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Imported *Strongyloides stercoralis* infections in Germany: descriptive study of cases over 5 years in a referral center in Berlin

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ABSTRACT

Background: *Strongyloides stercoralis* is a widespread helminth in tropical and subtropical regions, which can persist in humans for life through autoinfection. The clinical picture varies from asymptomatic to life-threatening hyperinfection syndrome. There is concern about increasing prevalence in Europe due to the number of cases imported by migrants and travelers.
Methods: This is a retrospective chart review of patients evaluated at the Charité Tropical Medicine outpatient clinic in Berlin, Germany. Cases were identified based on either a positive serologic test for *Strongyloides* (i.e., probable cases) or the detection of *Strongyloides* larvae in stool samples (i.e., confirmed cases).
Results: From April 2018 to November 2023, 162 patients with *Strongyloides* infection were identified. Diagnosis was confirmed in 49 patients (30.2 %) and probable in 113 patients (69.8 %). About half of the patients (48.8 %) were classified as migrants, who were diagnosed through screening in 48.1 %. Eosinophilia was present in 27.6 % of all patients, with no significant differences between migrants and non-migrants, or between probable or confirmed infections. In patients with a positive stool microscopy, only 8/37 (21.6 %) had a positive serology.
Conclusion: Nearly half of the migrant cases were detected through serology as part of screening. Most patients had no eosinophilia, and the positivity of serological tests was very low in patients with positive stool microscopy. These findings highlight the usefulness of targeted screening strategies in risk populations and suggest implementing sensitive stool tests detecting larvae combined with serology, to improve case detection.

1. Introduction

Strongyloides (S.) stercoralis was first identified in 1876 in the stool of soldiers with severe diarrhea returning from Southeast Asia [1]. Since then, the soil-transmitted helminth has been identified as an emerging medical problem worldwide. According to prevalence estimates, *S. stercoralis* affected more than 600 million people globally in 2017 [2]. While the parasite is most prevalent in tropical and subtropical regions, it also occurs in temperate climates, including parts of Europe [2]. In recent years, there have been concerns about a potential rise of the disease in Europe due to travel, migration, and climate change [3–6].

S. stercoralis larvae enter the body by penetrating healthy skin. Once inside the host, the parasite can replicate and cause chronic infection, also *via* autoinfection [7,8]. The infection may remain asymptomatic or manifest typically as chronic diarrhea with eosinophilia, the latter serving as a common laboratory marker to guide suspicion of infection [5]. In patients with certain alterations of immunity, increased worm loads can cause "hyperinfection syndrome" with chronic diarrhea and severe malabsorption. This manifestation most commonly results from immunosuppresive therapy or HTLV-1 coinfection, but can also occur in patients with malnutrition, diabetes mellitus or alcohol use disorder [9]. Hyperinfection syndrome with dissemination of adult worms is the most

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severe form of strongyloidiasis and has a high fatality rate. This syndrome is mostly triggered by corticosteroid treatment [3,9,10].

Diagnosis of strongyloidiasis is challenging because of a lack of standardized diagnostic methods [11]. Routine parasitological methods such as direct stool smear examination or formol-ether concentration technique have a low sensitivity [12]. Other fecal-based tests, including the agar plate culture, Baermann technique, Harada-Mori technique or PCR methods are more sensitive. However, they are often not routinely available and may not identify cases with intermittent shedding of larvae [12–16]. Although different PCR protocols for the detection of Strongyloides DNA in stool samples have been developed, their application and role in routine diagnosis is still under investigation [15,16].

Considering the limitations of direct methods, serological tests are an additional diagnostic tool for *S. stercoralis* infections. Methods such as the enzyme-linked immunosorbent assays (ELISA) have acceptable diagnostic sensitivity and specificity rates and offer a more accessible and less operator-dependent alternative. However, they have limitations due to cross-reactivity with other helminth infections, low sensitivity in acute cases, and inability to distinguish active from past infections [11,17,18].

