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Global Incidence of Neglected Intestinal Parasites - A Perspective

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Infection diseases (IDs) caused by bacterial, viral, helminth, and protozoan parasites have been a factor in shaping the course of human societies. One fourth of the know human IDs are caused by the helminth/protozoan group. Refernces to human parasites such as *Ascaris lumbricoides* and *Enterobius vermicularis* are found in biblical and medieval writings (Cleaveland, et al. 2001). *Ascaris* eggs have been detected in the archeological sites all over the globe. During 12th and 13th centuries Crusaders armies suffered from repeated gastroenterities outbreaks due to *Giardia* and Entamoeba, which was a major reason for their retrieval / retreat from Palesttine (Piers, et al. 2008). Intestinal parasitic diseases have conventionally been associated with underdeveloped socities; however, developed countries are not competely free of these parasitic infestations. Populations in different parts of the world face diverse parasitic challegnes for example. *E. vermicularis* is more prevalent in temperate area (Vermund and Wilson, 2000) and *A. lumbricoides* reported in China, southeast Asia, coastal regions of West Africa, and Southeast Asia. Hookworm infections are most common in sub-Saharan Africa, South China, and Southeast Asia (Figure 1 and 2.)

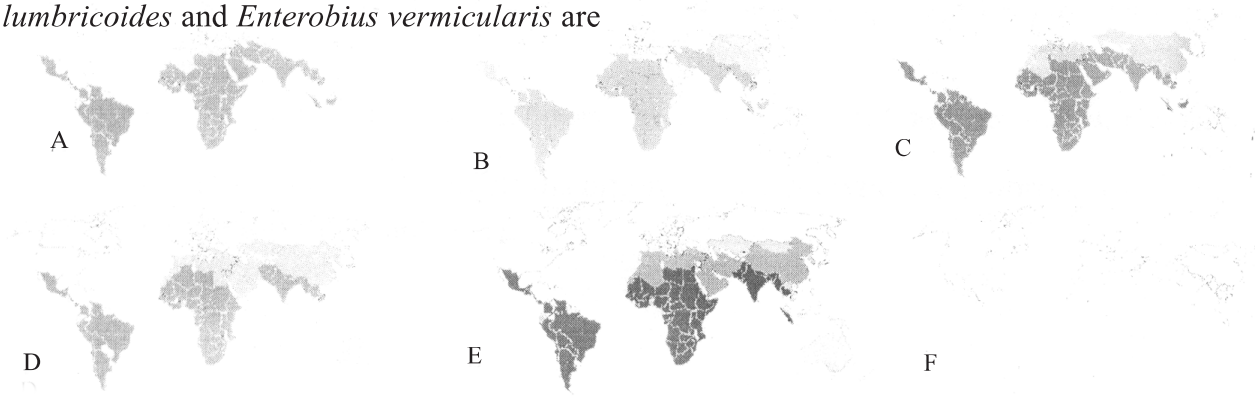

Figure 1. Global prevalence of major helminthic parasites

A - Cryptoporidium B - Hookworm C - Pinworm
D - Ascaris E - Trichuris F - Giardia

Color intensity shows the prevalence rates (dark color = > 5%; medium color 1-5%; light color = 0-1%)

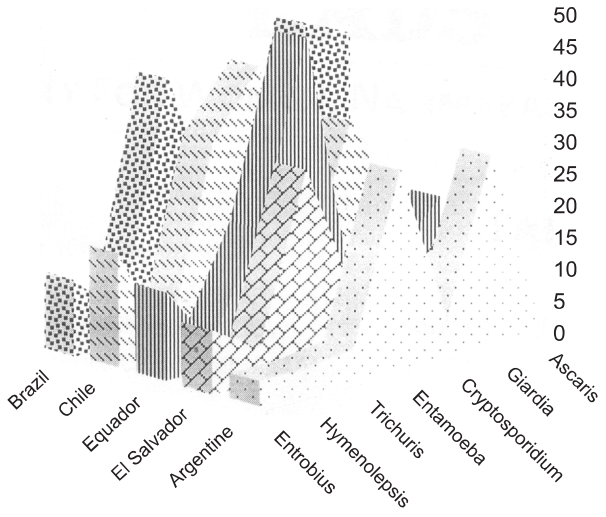

Figure 2. Parastic disease frequencies in Central and South America: Based on Wang and Bund (1990).

