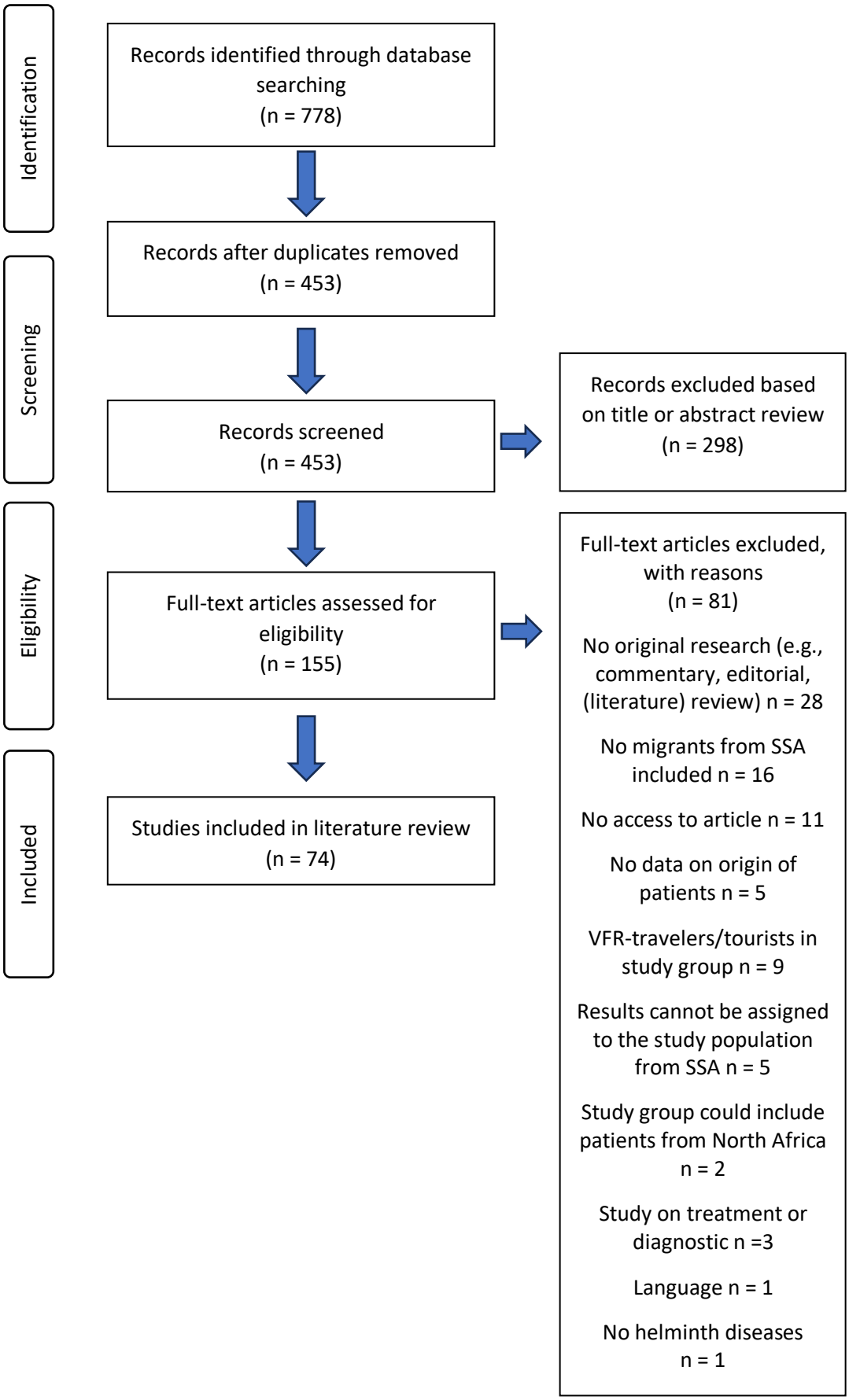

Figure 6: Flowchart depicting the selection of the reviewed articles (flowchart template modified after Moher D, Liberati A, Tetzlaff J, Altman DG and The PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009; 6:e1000097)

3.2.1 Schistosomiasis

Overall, schistosomiasis was the helminthiasis that was most frequently discussed in the papers analyzed. Prevalence of the disease in studies with more than 50 participants ranged between 5.8% and 50.5%, when serology was used for diagnosis; between 0 and 27% when microscopy was used and between 17 to 58.9% when several diagnostic methods were combined (see **tables A 2 a,b,c in the annex**) (4).

3.2.1.1 Time to diagnosis

Some studies determined the time it takes to diagnose schistosomiasis in migrants. In a study by Tilli et al. with 170 migrants from SSA, it took an average of 5 months from arrival in Italy or the onset of symptoms of urogenital schistosomiasis to diagnosis. The majority of the patients examined had already suffered from the symptoms for a median of 5 years; two thirds already had lesions in the urinary tract upon admission (4, 66). In a study by Cobo et al. 42.3% of schistosomiasis patients had already lived in Spain for 3 years before they were diagnosed, 16.7% had lived there for more than 5 years and 2.8% for more than 10 years (4, 67). Potters et al. report on the case of a 31-year-old migrant from Sierra Leone who was diagnosed with *S. mansoni* infection after living in Europe for 20 years (68). The patient had not left Europe during this time.

Riccardi et al. and Brindicci et al. described patients from SSA with *S. haematobium* infection and hematuria who received unnecessary (initial) examinations (such as cystoscopy) or antibiotic therapies before schistosomiasis was even considered (4, 69, 70).

3.2.1.2 Long term complications

Long term complications of schistosomiasis were mentioned among others in an article by Mendoza-Palomar et al. in which data from 43 migrant children from SSA with schistosomiasis was retrospectively analyzed: Two cases of pulmonary hypertension and one of cardiomyopathy could be attributed to chronic schistosomiasis (4, 71). In a study by Roure et al. 22 of 61 (36.1%) schistosomiasis patients from SSA had chronic complications, including renal failure with the need of hemodialysis or transplantation (4, 72). In a study by Salas-Coronas et al. severe complications of chronic schistosomiasis were found in 4% of the 326 patients with parasitologically confirmed schistosomiasis (4, 73).

Other long-term complications described in case reports included liver fibrosis, esophageal varices, splenomegaly and portal hypertensive gastropathy (4, 74, 75).

3.2.1.3 Co-Infection with hepatitis B virus

In two studies the co-infection of schistosomiasis (with an emphasis on *S. mansoni*) and chronic hepatitis B was investigated (76, 77). The background to these studies were results from endemic countries which indicated that the co-infection increased the risk of aggravated liver disease. However, this could not be confirmed for non-endemic countries. The authors discuss various factors that could contribute to the divergent results such as a higher parasite load of patients living in endemic countries under continuous risk of re-infection. The studies in the non-endemic countries also included migrants whose schistosomiasis diagnosis was based on serology, which could include patients with *S. haematobium* infection or past infection; in some cases, the sample sizes were small and no liver biopsies or elastography was performed (4).

3.2.1.4 Other

Less common manifestations of schistosomiasis were discussed in some case reports, such as the occurrence of pulmonary nodules or neurological deficits (4, 78-81).

Le Govic et al. published a case of a *S. haematobium - S. mansoni* hybrid infection in a young migrant from Ivory Coast. After genotyping, the authors suspect the origin of the hybrid in Senegal. Since the patient has never been to this country before, Le Govic and colleagues suspect that hybrids are more common than expected (82).

Carrai et al. describe the case of a patient in whom schistosome eggs (probably *S. haematobium* or a hybrid species) were discovered in the donor liver after a transplant. The donor was previously undiagnosed, and the explanted liver was free of schistosome flukes. As *S. haematobium* eggs are not typically found in the liver, the authors speculate that the surgical procedure caused the eggs produced by worms in the bladder plexus veins to travel in an unusual manner eventually reaching the liver (83).

3.2.2 Strongyloidiasis

Prevalence in studies with more than 50 participants was between 10.7 and 38.1% when several diagnostic methods were combined, between 1.1 and 10.9% in studies with serological diagnostics and between 0 and 3.6% in studies which used microscopy (see **tables A 3 a,b,c in the annex**) (4).

In a systematic screening program for strongyloidiasis, Casado et al. showed a high risk of infection in migrants from East Africa. Infected migrants reported that they used to walk barefoot in their home country (4, 84).

Martinez-Perez et al. described three cases of hyperinfection syndrome in patients from SSA. In one case strongyloidiasis was diagnosed after 31 years of living in Spain. The patient suffered from a myelodysplastic syndrome with pancytopenia and died after 30 days (4, 85).

3.2.3 Other helminth diseases

3.2.3.1 Filariasis

In the reviewed papers mostly infections with *Mansonella (M.) perstans* and *L. loa* were diagnosed. In studies with over 50 participants prevalence ranged from 4.5 to 50.4% for *M. perstans* and from 0 to 12.7% for *L. loa* – considering the studies in which microfilariae could be detected (see **table A 4 in the annex**) (4).

Infections with *Onchocerca (O.) volvulus* were rarely described, although in some studies skin snips were used to diagnose patients in which the infection was suspected (4, 86, 87). An exception are two studies by Puente et al. in which data from patients over a period of 20 years was collected. In these studies, 27.4% of migrants with mansonelliasis and 16.8% of migrants with loiasis were coinfected with *O. volvulus* (4, 88, 89).

Four cases of onchocerciasis were described in more detail: One in a migrant from Ghana with pruritus, two in migrants from Senegal and one in a migrant from Cameroon, although in the latter three, microfilariae could not be demonstrated in skin snip biopsies (4, 90, 91).

Infections with *Wuchereria (W.) bancrofti* have only been reported sporadically (4, 88, 89, 91).

3.2.3.2 Geohelminths

Stool prevalence of infection with geohelminths (other than *S. stercoralis*) ranged from 0.3 to 41.2% for hookworms, from 0 to 27.2% for *Trichuris* (*T.) trichiura* and from 0 to 17.9% for *Ascaris* (*A.) lumbricoides* in studies over 50 participants (4, 89, 92, 93). Especially high prevalences were found in studies, in which the examined population was co-infected with filariae. If these studies were excluded, the highest prevalence of hookworm was 25.6% in eosinophilic patients (4, 86). Prevalence of *A. lumbricoides* reached 3.6% and prevalence of *T. trichiuria* 4.1% (4, 94, 95).

3.2.3.3 Taeniasis/ neurocysticercosis

Both taeniasis, the infection with the adult form of *Taenia spp*., and (neuro)cysticercosis, the infection with cystic larvae of *Taenia (T.) solium*, were described in the reviewed papers. Prevalence of taeniasis (diagnosed by stool microscopy) was not very high, the highest being 1.2% in a group of 488 newly arrived SSA migrants to Spain (4, 94). Only a few cases of neurocysticercosis (infection of the nervous system) in SSA migrants were described: seven active cases from the United Kingdom, one definite and two probable cases of in two Belgian medical institutions and one case from a university hospital in Germany (4, 74, 96, 97). There were however no studies in which systematic screening using neuroimaging was conducted (4).

3.2.3.4 Echinococcosis (hydatid disease)

Echinococcosis was described very sporadically in SSA migrants: In some studies, it had not been found at all or it had only been found in migrants from other regions, but not in the subgroup of SSA migrants (4). In a study by Cobo et al. for example no case of hydatid disease (infection with *Echinococcus (E.) granulosus*), could be found in 1930 migrants from SSA, but in 5.9% of the 255 migrants from Maghreb and in 6.7% of the 45 migrants from Eastern Europe (67). A positive *E. granulosus* serology could be found in 2.4% of 337 SSA migrants and in 4.2% of 48 migrants from Northern Africa (4, 98). There was one case report of a 26-year-old migrant from Niger with a hydatid liver cyst (4, 99). It has to be said, that ultrasound – the technique of choice for diagnosing echinococcosis – was rarely used as a screening tool in the studies (100). In a study by Salas-Coronas et al. an abdominal ultrasound was used to detect "signs of chronic hepatic disease" in another study, also by Salas-Coronas, "further proper diagnostic procedures were performed", if hydatidosis was suspected (86, 94). In both studies echinococcosis was not detected in SSA migrants.

