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Epidemiology of fascioliasis in human endemic areas

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Abstract

Considered a secondary zoonotic disease until the mid-1990s, human fascioliasis is at present emerging or re-emerging in many countries, including increases of prevalence and intensity and geographical expansion. Research in recent years has justified the inclusion of fascioliasis in the list of important human parasitic diseases. At present, fascioliasis is a vector-borne disease presenting the widest known latitudinal, longitudinal and altitudinal distribution. *Fasciola hepatica* has succeeded in expanding from its European original geographical area to colonize five continents, despite theoretical restrictions related to its biology and in turn dependent upon environmental and human activities. Among the different epidemiological situations, human hypo- to hyperendemic areas, including epidemics, are noteworthy. A global analysis of the distribution of human cases shows that the expected correlation between animal and human fascioliasis only appears at a basic level. Areas presenting very high human prevalences and intensities, especially in children and females, have been recently described. In hypo- to hyperendemic areas of Central and South America, Europe, Africa and Asia, human fascioliasis presents a range of epidemiological characteristics related to a wide diversity of environments. Thus far well-known epidemiological patterns of fascioliasis may not always explain the transmission characteristics in any given area and control measures should consider the results of ecoepidemiological studies undertaken in the zones concerned.

Introduction

Two trematode species of the family Fasciolidae, *Fasciola hepatica* and *F. gigantica*, are able to infect and develop in humans. *Fasciola hepatica* is believed to be of European origin, with *Galba truncatula* as the original intermediate host species. In Europe it has been found in prehistoric human populations of the Stone Age, towards the end of the Mesolithic period, 5000–5100 years ago and the Neolithic (Bouchet, 1997; Aspöck *et al.*, 1999; Dittmar & Teegen, 2003), a period marked by the domestication of animals and the development of agriculture. This disease has great expansive powers due to the large colonization capacities of its causal agents and vector species (Mas-Coma *et al.*, 2003). Thus, *F. hepatica* was able to spread and is today present in Europe, Africa, Asia, the Americas and Oceania. On the other hand, *F. gigantica* does not seem to have such a colonization power and its geographical distribution shows a continuum covering Africa and Asia and, to a lesser extent, southern parts of Europe, Turkey, the Near East, and some southern states of the old USSR, particularly Armenia (Mas-Coma & Bargues, 1997). In North America, although sporadically mentioned a long time ago (Price, 1953), *F. gigantica* has not been cited in the past few decades.

Considered a secondary zoonotic disease until the mid-1990s, human fascioliasis is at present emerging or re-emerging in many countries, including increases of prevalence and intensity and geographical expansion (Mas-Coma, 2004). Hence the World Health Organization launched a worldwide initiative against human fascioliasis with particular emphasis on (i) transmission and epidemiology studies, and (ii) control mainly by treatments with triclabendazole (Egaten®), a single-dose highly effective drug. Recent results from this WHO initiative have provided new knowledge which has been

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sufficient to justify the inclusion of fascioliasis in the list of important human parasitic diseases, with estimates of up to 2.4 million (Rim *et al.*, 1994) or 17 million people (Hopkins, 1992) or even higher depending upon the hitherto unknown situations in many countries, mainly in Asia and Africa (Mas-Coma, 2004)

Environmental distribution of fascioliasis

At present, fascioliasis presents the widest latitudinal, longitudinal and altitudinal distribution known among vector-borne parasitic diseases (Mas-Coma *et al.*, 2003), mainly due to *F. hepatica*. This species has succeeded in expanding from its European original geographical area, to colonize five continents, despite the restrictions imposed by its biology which is very dependent upon the environment.

The two-host life cycle of both fasciolid species is similar and comprises four phases: (i) infection of the definitive host, larval migration and liver fluke adult stage development, and shedding of eggs; (ii) transit between definitive mammal and intermediate snail hosts including the long development time of the egg and the short active phase of the miracidium; eggs shed with the mammal faeces will continue their development in freshwater of appropriate physico-chemical characteristics (at a temperature range of 15–25°C); (iii) development in the snail including miracidium penetration, sporocyst, redial generations, cercarial production, and shedding into water; the prepatent period (38–86 days) is dependent on temperature, with higher temperatures reducing this period; (iv) transit between snail and mammalian hosts including the short swimming phase of cercariae and the long life of the metacercariae; the shedding process takes place between 9 and 26°C, independent of light or darkness.