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North America and Western Europe

Intestinal parasites have prevalent in the "New World" for ages. In Brities Columbia, Canda 60% (9/15) of sites known for fossilized evidence of intestinal parasites tested positive for human roundworm eggs, yielding a total of 77 eggs of *A. lumbricoides*. Results of archaeoparasitological studies indicate that areas around the polar regions had widespread tapeworm infestation during pre-histroric times. Despite improved hygiene conditions, intestinal parasites still have a high incidence rate in the U.S. and the historical trend of intestinal infections in the New World has not changed much (Horne, 1985). Intestinal parasite infections have been reported in both urban and rural areas. In industrialized countries the prevalence of intestinal parasites such as *Giardia* ranges from 2% to 5% (Meyer, 1985; Ortega and Adams, 1997; Ali and Hill, 2003).

It was reported that infections with *Entamoeba coli, E. histolytica, E. hartmanni, G. lamblia,* and *Diphylllobothrium* are still common in a broad range of the population in Labrador, Canada (Sole and Croll, 1980). In the Tornoto metropolition area, intestinal parasites have been reported in 14% of the staff members and 19% of the children attending day care centers (DCCs) *Dientamoeba fragilis* was the most common parasite, with and 8.6% and 4.0% infestation rate among children and staff, respectively. *G. lamblia* was most frequently detected in the6-year-olds and the rate of infestation amoung children and staff was 7.8% and 2.0% respectively (Keystone, et al. 1980).

Day care centers in the U.S. also present a similar picture. In one study 16% of children attending DCCs in the Colorado area tested positive for *G. lambila* (Novotny, et al. 1990). Millet and other (1983) studied the prevalence of protozoan parasite in a large semicommunal group in Los Angeles (Millet, et al. 1983). Stool samples from 76% (105/138) of the children and 56% (46/82) of hte adults tested positive for protozoan parasites. *D. fragilis* (52%) was the most common parasite followed by *G. lamblia* (23%) and *E. histolytica* (4%). In terms of age, 2-4 year-olds (89%) had the highest rate of incidence followed by 8-15 year-olds (78%) and adults (56%). *G. lamblia* was most prevalent in children younger than 6 years. In a cross-section of high-income Americans, 20% are infected with intestinal parasites and an estimated 50% of the population on India reservations is infected with intestinal parasite (Healy, et al. 1969; Clark, 1995; Weintraub, 2000). According to the recent data, Giardiasis is one of the most common parasitic disease in the U.S., with more than 15,40 cases reported during 2005 (CDC, 2006).

In European countries, similar trends in parasitic infestation have been reported. In Spain, *Cryptosporidium* and *Giardia* infestations are common among children attending day care centers, with infestation rates of 10% and 25.3%, respectively (Rodriguez-Hernandez, et al. 1996). In the UK, Strategic Health Authorities studied the prevalence of cryptosporidiosis in children and reported and increase in the parasite's incidence rate during the 1990s. They concluded that for every diagnosed case, these are 15 undiagnosed cases within the community. They estimated 64,000 *Cryptosporidum* cases per year (rage 45,000-88,000) over the last ten year.

The Developing World

Developing countries of the world are particularly impacted by parasitic diseases. The high incidence is associated with public sanitary conditions, availability of clean water and food, lack of health education, and personal hygience

practices, in addition to the variation in geopraphical/ecological conditions. In general, no geographical location on our globe is exclusive to parasitic invasion. However, we can see changes in parasitic disease complexes as we move from tropical to emperate regions on different continents.

Turkey: Turkey is located at the juncture of Asia and Europe and it manifests parasitic disease characteristics of bothe countinents. A study comparing the parasitic infection rate in school children in the shantytown, apartment, and rural districts found that the prevalence of helminthic infections was 77.1, 53.2, and 53.31% in the respective districts. *A. lumbricodies* was the most prevalent species followed by *T. trichiura, H. nana,* and *Taenia* species (Ulukanligil and Seyrek, 2003). In another study, Aksoy and others (2007) examined the prevalence of intestinal parasitic infections in school children in Izmir, Turkey (Aksoy, et al. 2007). They reported that stool samples from 33.4% of students had one or more parasites. The most common parasite was *B. hominis* (14.6%), followed by *E. vermicularis* (10.1%) and *G. intestinalis* (7.8%). Multiple parasitic infections were more prevalent in crowded families (either extended or with many children). The probability of parasitic infection in school children in the shantytown group was significantly higer ($p<0.05$) than in the apartment group, which can be associated with poor hygienic conditions in shantytowns. Celi-Kosz and others (2005) studied the infection rate of *E. vermicularis* and *Taenia* in primary school children in Sivas, Turkey (Celi-Kosz, et al. 2005). Among the 2,029 students, 3166 (15.6%) were positive for *E. vermicularis* eggs and 32 (1.6%) were positive for *Taenia* spp. eggs. *E. vermicularis* was more prevalent in the urban slum regions (18.7%) than in the urban central regions (11.5%).

South America

Central and South American countries have high incidence rates of intestinal parasites (Fingure 2). Wang and Bund (1990) studied different localities for spatial and temporal dynamics of soil contamination with geo-helminth eggs (Wang and Bund, 1990). They found that homes which had higher human infection levels also had a higher prevalence and density of eggs in soil.

Mexico: In Mexico, the overall prevalence rate of intestinal parasites is 67%, out of which 60% of cases are due to multiple parasites, *E. histolytica/E. dispar* (51.2%) is the most common protozoan parasite, followed by *G. lamblia* (18.3%). Amongst helminthic Chiapas has the highest death rate due to infections intestinal diseases (23.9) per 100,000).28 Similar infestation rates have been reported previously (Direccion General de Estadistica e Informatica,Secretaria de Salud, Mexico, 2000).

Equatorial Guinea: Roche and Benito (1999) studied the prevalence of intestinal parasites among rural home dwellers (n=557) and patients (n=1633) at the General Hospital of Malabo, Equatorial Guinea (Roche and Benito, 1999). The most common parasite with average prevalence in rural and urban areas, respectively, was *A. lumbricoides* (45.8%) and (31.4%) respectively, followed by *T. trichiura* (25.7%) and (36.4%), *E. histolytica/E.dispar* (14.9%) and (32.7%), and *G. lamblia* (7.2%) and (8.6%). It apperars that parasitic infections in Equatorial Guinea are a major health problem. In the rural areas, children between 5 ages and 14 have the highest rate of intestinal parasite infestation, whereas adults had the highest rate of intestinal parasite infestation amoung the subjects visiting the hospital.

Asia and Africa

Pakistan: Intestinal parasites are one of the major health concerns, especially in the rural areas, of Pakistan. Rural areas (e.gs., Gadap District) around East Karachi, the biggest metropolitan area in Pakistan, have high (47%) parasitic infestation rates. *G. lamblia* is the most common parasite (50%) followed by *E. histolytica* (48%) (Siddiqui, et al. 2002). A cross-sectional observational study in a neighboring urban area revealed lower infestation rates, with *G. lamblia* (14.7%) as the most prevalent intestinal parasite, followed by *E. histolytica* (8%). *A. lumbricoides* (8%), *Hymenolepis nana* (4.7%), and *Cryptosporidum* (2%) (Shoaib, et al. 2003; Bughra, et al. 2004).

In rural areas around Lahore, the second biggest metropolitan area in Pakistan, 44.7% of young children are infested with geo-helminths. *A. lumbricoides* (60.53%) is the most common parasite, followed by *T. trichiura* (42.10%). Children in the 2-8 year age group have the highest rate of helminthic infestation and 25% of the adults in the surrounding areas are infested with hookworms (Hafeez,et al. 2003). In Pakistani children, intestinal parasitic infestation is a major cause of hemoglobin deficiency and low packed cell volume of blood (Anjum, 2006; Ajnum, 2007).

In northern areas of Pakistan 91% of children (less than 15 years of age) were found to be infested with one or more parasites (Waqar, et al. 2003). Intestinal helminths (55.33%) are more prevalent than protozoa (19.33%). The most common infestation is of *A. lumbricoides* (35-66.3%). Other common parasites include *T. trichiura* (9.3-15.7%), *E. histolytica* (8-27%), and *G. lamblia* (3.45-26.96%) (Hussain, et al. 1997; Khan, et al.2004). Similar infestation trends have been reported from Islamabad (Pal and Rana, 1983; Tanwani, et al. 1995). and Quetta (Wadood, et al. 2005).

Bangladesh: In the northern part of Bangladesh, 53% of the population is infected with intestinal parasites. Ascariasis has the highest prevalence rate (36.2%) followed by hookworm (10.7%) (Hosain, et al. 2003). In rural communities, the gross prevalence of intestinal parasites has been reported at 33%. The highest prevalence rate (40%) was found among the 16-36 year age group followed by age group>36 (27.6%) and 12-15 (26.9). *A.lumbricoides* was the most common parasite followed by *A. duodenalis, E. histolytica, G. lamblia,* and *E. vermicularis* (Hyder, et al.1998). Haque *et al.,* (2003) studied the epidemiology and causative agents of diarrhea in school children in Dhaka, Bangladesh. *E. histolytica* was detected in 8.7% of dysenteric stool samples (Haque, et al. 2003).However, *Giardia* has a much higher infection rate (18%) in the general population, and *Giardia* assemblage B is the more prevalent genotype in Dhaka (Haque, et al. 2003).

India: In Northern India, overall prevalence of intestinal parasites ranges from 12.5% to 66% with varyig prevalence rates. In rural areas, 97.4% of the population is infested with one or more parasites, In those areas, the majority of cases (74.3%) involve infection with multiple parasites (Singh, et al. 1993). In general, infections with helminths were more prevalent compared to protozoa. *Giardia* (53.8%) and hookworm (61.5%) were the most common etiological agents among protozoa and helminths, respectively (Kang, et al. 1998).

India has one of the highest incidence rates of immunodeficiency virus (HIV) in the world (Steinbrook, 2007). Among the HIV positive patients, common parasitic infections include *C. parvum* (10.8%), *G. lamblia* (8.3%),

Cyclospora cayetanensis (3.3%), *Balstocystis hominis* (3.3%), *Isospora helli* (2.5%), and *Enterocytozoon bieneusi* (2.5%) (Mohandas, et al. 2002).

China: High prevalence of intestinal parasites in rural China (62.6%) has been reported (Yu, et al. 1994). In semi-urban areas, 51.7% of the population is infected wtih enteric parasites, 51.7% and 12.7% of which are infested with two parasites. *A. lumbricoides* (41.4%) is the most common parastie, followed by *Ancylostoma duodenale* (17.7%), *T. trichiuria* (8.25%), *B. hominis* (1.37%), *Entamoeba coli* (0.47%), *E. vermicularis* (0.43%), *E. histolytica* (0.16%), *G. lamblia* (0.04%), *Strongyloides stercoralis* (0.04%), and *Clonorchis sinensis* (0.04%) (Tang and Luo, 2003). In Yunnan province the prevalence of *A. lumbricoides, Taenia* spp., *T. trichiuria.* and hookworms was 15.4%, 3.5%, 1.7% and 0.3% respectively (Steinmann, et al. 2007).

Malaysia: Sinniah (1984) reported that 86.3% of the school children from the rural areas in Malaysia are infected with one or more intestinal parasites (Sinniah, 1984). *T. trichiura,* with a 74.2% incidence rate, is the most prevalent parasite followed by *A. lumbricodies* (41.7%), hookworm (28.0%), *Entamoeba coli* (8.9%), and *G. lamblia* (8.5%). No significant difference in the infection rates for male (87.3%) and female (85.6%) students was noted.

Israel and Palestinian territories: Study of intestinal parsites in Israel and Palestinian territories provides a good insight into the effect of improved personal hygiene and sanitation. In Israel, incidence rates of intestinal parasites among the Jewish population in Jerusalem significantly declined during the 1950s and 1960s (Ben-Ari, 1962). This period of decline of intestinal parsites coincides with the period in which wastewater use for irrigation was becoming popular in Israel (Katzenelson, et al. 1976). The decrease in the incidence of intestinal parasite was achieved by stopping the supply of contaminated vegetables. Contrary to the Israeli experiment, conditions in Palestinian territories have not changed over the years. El-Astal (2005) studied the prevalence of intestinal parasites amoung children in Khan Younis Governorate, Gaza Strip, and Palestinian Authority (El-Astal, 2005). He reported that 32.4% children were infected with one or more intestinal parasites. *Enterobius vermicularis* was found to be the most common parasite (20.9%) followed by *A. lumbricoides* (12.8%), *G. lamblia* (8.0%). *E. histolytic* ((7.0%), *E. coli* (3.6%), *T. trichiura* (1.6%), and *H. nana* (1.0%) (El-Astal, 2005).

Saudi Arabia: In southwestern Saudi Arabia 24.4% of school children were infected with one or more species of intestinal protozoa and helminths. *G. lamblia* (10.9%) was the most common parasite followed by *E. histolytica* (4.1%). The intestinal helminths commonly detected in stool samples included *H. nana. A. lumbricoides, T. trichiura, Schistosoma mansoni and D. dendriticum* (Omar, et al. 1991). Among the patients (1-15 years) at medical centers in Riyadh, the most common etiological agents were *E. histolytica* (8.8%) and *G. lamblia* (6.3%). The other commonly detected intestinal parasites included *A. lumbricoides, T. trichiura. S. mansoni, S. hematotium, H. nana, A. duodenale, E. vermicularis* and *Taenia saginata* (Abdel-Hafez, et al. 1986).

Morocco: Moubarrad and Assobhei (2007) compared the incidence of Ascariasis among groups of children living near the area of wastewater effluents and far from the discharge area and reported incidence rates of 18.1 and 1%, respectively (Moubarrad and Assobhei,

2007). Boys between the ages of 7 and 10 appeared to be the most vulnerable to Ascaris infection. This study demonstrates that proximity to untreated wastewater significantly increases the risk of parasitic infection.

Kenya: Olsen (1998) studied the prevalence of parasitic infections in Kisumu District Western Kenya (Olsen, 1998). Overall prevalence of hookworm, *A. lumbricoides, T. trichiura*, and *S. mansoni* infections were 63%. 16%, 24%, and 24%, respectively. He reported that non-enrolled school-aged children and preschool children represent more than halt of the helminth-infected segment of the population and they excrete between half and 85% of the total burden of helminth eggs in the study area. He concluded that mass chemotherapy of school children would be less effective in the control of at least hookworm and *S. mansoni* infections in this specific community. Instead he suggested using sanitation and personal hygiene based approaches for controlling helminthic infections.

South Africa: African countries also have high incidence rates of intestinal parasites. Adams *el al.,* (2005) studied the relationship among gender, age, schooling, and overall prevalence of helminthiasis and giardiasis in a low-income but well-serviced community in Cape Town. South Africa (Adams, et al. 2005). They reported the overall geo-helminth infection rate to he 55.8%. *Trichuris* was found to be the most common parasite (50.6%) followed by *Ascaris* (24.8%), *Giardia* (17.3%). *H. nana* (2.2%), *Enterobius* (0.6%). *Trichostrongylus* (0.1 %). and hookworm (0.08%). They concluded that in the old community of Cape Town. contaminated food or water is the major source of infection rather than exposure to polluted soil.

Australia

In urban Australia. cases of intestinal helminthic infections are occasional: however. the incidence rates of these parasites in Australian Aboriginal comunities are similar to those in developing countries. Pinworm is the most common nematode parasite among all populations of rural communities. In general. infections with tapeworms are less frequent. with the exception of flymenolepis, which is prevalent in Aboriginal communities (Procir, 2001). Among urban populations, enteric protozoa are more prevalent (52.k/o) among men who have sex with men (MSM). The parasites most commonly detected among MSM include *Blastocystis hominis, Endolimax nana, Entamoeba histolytica/dispar* complex, *Entamoeba hartmanni, lodamoebo butschlii,* and *Enteromonas hominis* (Stark, et al. 2007).

TRAVEL AND INTERNATIONAL TRADE

Globalization has emerged as a new paradigm in different facets of human life and infectious disease transmission is no exception. It has shattered the myth of the developed world as an "*island isolaledfrom wormy world.*" International travel is an indication of this changing world. People who travel frequently have a greater chance of exposure to infectious diseases not known of encountered by those living in their own region. Besides risking their own health. they can compromise public health by transmitting the Infectious agents along their entire route. In this age of rapid and frequent travel, there is a greater than ever need to control the spread of infectious diseases.

An estimated 1.4 billion people travel internationally by air each year compared to 5 million in 1950 (Paci, 1995). It is estimated that 40% of travelers visiting developing countries suffer from traveler's diarrhea (Ericsson, 1998). and a significant part of those suffer from parasites such as *Cryptosporidium and Giardia*

(Okhuysen, 2001).

In a study conducted in the UK, stool samples of 989 children (3-18 years) who spent a period of 2 to 12 months abroad were examined for intestinal parasites (Figure 3). The subjects who traveled to and returned from the Indian sub-continent had higher rates of intestinal parasite infections compared to the children who traveled to other parts of the world (Joanes and Srivastav, 1984). A later study reported that feces of 22% (86/391) of children and 36% (31/85) of adults were positive for ova/cysts. Parasitic attack rate was almost twice as high (4004) in travelers in comparison to new immigrants (22%), which might he due to reduced immunity in people living in improved sanitary conditions. The most frequent parasite detected was *G. lamblia* followed by *T. trichiura* (whipworm), *A. lumbricoides* (roundworm), *A. cluodenale* (hookworm), *H. nana*, and *E. histolytica* (Chattopadhyay and Fricker, 1988). The higher incidence rate of Giardia might he due to acuteness of the disease compared to the other parasites reported in the study. Furthermore, the data from these studies does not reflect the infestation rates of the countries studied. A sampling bias can not be ruled out due to the ethnicities of participating physicians and investigators because the selection of family doctor is generally influenced by ethnicity.

LIFE/SURVIVAL OF LIFE CYCLE/SURVIVAL OF OVA/00(CYSTS) IN THE ENVIRONMENT

Intestinal parasites go through successive developmental stages of growth, maturation. and reproduction to complete their life cycles. The continuation and persistence of parasitic protozoa and helminths in the environment depends upon the completion of their life cycles. Their transmission and spread depend, in turn, on their ability at certain stages to infect a new host. These infective stages can be either an adult reproductive form or an intermediate/ immature form. or sometimes both. Depending upon the stages that infect a host can be categorized as a primary host, intermediate host, or alternate host. Most human intestinal parasites can complete their life cycles in their primary host (human). All the intestinal protozoa display a host-to-host cycle (Enterobius and Entamoeba) or a host-to-soil-to-host cycle (Ascaris and Trichuris). The rate at which a parasite can spread is determined by its transmissibility from the source and its incubation period. Intestinal parasites can enter the digestive tract

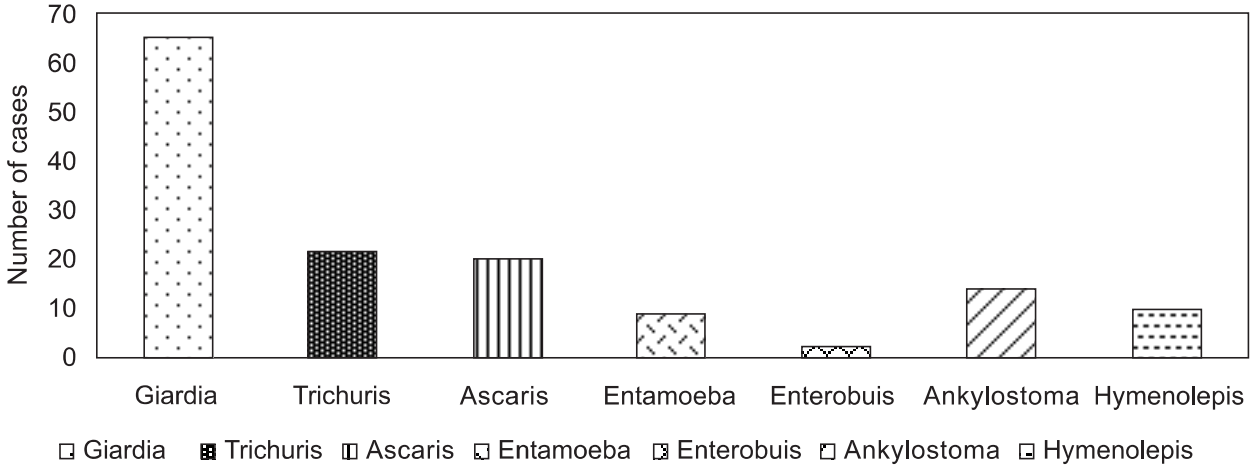

Figure 3. Intestival parasitic infections among travelers who went abroad to visit their relatives in developing countries.

through parasitic ova/oo(cyst)- contaminated food and water or by hands or objects placed in mouth. The gastrointestinal tract acts as a portal of exit and route of entry for these parasites and feces as a transmitting agent. Transmission of infectious parasites can occur in several ways: 1) by direct fecal-oral transmission from person to person via soiled hands, 2) by indirect contact with fecal contaminated objects. 3) by indirect contact with contaminated food and water. 4) indirectly from contaminated soil objects. and 5) through air currents lightweight eggs (e.g.. pinworm) can be wafted on air currents to contaminate food and surfaces (Reinhand, 1985). Parasitic eggs inhaled by the host can he translocated via broncho-cilliary action into the GI tract where they complete their life cycle similar to enteric viruses transmitted by an airborne route (Sattar and Ijaz, 2007). Fecal-oral transmission of these parasites is a result of failure in hand washing following contact with fecal-contaminated animate/inanimate surfaces, including consumption of food and water. The parasitic diseases spread through this route are normally seen spreading among close contacts.

Despite the diversity of enteric parasitic pathogens and ecological zones where they survive, intestinal parasites have a common link—an egg/ova/oo(cyst)—in their life cycle. These structures are very resistant to environmental stresses and help parasites to survive harsh environments. Additionally, these life stages are critical in disease transmission and dissemination of parasites. Environmental conditions enormously influence the survival of eggs/ova/oo(cyst)s, thereby impacting the pattern and incidence of diseases in humans. Malnutrition and crowded, unsanitary living conditions result in a huge burden of parasitic infections.

CONCLUDING REMARKS

The infectious agents are an eternal battle front for human societies. As we are intensifying our war against infectious diseases, the number of new protozoan and helminthic parasites are emerging at a greater rate. The number of agencies and organizations/foundations currently participating in the fight against parasitic diseases are limited and some of these agencies are focused on one or two agents. For example. Human Hookworm Vaccine Initiative, International Trachoma Initiative. Global Alliance to Eliminate Lymphatic Filariasis, African Programme for Onchocerciasis Control and Schistosomiasis Control A few agencies such as Partnership for Parasite Control. Drugs for Neglected Disease Initiative, WHO Programme to Eliminate Sleeping Sickness, and Neglected Tropical Disease Coalition have broader mandate. While the efforts of these organizations to control intestinal parasites in poor countries of developing world are worthwhile, the incidence of such parasites in inner cities and rural/native communities needs a closer look in the developed world. The parasites, such as pinworm. which occur non-acutely are still ignored because of the lack of data on their true occurrence. Therefore, out of the box thinking and strategies need to be used to assess the global occurrence of neglected-intestinal parasites.

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