3.2.3.5 Other

Other helminths diagnosed in SSA migrants were *Dicrocoelium (D.) dendriticum* (although some cases might be false parasitism), *Hymenolepis (H.) nana, F. hepatica, Enterobius (E.) vermicularis* and *Toxocara spp*. (see **table A 1 in the annex**) (4).

3.3 Discussion

This review shows a wide range of helminth diseases among migrants from SSA. Judged by the number of publications, especially schistosomiasis has received attention in scientific publications in recent years (4).

Regarding the publications on filariasis, mostly infections with *M. perstans* and *L. loa* were described in migrants. The prevalence of loiasis did not exceed 1% in most publications, whereas the prevalence of mansonelliasis reached up to almost 14% in patients with eosinophilia and 9.1% in unselected patients (4). This may be due to the fact, that *M. perstans* is more widespread than *L. loa* and studies also included people from countries not endemic for the latter, like

Senegal or Mali (see **table A 4 in the annex**) (101, 102). Nevertheless, due to the number of cases, there is a great need for research on mansonelliasis, since little is known about mortality and morbidity of this diseases and there are no specific treatment options (4, 88, 101, 103).

Infections with *W. bancrofti* (lymphatic filariasis) and *O. volvulus* (onchocerciasis or river blindness) were hardly described in the recent literature on SSA migrants (4). Reasons for this small number of cases could be the labor-intensive diagnosis, which includes nocturnal blood smears in the case of *W. bancrofti* and skin snips in the case of *O. volvulus,* which were not systematically performed in every study (4, 104). Also, both diseases lead to severe disabilities, which could make migration impossible ("healthy migrant effect") (4, 105, 106). Finally, the small number of cases could be due to the success of eradication programs (4, 107, 108).

Among the publications on filariasis, two by Puente et al. stand out (4, 88, 89). In both, a high number of co-infections with filariae, especially *O. volvulus*, were detected in migrants mainly from Equatorial Guinea. It must however be mentioned that the examined migrants were preselected: Since they already had a filarial infection (in this case mansonelliasis or loiasis) they seem to come from particularly affected areas and thus also have a risk of further filarial infection. The evaluated data also covers a span of around 20 years, so might reflect a period when eradication campaigns were only just beginning, such as the African Program for Onchocerciasis Control, which was established in Equatorial Guinea in 1998. Today the country is mostly free from onchocerciasis (4, 109, 110).

Other helminth diseases were less common in the reviewed papers, like taeniasis or echinococcosis. The latter is diagnosed by ultrasound, which was not used in many studies for screening (4, 86, 94). Taeniasis on the other hand is diagnosed by stool microscopy. Most studies did not indicate whether the infections were caused by *Taenia (T.) saginata* ("beef tapeworm") or *T. solium* ("pork tapeworm"), possibly because their eggs cannot be distinguished with standard microscopy (4, 97, 111, 112). Of both pathogens, an infection with *T. solium* is more serious as it can lead to neurocysticercosis, which is a common cause of epilepsy in high-risk-communities (4, 112). As the intermediate host of *T. solium* are pigs, in studies in which a majority of the participants came from Muslim countries like Mali, Somalia or Senegal, low prevalence may be explained by religious food restriction (4, 67, 86, 94). However, in countries with a religiously mixed population, where grazing of pigs is common, people who do not eat pork can also be infected via the fecal-oral route (4, 113).

Neurocysticercosis is diagnosed by computed tomography (CT) scan or magnetic resonance imaging (MRI) of the brain – not many studies in this review systematically screened migrants from SSA on this disease (114).

Infections with geohelminths, which were also found in this review, produce often only little morbidity. The shorter life span of these helminths and the lower risk of reinfection in countries with better hygienic condition could lead to a decrease of prevalence of these helminths with the length of stay in the host country (4, 67, 115). However, geohelminthiases could be relevant for risk groups such as pregnant women or children (4, 93, 94, 116).

Focusing on schistosomiasis and strongyloidiasis, the prevalence of these diseases in this review had a great range. This can have multiple reasons. As already mentioned in the introduction, all diagnostic methods have certain weaknesses. Screening solely based on microscopic

examinations may underestimate disease prevalence due to the low sensitivity of the test, in particular in migrants who often have a low parasite burden (4, 15, 16, 93, 117). Serology on the other hand may overestimate the prevalence as there is the risk of cross-reactions. Furthermore, serology may stay positive even after treatment or recovery (28, 32, 56, 58). There is also the risk of a false negative test result: In a study by Salas-Coronas et al. almost 30% of migrants with microscopically confirmed schistosomiasis (predominately *S. haematobium*) were negative upon serology; in a study by Cobo et al. also around 30% of migrants with confirmed schistosomiasis had negative serology (4, 67, 73). Tests other than serology and microscopy were hardly used in the reviewed studies (4). Generally, studies where more than one diagnostic method was used, tended to find higher prevalence.

In addition, the preselection of patients could also play a role: If symptomatic patients or patients with eosinophilia are examined, prevalence may tend to be higher. Furthermore, the prevalence in hospitalized patients or patients who were recruited in outpatient departments may be higher than in study participants recruited outside medical settings, for example in refugee shelters. Length of stay in the host country could also influence the outcome, as well as the migrants' country of origin. Some authors noticed higher prevalence of schistosomiasis among migrants from Mali, Senegal or the Ivory Coast (4, 70, 76, 118). Chernet et al. found a high prevalence of *S. mansoni*-infections among asymptomatic Eritrean migrants (21.5% in stool screening), which is unusual since Eritrea is rather a low prevalence-country (4, 25, 119, 120). Unfortunately, only a few studies could be found in the review in which the country of origin of the infected was mentioned. This is a missed opportunity to gather information about the epidemiological situation in the country of origin. However, infections in transit countries must also be considered. Also, migrants, who are mostly young males, may not necessarily be representative for the general population (4).

Asundi et al. published a meta-analysis in 2019 of the prevalence rates for schistosomiasis and strongyloidiasis among migrants from SSA and reported an overall serological prevalence of 24.1% for schistosomiasis and 14.6% for strongyloidiasis. The prevalence on microscopic stool examination was 5.1% for schistosomiasis and 0.7% for strongyloidiasis; the prevalence of *S. haematobium* in urine examination was 6.8%. The results of this extensive meta-analysis of 88 studies can serve as a benchmark, but the authors also state the high heterogeneity for the pooled prevalence estimates as a limitation of their study, which remained high even after stratification by criteria like age, region of origin and migrant status (4, 121).

Although the prevalence of both diseases may be high in SSA migrants, there is often a delay in diagnosis, which – in the case of schistosomiasis – can lead to long-term organ damage (4, 66, 67). In the case of strongyloidiasis, the lack of diagnosis and treatment can be fatal if the patient is treated with an immunosuppressant including corticosteroids (16).

Both diseases are hard to diagnose, not only because of the lack of reliable diagnostic methods but also because they are often asymptomatic or symptoms are not very specific (4, 15, 16). In addition, many physicians may lack knowledge about these NTDs (4). In a survey for example, Mantica et al. revealed gaps in knowledge about schistosomiasis in European urologists: While 97.3% of African urologists had sufficient knowledge about this disease, only 39.2% of European urologist did (122). This lack of knowledge may also lead to unnecessary diagnostic procedures or inappropriate treatment in migrants showing symptoms of the disease (69, 70).

Another problem is that migrants often have a more difficult access to healthcare, be it due to language, cultural or bureaucratic barriers or the lack of health insurance (4, 10, 26). Müllerschön et al. showed in a study, that migrants from SSA without insurance sought medical help less often than those with insurance cards (41.2% vs. 90%) (123). Also, migrants may not see a reason to seek medical help when they have no or only little symptoms.

In summary, there is a need for schistosomiasis and strongyloidiasis screening programs for migrants from SSA. A meta-analysis by Agbata et al. showed, that screening and treatment could reduce mortality and morbidity in newly arrived migrants, and also the European Centre for Disease Prevention and Control (ECDC) recommends this approach (4, 124, 125). Two studies by Zammarchi et al. suggest, that screening or presumptive treatment of schistosomiasis and strongyloidiasis could be more cost-effective than the current strategy of passive diagnosis (126, 127). Unfortunately, such programs have not been introduced at a national level in Germany so far (4).

In addition to the health benefits for those infected, screening could also prevent the spread of schistosomiasis in Europe. Snail vectors for schistosomiasis are present in some parts of southern Europe, and autochthonous transmission has been reported in Corsica and Almería (4, 128, 129). The hybridization of zoonotic with primarily anthroponotic *Schistosoma spp*, as for example observed in Corsica, carries the risk of increased infectivity, virulence and longevity of the pathogen and could widen the host range which would hamper eradication (82).

As for now, serology seems to be the best option for screening as it is more sensitive than microscopical methods (4, 125). A combination of several methods could further improve the diagnosis but is also more complex. It would be desirable to have a simple and reliable diagnostic method that ideally can be carried out without much technical effort. PCR-based methods may be promising. Another option might be a presumptive treatment as it is practiced in the United States of America (4, 130). However, in this case, it lacks the opportunity to learn more about the epidemiology of the disease.

3.4 Limitations

This literature review has several limitations (4):

1. The literature search starts with the beginning of the “migrant crisis” in the year 2015, but the publications also include data collected before this period, so the results may therefore partly not reflect the current epidemiology.
2. The review only included data in English or German. Data only published in the respective local languages from countries like France, Italy or Spain, which host many migrants, may be missing (5).
3. Only a few studies used imaging methods for screening, such as ultrasound to detect echinococcosis, or CT-scan/MRI for neurocysticercosis. Therefore, the prevalence of these infections may be underestimated.
4. In many studies participants were recruited in specialized units, so prevalence may be higher than in the general migrant population. In addition, not every study mentioned, which diagnostic methods were used, or the characteristics of the study participants.
5. The term “migrant” was not always clearly defined. Asylum seekers, that migrated to Europe on foot or by boat may be more vulnerable than people who immigrated legally to work or study in Europe. This may also affect the prevalence of the disease.

6. Some of the screened diseases are endemic in Europe, like taeniasis or echinococcosis, so infection could also have been acquired in Europe.
7. SSA as a region is not always clearly defined (see methods section 3.1). Depending on the definition of the region, data on migrants from Sudan may be missing.

4. Analysis of the patient database of the Division of Infectious Diseases and Tropical Medicine

4.1 Methods

To determine the prevalence of schistosomiasis and strongyloidiasis among patients from SSA attending the Division of Infectious Diseases and Tropical Medicine at the University Hospital LMU Munich anonymized data from the patient database collected during the period from February 12, 2016 (first SSA migrant case since establishment of the most recent version of the database) to December 31, 2020, was retrospectively analyzed. Patients for whom "migration" was entered as the main reason for travel and for whom a SSA country was registered as their place of birth, were considered for this analysis. Patients who were migrants but for whom the main reason for the present travel was different from migration (for example VFR) or who had visited their home country after their arrival in Germany were excluded.

Age (at the time of initial admission) and sex of the patients, country of origin, length of stay in Germany or Europe (if specified) and diagnostic tests performed (examinations for schistosomiasis and strongyloidiasis, eosinophil blood counts) were analyzed.