It is evident that liver fluke development is very dependent on environmental characteristics as infection of both definitive and intermediate hosts involves an association with external fresh water, and larval development occurs completely within species of freshwater snails which are in turn very dependent upon environmental factors. Moreover, the transmission of *Fasciola* is also markedly influenced by human activities, with the main definitive host species being domestic animals.

Dispersion of fascioliasis

The capacity of fasciolids to colonize and adapt to new environments has clearly contributed to the spread of fascioliasis, even in extreme environments located at high altitudes. On the Northern Bolivian Altiplano high altitude endemic area (3800–4100 m), studies performed showed that there is no phase of the life cycle in which the parasite development appears to be modified in a way to reduce transmission. However, given aspects seemed to favour transmission, such as the longer cercarial shedding period and the higher cercarial production, these two aspects appearing to be related to a longer survival of the infected lymnaeid snails. When compared to lowlands, these differences may be interpreted as strategies for adaptation to high altitude conditions (Mas-Coma *et al.*, 2001).

Fasciola hepatica has succeeded in expanding from its original geographical area in Europe due to the exportation of European livestock to the five continents where the liver fluke has adapted to other autochthonous mammal species such as camelids in Africa, Andean camelids in South America, and marsupials in Australia (Mas-Coma *et al.*, 2003). The capacity of this fasciolid species to rapidly adapt to new definitive host species is illustrated by examples of worms found in black rats in Corsica island (Valero *et al.*, 1998, 2002; Mas-Coma *et al.*, 2003), nutria in France (Menard *et al.*, 2001) and pigs in Andean countries (Mas-Coma *et al.*, 1997; Valero & Mas-Coma, 2000; Valero *et al.*, 2001a,b). In all these cases, newly acquired hosts play an important role as reservoir host in the transmission of fascioliasis, contributing to the spread of the disease, and must, consequently, be taken into account when applying control measures.

Colonization by fascioliasis of new environments and geographical areas has also taken place mainly due to adaptations of the parasite to a range of authochthonous lymnaeid species. Differences in the specificity of *F. hepatica* and *F. gigantica* are epidemiologically very important, because of the different ecological requirements of their respective *Galba*/*Fossaria* and *Radix* vector species. Lymnaeids harbouring *F. hepatica* are species showing marked amphibious trends and inhabit small or very small water bodies, depending upon seasonal rainfall. Lymnaeids responsible for *F. gigantica* transmission are species preferring large, deep and more permanent water bodies rich in aquatic vegetation. These habitat characteristics suggest that the transmission foci of both fasciolids are different and appear separate, even in the same endemic locality, and that the occurrence of *F. hepatica* is more seasonal than *F. gigantica*. However, there are exceptions to be found in human hyperendemic areas at very high altitudes, where *Galba truncatula* occurs in permanent water bodies due to high evapotranspiration rates at high altitude (Mas-Coma *et al.*, 1999c).

Fasciola gigantica appears to be geographically restricted to regions where *Radix* species are present, and this preference may explain its limited spread into areas where *Radix* representatives are absent. In contrast, *F. hepatica* shows a preference for lymnaeids in the *Galba*/*Fossaria* groups, which are present and well distributed in all continents (see reviews in Mas-Coma & Bargues, 1997; Bargues *et al.*, 2001). The capacity of stagnicolines and lymnaeid species other than those of *Galba*/*Fossaria* to act as intermediate hosts partially explains the presence of *F. hepatica* in habitats where normal lymnaeid vectors are absent (Bouix-Busson & Rondelaud, 1985, 1986; Dreyfuss *et al.*, 1994).

Another phenomenon also potentially related to the colonizing power of fasciolids is their capacity to produce more larval stages when infecting the same lymnaeid species from another locality (Gasnier *et al.*, 2000).

The distribution and spread of lymnaeid vectors are also related to the colonization of fascioliasis in new environments and geographical areas. The European *Galba truncatula* spread into other continents most probably with the commercial exportation of livestock (i.e. in mud attached to the feet of sheep and cattle).