In the absence of systematic screening and clinical awareness, strongyloidiasis may remain undetected, particularly in individuals without symptoms and/or eosinophilia. This is of concern for the individual patient, who might develop chronic infection with potentially severe complications in the future, but also for public health, since *S. stercoralis* might cause secondary cases if suitable soil conditions are present [19]. The European Centre for Disease Prevention and Control (ECDC) and European experts recommend that screening for strongyloidiasis should be offered to high-risk groups in non-endemic countries, such as migrants from high-endemic countries [20,21]. In our experience, outside of reference centers, these screening recommendations are rarely implemented in clinical practice in Germany. However, the usefulness of diagnostic and management strategies for strongyloidiasis may vary significantly across settings and affected populations.

Against the background of limited data on the clinical presentation and diagnostic test performance in imported strongyloidiasis, the present study aims at analyzing the clinic-epidemiological characteristics of cases diagnosed in a large referral center in Berlin over 5 years.

2. Methods

2.1. Ethics statement

Approval for the use of routinely collected data from patients with *Strongyloides* infection was provided by the ethics committee of Charité-Universitätsmedizin Berlin (EA2/070/24). In compliance with the Berlin State Hospital Act, patient consent was not required for the retrospective analysis of routine clinical data.

2.2. Study setting

The study was conducted at the Tropical Medicine Outpatient Clinic at the Institute of International Health (IIH), Charité University Hospital Berlin, a regional referral center for tropical medicine and parasitology. The IIH is a facility that serves a population of approximately 6 million people in the Berlin-Brandenburg area, Germany, and provides care for more than 7000 returning travelers, migrants, and refugees annually. This number declined by approximately half during the COVID-19 pandemic (2020–2022), reflecting reduced international travel and migration. Patients present to the clinic through self-referral or referral by primary care physicians and specialists. As part of routine clinical care, patients complete a standardized questionnaire on travel history from the past five years and migration history and undergo a physician examination and diagnostic testing as needed, with findings documented in the electronic health record.

2.3. Study design

Cross-sectional analysis of all patients with either confirmed or probable strongyloidiasis who presented to the outpatient clinic at the Charité IIH from April 2018 to November 2023. All patients with either a direct parasitological proof of *S. stercolaris* or a respective positive serology were included. We subsequently extracted relevant clinical and laboratory data from the electronic health records using a standardized form, which included demographic, epidemiological, clinical, and laboratory parameters. For analysis, we classified patients as migrants if they resided in Germany but were born abroad. All analyses were stratified by migrant status because for this group, specific screening approaches apply, which could influence symptom detection, diagnostic approach and diagnostic yield. For migrants, the exposure site was defined as the region of origin. In non-migrants, the exposure site was defined as the region of most recent travel. Region of travel or origin were recorded based on the classifications provided by the GeoSentinel Surveillance System [22]. Symptoms were categorized into four groups: 1) gastrointestinal (e.g., diarrhea, obstipation, nausea, vomiting, epigastric pain, loss of appetite, weight loss), 2) skin manifestations (e.g., pruritus, dermatoses), 3) respiratory symptoms (e.g., cough, shortness of breath), and 4) other systemic complaints (e.g., fever, fatigue, headache, joint pain). Immune system disorders referred to infections with human immunodeficiency virus (HIV) or human T-cell lymphotropic virus 1 (HTLV-1), active malignant disease, current immunosuppressive therapy (e.g., anticancer treatment, high-dose corticosteroids, biologics), diabetes mellitus, alcohol use disorder, and malnutrition. Confirmed cases of *S. stercoralis* infection were defined by the detection of larvae in clinical samples and probable cases by the presence of *Strongyloides* antibodies in the absence of direct parasite detection.

2.4. Diagnostic testing

During the study period, all patients with a history of migration from or long-term travel to endemic regions underwent *Strongyloides* screening. Other patients were tested for *Strongyloides* infection based on their clinical presentation and laboratory results.

All microbiological tests were performed in the IIH's diagnostic laboratory. Direct parasite detection method for *S. stercoralis larvae* included microscopic examination of fresh stool samples and after merthiolate-iodine-formaldehyde (MIF) concentration as well as the Baermann technique [23,24]. For fresh stool microscopy and the Baermann technique, patients were routinely instructed to produce stool samples in the laboratory toilet at the institute. Samples were then transferred to the laboratory at 36 °C and processed without delay.

For serological diagnosis, commercial *Strongyloides* IgG ELISAs (DRG Instruments GmbH, Marburg, Germany) were used (2018–2020: EIA-4208, 2020–2023: EIA 5812). The manufacturer indicates a diagnostic sensitivity of 89.47 % (95 % confidence interval 75.2 %–97.06 %) and a specificity of 94.12 % (95 % confidence interval 83.76 %–98.77 %). Tests were performed and interpreted according to the manufacturer's recommendations. In addition, we calculated the ratio of the patient's IgG result to the cutoff for positivity provided by the manufacturer. The serological testing was conducted in compliance with the Guideline of the German Medical Association on Quality Assurance in Medical Laboratory Examinations (Rili-BÄK), with successful participation in semi-annual external quality assessment schemes [25].

Eosinophilia was defined as a peripheral absolute eosinophil count of $\geq 0.5 \times 10^9$/L, hypereosinophilia as $\geq 1.5 \times 10^9$/L [26]. To evaluate possible coinfections, available serological results for other helminth infections were recorded. ELISAs were used to test for *Ascaris lumbricoides, Toxocara canis,* filariasis *(Acanthocheilonema viteae* antigen*), and Fasciola hepatica* applying commercial assays. A combination of haemagglutination tests (HAT) and ELISA were used for echinococcosis and schistosomiasis.

Table 1
Characteristics and laboratory results of migrant (n = 79) and non-migrant (n = 78) patients with *Strongyloides* infection diagnosed during 2018–2023.

	Total		Migrant		Non-migrant	
	n = 162 [+]		n = 79		n = 78	
Sex						
Female	67/162	41.4 %	21/79	26.6 %	43/78	55.1 %
Male	95/162	58.6 %	58/79	73.4 %	35/78	44.9 %
Median age in years (IQR, range)	29 (18–44, 6–86)		18 (16–40, 6–79)		31 (24–43, 17–80)	
Region of exposure						
Europe	4/154	2.6 %	2/79	2.5 %	2/75	2.7 %
Asia	62/154	40.3 %	35/79	44.3 %	27/75	36.0 %
Africa	70/154	45.5 %	38/79	48.1 %	32/75	42.7 %
America	18/154	11.7 %	4/79	5.1 %	14/75	18.7 %
Immuno-compromise						
HIV	7/162	4.3 %	2/79	2.5 %	5/78	6.4 %
HTLV-1	1/162	0.6 %	1/79	1.3 %	0/78	0.0 %
Alcohol use disorder	1/162	0.6 %	1/79	1.3 %	0/78	0.0 %
Reason for testing						
Screening	46/162	28.4 %	38/79	48.1 %	8/78	10.3 %
Clinical suspicion	116/162	71.6 %	41/79	51.9 %	70/78	89.7 %
Symptomatic	119/161	73.9 %	45/79	57 %	70/78	89.7 %
Gastrointestinal	88/119	73.9 %	29/45	64.4 %	57/70	81.5 %
Cutaneous	36/119	30.3 %	14/45	31.1 %	21/70	30.0 %
Respiratory	25/119	21.0 %	9/45	20.0 %	16/70	22.9 %
Others	72/119	60.5 %	34/45	75.6 %	37/70	52.9 %
Laboratory studies						
Eosinophilia	43/156	27.6 %	24/76	31.6 %	16/75	21.3 %
Hypereosinophilia	9/156	5.8 %	5/76	6.6 %	3/75	4.0 %
S.s. larvae in stool	49/142	34.5 %	15/65	23.1 %	33/73	45.2 %
S.s serology positive	121/150	80.7 %	67/76	88.2 %	50/70	71.4 %
Diagnosis strongyloidiasis						
Confirmed	49/162	30.2 %	15/79	19.0 %	33/78	42.3 %
Probable	113/162	69.8 %	64/79	81.0 %	45/78	57.7 %

IQR, interquartile range; HIV, human immunodeficiency virus; HTLV-1, Human T-cell lymphotropic virus type 1; *S.s.*, *Strongyloides stercoralis*.
[+] including 5 patients with unknown migration status.
The denominators in the table represent the number of patients for whom data was available in the respective category.
Statistically significant differences between migrants and non-migrants ($p < 0.05$) were observed for sex, median age, region of exposure, reason for testing, symptomatic presentation at diagnosis, symptom: Others, *S.s.* larvae in stool and *S. s.* serology positivity.

2.5. Statistical analysis

Categorical data is presented as frequencies with percentages. Nonparametric continuous data is presented as medians with interquartile ranges (IQR). Percentages were calculated using the total number of non-missing observations for the respective variable as the denominator. Comparisons were made between migrants (including refugees), and non-migrants for baseline characteristics (e.g., demographic data, region of origin and region of exposure, history of recent travel), reason for testing (screening vs. clinical suspicion), presence of symptoms at presentation, and presence of eosinophilia. Categorical variables were compared using Fisher's exact test or Chi-square test as appropriate. Non-parametric continuous data was compared using the Mann-Whitney *U* Test. As part of a *post hoc* exploratory analysis, we further explored differences in the demographic, clinical, and laboratory characteristics of patients with confirmed vs. probable infections. A two-tailed p-value of <0.05 was considered statistically significant for all. The statistical analysis was conducted using R Studio v.4.5.0.

3. Results

Between April 2018 and November 2023, we identified 162 patients with *S. stercoralis* infection (Table 1). Of those, 30.2 % were confirmed cases and 69.8 % were probable cases. Males (58.6 %) slightly dominated. The median age was 29 years (IQR, 18–44; range, 6–86); 27.2 % of patients were underage (<18 years), the majority of whom were unaccompanied minor refugees (UMRs, 39/44). Approximately half of the patients (48.8 %) were categorized as migrants, and half (48.2 %) as non-migrants. Between these groups, sex, age, region of exposure, reason for testing, symptomatic presentation at diagnosis, other symptoms, *S. strongyloides* larvae in stool and *S. strongyloides* serology positivity differed significantly (Table 1). Most infections were acquired in Africa (45.5 %) and Asia (40.3 %) (Table 1, Fig. 1). Although nine patients were classified as immuno-compromised (including one co-infection with HTLV-1), no patient was diagnosed with hyperinfection syndrome. Almost all patients (96.8 %, 153/158) were treated with ivermectin at a dose of 0.2 mg/kg/day for 1–4 days.

3.1. Migrants

Among migrants with *S. stercoralis* infection, almost three in four were male (73.4 %) and the median age was 18 years (IQR, 16–40; range, 6–79). In this group, 19.0 % of diagnoses were confirmed by microscopy, while in 81.0 %, antibody testing was positive (Table 1). The most frequent subregion of exposure was Sub-Saharan Africa (43.0 %), followed by South Central Asia (19.0 %), and the Middle East (15.2 %) (Fig. 1). Thirty-two (40.5 %) of migrant patients had a history of recent travel, with a median travel duration of 35 days (IQR, 24–62). Most common travel reasons were visiting friends and relatives (65.6 %) and tourism (18.8 %). Almost half of migrant patients (48.0 %) were diagnosed for *S. stercoralis via* routine screening. Fifty-seven percent of cases presented clinical manifestations, most frequently non-specific systemic symptoms (75.6 %) and gastrointestinal symptoms (64.4 %). Eosinophilia was present in a third of patients (31.6 %), of whom five (6.6 %) had hypereosinophilia.

3.2. Non-migrants

Among non-migrant patients, *S. stercoralis* infection was confirmed in 42.3 %, and was probable in 57.7 %. Females (55.1 %) slightly predominated; the median age was 31 years (IQR, 24–43; range, 17–80)

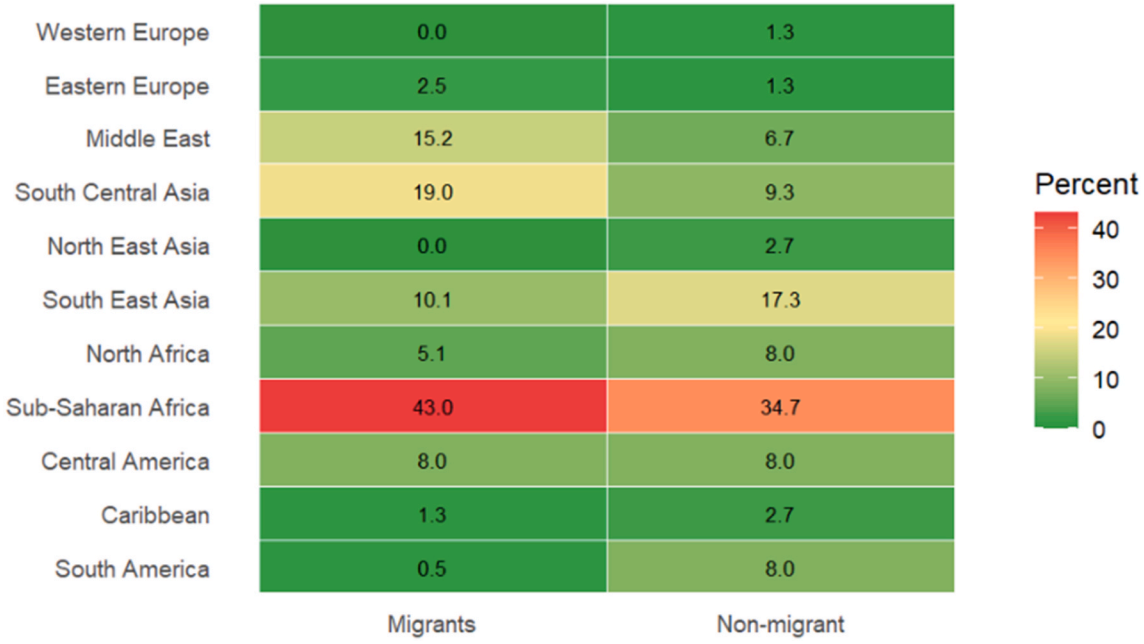

Fig. 1. Percentage distribution of confirmed or probable *Strongyloides* infections among migrants (n = 79) and non-migrants (n = 78), by GeoSentinel region of exposure. Percentages are calculated column-wise, such that each column sums to 100 % within migrant and non-migrant groups. Colours represent a heat-map scale, indicating lower (green), moderate (yellow) and higher proportions (red) of *Strongyloides* infections.

(Table 1). The predominant subregion of exposure was Sub-Saharan Africa (34.7 %), followed by South East Asia (17.3 %), and South Central Asia (9.3 %) (Fig. 1). Almost all patients (96.2 %) had a history of recent travel. The most common travel reason was tourism (61.3 %), followed by work (25.3 %), being an expatriate (6.7 %), and visiting friends and relatives (6.7 %). Median travel duration was 46 days (IQR, 23–160). Immune system disorders were present in 5 patients (6.4 %), all who were HIV positive. The majority of patients (89.7 %) was tested due to present symptoms. The most frequent symptoms were gastrointestinal (81.5 %) and non-specific systemic symptoms (52.9 %). Eosinophilia and hypereosinophilia were present in 16 patients (21.3 %) and three patients (4.0 %), respectively.

3.3. Confirmed vs. probable cases

The characteristics of confirmed vs. probable cases of *S. stercoralis* infection are displayed in Table 2. The proportion of confirmed strongyloidiasis was higher in non-migrants than in migrants (42.3 % vs. 19.0 %) (Table 1) and as a consequence, more than two thirds of confirmed cases were seen among non-migrants (Table 2). Confirmed cases were most frequently exposed in Sub-Saharan Africa (23.9 %), South East Asia (17.4 %) and South America (13.0 %) (Table 2). Confirmed cases were significantly more likely to present with symptoms suggestive of the disease (89.6 % vs. 67.3 %). Eosinophilia was non-significantly more common in confirmed cases (33.3 %) than in probable cases (25.2 %), the same applied to hypereosinophilia (11.1 % vs. 3.6 %). Of the 37 confirmed cases that underwent S*trongyloides* serology, eight (21.6 %) showed a positive serological result. Among migrants, there was a higher proportion of positive serology results in confirmed cases (3/12, 25.0 %) than in non-migrants (5/25, 20.0 %). The median antibody index of confirmed cases was 5.2 (IQR 1.3–2.5), which was higher than the median antibody index of probable cases (1.6, IQR 1.2–2.4).

Of 121 patients with positive *Strongyloides* serology, 112 patients were examined by additional serologic assays for other helminth infections. Of those, 36 showed one or more positive results for other helminths. Such reactivity was mostly observed with other nematode antigens such as *Ascaris* and filarial antigens. Positive results were less frequently reported for cestode and trematode helminths (Supplementary Table).

4. Discussion

Our descriptive study included 162 patients with *S. stercoralis* infection who were evaluated in a large German Tropical Medicine center from 2018 to 2023. The demographic characteristics reflect the patient profile of Tropical Medicine facilities in Germany, which predominantly serve returning travelers, migrants, and refugees.

In migrants and non-migrants, strongyloidiasis was most frequently acquired in Africa and Asia. The predominant subregion in both patient groups was Sub-Saharan Africa. Migrants with strongyloidiasis more often derived from South Central Asia and the Middle East than non-migrants. This partly differs to strongyloidiasis cases of the +REDIVI study in Spain, where most migrants came from South America, and most travelers had visited Sub-Saharan Africa. These discrepancies likely reflect differences in migration backgrounds between Germany and Spain [27]. The younger age distribution and the predominance of male patients among migrants are consistent with global migration patterns [28].

Our results demonstrated the challenge to identify patients with *Strongyloides* infection. Eosinophilia, which is a known indicator of helminthic infection including strongyloidiasis, was observed in only one-third of parasitologically confirmed cases. This low rate is consistent with previous findings [6,29,30], even though substantially higher proportions of eosinophilia have been reported by other studies [31]. Serological testing is a practical diagnostic tool for strongyloidiasis but has important limitations. The main problem is the lack of a serological reference standard, which is why reported performance data highly depend on the tested populations and diagnostic comparators. Two previous diagnostic studies reported sensitivities of commercial ELISA tests ranging from 83 % to 93 % [32,33]. A study in our institution evaluated three serological assays in parasitological confirmed cases, most of them travellers, showing sensitivities of 56 %–64 %. Specificities were 92 %–96 % in healthy controls, but decreased to 63 %–77 % in patients with other helminth infections [11]. Of the 37 confirmed cases in the present cohort, only eight (21.8 %) tested positive using ELISA tests. Although our study design does not enable a diagnostic evaluation

Table 2
Selected characteristics and laboratory studies of patients specified by parasitologically confirmed (n = 49) or serologically probable (n = 113) *Strongyloides* infection.

	Total n = 162		Confirmed n = 49		Probable n = 113	
Sex						
Female	67/162	41.4 %	23/49	46.9 %	44/113	38.9 %
Male	95/162	58.6 %	26/49	53.1 %	69/113	38.9 %
Age in years, median (IQR, range)	29 (18–44, 6–86)		31 (26–44, 17–19)		26 (17–42.5, 6–86)	
Subregion of exposure						
Caribbean	3/156	1.9 %	1/46	2.2 %	2/110	1.8 %
Central America	7/156	4.5 %	3/46	6.5 %	4/110	3.6 %
South America	9/156	5.8 %	6/46	13.0 %	3/110	2.7 %
Middle East	17/156	10.9 %	3/46	6.5 %	14/110	12.7 %
North East Asia	2/156	1.3 %	1/46	2.2 %	1/110	0.9 %
South Central Asia	22/156	14.1 %	6/46	13.0 %	16/110	14.5 %
South East Asia	21/156	13.5 %	8/46	17.4 %	13/110	11.8 %
North Africa	10/156	6.4 %	4/46	8.7 %	6/110	5.5 %
Sub-Saharan Africa	61/156	39.1 %	11/46	23.9 %	50/110	45.5 %
Western Europe	1/156	0.6 %	1/46	2.2 %	0/110	0.0 %
Eastern Europe	3/156	1.9 %	2/46	4.3 %	1/110	0.9 %
Migration status						
Migrants	79/157	50.3 %	15/48	31.2 %	64/109	58.7 %
Non-migrants	78/157	49.7 %	33/48	68.8 %	45/109	41.3 %
Reason for testing						
Screening	46/161	28.6 %	5/48	10.4 %	41/113	36.3 %
Clinical suspicion	115/161	71.4 %	43/48	89.6 %	72/113	63.7 %
Symptoms at presentation	119/161	73.9 %	43/48	89.6 %	76/113	67.3 %
Gastrointestinal	88/119	73.9 %	33/43	76.7 %	55/76	72.4 %
Skin	36/119	30.3 %	13/43	30.2 %	23/76	30.3 %
Respiratory	25/119	21.0 %	7/43	16.3 %	18/76	23.7 %
Others	72/119	60.5 %	24/43	55.8 %	48/76	63.2 %
Eosinophilia ($\geq 0.5 \times 10^9$/L)	43/156	27.6 %	15/45	33.3 %	28/111	25.2 %
Hypereosinophilia ($\geq 1.5 \times 10^9$/L)	9/156	58 %	5/45	11.1 %	4/111	3.6 %
Positive stool microscopy	49/142	34.5 %	49/49	100.0 %	0/93	0.0 %
Positive *S. stercoralis* serology	121/150	80.7 %	8/37	21.6 %	113/113	100.0 %
Index serology, median (IQR)	1.7 (1.3–2.5)		5.2 (3.3–6.4)		1.6 (1.2–2.4)	

IQR, interquartile range.
The denominators in the table represent the number of patients for whom data was available in the respective category.
Statistically significant differences between confirmed and probable cases ($p < 0.05$) were observed for median age, subregion of exposure, migrant vs. non-migrant, reason or testing, symptomatic presentation at diagnosis, *S. stercoralis* serology positivity, and median index serology.

of the tests used, it reflects real-world conditions and the inherent challenges of diagnosing strongyloidiasis. These discrepancies may be related to our study population, which included returning travelers with early or acute infections in whom seroconversion may not yet have occurred. In contrast, migrants may more frequently have chronic infections acquired years earlier, resulting in higher IgG titers [11].

In cases of seropositivity without direct parasite detection, cross-reactivity with other common helminths in endemic regions must be considered, which may warrant further diagnostic evaluation. We found that a third of patients had at least one additional positive serologic test, possibly indicating cross-reactivity or helminth coinfections.

Sensitive and specific parasitological methods for stool analysis, such as agar plate culture or Baermann technique, are often unavailable in routine clinical practice [12]. If physicians rely on serology, this limitation may lead to missed diagnosis due to low sensitivity or over-diagnosis due to cross-reactivity [11]. In the absence of reliable diagnostic methods clinicians may initiate empirical treatment based on epidemiological and clinical criteria, as recommended in some countries for high-risk patients [17]. In our opinion, specialised laboratories should offer a broader range of diagnostic tests for *S. stercoralis*, particularly sensitive direct tests such as the Baermann technique and PCR. The performance of commercial serodiagnostic assays serological tests for *S. stercoralis*, require further evaluations; two-tier testing strategies, as established in other infections, might offer a promising approach [34]. The role of molecular methods for the routine diagnosis of strongyloidiasis is currently under investigation. PCR assays lack standardization and their performance varies depending on extraction methods and the used protocol [15]. A recent systematic review reported an overall sensitivity of 72 % compared to parasitological methods and concluded that to date PCR might rather serve as a confirmatory than screening tool [16]. Despite these limitations, PCR techniques are already mentioned in international guidelines and might gain importance in the future [35].

Among migrants, nearly half of the cases (confirmed or probable) were diagnosed through routine screening in the absence of symptoms, whereas this was the case for only 10 % of diagnoses among non-migrants. The ECDC issued public health guidance recommending serological screening for strongyloidiasis in migrants from endemic countries in Asia, Africa, the Middle East, Oceania, and Latin America [20]. However, the strength of the evidence supporting this recommendation was rated as low. Testing for strongyloidiasis should be easily accessible, especially for migrants who often face barriers when accessing healthcare [36].

In 2017, a European expert group recommended screening of individuals at high risk of infection in non-endemic settings (e.g. migrants from Africa, Latin America, Asia or Oceania, and expatriates with long-term or rural exposure). For this screening, a highly sensitive serological test should be used; if this is unavailable, specific faecal detection techniques (e.g. Baermann or PCR) should be used instead [21]. Based on our findings, we support previous recommendations for screening migrants and long-term travelers from highly endemic countries even in the absence of symptoms or eosinophilia. While cost-effectiveness studies are still needed, the potential clinical benefit, particularly the prevention of severe complications, may justify targeted screening approaches in these risk groups. For immunocompromised individuals, in whom serological tests may have reduced sensitivity, supplementary screening using stool-based methods is recommended [31].

This study was conducted at a single reference center in a non-endemic country limiting generalizability. Patients with probable diagnoses were included in the analysis; however, diagnostic uncertainty

persists for these cases, and false-positive serological results cannot be ruled out. The diagnostic work-up did not follow a standardized protocol and was performed as requested by the attending physician. The retrospective design inherently limits control over data quality and completeness. Symptom data were collected *via* self-reported questionnaires, which may be subject to recall bias and subjective interpretation These limitations should be considered when interpreting the results, and future studies across multiple centers and in different epidemiological settings are warranted to validate these findings and to inform population-specific screening strategies.

5. Conclusion

Migrant patients made up half of the detected *Strongyloides* infections, of which 48 % were detected through serological screening. Most patients had no eosinophilia, and the sensitivity of serological tests was low in microscopically confirmed cases. These findings support recommendations to screen high-risk populations regardless of symptoms or eosinophilia. It also suggests the use of combined stool-based and serological diagnostics to improve case detection. Future research should focus on validating population-specific screening strategies and developing improved diagnostic tools.

CRediT authorship contribution statement

Antonio Seigerschmidt: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Maria Cristina Moreno-del Castillo:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Gabriela Equihua Martinez:** Writing – review & editing, Investigation. **Paul Pitzinger:** Writing – review & editing, Investigation. **Janina Hammer:** Writing – review & editing, Investigation. **Susanne Georgi:** Writing – review & editing, Investigation. **Michael Nürnberg:** Writing – review & editing, Investigation. **Julian Bernhard:** Writing – review & editing, Investigation. **Franziska Olgemöller:** Writing – review & editing, Investigation. **Beate Kampmann:** Writing – review & editing, Supervision, Project administration, Conceptualization. **Frank P. Mockenhaupt:** Writing – review & editing, Supervision, Project administration, Conceptualization. **Thomas Weitzel:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Data curation, Conceptualization. **Andreas K. Lindner:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Data statement

All raw data analysis codes are available upon reasonable request to the corresponding author.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT 4o to improve the language and structure of the manuscript. The tool did not contribute to the scientific content. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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Declaration of competing interest

All authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

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