For serological diagnosis of schistosomiasis and strongyloidiasis ELISA-based in-house tests, which detect IgG antibodies in the serum, were used. Values > 14 antibody units (AU) were considered positive, values between 10 and 14 AU were borderline, and AU below 10 were considered negative. Up until the beginning of 2019, an in-house IFAT for IgG antibodies in the serum was also carried out for the diagnosis of schistosomiasis. For this test titers > 1:32 were considered positive, titers of 1:32 were borderline, and titers below this were considered negative (35). For this analysis borderline results were counted as positive. If both serological tests (ELISA or IFAT) were carried out and only one of them was positive or borderline, the serology was considered positive.

For the parasitological stool examination, one or more stool samples were concentrated and examined under the microscope. For the parasitological urine examination, the sediment of urine collected over 24 hours was examined microscopically ("collection sediment"). Some patients only submitted a convenience sample of spontaneously obtained midstream urine which was examined after concentration ("urine sediment") (35). In the analysis both methods are summarized under "urine microscopy". Midstream urine was only examined under the microscope if this had been explicitly ordered by the attending physician.

In addition, some patients were diagnosed with schistosomiasis by microscopy of biopsy material. The biopsy was carried out outside the Division of Infectious Diseases and Tropical Medicine.

For diagnosis of schistosomiasis also qPCR of stool, urine (Obeng et al. (131)) or serum (modified after Wichmann et al. (132) and Cnops et al. (133)) was used. Stool PCR and qPCR was also used to diagnose strongyloidiasis (until February 25, 2020, a PCR-test was used (Pompl et al. (134)),

from February 26, 2020 a qPCR was used (modified after Kramme et al. (135)). The stool and urine qPCR for schistosomiasis have a total of 50 cycles. The serum qPCR for schistosomiasis and the stool qPCR for strongyloidiasis have a total of 45 cycles. A significant increase in the fluorescent signal before the 40th cycle is considered positive. Increases after this are assessed individually. The PCR test for strongyloidiasis, which was used until February 2020, is qualitative and was analyzed by gel electrophoresis (presence of a band means, that the test is positive).

In the following the term PCR will be also used for qPCR.

The PCR tests were only used in a smaller proportion of patients as they were only introduced towards the end of the observation period.

Other test for diagnosis of schistosomiasis used at the Division of Infectious Diseases and Tropical Medicine at the University Hospital LMU Munich were the detection of CCA in urine, the ICT rapid test for IgG and / or IgM antibodies in serum, or the detection of antigens by means of immunoblot. These were also used to a lesser extent.

In the results section, the results of serologies, microscopies, and PCR examinations are considered.

Symptoms or signs of schistosomiasis or strongyloidiasis were not systematically recorded.

4.2 Results

In total, data from 257 migrants from SSA was available for analysis. 72.4% of the patients were men, the median age was 26 years. Most migrants had lived in Germany for 3 years or less (70.4%). Nigeria, Eritrea and Somalia were the most common countries of origin, 61.1% of the patients came from one these three countries.

29 patients (11.3%) did not receive any diagnostic tests for schistosomiasis or strongyloidiasis; 15 patients (5.8%) came for control after schistosomiasis therapy and two patients (0.8%) came after strongyloidiasis therapy, one patient (0.4%) had received both schistosomiasis and strongyloidiasis therapy in the past.

The characteristics of the patients are summarized in **table 1**.

Table 1: Characteristics of migrants from SSA attending the Division of Infectious Diseases and Tropical Medicine at the University Hospital LMU Munich

Characteristics	**Patients n= 257 (%)**
Age Average age Median age Range:	 27.5 years 26 years 3 – 71 years
Sex Men	 186 (72.4)
Duration of stay in Germany ≤ 3 years > 3 years Unknown	0-31 years 181 (70.4) 61 (23.7) 15 (5.8)
Country of origin	
Nigeria	71 (27.6)
Eritrea	53 (20.6)
Somalia	33 (12.8)
Mali	15 (5.8)
Sierra Leone	12 (4.1)
Senegal	10 (3.9)
Ethiopia	9 (3.5)
Republic of the Congo	8 (2.8)
Ghana	6 (2.3)
Democratic Republic of Congo, Uganda	4 (1.6) each
Guinea-Bissau, Madagascar, Kenia, Ivory Coast, Gambia	3 (1.2) each
Benin, Burkina Faso, Guinea, Mozambique, Tanzania, Cameroon, Togo	2 (0.8) each
Djibouti, Gabon, Malawi	1 (0.4) each
Diagnostic test(s) performed	
At least one stool microscopy	182 (70.8)
Urine microscopy	102 (39.7)
Serological test for schistosomiasis (IFAT/ ELISA)	205 (79.8)
Serological test for strongyloidiasis (ELISA)	148 (57.6)
Stool PCR for schistosomiasis	47 (18.3)
Urine PCR for schistosomiasis	31 (12.1)
Stool PCR for strongyloidiasis	34 (13.2)
No test for schistosomiasis or strongyloidiasis	29 (11.3)

To determine the prevalence of schistosomiasis, the serological diagnosis by an IFAT and ELISA based test was taken into account as well as direct diagnosis by stool and urine microscopy and/or PCR (see **table 2**). All patients with a positive stool and/or urine microscopy and/or PCR also had a positive serology. **Table 3** shows schistosomiasis prevalence according to country of origin for the five most common countries of origin of the patients.

Patients who were tested after having received therapy for schistosomiasis were excluded.

Table 2: Schistosomiasis prevalence (serology and microscopy/PCR)

Test	Patients tested	Positive (%)
Serology (IFAT/ELISA)	191	60 (31.4%)
Stool microscopy (at least one stool test)	168	14 (8.3%)
Urine microscopy	97	5 (5.2%)
Stool PCR	42	14 (33.3%)
Urine PCR	30	3 (10%)
Stool microscopy and/or PCR	168	21 (12.5%)
Urine microscopy and/or PCR	104	6 (5.8%)

Table 3: Schistosomiasis prevalence according to country of origin (sorted by number of patients tested)

Country of origin	Serology (IFAT/ELISA)	Microscopy and/or PCR (stool)	Microscopy and/or PCR (urine)
Nigeria	7/49 (14.3%)	2/42 (4.8%)	0/23 (0%)
Eritrea	24/39 (61.5%)	11/36 (30.6%)	3/21 (14.3%)
Somalia	2/27 (7.4%)	0/22 (0%)	0/9 (0%)
Mali	3/14 (21.4%)	0/10 (0%)	1/10 (10%)
Sierra Leone	4/10 (40%)	1/8 (12.5%)	0/6 (0%)

To determine the prevalence of strongyloidiasis, the serological diagnosis by an ELISA based test was taken into account as well as direct diagnosis by stool microscopy and/or PCR (see **table 4**). All patients with a positive stool microscopy and/or PCR also had a positive serology. **Table 5** shows strongyloidiasis prevalence according to country of origin for the five most common countries of origin of the patients.

Patients who were tested after having received therapy for strongyloidiasis were excluded.

Table 4: Strongyloidiasis prevalence (serology and microscopy/PCR)

Test	Patient tested	Positive (%)
Serology (ELISA)	145	29 (20%)
Stool microscopy (at least one stool test)	180	3 (1.7%)
Stool PCR	33	2 (6.1%)
Stool microscopy and/or PCR	180	5 (2.8%)

Table 5: Strongyloidiasis prevalence in patients according to country of origin (sorted by number of patients tested)

Country of origin	**Serology (ELISA)**	**Microscopy and/or PCR stool**
Nigeria	11/39 (28.2%)	1/45 (2.2%)
Eritrea	3/32 (9.4%)	1/44 (2.3%)
Somalia	3 /19 (15.8%)	0/22 (0%)
Mali	1/9 (11.1%)	0/10 (0%)
Sierra Leone	2/8 (25%)	1/8 (12.5%)

Other helminth infections identified in stool microscopy were hookworms in seven cases and *A. lumbricoides, Taenia spp. and H. nana* (one case each). See **table 6**.

Table 6: Infections with other helminths identified in stool microscopy

Number of patients	**Other helminth infection**	**(Possible) Coinfection**
2	Hookworm	-
2	Hookworm	*S. stercoralis* (positive serology)
1	Hookworm	*S. mansoni* + *S. haematobium* + *S. stercoralis* (positive serology)
1	Hookworm	*S. mansoni* + *S. stercoralis* (positive serology)
1	Hookworm	Schistosomiasis (positive serology)
1	*A. lumbricoides*	-
1	*Taenia spp.*	*S. mansoni* + *S. stercoralis* (positive serology)
1	*H. nana*	*S. mansoni*

In total, the diagnosis of schistosomiasis and/or strongyloidiasis was confirmed in 33 patients during the time period examined, with a diagnosis being considered confirmed if the pathogen could be detected microscopically (urine, stool or biopsy) or by PCR. 18 patients had a *S. mansoni*-infection (54.5%), seven had an infection with *S. haematobium* (21.2%), three were infected with *S. stercoralis* (9.1%). Another three patients were infected with both, *S. mansoni* and *S. haematobium* (9.1%), and finally, two patients were diagnosed with *S. mansoni* and *S. stercoralis* (6.1%).

In 27 of the patients, the pathogen could be detected using microscopy and/or PCR of stool or urine (81.8%). In two of the patients (6.1%) the schistosomiasis diagnosis was confirmed by serum PCR, one of these patients had a negative serology. All the other patients with confirmed diagnosis had a positive serology (97.0%). In four of the patients (12.1%), the diagnosis was confirmed only by biopsy material (stool and/or urine examination was either not performed or negative).

Of the patients with confirmed diagnosis, 18 (54.5%) had absolute eosinophilia (> 500 cells/µl); 21 (63.6%) had relative eosinophilia (> 7%).

4.3 Discussion

In this database analysis almost a third of the migrants examined had serological evidence of schistosomiasis, and a fifth had a positive strongyloidiasis serology. As expected, prevalence

determined using stool or urine microscopy and/or PCR was lower, with 12.5% for *S. mansoni*, 5.8% for *S. haematobium* and 2.8% for *S. stercoralis.*

What is striking is, that the prevalence based only on PCR testing is much higher than the prevalence determined only by microscopy. Although these results are only comparable to a limited extent – fewer patients were tested using PCR than microscopy – they suggest that (additional) PCR could be helpful in confirming the disease.

All patients with positive stool or urine microscopy and/or PCR also had positive serology in this database analysis. The only exception being a patient with a positive serum PCR for schistosomiasis, so the risk of false negative results in serological examinations should be kept in mind.

Regarding patients with confirmed diagnosis of schistosomiasis and/or strongyloidiasis, 54.5% had absolute and 63.6%, had relative eosinophilia. The observation corresponds to those from other studies, such as the study by Cabezas-Fernandez et al. Here, 45% of the patients with strongyloidiasis (diagnosed serologically and/or parasitologically) had eosinophilia (134). In a study by Comelli et al. 26.8% of the schistosomiasis patients (serologically and/or parasitologically confirmed) had eosinophilia (26). This fact reinforces the demand for a systematic screening of migrants from affected areas since the disease is not necessarily associated with changes in the blood count.

As far as other helminthiases are concerned, hookworms should be mentioned, of which seven cases could be identified over a period of about 4 years (prevalence 3.8%). There was no confirmed case of filariasis, however the number of patients examined for filariae was not recorded. There are various reasons for the small number of other helminth diseases, some already has been discussed in chapter 3.3. On the one hand, no systematic screening of the migrants was carried out at the Division of Infectious Diseases and Tropical Medicine that also included ultrasound to diagnose echinococcosis or blood tests for filariae. Such examinations are usually only carried out if an infection is suspected. On the other hand, stool tests have a rather limited sensitivity so they might underestimate the prevalence for *taenia spp.* or geohelminths (135). Furthermore, almost a quarter of the migrants had been living in Germany for longer than 3 years. As geohelminths only have a limited lifespan – hookworms for example usually live only 1 to 2 years – the infection could have ended naturally (67, 136).