Galba truncatula also has the capacity for widening ecological niches, as observed on the low human hypoendemic, Mediterranean island of Corsica (Gil-Benito *et al.*, 1991). This large island is very mountainous and climatic conditions (low rainfall, high temperatures) made it difficult to understand why fascioliasis is endemic on this island. Studies by Oviedo *et al.* (1992) showed that *G. truncatula* is distributed throughout the insular periphery (coastal zones) as well as in the inner regions of the island, up to 1500 m altitude. The habitats of *G. truncatula* on Corsica can be classified into reservoir habitats (permanent presence and renewal of water) and invasion habitats (only seasonal presence of water). From an ecological point of view, a number of biotopes can be distinguished, namely from large to small rivers, from natural (rivers; water-filled fields; flooding zones; pasture plains) to artificial man-made habitats (large water reservoirs; irrigation channels; fountains; animal drinking-troughs of different types; roadside ditches) (Oviedo *et al.*, 1992). Several atypical habitats may be part of the ecological niche widening, as a consequence of the influence of insularity. This fact is in turn related to the extraordinary distribution of the disease on the island.

Pseudosuccinea columella is another lymnaeid species linked with the spread of fascioliasis. This is a rapidly colonizing, more aquatic, more heat-tolerant species, which originated from Central America, the Caribbean and the southern part of North America, but is present today in South America, Europe, Africa, Australia, New Zealand and even Tahiti. In Brazil, for instance, *P. columella* appears to be the only lymnaeid present in many fascioliasis areas (Mas-Coma *et al.*, 2003). Interestingly, a resistant strain of *P. columella* to liver fluke infection has recently been detected in Cuba, where fascioliasis is transmitted by both *Fossaria cubensis* and *P. columella* (Gutierrez *et al.*, 2003a,b; Fernandez Calienes *et al.*, 2004). This finding opens up the possibility of investigating the genes responsible for resistance and future application in control strategies.

Human fascioliasis situations

Fascioliasis is a well-known veterinary problem throughout its large geographical distribution. Moreover, studies carried out in recent years have shown it to be an important public health problem as well (Chen & Mott, 1990; WHO, 1995; Mas-Coma *et al.*, 1999a,b). Human cases have been increasing in 51 countries of the five continents (Esteban *et al.*, 1998; Mas-Coma *et al.*, 1999a,b), with a total of 7071 human cases reported in the past 25-year period: Europe, 2951; America, 3267; Asia, 354; Africa, 487; Oceania, 12 (Esteban *et al.*, 1998). Care must be taken with these data, as from personal experience, numerous cases are diagnosed but only noted in non-published internal documents, reports or university theses, or published in local journals of very limited distribution (i.e. Bolivia – see Mas-Coma *et al.*, 1995). In addition, human fascioliasis is not a notifiable disease (i.e. Spain – see Sorribes *et al.*, 1989). Other limitations are related to differences in the methodologies used and difficulties also occur when analysing detailed results of several community-based or epidemiological surveys (Esteban *et al.*, 1998). Finally, as the infection may be asymptomatic, and the symptoms and signs are not pathognomonic, many human infections may be misdiagnosed, or simply not diagnosed because patients may not request a physician, and hence, the number of human cases is likely to be greater than that in the published domain.

When comparing human fascioliasis cases described in the literature, different situations may be found and, to facilitate the evaluation of results of surveys and case studies, an epidemiological classification of human fascioliasis has been recently proposed (Mas-Coma *et al.*, 1999a).

1. Two situations which were considered normal in the literature up to the 1990s include:
    (i) Autochthonous, isolated, non-constant cases: humans acquire the infection in an area where they live and where animal fascioliasis is also present; these human cases appear sporadically, without any constancy.
    (ii) Imported cases: human cases diagnosed in a zone lacking the parasite, even in animals, who are infected in an area where transmission occurs.
2. In results from surveys developed during the 1990s, three types of human endemic situations are distinguished:
    (i) Hypoendemic: prevalences less than 1%; arithmetic mean intensities less than 50 epg; high epg numbers only in sporadic cases; human participation in transmission through egg shedding may be neglected; hygiene-sanitation characteristics usually including latrines and waste or sewage disposal facilities; outdoor defecation is not commonly practiced.
    (ii) Mesoendemic: prevalences between 1 and 10%; 5- to 15 year-old children may present higher prevalences (holoendemic); arithmetic mean intensities in human communities usually between 50 and 300 epg; individual high epg numbers can be found, although intensities over 1000 epg are rare; human subjects may participate in transmission through egg shedding; hygiene-sanitation characteristics may or may not include latrines and waste or sewage disposal facilities; outdoor defecation may be practiced.
    (iii) Hyperendemic: prevalences more than 10%; 5- to 15 year-old children usually present higher prevalences (holoendemic); arithmetic mean intensities in human communities usually more than 300 epg; individual very high epg numbers are encountered, intensities over 1000 epg being relatively frequent; human subjects significantly participate in transmission through egg shedding; hygiene-sanitation characteristics do not include the use of latrines; no proper waste or sewage disposal facilities; indiscriminate defecation is commonly practiced.
3. Two different types of outbreaks are distinguished according to the endemic/non-endemic situation of the zone:

(i) Epidemics in non-human endemic but animal endemic areas: outbreaks appearing in zones where previous human reports have always been isolated and sporadic; such outbreaks usually concern very few subjects infected from the same contamination source (family or small group reports; contaminated wild, home-grown or commercially grown watercress or other metacercariae-carrying vegetables).

(ii) Epidemics in human endemic areas: outbreaks appearing in zones presenting human endemics; a more important number of subjects may be concerned; usually related to previous climatic conditions having favoured both the parasite and snail life cycles; epidemics can take place in hypoendemic, mesoendemic and hyperendemic areas.

Main human endemic areas

A global analysis of the distribution of human cases shows that the expected correlation between animal and human fascioliasis only appears at a basic level (Mas-Coma *et al.*, 1999b). Although the major sources of the infection, domestic herbivorous mammals, are widely distributed in the world (Chen & Mott, 1990), high/low human prevalences are not related to high/low animal prevalences, respectively. Thus, high prevalences in humans do not seem to be necessarily related to areas where fascioliasis poses a great veterinary problem. In western Europe there is a concentration of human cases in France, Spain and Portugal, whereas, due to climatic conditions, animal fascioliasis is more linked to northern countries where human cases are only sporadic. Similarly, in South America hyperendemics and mesoendemics are found in Bolivia and Peru, whereas the veterinary problem occurs mainly in countries such as Uruguay, Argentina and Chile where only sporadic cases or hypoendemic areas are found. In Australia, livestock fascioliasis is well known, whereas human cases are only sporadic. Such geographical differences between human and animal fascioliasis are related to differences in human dietary habits, as well as to economic and hygienic-sanitation conditions (Mas-Coma *et al.*, 1999b).

At present, major health problems are known in Andean countries (Bolivia, Peru, Chile, Ecuador), the Caribbean area (Cuba), northern Africa (Egypt), western Europe (Portugal, France and Spain) and the Caspian area (Iran and neighbouring countries) (Mas-Coma, 2004). True human endemic areas exist.

In Andean countries, well-known human hyperendemic areas are the Northern Altiplano in Bolivia (see reviews in Mas-Coma *et al.*, 1995, 1999c), and three areas in Peru: the Puno Altiplano (Esteban *et al.*, 2002), the Cajamarca valley (Knobloch, 1985; Knobloch *et al.*, 1985) and the Mantaro valley (Bendezu, 1969; Stork *et al.*, 1973; Marcos Raymundo *et al.*, 2004). In the Caribbean, in Cuba, in Pinar del Rio Province more than 10,000 people were infected between 1947 and 1948 (Mitterpak, 1968) and a new outbreak involving 81 subjects occurred in 1995 (Perez *et al.*, 1997), whereas in Villa Clara Province an outbreak involved more than 1000 subjects in 1983 (Gonzalez *et al.*, 1985, 1987; Diaz *et al.*, 1990) and patients are being continuously diagnosed (Millan *et al.*, 2000).

Concerning Europe, France is considered an important human endemic area (Anon., 1988). The first large modern epidemic of human fascioliasis occurred in 1956 (Coudert & Triozon, 1958). Between 1950 and 1983, 3297 cases have been reported (Gaillet *et al.*, 1983). Most cases occurred in areas of Lyon, Bretagne Nord – Pas de Calais and the south-west. Recent reports in the south-west of France refer to more than 300 cases (Laborde, 1985; Giap, 1987; Ripert *et al.*, 1987). However, cases compiled in those reviews only refer to published reports; the paper by Danis *et al.* (1985), which reported on 5863 human cases recorded from only nine hospitals between 1970 and 1982, demonstrates that published data largely underestimate the real situation. The French Mediterranean island of Corsica maintains a low hypoendemia (Gitard *et al.*, 1965; Gil-Benito *et al.*, 1991).

The disease is also important in Portugal, especially in the northern part of the country where Rombert & Gracio (1984) reported 77 cases and Sampaio Silva (in Chen & Mott, 1990) referred to 561 cases in only three communities in northern Portugal. Sampaio-Silva *et al.* (1996) referred to 1011 cases diagnosed in the laboratory of Porto between 1970 and 1992. Cases reported in other parts of Portugal include those in residents from three islands, Madeira, Azores and Cape Verde (Rombert & Gracio, 1984; Abreu *et al.*, 1996; Mendonça *et al.*, 1996).

In Spain, according to the review by Sorribes *et al.* (1989, 1990), human fascioliasis is underestimated and mainly distributed in northern Spain (autonomic communities of the Pais Vasco, Castilla-León, Cantabria, Navarra and Rioja). More recently, imported cases have been added to autochthonous ones (Turrientes *et al.*, 2004).

In Africa the main problems are found in the Nile Delta in Egypt (Curtale *et al.*, 2000, 2003a,b; Esteban *et al.*, 2003). Among Asian countries, fascioliasis is present in many Iranian provinces: Kurdistan, Zandjan, Kermanshah, Mazandaran, Tehran, Azarbaijan and Gilan. Although human cases have been reported throughout Iran over 30 years ago (Sahba *et al.*, 1972), the main focus occurs in the Gilan province, besides the Caspian Sea. In this northwestern area of Iran, high prevalences of fascioliasis in livestock and human infections have long been known (Sabokbar, 1960; Sohrabi, 1969). Moreover, from the end of the 1980s and during the 1990s several large epidemics, including thousands of human cases, were reported (Massoud, 1990, 1993; Pourtaghva *et al.*, 1990; Yadegari *et al.*, 1990, 1999; Assmar *et al.*, 1991; Forghan-Parast, 1993; Yadegari & Talaie, 1996; Talaie *et al.*, 2004; Ashrafi *et al.*, 2004). Furthermore, in the Mazandaran province, fascioliasis has recently been shown to be a big human health problem (Moghaddam *et al.*, 2004a,b).

Epidemiological characteristics of human endemic areas

Among human hyperendemic areas, the highest prevalences and intensities have been recorded in the Northern Bolivian Altiplano. In this area, prevalences in some communities were up to 72% and 100% in coprological and serological surveys, respectively (Hillyer *et al.*, 1992; Mas-Coma *et al.*, 1995, 1999c; Bjorland *et al.*, 1995; Esteban *et al.*, 1997a,b, 1999; O'Neill *et al.*, 1998), and intensities reached up to more than 5000 epg in children (Esteban *et al.*, 1997a,b, 1999). The results of the surveys showed that, although more prevalent and intense in children (with a peak in the 9–11 age group), adults in the 21–40 and >40 year-old age categories were also infected, with prevalences of up to more than 40% in both categories and arithmetic mean intensities of up to 752 and 616 epg, respectively, in given communities (Esteban *et al.*, 1997a,b, 1999). Despite a decrease in prevalence in adults compared with children and young subjects, these results demonstrate that in this high endemic zone adults either continue to harbour *Fasciola* acquired when young or become newly infected as a consequence of inhabiting a zone of high infection risk (Esteban *et al.*, 1999). This suggests that the majority of adults should be in the chronic phase, acute lesions by repetitive infections being superimposed on chronic disease with relative frequency. Thus, the acute phase may be prolonged and overlap with both latent and obstructive phases. Although at a lower level, prevalence and intensity situations found in other Andean and African countries (Peru, Egypt) were similar (Esteban *et al.*, 2002, 2003).

Prevalences and/or intensities of infection in human hyperendemic areas appear to be significantly higher in females. Females shed significantly more eggs than males in Andean countries (Esteban *et al.*, 1999, 2002), whereas in Egypt the prevalence in females is significantly higher than in males (Esteban *et al.*, 2003). This result contrasts with Andean countries, where prevalences do not differ between both sexes (Esteban *et al.*, 1999, 2002). The gender role in Egypt may be probably related to cultural, hygiene and behavioural factors, with females being more involved in the washing of clothes and kitchen utensils in large canals where infected lymnaeids are present, and with agricultural tasks in irrigated plantations such as rice fields, as well as meal preparation in houses including the management of freshwater plants potentially carrying attached metacercariae. In Egypt, many species of vegetables and weeds are eaten raw as salads. At a young age, girls may be more in contact with transmission foci, as girls are more likely than boys to be absent from schools (Esteban *et al.*, 2003).

Environmental variation: from below sea level up to high altitudes

In hypo- to hyperendemic areas of Central and South America, Europe, Africa and Asia, human fascioliasis presents a wide spectrum of epidemiological characteristics related to habitat diversity. Fascioliasis occurs in human endemic areas from below sea level (as in the Gilan province, beside the Caspian Sea, in Iran) up to very high altitude (as in the Andean altiplanos and valleys of Bolivia, Peru, Ecuador and Venezuela). No other vector-borne disease presents such a wide altitudinal range (Mas-Coma *et al.*, 2003).

When comparing different human endemic areas, a large diversity of situations and environments appear (table 1). These include differences in human endemic/epidemic situations, human demographies, races, diets, habits, traditions and religions, different domestic and wild mammal reservoir species, different lymnaeid species, zones in both the northern and southern hemispheres, altitudes from −27 m up to 4200 m, hot and cold weathers, seasonal and yearly constant temperatures, scarce to pronounced annual rainfall, low and high mean annual potential evapotranspiration, and dry and wet periods producing different dryness/humidity rates. Moreover, from the landscape point of view, these areas range from altiplanos to valleys, islands to mainlands, natural to artificial irrigations, lakes to lagoons, large rivers to small streams, and from permanent to temporal water bodies (Mas-Coma *et al.*, 2003).

Epidemiological patterns

Recent research has shown that human endemic areas present different transmission and epidemiological patterns:

1. A very high altitude pattern related to only *F. hepatica* transmitted by imported *Galba truncatula* in Andean countries following transmission throughout the year. Within this category, two subpatterns may be distinguished according to physiographic and seasonal characteristics:
    (i) the altiplanic pattern, with transmission throughout the whole year (Mas-Coma *et al.*, 1999c), e.g. in the Northern Bolivian Altiplano and the Puno Altiplano;
    (ii) the valley pattern, with seasonality (Claxton *et al.*, 1997) and prevalences and intensities related to altitude (Gonzalez *et al.*, unpublished), e.g. in the valleys of Cajamarca and Mantaro.
2. A Caribbean insular pattern, with reduced but repeated outbreaks in human hypoendemic areas and lymnaeid species other than the main vector species being involved in the transmission (Gonzalez *et al.*, 1985, 1987; Diaz *et al.*, 1990; Perez *et al.*, 1997; Millan *et al.*, 2000), e.g. the Pinar del Rio Province in Cuba.
3. A pattern related to Afro-Mediterranean lowlands, including overlapping *F. hepatica* and *F. gigantica* and several *Galba/Fossaria* and *Radix* lymnaeids together with secondary transmitting *Pseudosuccinea*, and where seasonality is typical (Esteban *et al.*, 2003), e.g. the Behera Governorate in Nile Delta region in Egypt.
4. A pattern related to Caspian surrounding areas, including human hypoendemic areas in which large epidemics occur, occasionally involving up to 10,000 people and with overlapping of *F. hepatica* and *F. gigantica* and several *Galba/Fossaria*, *Radix* and stagnicoline lymnaeids (Ashrafi *et al.*, 2004), e.g. the area of Rasht and Bandar-e Anzali in the Gilan province in Iran.

Within a human endemic area, the parasite distribution appears irregular, the transmission foci being patchily

Table 1. Environmental characteristics of human fascioliasis endemic areas presently known in Asia, