CHAPTER 45

Common Intestinal Roundworms

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The worms crawl in,
The worms crawl out,
The worms play pinochle on your snout.
Anonymous (children's song)

GENERAL CONSIDERATIONS

Medically important worms belonging to the phylum Nematoda (roundworms) parasitize the gastrointestinal tract of humans. It is estimated that 60% of the world population is infected with at least one intestinal helminth. The worms are commonly acquired through ingestion of contaminated food (especially raw or undercooked vegetables), through skin contact with contaminated soil, or, in some instances, from direct contact with infected persons or their fomites.

Individuals most likely to be infected with intestinal nematodes will frequently give a history of one of the following: (1) travel or residence in the developing world, (2) emigration from the developing world, (3) residence in a rural farming community, (4) ingestion of organically grown vegetables, (5) the use of untreated wastewater for agriculture, or (6) pica. In low-resource tropical countries, environmental sanitation may be substandard or absent. However, unsanitary conditions may be found in isolated rural areas and in farming communities in high-resource countries as well.

Fresh vegetables can serve as a major source of food-borne parasitic disease. A study performed by Duedu et al. (2014) in Ghana showed that vegetables (cabbage, sweet bell pepper, carrot, lettuce, tomato, and onion) sold at open-aired markets in Accra were more heavily contaminated than those sold at supermarkets. Lettuce (61%) and cabbage were the most contaminated, and the least was tomato (18%). The most prevalent parasites were *Strongyloides stercoralis* larvae (43%) and *Cryptosporidium parvum* oocysts (16%). Helminth eggs detected included those of hookworm nematodes (*Ancylostoma duodenale, Necator americanus*), *Trichuris trichiura*, *Enterobius vermicularis*, and the trematode *Fasciolopsis buski*. Other pathogens contaminating the vegetables included *Entamoeba histolytica*, *Giardia lamblia*, *Cyclospora cayetanensis*, *Entamoeba coli*, and *Isospora belli*.

In rural El Salvador, the use of solar urine-diverting desiccating latrines was found to be associated with a lower risk of intestinal helminths relative to use of pit latrines, or the absence of any type of latrine, presumably because the solid waste dries out more quickly in such a system, and eggs require a certain amount of time in moist soil to embryonate. In Mexico, intestinal helminth prevalence rises in children from low-income families and unemployed or less educated mothers. In Alexandria, Egypt, the risk of vegetable-transmitted parasites including *Ascaris lumbricoides* was found to be reduced by soaking leafy vegetables in water with an added substance such as vinegar, lemon juice, or salt; however, only 9.6% of households did this.

In general, the prevalence of intestinal parasites is higher in rural regions. For example, in a study of Bangladeshi men seeking work abroad, geohelminth infection rates were found to be 5.2% in those from urban areas and 27.6% in those residing in rural areas. However, in a study performed in India that looked at intestinal parasite rates in slum, rural, and urban

populations, the highest prevalence (19%) was found in those residing in slums. Thus, insufficient access to sanitation of solid human waste is a key factor in transmission of these pathogens.

Pica, or geophagy, is not rare: in one study in Kenya, 77% of children ate soil daily, presumably triggered by iron-deficiency anemia. Intestinal roundworms transmitted by contact with contaminated soil are known collectively as "geohelminths" or "soil-transmitted helminths" (STHs).

ETIOLOGY

Species of geohelminths causing infections in humans include *A. lumbricoides* ("common roundworm"), *Ascaris suum* ("pig roundworm"), *Ancylostoma duodenale* and *Necator americanus* ("human hookworms"), *T. trichiura* ("whipworm"), *S. stercoralis*, and *E. vermicularis* ("threadworm" or "pinworm"). Human intestinal infection with the marine roundworm *Anisakis* will also be considered in this chapter.