Although the prevalence determined on selected patients at the Division of Infectious Diseases and Tropical Medicine cannot be applied to the general population of migrants, the numbers of affected people is not negligible. Despite eradication programs, as for example for schistosomiasis, tropical helminth diseases remain a problem that not only affects the population in the home countries, but also affects Germany through migration. In addition, the COVID-19 pandemic has led to the suspension of eradication programs in affected countries, which raises concerns that the problem will persist or even worsen in the future (137).

In this database analysis the country of origin was evaluated. The high schistosomiasis prevalence among migrants from Eritrea is particularly noticeable. It is comparable to the high prevalence found in the study by Chernet et al. (25). As already mentioned in the review section, this is interesting, because the prevalence rates of *S. mansoni* infections in Eritrea are reported to be rater low. In an analysis by Lai et al. the population-adjusted prevalence of *S. mansoni*

infections for Eritrea is reported to be 3.4% (119). The Eritrean Ministry of Health states a national prevalence of 2.8%; in the most affected region – Debub – on the Ethiopian border, it is 8.7%, which is still lower than the prevalence found by Chernet et al. and in this database analysis (120). The question arises as to whether the infections were acquired in Eritrea – and the prevalence there is thus higher than expected – or in transit countries on the way to Europe. The migration route from Eritrea leads through Ethiopia or Sudan (11). In Sudan, the prevalence of *S. mansoni* infections is generally rather low. In a meta-analysis by Cha et al. a population prevalence (based on microscopy) for the entire country of 0.06% was stated, whereby it was 5.89% in the state of Kassala, on the border of Eritrea (138). Lai et al. stated in their meta-analysis a population adjusted *S. mansoni* prevalence (based on microscopy) of 7.5% for Sudan (119).

Regarding Ethiopia, two studies found particularly high prevalence in the Tigray region, which is located between Eritrea and Ethiopia: In a study by Hussen et al. the prevalence was 20.2%, in a paper by Ponpetch et al. it was even estimated to be 73.0% (139, 140). As this region is home to many refugees from Eritrea, the infections could also have been acquired there (141). Since Eritreans are among the largest group of migrants from SSA to Germany, it is important to be aware of their risk, even if Eritrea itself is not considered a highly affected area (5).

4.4 Limitations

There are a few limitations of this database analysis:

1. Not every patient received the same screening examinations. A prospective investigation with a standardized screening protocol and systematic query of symptoms would be desirable in the future.
2. A collective of outpatients was evaluated in this analysis. This may lead to a selection bias. Studies of the general population of migrants could reveal lower prevalence.
3. There was no information about the exact circumstances of migration, including the migration route, transportation or duration.
4. It is not possible to determine whether all urine samples were ultimately microscopically examined. This could have led to an underestimation of the *S. haematobium* prevalence.
5. Borderline serological results were counted as positive, which may have overestimated the prevalence.

5. Questionnaire survey

Originally, this work was also intended to include a questionnaire survey to ask migrants from SSA about their knowledge of schistosomiasis and possible risk factors. Ultimately, it was difficult to recruit enough participants for this survey, which is why this part was omitted. Nevertheless, I would like to use this chapter to share the experiences from this project. Based on this experience, future awareness campaigns could be improved.

It was planned to visit migrant communities and to carry out a voluntary, anonymous questionnaire-based survey as part of an information event. The survey should determine the level of knowledge about schistosomiasis, as well as possible risk factors of infection (for example bathing in freshwater bodies in the home country), and possible symptoms that could indicate this disease. Age, gender, country of origin and length of stay in Germany were also asked in the survey. The questionnaires were available in German, English and French. An online

version was also available via the LimeSurvey application. The information event was intended to provide information about schistosomiasis. In addition, the offer was made to be screened for schistosomiasis at the Division of Infectious Diseases and Tropical Medicine at the University Hospital LMU Munich.

Unfortunately, it was difficult to find enough study participants. A total of 48 potential contacts were emailed in the course of 2021, including refugee aid organizations, African or foreign-language church communities, vocational schools (with integration classes) and African associations. In the end, only three events took place: an event with an organization that trains health mediators (migrants who educate their compatriots about health issues), another organization that offers qualification measures for migrant women, and a vocational school with a high proportion of migrant students.

We did not reach the desired number of 100 completed questionnaires and many of the returned questionnaires could hardly be evaluated, because they were incomplete. In addition, at two of the events, the majority of migrants did not come from SSA.

In retrospect, the following conclusions can be drawn from this project:

SSA migrants were difficult to reach for this information campaign. This may be due to the fact that the campaign was carried out during the COVID-19-pandemic and events were only possible to a limited extent or were completely avoided in order to prevent infections. Also, COVID-19 was perceived as a greater problem than NTDs. In addition, many organizations took care of migrants from diverse backgrounds, so the proportion of people from SSA may have been small.

The few questionnaires that were returned, were insufficiently filled out. Some questions may have been overly complicated or misunderstood. Simpler questions or, even better, interviews could help to avoid misunderstanding.

Ultimately, it is important to design information events like these very sensitively so as not to give migrants the impression that they are only being associated with diseases.

A possibility to raise awareness for schistosomiasis among the risk group could be to provide information during a visit at the general practitioner, pediatrician or gynecologist – ideally with the option of submitting samples. However, this requires medical staff of all specializations to be aware of these neglected diseases. Also, health mediators from the home countries could educate about schistosomiasis as they may have easier access to the communities. Finally, a general screening offer for newly arrived migrants in reception centers or refugee shelters could help to identify cases.

6. Conclusion

Both the literature review and the database analysis show a need for systematic screening of migrants from SSA for schistosomiasis and strongyloidiasis. So far, serology seems to be the most suitable method for this; but the development of more reliable and simpler tests is desirable. Physicians outside of tropical medicine should be sensitized to think about these NTDs in migrants from SSA, even if no symptoms are present. It is also necessary to find ways to educate migrants – including those who have already been living in Germany for several years – and to give them the opportunity to be screened quickly and easily.

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Annex

Table A 1: Short summary of articles on helminth diseases in SSA migrants (in alphabetical order by first author)

First author, year, country	Helminth infections found in SSA migrants*	Summary
Alberer, 2016, Germany (142)	Schistosomiasis	Retrospective analysis of data from 548 diseased refugees and asylum seekers. Cases from three different institutions were summarized. Schistosomiasis was found in 15 patients (11 from Eritrea, three from Somalia and one from Senegal).
Angheben, 2017, Italy (99)	Echinococcosis	Case report of a 26-year-old patient from Niger with cystic echinococcosis.
Antinori, 2017, Italy (90)	Onchocerciasis	Case report of a 31-year-old patient from Ghana diagnosed with onchocerciasis.
Argirovic, 2016, Germany (143)	Schistosomiasis	Case report of a 33-year-old refugee from Nigeria with *S. mansoni*-Infection.
Baekby, 2017, Denmark (75)	Schistosomiasis	Case report of a 27-year-old refugee from Eritrea with *S. mansoni*-infection.
Barrett, 2017, United Kingdom (144)	Schistosomiasis Strongyloidiasis Filariasis	Prospective analysis of patients with eosinophilia attending a hospital for tropical diseases outpatient department. Of 46 immigrants from West Africa, 63% had a positive strongyloides serology, 7% a positive strongyloides culture, 22% a positive schistosomal serology and 14% a positive filarial serology. *S. haematobium* was not found in the terminal urine sample of any patient. In 9% of the cases ova, cyst and parasites were found in the stool samples, but the helminth species is not mentioned in the paper.
Becker, 2015, Germany/Switzerland (145)	Schistosomiasis	Description of two cases of patients from Eritrea with *S. mansoni* infection. In both patients the infection could be confirmed by means of POC-CCA.
Belhassen-Garcia, 2017, Spain (116)	Schistosomiasis Strongyloidiasis Filariasis Geohelminths *F. hepatica*	Prospective analysis of immigrant children under 18 years of age from tropical or subtropical regions attending for routine screening and without absolute eosinophilia. A total of 99 children were from SSA, 19 of them had relative eosinophilia. In the children with relative eosinophilia 9/19 (36%) had positive filarial serology, 4/19 (21%) had positive *Strongyloides* serology, 4/19 (21%) had positive schistosomal serology, 1/19 (5%) had a positive serology for *F. hepatica*, none had a positive *Echinococcus* serology, and 2/19 (10%) of the patients had *A. lumbricoides* found by direct diagnosis.

First author, year, country	Helminth infections found in SSA migrants*	Summary
Beltrame, 2017, Italy (118)	Schistosomiasis	Retrospective review of the results of a screening for schistosomiasis in African immigrants at a tropical disease center. Prevalence see **table A 2 a-c**.
Boga, 2020, Spain (146)	Schistosomiasis Filariasis	Prospective infectious disease screening program performed on immigrant women attending a tropical medicine unit in Spain. Prevalence see **table A 2 c and A 4**. There was also a screening for strongyloidiasis, but no data specifically for women from SSA.
Brindicci, 2017, Italy (70)	Schistosomiasis	Retrospective analysis of consecutive immigrants referring to an outpatient clinic for the first time. A total of 1762 immigrant patients were visited in this time (countries of origin not known), nearly 51% came from countries which are moderate or high endemic for schistosomiasis. In nine cases diagnosis of urinary schistosomiasis was made: four confirmed cases (detection of eggs in urine or histopathological diagnosis), three probable cases (positive serology), two suspect cases (swelling of the bladder, response to treatment). The patients were from Mali, Senegal, Eritrea and Nigeria.
Buonfrate, 2016, Italy (147)	Strongyloidiasis	Case-control study including a screening for *S. stercoralis* infection of patients (migrants and natives) at an outpatient clinic. 14 of 48 screened patients from SSA (29.2%) with elevated eosinophil count were positive of *S. stercoralis* infection (serology and/or stool culture).
Buonfrate, 2018, Italy (148)	Schistosomiasis Strongyloidiasis Geohelminths	Retrospective analysis of data from an infectious disease screening in refugee shelters. A total of 358 asylum seekers from SSA were included. For schistosomiasis and strongyloidiasis prevalence see **table A 2 a and c, and table A 3 and c**. 34/270 (12.6%) had a positive stool test for hookworm, 4/270 (1.5%) for *T. trichiura* and 2/270 (0.7%) for *A. lumbricoides*.
Cabezas-Fernandez, 2015, Spain (134)	Strongyloidiasis	Retrospective analysis of data from patients treated for strongyloidiasis at a tropical medicine unit from April 2004 to May 2012. A total of 285 immigrants from SSA have been diagnosed with strongyloidiasis. Diagnosis was made by microscopy, charcoal culture or serology.
Cappella, 2019, San Marino (149)	Strongyloidiasis	Retrospective analysis of data from patients considered to be at risk for strongyloidiasis and screened with serology at a hospital between 2017 and 2018. A total of 42 patients were tested. There were two positive cases, one being a 31-year-old man born in Nigeria.
Carrai, 2018, Italy (83)	Schistosomiasis	Case report of a post-transplant liver graft schistosomiasis (*S. haematobium* or a hybrid) in a 20-year-old migrant from Liberia transplanted for hepatitis B virus (HBV) related cirrhosis. Schistosomiasis was undiagnosed before transplantation.

First author, year, country	Helminth infections found in SSA migrants*	Summary
Casado, 2019, Spain (84)	Strongyloidiasis	Prospective serological screening program for strongyloidiasis performed between 2009 and 2014 for immigrants attending a tropical medicine unit. Prevalence see **table A 3 c**.
Chauvin, 2019, France (81)	Schistosomiasis	Case report of a 17-year-old migrant from Guinea with acute paraplegia caused by schistosomiasis (*S. mansoni*).
Chernet, 2018, Switzerland (25)	Schistosomiasis Strongyloidiasis Hymenolepiasis	Cross-sectional study including a screening of 107 asymptomatic Eritrean migrants recruited at refugee centers. For schistosomiasis and strongyloidiasis prevalence see **table A 2 a-c and table A 3 a, b**. *H. nana* was found in the stool of 11 migrants (10.3%).
Cobo, 2015, Spain (92)	Schistosomiasis Strongyloidiasis Filariasis Geohelminths	Retrospective review of clinical records of all patients seen in a tropical medicine unit from January 2004 to May 2012. Of the 1280 SSA patients included in the study, 97 (7,5%) were positive for filariasis. The following co-infections were found: Hookworm in 40 (41.2%) patients, *S. stercoralis* in 37 patients (38.1%), *S. haematobium* in nine patients (9.3%) and *S. mansoni* in six patients (6.2 %). See also **table A 2 a, table A 3 c and table A 4**.
Cobo, 2016, Spain (67)	Schistosomiasis Strongyloidiasis Filariasis Geohelminths Taeniasis Hymenolepiasis	Descriptive analysis of the most important infections treated at a tropical medicine unit in Spain. Patients received a screening for domestic and imported infections according to an established protocol. The prevalence of diseases amongst people who had lived in Spain for less than 3 years was compared with the prevalence amongst those who had lived in Spain for more than 3 years. There were 1255 SAA migrants who lived in Spain for less than 3 years and 675 who lived there for more than 3 years. Helminth disease prevalence for all SSA migrants (n = 1930) were: hookworms (266/13.8%), *A. lumbricoides* (15/0.7%), *T. trichiura* (40/2.1%), *H. nana* (17/0.9%), echinococcosis (0/0%), *Taenia spp.* (7/0.4%). For prevalence for schistosomiasis, strongyloidiasis and filariasis see **table A 2 a, table A 3 c and table A 4**.
Comelli, 2020, Italy (26)	Schistosomiasis	Retrospective review of schistosomiasis cases diagnosed in people from endemic countries in five infectious diseases centers. A total of 104 patients from SSA with diagnosed schistosomiasis were included.
Cuenca-Gomez, 2016, Spain (76)	Schistosomiasis	Retrospective observational study of SSA migrants attending a tropical medicine unit. Patients with chronic HBV infection and with or without schistosomiasis were compared. Prevalence see **table A 2 a and c**.
Da Silva Santos, 2018, Switzerland (150)	Schistosomiasis Strongyloidiasis	Cross-sectional prevalence study including 172 prisoners from SSA, who were serologically tested for schistosomiasis and strongyloidiasis and answered a questionnaire. For prevalence see **table A 2 b and table A 3 b**.

First author, year, country	Helminth infections found in SSA migrants*	Summary
Deniaud, 2020, France (27)	Schistosomiasis Enterobiasis	Retrospective cohort study on cases of urogenital schistosomiasis detected at an outpatient clinic from 2004 to 2017. A total of 105 cases of urogenital schistosomiasis in SSA patients were included. One of the patients had a co-infection with *E. vermicularis*.
Dermauw, 2019, Belgium (97)	Taeniasis/ Neurocysticercosis	Retrospective analysis of data on suspected and confirmed taeniasis and cysticercosis cases diagnosed between 1990 and 2015 in two medical institutions. One case of definitive neurocysticercosis and two cases of probable neurocysticercosis were diagnosed in migrants from SSA (based on Del Brutto criteria).
Detzler, 2018, Germany (80)	Schistosomiasis	Case report of a 27-year-old migrant from Eritrea presented with a progressive, painful radiculopathy caused by a *S. mansoni*-infection.
Develoux, 2017, France (91)	Filariasis	Review of cases of filariasis diagnosed at an university center between 2002 and 2011. Of the 31 cases identified, 21 were migrants from SSA: 14 had loiasis (eight proven by demonstration of microfilariae in a clinical sample, six probable because of positive serology and suggestive clinical symptoms), three had probable onchocerciasis, two had proven mansonelliasis, one patient had proven wuchereriasis and one had serological filariasis.
Ehlkes, 2018, Germany (93)	Schistosomiasis Geohelminths Taeniasis Enterobiasis Hymenolepiasis	Analysis of data from a stool screening including 985 migrants from eastern Africa. *A. lumbricoides* was found in two patients (0.2%), *T. trichiura* in 20 (2%), *H. nana* in four (0.4%), *E. vermicularis* in two (0.2%), hookworms in three (0.3%) and *Taenia spp.* in five patients (0.5%). For schistosomiasis prevalence see **table A 2 a**.
Fontanelli Sulekova, 2019, Italy (151)	Schistosomiasis Strongyloidiasis Geohelminths Taeniasis Hymenolepiasis	Cross-sectional study including a screening of newly arrived migrants for intestinal and urinary parasites hosted at an asylum seekers center. 328 came from SSA countries. Infections with hookworms, *T. trichiura, S. mansoni, H. nana, T. saginata and S. stercoralis* were found in migrants from SSA countries (no exact prevalence).
Gautschi, 2015, Switzerland (79)	Schistosomiasis	Case report of a 34-year-old Eritrean with *S. mansoni*-Infection who developed neurologic symptoms.
Gobbi, 2017, Italy (152)	Filariasis	Retrospective review of medical records from patients admitted to a hospital between 1993 and 2016 for information about presence of *M. perstans* microfilaremia and most likely country of acquisition. 23 cases of SSA migrants with *M. perstans* were identified.

First author, year, country	Helminth infections found in SSA migrants*	Summary
Gobbi, 2017, Italy (78)	Schistosomiasis Strongyloidiasis	Description of seven cases of patients of SSA origin, diagnosed with chronic schistosomiasis and pulmonary nodules. In each of the patients schistosomal eggs could be visualized. One of the patients was co-infected with *S. stercoralis* (diagnostic method unknown).
Hunter, 2018, United Kingdom (96)	Neurocysticercosis	Case series of patients with active neurocysticercosis admitted to a hospital for anthelminthic treatment between 2001 and 2015. Seven of the 26 active cases included were migrants from SSA (countries of origin: Guinea, Madagascar, Malawi, South Africa, Zimbabwe). Another two cases in SSA migrants from Malawi and South Africa were not included in this case series because they were not treated at the hospital, or the disease was considered inactive.
Le Govic, 2019, France (82)	Schistosomiasis	Case report of a *S. mansoni–S. haematobium* hybrid infection in a 14-year-old boy from Ivory Coast.
Leblanc, 2017, France (153)	Schistosomiasis	Retrospective review of data from children admitted for imported schistosomiasis to tertiary care centers between 2010 and 2015. A total of 27 of 40 cases included were migrant children from SSA. Schistosomiasis was diagnosed by microscopy or a serological test.
Maaßen, 2017, Germany (154)	Schistosomiasis Strongyloidiasis Hymenolepiasis	Retrospective analysis of data from a screening of refugees under the age of 18 years. Amongst others 20 minors from Eritrea and 24 from Somalia were included. *Schistosoma* spp. were found in 9/16 Eritreans (56.3%) and 1/21 Somalis (4.8%). *S. stercoralis* was found in 1/16 Eritreans (6.3%) and *H. nana* was found in 1/21 Somalis (4.8%). Diagnostic methods included microscopy of stool samples and PCR.
Marchese, 2020, Italy (77)	Schistosomiasis	Retrospective review of medical records of migrants (≥ 14 years) with a diagnosis of chronic HBV infection, schistosomiasis, or co-infection admitted at a department of infectious tropical diseases and microbiology. A total of 171 SSA patients with schistosomiasis and 35 with schistosomiasis/HBV-coinfection were included.
Martelli, 2017, Italy (58)	Schistosomiasis Strongyloidiasis Filariasis Toxocariasis	Cross-sectional study including serological testing on NTDs according to country of origin and presence of eosinophilia. The survey was performed in infectious and tropical disease units. A total of 330 patients came from SSA. 1/39 had a positive toxocariasis serology (2.6%) and 5/34 (14.7%) had a positive filarial serology. For schistosomiasis and strongyloidiasis prevalence see **table A 2 b and table A 3 b**.
Martinez-Perez, 2018, Spain (85)	Strongyloidiasis	Retrospective analysis of cases of disseminated *S. stercoralis* infection or hyperinfection syndrome in eight centers in the time from 2000 to 2015. From the 18 cases identified, three were migrants from SSA.
Martinez-Perez, 2020, Spain (155)	Strongyloidiasis	Case-control study on clinical features associated with strongyloidiasis and the potential impact of immunosuppression. A total of 41 of the 158 cases in the study were migrants from SSA.

First author, year, country	Helminth infections found in SSA migrants*	Summary
Mazzitelli, 2018, Italy (95)	Schistosomiasis Geohelminths	Prospective observational study including a screening for parasitic infections (examination of stool and urine) of migrants living in refugee centers. From 174 study participants, 112 came from SSA. 19 (17.0%) had an infection with one or more helminth: seven cases of hookworms (6.3%), four cases of *A. lumbricoides* (3.6%), and one case of *T. trichiura* infection (0.9%). For schistosomiasis prevalence see **table A 2 a**.
Mendoza-Palomar, 2020, Spain (71)	Schistosomiasis	Retrospective analysis of data from all consecutive pediatric schistosomiasis cases between January 2010 and December 2017 at an international health unit. Of the total of 51 cases, 43 were migrant children from SSA countries. Diagnostic was made by direct visualization or serology.
Milesi, 2019, Italy (156)	Schistosomiasis Strongyloidiasis Geohelminths	Retrospective analysis of cases of urinary schistosomiasis in migrants, who have been in clinical care at an infectious disease outpatient clinic. A total of 214 patients (origin unknown) had a urine test, *S. haematobium* eggs were found in the urine of 90 patients, all came from SSA countries. A stool examination was performed in 25 patients in whom eosinophilia persisted after therapy. Two were positive for hookworms and two were positive for *S. stercoralis*.
Ming, 2019, United Kingdom (157)	Strongyloidiasis	Retrospective analysis of data from 413 consecutive outpatients treated for strongyloidiasis at a hospital for tropical diseases between 1999 and 2017. The study included migrants from SSA.
Monge-Maillo, 2015, Spain (158)	Schistosomiasis Strongyloidiasis	Analysis of data from 317 asymptomatic SSA immigrants who attended a tropical medicine unit. Infectious disease screening included schistosomiasis and strongyloidiasis serology. Strongyloidiasis was found in 46.2% of SSA migrants (with eosinophilia) but the absolute number of screened patients is unclear. For schistosomiasis prevalence see **table A 2 b**.
Moure, 2017, Spain (159)	Schistosomiasis *D. dendriticum*	Series of six cases of *D. dendriticum* diagnosed in SSA patients at a reference international health unit between April 2015 and January 2016. Five of the cases were considered false parasitism. In one patient schistosoma eggs were visualized in the stool.
Patamia, 2017, Italy (160)	Taeniasis	Coproparasitological examination of stool samples from people hosted in a refugee center. A total of 233 migrants were from SSA. Six cases of *Taenia spp.* carriers were identified, all coming from Ethiopia and Eritrea.
Poddighe, 2015, Italy (161)	Schistosomiasis	Case report on a 16-year-old refugee from Gambia with urinary schistosomiasis caused by *S. haematobium*.
Potters, 2019, Belgium (68)	Schistosomiasis	Case report of a 31-year-old migrant from Sierra Leone, who had been diagnosed with schistosomiasis (*S. mansoni*). The patient had not travelled outside Europe for 20 years.

First author, year, country	Helminth infections found in SSA migrants*	Summary
Puente, 2020, Spain (89)	Schistosomiasis Strongyloidiasis Filariasis Geohelminths	Retrospective analysis of the data of 503 SSA patients (mostly from Equatorial Guinea) with mansonelliasis. A total of 137 (27.2%) of them were coinfected with *T. trichiura*, 90 (17.9%) with *A. lumbricoides*, 25 (5.0%) with hookworms. For prevalence of the other coinfections see **table A 2 a, table A 3 a and table A 4**.
Puente, 2020, Spain (88)	Strongyloidiasis Filariasis Geohelminths	Retrospective analysis of 131 cases of loiasis in migrants from SSA (mostly from Equatorial Guinea). A total of 34 (26.0%) were coinfected with *T. trichiura*, 20 (15.3%) with *A. lumbricoides*, 11 (8.4%) with hookworms. For prevalence of the other coinfections see **table A 2 a, table A 3 a and table A 4**.
Recio, 2018, Spain (162)	Filariasis	Case of a 68-year-old woman from Equatorial Guinea diagnosed with loiasis.
Requena-Mendez, 2019, Spain (163)	Strongyloidiasis	Cross-sectional study including a systematic screening for in- and out-patients in six hospitals for *S. stercoralis* based on serology. 459 patients from SSA were screened. Prevalence see **table A 3 b**.
Riccardi, 2017, Italy (69)	Schistosomiasis	Review of the clinical history, laboratory findings, and imaging findings of eight patients with schistosomiasis from West Africa consecutively encountered in a practice.
Romero-Alegria, 2016, Spain (98)	Echinococcosis	Descriptive retrospective study in which the seroprevalence of cystic echinococcosis was studied in serum samples from non-European immigrants treated at a tropical medicine unit. Eight of 337 (2.4%) tested SAA migrants had a positive serology.
Roure, 2017, Spain (72)	Schistosomiasis	Evaluation of data from patients diagnosed with schistosomiasis at an international health unit between 2002 and 2016. In this study period, 61 individuals from SSA were diagnosed with *Schistosoma spp.* infection. Schistosomiasis was diagnosed through examination of stool/urine, serology or high clinical and/or radiological suspicion.
Saito, 2015, United Kingdom (164)	Filariasis	Retrospective analysis of loiasis cases in a hospital for tropical diseases. A total of 29 of the cases were in migrants from endemic countries, mostly Nigeria and Cameroon, 20 of them had microfilaremia detected and 14/27 a positive filarial serology.

First author, year, country	Helminth infections found in SSA migrants*	Summary
Salas-Coronas, 2015, Spain (86)	Schistosomiasis Strongyloidiasis Filariasis Geohelminths Taeniasis *D. dendriticum* Hymenolepiasis	Prospective study of migrants with eosinophilia attended in a reference tropical medicine unit and evaluated using a tailored screening and treatment protocol. A total of 492 patients were of SSA origin. The following prevalence was found: 126 patients (25.6%) had hookworms, 15 (3%) *T. trichuria*, five patients (1%) had *H. nana*, seven patients (1.4%) had *A. lumbricoides*, one patient (0.2%) had *Taenia spp*. and 25 (5.1%) had *D. dendriticum*. Echinococcosis has not been diagnosed. For prevalence of schistosomiasis, strongyloidiasis and filariasis see **table A 2 a table A 3 c and table A 4**.
Salas-Coronas, 2018, Spain (94)	Schistosomiasis Strongyloidiasis Filariasis Geohelminths Taeniasis *D. dendriticum* Hymenolepiasis	Retrospective analysis of epidemiological profiles, clinical characteristics and microbiological findings in 488 newly arrived SSA migrants attended at a tropical medicine unit. The following prevalence was found: hookworms 70/488 (14.3%), *A. lumbricoides* 15/488 (3.1%), *T. trichuria* 20/488 (4.1%), *Taenia spp.* 6/488 (1.2%), *H. nana* 7/488 (1.4%), *D. dendriticum* 15/488 (3.1%). For schistosomiasis, strongyloidiasis and filariasis prevalence see **table A 2 a, table A 3 c and table A 4**.
Salas-Coronas, 2020, Spain (73)	Schistosomiasis Strongyloidiasis Filariasis Geohelminths Taeniasis *D. dendriticum* Hymenolepiasis	Retrospective analysis of data from a screening of 3090 SSA migrants. The screening took place at a tropical medicine unit from October 2004 to February 2018. A total of 326 (10.5%) of the screened migrants had confirmed schistosomiasis (diagnosis based on detection of ova in feces, urine or in biopsy). Another 830 patients (26.9%) had positive schistosoma serology and/or suggestive imaging findings but were not included in the analysis. Other helminth co-infections found in the 326 patients with confirmed schistosomiasis were: hookworms in 30 cases (9.2%), *A. lumbricoides* in one (0.3%), *T. trichiura* in six (1.8%), Taenia spp. in one (0.3%), *H. nana* in two (0.6%), and *D. dendriticum* in nine cases (2.8%). For schistosomiasis, strongyloidiasis and filariasis prevalence see **table A 2 a, table A 3 c and table A 4**.
Salvador, 2019, Spain (165)	Strongyloidiasis	Observational retrospective study including all patients diagnosed with strongyloidiasis registered in the +REDIVI Collaborative Network from January 2009 to February 2017. Of the 1245 cases identified, 191 were migrants from SSA. Diagnosis was made by stool microscopy or serology.
Sanchez-Montalva, 2016, Spain (166)	Nothing	Prospective study including migrants with diagnosis of an oncohematological disease. Patients were screened (amongst others) for geohelminths including *S. stercoralis* (stool microscopy, culture and serology) and schistosomiasis (serology and microscopy). Seven migrants from SSA were included. No helminth infections could be found.

First author, year, country	Helminth infections found in SSA migrants*	Summary
Serre Delcor, 2016, Spain (87)	Schistosomiasis Strongyloidiasis Filariasis Geohelminths Hymenolepiasis Toxocariasis	Retrospective review of 180 SSA migrants screened for infectious diseases at an international health center. The following prevalence was found: hookworm 16/171 (9.4%), Schistosoma serology 3/45 (6.7%), *S. stercoralis* serology 6/45 (13.3%), Toxocara serology 2/45 (4.4%), *A. lumbricoides* 1/171 (0,6%), *T. trichiura* 1/171 (0.6%), *H. nana* 1/171 (0.6%). Serology for echinococcosis, *F. hepatica*, taenaisis, onchocerciasis, *W. bancrofti/Brugia malayi* was performed when microscopic examinations were negative. For further schistosomiasis, strongyloidiasis and filariasis prevalence see **table A 2 a, table A 3 a and table A 4**.
Spertilli Raffaelli, 2018, Italy (167)	Strongyloidiasis Geohelminths	Case report of a 20-year-old Nigerian migrant with chronic hepatitis B and D, hookworm infection and positive *S. stercoralis* serology.
Stojkovic, 2018, Germany (74)	Schistosomiasis Cysticercosis	Short case reports of a 25-year-old Eritrean patient with liver fibrosis, esophageal varices and splenomegaly resulting from *S. mansoni* Infection and a 22-year-old patient from Togo with cysticercosis.
Tamarozzi, 2019, Italy (168)	Schistosomiasis	Case report of a 19-year-old migrant from Gambia diagnosed with *S. haematobium* infection.
Theunissen, 2020, Belgium (169)	Strongyloidiasis	Retrospective analysis of data from a serological screening for *S. stercoralis* of HIV-infected migrants. A total of 28 of 508 HIV-positive SSA migrants had a positive serology (5.5%). See also **table A 3 b**.
Theuring, 2016, Germany (170)	Schistosomiasis Strongyloidiasis Geohelminths Hymenolepiasis	Cross-sectional study including an infectious disease screening among unaccompanied minor refugees. A total of 194 came from SSA. For intestinal helminths stool samples were microscopically examined; schistosomiasis was diagnosed serologically. Four migrants (2.1%) were infected with *A. lumbricoides*, five (2.6%) with *T. trichiura*, five (2.6%) with hookworm, and two migrants (1.0%) with *H. nana.* For schistosomiasis and strongyloidiasis prevalence see **table A 2 b and table A 3 a**.
Tilli, 2019, Italy (66)	Schistosomiasis	Retrospective cohort study of cases of 170 migrants from SSA with urogenital schistosomiasis attending three centers for tropical diseases.
Tilli, 2020, Italy (111)	Schistosomiasis Strongyloidiasis Filariasis Taeniasis/ Cysticercosis	Calculation of number and rate of hospitalizations for different NTDs in the period between 2011 and 2016 using hospital discharge records and number of residents in Italy. The average hospitalization rates for schistosomiasis in Sub-Saharan Africans was 44.63 per 100,000, for strongyloidiasis it was 11.49, for cysticercosis 1.30, for filariasis 2.62 and for *T. solium* taeniasis 0.13.
Tilli, 2020, Italy (171)	Schistosomiasis Strongyloidiasis	Investigation on seroprevalence of schistosomiasis and strongyloidiasis in migrants from SSA using a dried blood spot on filter paper. For prevalence see **table A 2 b and table A 3 b**.

First author, year, country	Helminth infections found in SSA migrants*	Summary
Williams, 2020, United Kingdom (172)	Schistosomiasis Strongyloidiasis	Retrospective analysis of patient data from unaccompanied asylum-seeking children referred in two pediatric infectious disease clinics. Schistosomiasis was either detected by stool microscopy or serology, strongyloidiasis was screened serologically in patients with eosinophilia or from high endemicity countries. Schistosomiasis was found in 13 of 42 screened Eritrean children (31%), in 10 of 27 Sudanese children (37%) and in four of 21 Ethiopian children (19%). Strongyloidiasis was not found in the four screened Eritrean children and in five Sudanese children but in two of seven Ethiopian children (29%).
Zammarchi, 2019, Italy (173)	Taeniasis	Prevalence study including a screening for taeniasis of SSA migrants ≥ 18 years hosted in reception centers. A total of four out of 164 migrants (2.4%) had positive serology. In none of the stool samples *T. solium* could be detected.

*Although *S. stercoralis* also is a geohelminth, the infection is listed separately due to its special pathogenesis

Table A 2 a: Schistosomiasis prevalence using microscopy as diagnostic method (studies with over 50 participants). Articles sorted according to the prevalence found at screening. From (4)

First author, year, country	**Characteristic of tested collective**	**Most frequent countries of origin of collective**	**Species (if mentioned): no of positive/ no of tested (positive %)**	**Diagnostic method**
Salas-Coronas, 2015, Spain (86)	Adults with eosinophilia, attending tropical medicine unit Characteristics not mentioned for SSA migrants	Senegal, Guinea Bissau, Mali	all: 133/492 (27%) *S. haematobium*: 86/492 (17.5%) *S. mansoni*: 30/492 (6.1%) *S. intercalatum*: 2/492 (0.4%) *S. spp.*: 17/492 (3.5%)	Examination of 3 (up to 9) concentrated stool samples (Ritchie's method) and microscopy of one (up to 3) concentrated urine sample; in some cases, biopsy
Chernet, 2018, Switzerland (25)	Asymptomatic, living in centers for asylum seekers Median age (inter-quartile range, IQR): 25 years (21-29) 88.8 % male Months since arrival in Switzerland (IQR): 11 (8-22)	Eritrea	*S. mansoni*: 23/107 (21.5%)	Microscopy of 2 stool samples (one with sodium acetate-acetic acid-formalin (SAF) as fixative, one native)
Buonfrate, 2018, Italy (148)	Living in refugee shelters, arrival in the last 6 months Median age (IQR): 23 years (20-27) 94.4% male	Mali, Nigeria	*S. haematobium:* 20/96 (20.8%) *S. mansoni:* 19/270 (7%)	Examination of 3 concentrated stool samples (formol-ether), urine examination after micropore filtration
Beltrame, 2017, Italy (118)	Referred to a center for tropical diseases Characteristics not mentioned for SSA migrants	Nigeria, Mali, Ghana	All species: 54/300 (18%)	Microscopy of 3 concentrated (formol-ether) stool samples, urine microscopy after micropore filtration
Cobo, 2016, Spain (67)	Attending tropical medicine unit Characteristics not mentioned for SSA migrants	Senegal, Mali, Guinea-Bissau	All species: 278/1930 (14.4%) *S. mansoni*: 59/1930 (3.1%) *S. haematobium:* 165/1930 (8.5%) *S. intercalatum:* 2/1930 (0.1%) *S. spp.:* 52/1930 (2.7%)	Examination of 3 stool samples (Ritchie's method) and urine

First author, year, country	Characteristic of tested collective	Most frequent countries of origin of collective	Species (if mentioned): no of positive/ no of tested (positive %)	Diagnostic method
Salas-Coronas, 2018, Spain (94)	Attending a tropical medicine unit Mean age (range): 27.88 years (14–74) 83.8% male Mean time living in Spain (range): 6.06 months (1–12)	Senegal, Guinea Bissau, Mali	*T*otal: 60/488 (12%) *S. haematobium:* 42/488 (8.6%) *S. mansoni:* 11/488 (2.3%) *S. intercalatum:* 3/488 (0.6%) *S. spp.:* 4/488 (0.8%)	Examination of 3 concentrated stool samples (Ritchie's method), microscopy of one concentrated urine sample
Cuenca-Gomez, 2016, Spain (76)	Patients with chronic hepatitis B Mean age (± standard deviation, SD): 29.8 years (± 7.18) 94.7% male Mean length of residence in Spain (± SD): 50.42 months (± 43.28)	Senegal, Mali	Total: 62/507 (12%) *S. mansoni:* 23/507 (4.5%) *S. haematobium:* 39/507 (7.7%)	Examination of 3 stool samples (Ritchie's method) and microscopy of concentrated urine sample or biopsy
Salas-Coronas, 2020, Spain (73)	With or without symptoms, attending primary care or tropical medicine clinic Confirmed cases: Mean age (range): 27.3 years (11–52) 93.9% male Mean time living in Spain (range): 39.6 months (1–288)	Mali, Senegal (diagnosed patients)	Total: 326/3090 (10.5%) *S. haematobium:* 196/3090 (6.3%) *S. mansoni:* 65/3090 (2.1%) *S. intercalatum.* 8/3090 (0.2%) *S. haematobium + S. mansoni:* 2/3090 (0.06%) *S. haematobium + S. mansoni + S. intercalatum:* 1/3090 (0.03%) *S. spp.:* 54/3090 (1.7%)	Examination of 3 concentrated stool samples (Ritchie's method) and one concentrated urine sample, biopsy (if required)

First author, year, country	Characteristic of tested collective	Most frequent countries of origin of collective	Species (if mentioned): no of positive/ no of tested (positive %)	Diagnostic method
Serre Delcor, 2016, Spain (87)	With or without symptoms, living in shelters, attended at unit of international health Median age (range): 17.0 years (12.0–49.0) 98.9% male Median time from arrival in Spain to consultation (IQR): 4 months (1.0–9.0)	Ghana, Gambia, Senegal, Guinea	*T*otal: 16/171 (9.4 %) *S. mansoni:* 10/171 (5.9%) *S. haematobium:* 6/171 (3.5%)	Examination of one stool and urine sample; 3 stool samples if high eosinophilia or hyper-IgE and negative results in first screening
Cobo, 2015, Spain (92)	Patients diagnosed with filariasis Characteristics not mentioned for SSA migrants	Guinea-Bissau, Senegal, Equatorial Guinea	*S. haematobium*: 9/97 (9.3%) *S. mansoni*: 6/97 (6.2%)	Examination of stool (Ritchie's method) and urine
Mazzitelli, 2018, Italy (95)	Living in centers for asylum and refugee protection, coming to an outpatient clinic with or without symptoms Characteristics not mentioned for SSA migrants	Gambia, Nigeria, Ivory Coast, Mali	Total: 8/112 (7.1%) *S. mansoni:* 4/112 (3.6%) *S. haematobium:* 4/112 (3.6%)	Examination of one stool sample (Ritchie's method) and one urine sample
Ehlkes, 2018, Germany (93)	Characteristics not mentioned for SSA migrants	Eritrea, Somalia	*S. mansoni*: 40/985 (4.1 %)	Microscopy of one cellophane thick stool smear
Puente, 2020, Spain (89)	Patients diagnosed with mansonelliasis (*M. perstans*) Mean age (± SD): 44.6 years (± 18.2) 47.5% male Mean time in Spain (± SD): 8.6 months (± 18)	Equatorial Guinea	*S. spp.:* 3/503 (0.6%)	Stool tests (not specified)

First author, year, country	Characteristic of tested collective	Most frequent countries of origin of collective	Species (if mentioned): no of positive/ no of tested (positive %)	Diagnostic method
Puente, 2020, Spain (88)	Patients diagnosed with loiasis Mean age (± SD): 42.3 years (± 17.3) Median age (range): 41 years (16-88) 37.4% male Time to first assessment in consultation, months Mean (± SD): 10.9 months (± 22.8) Median (range): 2 months (1-119)	Equatorial Guinea	*S. spp.:* 0/131 (0%)	Examination of stool (Kato-Katz) and urine

Table A 2 b: Schistosomiasis prevalence using serology as diagnostic method (studies with over 50 participants). Articles sorted according to the prevalence found at screening. Modified after (4)

First author, year, country	Characteristic of tested collective	Most frequent countries of origin of collective	No of positive/ no of tested (positive %)	Diagnostic method
Chernet, 2018, Switzerland (25)	Asymptomatic, living in centers for asylum seekers Median age (IQR): 25 years (21-29) 88.8 % male Months since arrival in Switzerland (IQR): 11 (8-22)	Eritrea	54/107 (50.5%)	ELISA and immunofluorescent antibody tests
Salas-Coronas, 2018, Spain (94)	Attending a tropical medicine unit Mean age (range): 27.88 years (14–74) 83.8% male Mean time living in Spain (range): 6.06 months (1–12)	Senegal, Guinea Bissau, Mali	139/432 (32.2%)	ELISA
Beltrame, 2017, Italy (118)	Referred to a center for tropical diseases Characteristics not mentioned for SSA migrants	Nigeria, Mali, Ghana	77/300 (25.7%)	ELISA
Theuring, 2016, Germany (170)	Unaccompanied minor refugees Characteristics not mentioned for SSA migrants	Guinea, Gambia, Somalia	48/194 (24.7%)	Not specified

First author, year, country	Characteristic of tested collective	Most frequent countries of origin of collective	No of positive/ no of tested (positive %)	Diagnostic method
Da Silva Santos, 2018, Switzerland (150)	Prisoners Mean Age (± SD): 31.2 years (± 8.5) 94.8% male Mean time living in Europe (± SD): 9.7 years (± 7.1)	Guinea, Nigeria, Guinea-Bissau	35/172 (20.3%)	ELISA
Tilli, 2020, Italy (171)	Living in reception centers, with and without symptoms Median age (range): 25 years (18–49) 97% males Median time in Italy (range): 25 months (3–36)	Nigeria, Guinea, Ivory Coast, Gambia	26/254 (10.2%)	ELISA, dried blood spot testing
Martelli, 2017, Italy (58)	Attending hospitals or an outpatient clinic for any reason Median age 37.1 53.55% male Time since arrival to Italy: 0-4 years: 35.8% 5-9 years: 27.6% ≥ 10 years: 36.7%	unknown	25/323 (7.7%)	ELISA

First author, year, country	Characteristic of tested collective	Most frequent countries of origin of collective	No of positive/ no of tested (positive %)	Diagnostic method
Monge-Maillo, 2015, Spain (158)	Asymptomatic, attending tropical medicine unit for health exam Median age (IQR): 27 years (21 - 32) 83% male Median pre-consultation time (IQR): 5 months (2–10)	Senegal, Nigeria, Cameroon	8/139 (5.8%)	ELISA

Table A 2 c: Schistosomiasis prevalence based on a combination of diagnostic methods (studies with over 50 participants). Articles sorted according to the prevalence found at screening. Modified after (4)

First author, year, country	Characteristic of tested collective	Most frequent countries of origin of collective	No of positive/ no of tested (positive %)	Diagnostic method
Chernet, 2018, Switzerland (25)	Asymptomatic, living in centers for asylum seekers Median age (IQR): 25 years (21-29) 88.8 % male Months since arrival in Switzerland (IQR): 11 (8-22)	Eritrea	63/107 (58.9%)	POC-CCA, ELISA and immunofluorescent anti-body tests, microscopy of 2 stool samples (one SAF-fixed, one native)
Beltrame, 2017, Italy (118)	Referred to a center for tropical diseases Characteristics not mentioned for SSA migrants	Nigeria, Mali, Ghana	101/300 (33.7%)	CCA urine dipstick test, ELISA, microscopy of 3 concentrated (formol-ether) stool samples, urine microscopy after micropore filtration
Cuenca-Gomez, 2016, Spain (76)	Patients with chronic hepatitis B Mean age (±SD): 29.8 years (± 7.18) 94.7% male Mean length of residence in Spain (± SD): 50.42 months (± 43.28)	Senegal, Mali	170/507 (33.5%)	Examination of 3 stool samples (Ritchie's method), microscopy of concentrated urine sample and/or biopsy, ELISA
Buonfrate, 2018, Italy (148)	Living in refugee shelters, arrival in the last 6 months Median age (IQR): 23 years (20-27) 94.4% male	Mali, Nigeria	76/358 (21.2%)	Examination of 3 concentrated stool samples (formol-ether), urine examination after micropore filtration, ELISA

First author, year, country	Characteristic of tested collective	Most frequent countries of origin of collective	No of positive/ no of tested (positive %)	Diagnostic method
Boga, 2020, Spain (146)	Women attending tropical medicine unit with or without symptoms Characteristics not mentioned for SSA patients	Equatorial Guinea, Senegal, Nigeria	44/259[1] (17%)	Microscopy of 3 concentrated stool samples, ELISA

[1]absolute number estimated as it is not mentioned in the paper

Table A 3 a: Strongyloidiasis prevalence based on microscopy and/or coproculture as diagnostic method (studies with over 50 participants). Articles sorted according to the prevalence found at screening. From (4)

First author, year, country	Characteristic of tested collective	Most frequent countries of origin of collective	No of positive/ no of tested (positive %)	Diagnostic method
Theuring, 2016, Germany (170)	Unaccompanied minor refugees Characteristics not mentioned for SSA migrants	Guinea, Gambia, Somalia	7/194 (3.6%)	Microscopy of 3 concentrated (merthiolate-iodine-formalin) stool samples
Buonfrate, 2018, Italy (148)	Living in refugee shelters, arrival in the last 6 months Median age (IQR): 23 years (20-27) 94.4% male	Mali, Nigeria	9/270 (3.3%)	Examination of 3 concentrated stool samples (formol-ether)
Puente, 2020, Spain (88)	Patients diagnosed with loiasis Mean age (± SD): 42.3 years (± 17.3) Median age (range): 41 years (16-88) 37.4% male Time to first assessment in consultation, months Mean (± SD): 10.9 months (± 22.8) Median (range): 2 months (1-119)	Equatorial Guinea	4/131 (3.1%)	Coproculture

First author, year, country	Characteristic of tested collective	Most frequent countries of origin of collective	No of positive/ no of tested (positive %)	Diagnostic method
Serre Delcor, 2016, Spain (87)	With or without symptoms, living in shelters, attended at unit of international health Median age (range): 17.0 years (12.0–49.0) 98.9% male Median time from arrival in Spain to consultation (IQR): 4 months (1.0–9.0)	Ghana, Gambia, Senegal, Guinea	3/171 (1.8%)	Examination of one stool sample or 3 stool samples and charcoal fecal culture if high eosinophilia or hyper-IgE and negative results in first screening
Puente, 2020, Spain (89)	Patients diagnosed with mansonelliasis (*M. perstans*) Mean age (± SD): 44.6 years (± 18.2) 47.5% male Mean time in Spain (± SD): 8.6 months (± 18)	Equatorial Guinea	7/503 (1,4%)	Stool tests (not specified)
Chernet, 2018, Switzerland (25)	Asymptomatic, living in centers for asylum seekers Median age (inter-quartile range, IQR): 25 years (21-29) 88.8 % male Months since arrival in Switzerland (IQR): 11 (8-22)	Eritrea	0/107 (0%)	Microscopy of 2 stool samples (one with SAF as fixative, one native)
Deniaud, 2020, France (27)	Patients with urogenital schistosomiasis Characteristics not mentioned	Mali, Senegal	0/79 (0%)	Microscopy of stool samples
Ehlkes, 2018, Germany (93)	Characteristics not mentioned for SSA migrants	Eritrea, Somalia	0/985 (0%)	Microscopy of one cellophane thick stool smear

First author, year, country	Characteristic of tested collective	Most frequent countries of origin of collective	No of positive/ no of tested (positive %)	Diagnostic method
Mazzitelli, 2018, Italy (95)	Living in centers for asylum and refugee protection, coming to an outpatient clinic with or without symptoms Characteristics not mentioned for SSA migrants	Gambia, Nigeria, Ivory Coast, Mali	0/112 (0%)	Examination of one stool sample (Ritchie's method)

Table A 3 b: Strongyloidiasis prevalence based on serology as diagnostic method (studies with over 50 participants). Articles sorted according to the prevalence found at screening. Modified after (4)

First author, year, country	Characteristic of tested collective	Most frequent countries of origin of collective	No of positive/ no of tested (positive %)	Diagnostic method
Requena-Méndez, 2020, Spain (163)	Attending in- and outpatient clinics Characteristics not mentioned for SSA migrants	Mali, Senegal, Equatorial Guinea	50/459 (10.9%)	ELISA
Da Silva Santos, 2018, Switzerland (150)	Prisoners Mean Age (± SD): 31.2 years (± 8.5) 94.8% male Mean time living in Europe (± SD): 9.7 years (± 7.1)	Guinea, Nigeria, Guinea-Bissau	14/172 (8.1%)	ELISA
Martelli, 2017, Italy (58)	Attending hospitals or an outpatient clinic for any reason Median age 37.1 53.55% male Time since arrival to Italy: 0-4 years: 35.8% 5-9 years: 27.6% ≥ 10 years: 36.7%	unknown	20/330 (6.1%)	ELISA
Theunissen, 2020, Belgium (169)	Patients with HIV-infection Characteristics not mentioned for SSA migrants	Cameroon, Democratic Republic of the Congo, Nigeria, Rwanda, Burundi	28/508 (5.5%)	ELISA

First author, year, country	Characteristic of tested collective	Most frequent countries of origin of collective	No of positive/ no of tested (positive %)	Diagnostic method
Tilli, 2020, Italy (171)	Living in reception centers, with and without symptoms Median age (range): 25 years (18–49) 97% males Median time in Italy (range): 25 months (3–36)	Nigeria, Guinea, Ivory Coast, Gambia	7 / 254 (2.7%)	ELISA, dried blood spot testing
Chernet, 2018, Switzerland (25)	Asymptomatic, living in centers for asylum seekers Median age (IQR): 25 years (21-29) 88.8 % male Months since arrival in Switzerland (IQR): 11 (8-22)	Eritrea	1/107 (1.1%)	ELISA

Table A 3 c: Strongyloidiasis prevalence based on a combination of diagnostic methods (studies with over 50 participants). Articles sorted according to the prevalence found at screening. Modified after (4)

First author, year, country	Characteristic of tested collective	Most frequent countries of origin of collective	No of positive/ no of tested (positive %)	Diagnostic method
Cobo, 2015, Spain (92)	Patients diagnosed with filariasis Characteristics not mentioned for SSA migrants	Guinea-Bissau, Senegal, Equatorial Guinea	37/97 (38.1 %)	Examination of stool (Ritchie's method), serology (not specified)
Salas-Coronas, 2015, Spain (86)	Adults with eosinophilia, attending tropical medicine unit Characteristics not mentioned for SSA migrants	Senegal, Guinea Bissau, Mali	166/492 (33.7%)	Examination of 3 (up to 9) concentrated stool samples (Richie's method), charcoal culture, ELISA
Buonfrate, 2018, Italy (148)	Living in refugee shelters, arrival in the last 6 months Median age (IQR): 23 years (20-27) 94.4% male	Mali, Nigeria	64/358% (17.9%)	Examination of 3 concentrated stool samples (formol-ether), immunofluorescence test
Salas-Coronas, 2018, Spain (94)	Attending a tropical medicine unit Mean age (range): 27.88 years (14–74) 83.8% male Mean time living in Spain (range): 6.06 months (1–12)	Senegal, Guinea Bissau, Mali	84/488 (17.2%)	Examination of 3 concentrated stool samples (Ritchie's method), ELISA
Cobo, 2016, Spain (67)	Attending tropical medicine unit Characteristics not mentioned for SSA migrants	Senegal, Mali, Guinea-Bissau	331/1930 (17.2%)	Examination of 3 stool samples (Ritchie's method), culture, ELISA

First author, year, country	Characteristic of tested collective	Most frequent countries of origin of collective	No of positive/ no of tested (positive %)	Diagnostic method
Casado, 2019, Spain (84)	Adults attending tropical medicine unit Characteristics not mentioned for SSA migrants	Equatorial Guinea, Senegal	59/418 (14.1%)	Examination of 3 formalin-ether concentrated stool samples, ELISA
Salas-Coronas, 2020, Spain (73)	Patients with schistosomiasis, with or without symptoms Mean age (range): 27.3 years (11–52) 93.9% male Mean time living in Spain (range): 39.6 months (1–288)	Mali, Senegal	35/326 (10.7%)	Examination of 3 concentrated stool samples (Ritchie's method), serology (not specified)

Table A 4: Prevalence of filarial infections based on direct filarial visualization (studies with over 50 participants). Articles sorted according to the prevalence found at screening. From (4)

First author, year, country	**Characteristic of tested collective**	**Most frequent countries of origin of collective**	**Species (if mentioned): no of positive/ no of tested (positive %)**	**Diagnostic method**
Puente, 2020, Spain (88)	Patients diagnosed with loiasis Mean age (± SD): 42.3 years (± 17.3) Median age (range): 41 years (16-88) 37.4% male Time to first assessment in consultation, months Mean (± SD): 10.9 months (± 22.8) Median (range): 2 months (1-119)	Equatorial Guinea	*M. perstans 50/131* (36.6%) *O. volvulus 7/131* (5.3%) *M. perstans + O. volvulus 12/131* (9.2%) *M. perstans + O. volvulus + M. streptocerca 3/131* (2.3%) *M. perstans + M. streptocerca + W. bancrofti 1/131* (0.8%)	Knott and/or skin snips
Puente, 2020, Spain (89)	Patients diagnosed with mansonelliasis (*M. perstans*) Mean age (± SD): 44.6 years (± 18.2) 47.5% male Mean time in Spain (± SD): 8.6 months (± 18)	Equatorial Guinea	*O. volvulus 110/503 (21.9%)* *L. loa 48/503 (9.5%)* *M. streptocerca 7/503 (1.4%)* *L. loa + O. volvulus 12/503 (2.4%)* *O. volvulus + M. streptocerca 13/503 (2.6%)* *L. loa + O. volvulus + M. streptocerca 3/503 (0.6%)* *L. loa + M. streptocerca + W. bancrofti 1/503 (0.2%)*	"Microfilaremia search"

First author, year, country	Characteristic of tested collective	Most frequent countries of origin of collective	Species (if mentioned): no of positive/ no of tested (positive %)	Diagnostic method
Salas-Coronas, 2015, Spain (86)	Adults with eosinophilia, attending tropical medicine unit Characteristics not mentioned for SSA migrants	Senegal, Guinea Bissau, Mali	*M. perstans*: 67/492 (13.6%) *L. loa*: 2/492 (0.4%)	Knott and/or saponin test Skin snips in case of clinical suspicion for onchocerciasis, or Mazzotti test, when skin snips were negative
Boga, 2020, Spain (146)	Women attending tropical medicine unit with or without symptoms Characteristics not mentioned for SSA patients	Equatorial Guinea, Senegal, Nigeria	M. perstans 23/259[1] (8.8%) L. loa 13/259[1] (5%)	Knott test
Salas-Coronas, 2018, Spain (94)	Attending a tropical medicine unit Mean age (range): 27.88 years (14–74) 83.8% male Mean time living in Spain (range): 6.06 months (1–12)	Senegal, Guinea Bissau, Mali	*M. perstans*: 38/417 (9.1%) *L. loa*: 3/417 (0.7%)	Knott and/or saponin test or tests for onchocerciasis if suspected
Cobo, 2015, Spain (92)	Attending in a tropical medicine unit Median age (of patients): 29.9 years (typical deviation 9.6) 88.7% male patients	Guinea Bissau, Senegal, Equatorial Guinea	*M. perstans*: 93/1280 (7.3%) *L. loa*: 1/1280 (0.08%) *M. perstans + L. loa*: 3/1280 (0.2%)	Knott and saponin test, nocturnal Knott test (when suspicion of *W. bancrofti* filariasis), PCR (when Knott and saponin tests were negative, but suspicion of filariasis was high)

First author, year, country	Characteristic of tested collective	Most frequent countries of origin of collective	Species (if mentioned): no of positive/ no of tested (positive %)	Diagnostic method
Cobo, 2016, Spain (67)	Attending tropical medicine unit, Characteristics not mentioned for SSA migrants	Senegal, Mali, Guinea-Bissau	*M. perstans:* 112/1930 (5.8%) *L. loa:* 4/1930 (0.2%)	Knott and/or saponin test
Salas-Coronas, 2020, Spain (73)	Patients with schistosomiasis, with or without symptoms Mean age (range): 27.3 years (11–52) 93.9% male Mean time living in Spain (range): 39.6 months (1–288)	Mali, Senegal	*M. perstans:* 18/326 (5.5%)	Knott and/or saponin test Tests on onchocerciasis if suspected
Serre Delcor, 2016, Spain (87)	With or without symptoms, living in shelters, attended at unit of international health Median age (range): 17.0 years (12.0–49.0) 98.9% male Median time from arrival in Spain to consultation (IQR): 4 months (1.0–9.0)	Ghana, Gambia, Senegal, Guinea	*M. perstans*: 7/157 (4.5%)	Microscopic examination, skin snips when chronic skin itching

[1]absolute number estimated as it is not mentioned in the paper

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