CLINICAL FEATURES

1. Patients with intestinal nematodes will frequently be asymptomatic.
2. Returned travelers should be reassured that, with the exception of *Strongyloides*, these parasites cannot complete their life cycle within the human host, and even without treatment they will die of old age, often within a year of infection.
3. Vague abdominal complaints are sometimes the only symptoms reported with light to moderate infections.
4. Chronic, heavy infections are associated with growth stunting in children.
5. Occasionally, asymptomatic patients will pass a recognizable worm, and this will be the first sign that they have acquired an intestinal parasite.
6. At other times, the diagnosis is suspected or made on finding eosinophilia on a routine white blood cell differential analysis or on finding ova or parasites in a stool examination done for screening purposes.

In general, the severity of signs and symptoms will be related to the intensity of the infection (worm burden). Young children, possibly because of unsanitary habits (a tendency to put dirty fingers and objects into their mouths, play outdoors without shoes, etc.) and possibly because of immature host defense mechanisms, tend to acquire heavier parasite loads than adults living in the same area.

These infections are remarkably prevalent. Ascariasis is commonly associated with diarrhea in the developing world. In a study performed in rural south Mozambique, *A. lumbricoides* was the second most common pathogen isolated from stool, following diarrheogenic *E. coli* (9.3% and 22.6%, respectively). Almost one billion people are infected with hookworm. The hallmark of human hookworm infection is iron-deficiency anemia. For salient features of infection with intestinal nematodes, see **Table 45.1**.

PREVENTION

General food safety practices should dramatically reduce the incidence of ascariasis and trichuriasis, which are spread via contaminated foods (see Chapter 8). Wearing shoes should also afford some protection against hookworm infection and strongyloidiasis, which are spread via skin contact with infested soil. There now exists a vaccine for canine hookworm; an antihookworm human vaccine is under clinical investigation.

DIAGNOSIS

Hematology

The absolute eosinophil count is usually normal when infection is established with *Ascaris*, *Trichuris*, hookworms, and *Enterobius*, because the adult worms live in the intestines and reveal few antigens to the gut-associated lymphatic tissue. Thus normal eosinophil counts do not rule out geohelminth infection. On the other hand, eosinophilia (>450/mm^3) may

TABLE 45.1 Intestinal Nematode Infections

Infection	Agent	Geographic Distribution	Mode of Infection	Clinical Features	Diagnosis	Indication for Treatment
Common roundworm Pig roundworm	*Ascaris lumbricoides* *Ascaris suum*	Worldwide	Raw fruits and vegetables, or contact with contaminated soil	Pneumonitis, colicky epigastric pain, nausea and vomiting, passage of a mature pencil-sized worm[a]	Ova in stool or identification of mature worm	A single retained worm, multiple worms, obstruction of a viscus, or presence of other parasites requiring treatment
Hookworm (Old World) Hookworm (New World)	*Ancylostoma duodenale* *Necator americanus*	Worldwide	Percutaneous or perioral infections from contaminated soil or vegetation	"Ground itch" (rash), pneumonitis, abdominal pain, diarrhea, anemia (with large worm burdens and iron-deficient diet)[b]	Ova in stool	Heavy infection (>2000 eggs/g of stool) Anemia Malnutrition
Strongyloides	*Strongyloides stercoralis*	Worldwide	Skin contact with wet, infected soil	Rash on buttocks or thighs, abdominal pain, nausea and vomiting, weight loss, eosinophilia, recurrent bacterial systemic infections with gastrointestinal flora in immunocompromised patients	Rhabditiform larvae in stool or jejunal aspirate Serology available	Documented infection
Whipworm	*Trichuris trichiura*	Worldwide	Raw fruits and vegetables, soil contact, flies on food	Mild anemia, bloody diarrhea, rectal prolapse in heavy infections	Ova in stool	Symptoms associated with heavy infection (>3000 eggs/g of stool) Not necessary to treat patients with low egg counts
Pinworm	*Enterobius vermicularis*	Worldwide	Anus–finger–mouth cycle, or from clothing, bedding, dust	Perianal itching, irritation, restlessness, sleeplessness	Ova from perianal skin seen on cellophane tape swab	Symptomatic infection, psychosocial reasons

[a]Rare: bile duct obstruction, acute pancreatitis, appendicitis.
[b]*A. duodenale* causes a more severe anemia than does *N. americanus*.

happen during lung migration in early infection due to *Ascaris* or hookworms or at any time during chronic autoinfection due to *Strongyloides*.

Microbiology

Examination for ova and parasites of up to three different stool specimens collected on three different days at 2- to 3-day intervals should be sufficient for diagnosis. It is not uncommon for stool examinations to be negative for diagnostic forms of *Strongyloides* or *Enterobius* (pinworm).

An epidemiologic study of geohelminth prevalence in Zanzibar, Tanzania, found that when used alone, Wisconsin flotation and simple gravity sedimentation yielded sensitivities for detecting geohelminth eggs of approximately 90%. When two methods were used in combination, either Kato-Katz plus simple gravity sedimentation or Wisconsin flotation plus simple gravity sedimentation, sensitivity improved to 99.0%. Thus, if clinical suspicion remains high in spite of negative fecal ova and parasite preparations, request that the laboratory perform two techniques.

Serology

Because *Strongyloides* autoinfection exposes the immune system to worm significant antigen load, serology may be helpful for diagnosing this condition. Both immunofluorescence assay and enzyme-linked immunosorbent assay (ELISA) serologic tests for *Strongyloides* (available through commercial laboratories or arranged through state health departments and performed by the Parasite Serology Laboratory at the Centers for Disease Control and Prevention, Atlanta, GA) can be helpful in making the diagnosis in a patient with an appropriate geographic history, peripheral blood eosinophilia, and negative stool examinations for ova and parasites. ELISA sensitivity and specificity are improved if used in conjunction with Western blot. All serologic diagnostic tests for *Strongyloides* are limited by the patient's ability to mount an immune response to the worm, and complicated by cross-reactivity with filarial antigens, meaning neither the positive nor the negative predictive value is perfect.

The String Test

The "Entero-Test" method for sampling proximal jejunal secretions may be a useful diagnostic procedure for *Strongyloides* diagnosis (see Chapter 32, under Giardia, Diagnosis).

Adhesive Tape Test

The diagnosis of *Enterobius* is best made from microscopic examination of adhesive tape pressed adhesive side down on the perianal skin (preferably in the morning on a patient who has been instructed not to bathe before the examination), and then directly mounted, adhesive side down, on a glass microscope slide. The distinctive dome-shaped eggs are rarely found in the stool.

Baermann Funnel Gauze Method

Strongyloides larvae do not float in hypertonic saline, which is used to concentrate other parasites. The Baermann method utilizes gauze, warm water, and larval sedimentation in the neck of a funnel.

TREATMENT

For treatment of common intestinal nematodes in patients without severe underlying health problems, see **Table 45.2**.

If *Ascaris* is present, this parasite generally should be treated during the first round of antiparasitic therapy, even if other drugs will be used subsequently to treat other parasites that are present. The reason for this is the propensity for mature *Ascaris* worms to migrate into unpredictable ectopic sites when they are irritated but not killed by drugs, fever, or even starvation in the host. Migrating worms may cause perforation of an abdominal viscus, appendicitis, biliary obstruction, pancreatitis, or intestinal obstruction. Antiparasitic therapy directed at *Ascaris* may be administered concurrently with antibiotics for other infections.

TABLE 45.2 Antihelminthic Drugs

Helminth	Primary Treatment (Adults)	Alternate Treatment (Adults)
Ascaris lumbricoides	Albendazole[a] 400 mg PO once; *or* mebendazole 100 mg bid PO × 3 days	Ivermectin[a] 150-200 mcg/kg PO once
Hookworm (*Ancylostoma duodenale* and *Necator americanus)*	Albendazole[a] 400 mg PO once; *or* mebendazole 100 mg bid PO × 3 days	Pyrantel pamoate[a] × 11 mg/kg base (max. 1 gram) PO daily × 3 days
Trichuris trichiura	Albendazole[a] 400 mg PO × 3 days	Mebendazole 100 mg b.i.d PO × 3 days; *or* ivermectin[a] 200 mcg/kg/day PO × 3 days
Strongyloides stercoralis	Ivermectin 200 mcg/kg/day PO × 2 days	Albendazole[a] 400 mg b.i.d. PO × 7 days
Enterobius vermicularis	Albendazole[a] 400 mg PO once, repeat dose in 2 weeks; *or* mebendazole 100 mg PO once, repeat dose in 2 weeks	Pyrantel pamoate 11 mg/kg base (max 1 g) once, repeat dose in 2 weeks
Anisakis simplex	Physical removal	Albendazole[a] 400 mg b.i.d. PO × 6-21 days.

[a]Not FDA-approved for this indication.
b.i.d., Twice per day; *PO*, by mouth.

Special Therapeutic Considerations

Intestinal Obstruction Due to Ascaris

A gastrointestinal tube should be placed, retained fluids aspirated, and an appropriate dose of piperazine citrate instilled (Antepar 75 mg/kg per day, not to exceed 3.5 g). The piperazine will paralyze the worms, allowing them to be passed out by the intestinal peristalsis of the host. If relief of the obstruction is not obtained within 1-2 days, a surgical procedure may be necessary, as in the other complications caused by migratory *Ascaris* worms. Approximately 20,000 people die from *Ascaris* infection each year, but given that one-quarter of the world, or 1.5 billion people are infected, the case-fatality rate is only 0.000013.

Surgery

If a person with an *Ascaris* infection needs anesthesia prior to treatment, the anesthesiologist should be informed because of the remote possibility that the anesthetic agent could cause ectopic worm migration into the trachea, causing respiratory obstruction.

Pregnant and Lactating Women

There are very few controlled data on the use of antiparasitic drugs in pregnancy and lactation. Both mebendazole and albendazole have been shown to have teratogenic potential in animal models. It would be prudent to withhold therapy during the first trimester and to delay therapy as long as possible, ideally until after delivery. There is no evidence for transplacental transmission of roundworm infections in humans. If antiparasitic therapy is inadvertently given during the first trimester of pregnancy, the patient should be advised that there is no consensus on the possible effects of therapy on fetal outcome. These medications have been administered countless times in mass drug administration settings overseas without confirmed harm. Thus, adverse fetal outcome directly related to antiparasitic drugs given during pregnancy is thought to be a very rare but possible occurrence.

If therapy of a lactating woman is contemplated, asking the patient to use mechanical means for milk expression during, and for 48 hours following, antiparasitic therapy would be prudent. In addition to teratogenic considerations, side effects including nausea, vomiting,

malaise, and rare cases of Stevens–Johnson syndrome have been associated with the use of some of the drugs mentioned in this section.

Infants

There are very few controlled data on the use of antiparasitic drugs in infants <2 years of age. In a severely ill infant, in whom the presence of parasites is thought to contribute to the disease process (intestinal obstruction due to ascarids, severe anemia due to hookworm, etc.), the possible risks of antiparasitic therapy must be weighed against the effects of the untreated infection, and the dosage of the appropriate drug adjusted for weight.

Altered Immune States

Disseminated strongyloidiasis ("strongyloides hyperinfection syndrome"), a potentially untreatable and fatal development, has been reported in patients with chronic underlying illnesses (diabetes, alcoholism, and human T-lymphotropic virus type 1 infection), in patients being treated with immunosuppressive drugs (corticosteroids, transplant immunosuppressants, cancer chemotherapeutic agents) or radiation therapy, and in patients with malignancy, particularly lymphoma and leukemia. The tiny strongyloides worms can disseminate to all the major internal organs, including the liver, lungs, heart, and central nervous system. Along with consideration of *Pneumocystis* and *Toxoplasma* infections, disseminated *Strongyloides* infection should be considered, especially in the case of immunocompromised patients who develop bilateral pulmonary infiltrates, sepsis, or polymicrobial bacteremia with gastrointestinal bacteria.

It is important to consider the diagnosis in asymptomatic patients from high-risk geographic areas and to immediately treat those who have positive stool examinations or unexplained hypereosinophilia and positive *Strongyloides* serologies. Serology is not entirely reliable; thus, regardless of results, high-risk patients should be treated empirically for *Strongyloides* with ivermectin before corticosteroid therapy, cancer chemotherapy, or radiation therapy is instituted. Frustratingly, many patients with *Strongyloides* hyperinfection do not have peripheral eosinophilia, and results of serology may take days to return; examination of sputum or bronchial lavage fluid may reveal larvae much more quickly. If parasite dissemination in a compromised host is believed to have occurred (usually diagnosed on the basis of tissue biopsy or sputum specimens), treatment with the appropriate dosage of ivermectin may be extended to ≥5 days. Subcutaneous ivermectin has been used for hyperinfection, although the evidence for this practice is poor and there is no form of this drug approved by the US Food and Drug Administration.

Another phenomenon described in immunocompromised patients and associated with disseminated *Strongyloides* infections is recurrent polymicrobial bacteremia with enteric bacteria. The bacteria are thought to stick to the cuticle of worm and to gain access to the circulation when *Strongyloides* larvae migrate out of the gut.

Chronic Strongyloides *Infections*

Infections persisting for >30 years are possible because of an autoinfective cycle, in which eggs laid by mature worms in the proximal small intestine hatch in transit with the fecal stream. The resulting rhabditiform larvae undergo maturational changes, becoming infective filariform larvae by the time they reach the rectum. These are capable of exiting from the anus and perforating the skin in the perianal area, buttocks, and upper thighs, thus initiating a new cycle of infection. Local rashes (larva currens) and perianal itching may be the presenting complaints. Among former Allied prisoners of war who worked on the Burma–Thailand railroad during the Second World War, rates of infection were found 30-40 years later to be 21-37%. Two-thirds of these former POWs had episodic, recurring symptoms. Diagnosis and treatment are the same as for more acute infections with *Strongyloides*.

Pinworm

Pinworm is probably the most common worm infection in the United States, occurring mainly in school-aged children (via anus–finger–mouth transmission) and their families (via

TABLE 45.3 Prevalence of Intestinal Nematodes in Rural Regions (%)

	Ascaris lumbricoides	*Trichuris trichiura*	Hookworm
China	63	60	87
Vietnam	83	94	59
Ethiopia	29-38	13	7-24
Madagascar	93	55	27
Mali			53 (*Necator americanus*)
Brazil	41	40	
Paraguay			59
Venezuela	27	33	6

Note: Additionally, studies on Pemba Island, Tanzania, and Barru district, Sulawesi, Indonesia, showed that 58% and 17.4%, respectively, of inhabitants were infected with all three of the above parasites.

household environmental transmission through dust and fomites). Pinworm infections have been linked to increased risk of urinary tract infection in young girls. Rarely, pinworm infection may cause appendicitis or peritonitis. In addition to antiparasitic therapy (**Table 45.3**), keeping fingernails trim and scrubbed, stopping thumb-sucking, thorough house cleaning, and washing of underclothes and bedclothes in hot soapy water will contribute to breaking the transmission cycle.

Other Roundworms

A. suum, the roundworm of pigs, is infective for humans and is grossly indistinguishable from the roundworm of humans, *A. lumbricoides*. Environmental contamination with pig excrement may account for acquisition of the common roundworm in patients who report no significant travel history. Anisakiasis (caused by marine roundworm) will be covered separately below.

Other Hookworm Species

Hookworm species other than *A. duodenale* and *N. americanus* (most commonly *Ancylostoma braziliense* and *Ancylostoma caninum*) can infest human skin but cannot penetrate deeper to continue their life cycle in humans. This aggravating condition, a leading dermatosis transmitted in the developing world, is called cutaneous larva migrans. It is discussed in Chapter 37.

Mass Drug Administration

In situations where solving sanitation problems is not feasible, scheduled treatment of whole populations may be appropriate. A study in a highly endemic area in Bangladesh found that mass chemotherapy with albendazole at 18-month intervals was superior to two regimens that involved health education. However, the cost/benefit analysis of targeted community mass drug programs is still an active topic of analysis and discussion. There are numerous published studies trying to assess the association of mass drug administration programs with markers of pediatric growth and development: stunting, cognitive performance, and micronutrient deficiencies (e.g., iron deficiency, vitamin A deficiency). Multivariate analysis of published studies suggests that future studies need to be done with an attempt to standardize age groups studied, measure pre-intervention parameters, ascertain the intensity of STH infection and efficacy of the antihelminthic drug(s) used, and standardize environmental factors (e.g., diet, tap water, latrines, maternal education) so valid comparisons and conclusions may be made.

ANISAKIASIS

Anisakiasis is a gastrointestinal illness occurring when humans are infected with larval forms of marine ascarids, or roundworms belonging to the family Anisakidae, most commonly

Anisakis simplex and *Pseudoterranova decipiens*. The larvae are present in the flesh of many market fish, including salmon, chum, mackerel, cod, pollock, herring, whiting, bonito, sole, pike, and squid. Man becomes infected by eating raw, pickled, or lightly salted fish. The larvae (third stage) are present in the muscles and visceral organs of the fish and can survive 51 days in vinegar, 50 days at 2° C, 6 days in 10% formalin at room temperature, and about 2 hours at −20° C. The larvae are killed in seconds at 60° C. The larvae are 18-36 mm in length and 0.24-0.69 mm in width.

Epidemiology

The disease was first recognized in the 1950s in Holland among people eating raw (green) or lightly pickled herring and was called "green-herring" disease. Thousands of cases have been reported from Japan, where raw or pickled marine fish dishes are consumed (e.g., sushi, sashimi, sunomono, and vinegared salads). Fewer cases have been reported from the United States and other countries. Gastric anisakiasis is the most common presentation in Japan, whereas in Europe and elsewhere, intestinal anisakiasis is the most common form.

The parasite's definitive hosts are marine mammals: *Anisakis* spp. infect Cetacea (whales, dolphins) and *Pseudoterranova* infects Pinnipedia (seals, sea lions, walruses). The adult parasites living in the stomach of these animals lay eggs, which exit in the feces and hatch in seawater. The larvae are eaten by squid, crustaceans, and other macro-invertebrates, which in turn are eaten by fish. Marine mammals then eat the fish, completing the life cycle. If man eats the fish or squid, the larvae cannot reach sexual maturity, and they never lay eggs.

Clinical Presentation

1. *Gastric anisakiasis* is an acute illness occurring 1-12 hours after the ingestion of raw seafood, with the sudden onset of severe stomach pain, nausea, and vomiting. In >50% of cases, there is a peripheral blood eosinophilia of up to 40% without a marked leukocytosis; in 70% of cases, occult blood is found in gastric juices and stools. Anaphylactoid reactions are common; arthralgia and arthritis occur rarely. Untreated infections usually become chronic, with similar manifestations lasting for >1 year. Penetrating lesions, abscess formation, or granulation may occur at the site of larval attachment to the stomach.
2. *Intestinal anisakiasis* is a more chronic disease. Severe pain in the lower abdomen, nausea, vomiting, fever, diarrhea, and occult blood in the stools begin about 1-5 days after ingestion of raw seafood. Marked leukocytosis with no or mild eosinophilia may be present. Over months, occasionally for years, infiltrative and mass lesions of the intestinal tract occur, with continued cramping, abdominal pain, diarrhea, and dysmotility. Perforation of the intestine, abscess formation, and granulation may occur at the site of the infection.

Diagnosis

The history of eating raw fish is the most important historic finding. While immunologic methods of detecting specific antibodies against *Anisakis* (cutaneous skin prick with *A. simplex* extract, and ELISA) may support the diagnosis of anisakiasis, usually the diagnosis is made by upper endoscopy. The histology of lesions in specimens from biopsy or resection is characterized by an eosinophilic granulomatous inflammation; the finding of characteristic larvae in cross section within the tissue confirms the diagnosis.

The gastric form is often misdiagnosed as ulcer, cancer, tumor, polyp, or food poisoning, while the intestinal form has been misdiagnosed as regional enteritis or appendicitis.

Treatment

Antiparasitic drugs appear to be ineffective. If the larva is seen during gastroscopy, it can be removed during the procedure. In chronic disease, surgical resection of the affected part may be necessary.

Prevention

Reinfections with additional larvae can occur in acute or chronic *Anisakis* infections. The best prevention is to avoid raw, undercooked, or lightly pickled marine fish and squid. If

raw fish is eaten, it should be frozen at −20° C for at least 24 hours; otherwise, it should be thoroughly cooked to a temperature of 60° C.

FURTHER READING

Behnke, J.M., De Clercq, D., Behnke, J.M., et al., 2000. The epidemiology of human hookworm infections in the southern region of Mali. Trop. Med. Int. Health 5, 343–354.

Booth, M., Bundy, D.A., Albonico, M., et al., 1998. Associations among multiple geohelminth species infections in schoolchildren from Pemba Island. Parasitology 116, 85–93.

Changhua, L., Xiaorong, Z., Dongchuan, Q., et al., 1999. Epidemiology of human hookworm infections among adult villagers in Hejiang and Santai Counties, Sichuan Province, China. Acta Trop. 73, 243–249.

Corrales, L.F., Izurieta, R., Moe, C.L., 2006. Association between intestinal parasitic infections and type of sanitation system in rural El Salvador. Trop. Med. Int. Health 11, 1821–1831.
Community sanitation methods can affect the prevalence of geohelminths.

Duedu, K.O., Yarnie, E.A., Tetteh-Quarcoo, P.B., et al., 2014. A comparative survey of the prevalence of human parasites found in fresh vegetables sold in supermarkets and open-aired markets in Accra, Ghana. BMC Research Notes 7, 836. Available at <http://www.biomedcentral.com/756-0500/7/836>.
Fresh vegetables sold in the open-aired markets in Accra were contaminated with multiple infective parasite forms and were more contaminated than vegetables sold in supermarkets.

Fawzi, M., El-Sahn, A.A., Ibrahim, H.F., et al., 2004. Vegetable-transmitted parasites among inhabitants of El-Prince, Alexandria and its relation to housewives' knowledge and practices. J. Egypt. Public Health Assoc. 79, 13–29.
A minority of housewives in Alexandria employed methods to wash vegetables that would decrease parasite contamination.

Geisslet, P.W., Mwaniki, D., Thiong'o, F., et al., 1998. Geophagy as a risk factor for geohelminth infections: a longitudinal study of Kenyan primary schoolchildren. Trans. R. Soc. Trop. Med. Hyg. 92, 7–11.
Among the Kenyan children studied, 77% of them ingested soil daily.

Jemaneh, L., 1998. Comparative prevalences of some common intestinal helminth infections in different altitudinal regions in Ethiopia. Ethiop. Med. J. 36, 1–8.

Khatun, M., Naher, A., 2006. Prevalence of soil transmitted helminth infections among Bangladeshi males seeking jobs abroad. Mymensingh Med. J. 15, 159–162.
In this population, residents from rural agricultural areas had a greater prevalence of intestinal parasites compared with urban dwellers.

Khurana, S., Aggarwal, A., Malla, N., 2005. Comparative analysis of intestinal parasitic infections in slum, rural and urban populations in and around union Territory, Chandigarh. J. Commun. Dis. 37, 239–243.
In this study, inhabitants of slums had the highest rate of intestinal parasitic infections, illustrating that crowding with unsanitary conditions and lack of access to sanitary disposal of feces serve as significant risk factors in parasite transmission.

Kightliner, L.K., Seed, J.R., Kightlinger, M.B., 1998. *Ascaris lumbricoides* intensity in relation to environmental, socioeconomic, and behavioral determinants of exposure to infection in children from southeast Madagascar. J. Parasitol. 84, 480–484.

Labiano Abello, N., Canese, J., Velazquez, M.E., et al., 1999. Epidemiology of hookworm infection in Itagua, Paraguay: a cross sectional study. Mem. Inst. Oswaldo Cruz 94, 583–586.

Morales, G., Pino, L.A., Artega, C., et al., 1998. Relationships in the prevalence of geohelminth infections in humans from Venezuela. Bol. Child. Parasitol. 53, 84–87.

Needham, C., Kim, H.T., Hoa, N.V., et al., 1998. Epidemiology of soil transmitted nematode infections in Ha Nam Province, Vietnam. Trop. Med. Int. Health 3, 904–912.

Pelletier, L.L., Jr., 1984. Chronic strongyloidiasis in World War II Far East ex-prisoners of war. Am. J. Trop. Med. Hyg. 33, 55–61.
Fascinating report on strongyloidiasis persisting for decades in veterans after exposure in an endemic area.

Pham-Duc, P., Nguyen-Viet, H., Hattendorf, J., et al., 2013. *Ascaris lumbricoides* and *Trichuris trichiura* infections associated with wastewater and human excreta use in agriculture in Vietnam. Parasitol. Int. 62, 172–180.
Contact with polluted river water and the use of human excreta as a fertilizer were associated with increased risk of helminth infections. Access to tap water in households was associated with a significant decrease in infection with both A. lumbricoides *and* T. trichiura.

Pinkus, G.S., Coolidge, C., Little, M.D., 1975. Intestinal anisakiasis. First case report from North America. Am. J. Med. 59, 114–120.
Provides a brief history of the recognition of human disease due to anisakiasis; eating raw or undercooked salmon was the risk factor in North America.

Quihui, L., Valencia, M.E., Crompton, D.W., et al., 2006. Role of the employment status and education of mothers in the prevalence of intestinal parasitic infections in Mexican rural schoolchildren. BMC Public Health 6, 225.
Children of employed and educated mothers had fewer intestinal parasites in rural Mexico.

Salam, R.A., Haider, B.A., Humayun, Q., 2015. Effect of administration of antihelminthics for soil-transmitted helminths during pregnancy. Cochrane Database Syst. Rev. (6), CD005547, doi: 10.1002/14651858.XD5547.pub3.
Multivariate analysis showing there is not enough evidence at the time of the study to demonstrate benefit resulting from the administration of anthelmintic drugs during pregnancy.

Saldiva, S.R., Silveira, S.A., Philippi, S.T., et al., 1999. *Ascaris–Trichuris* association and malnutrition in Brazilian children. Paediatr. Perinat. Epidemiol. 13, 89–98.

Suchdev, P.S., Davis, S.M., Bartoces, M., et al., 2014. Soil-transmitted helminth infection and nutritional status among urban slum children in Kenya. Am. J. Trop. Med. Hyg. 90, 299–305.
A cross-sectional survey of pre-school and school-aged children, of whom approximately 40% were infected with soil-transmitted helminths (STH), primarily Ascaris *and* Trichuris. *Multivariate analysis showed no significant association between STH and anemia and stunting in both study groups but did show a significant association between STH and iron-deficiency anemia and vitamin A deficiency in the pre-school children. This suggests that community treatment programs against STH and provision of micronutrient supplementation might be more advantageous in the pre-school population.*

Taylor-Robinson, D.C., Maayan, N., Soares-Weiser, K., et al., 2015. Deworming drugs for soil-transmitted intestinal worms in children: effects on nutritional indicators, haemoglobin, and school performance. Cochrane Database Syst. Rev. (7), CD000371.
Challenges the common belief that administration of deworming drugs is solely responsible for significant improvements in nutritional indicators, haemoglobin, and school performance. Observed benefits among children studied in mass drug administration programs against soil-transmitted helminths are multifactorial and may involve nutrient supplementation, maternal education, improved sanitation practices, and addressing concurrent infectious diseases in the community (e.g., diarrheal diseases and vaccine-preventable diseases), as well as antihelminthic drugs.

Toma, A., Miyagi, I., Kamimura, K., et al., 1999. Questionnaire survey and prevalence of intestinal helminthic infections in Barru, Sulawesi, Indonesia. Southeast Asian J. Trop. Med. Public Health 30, 68–77.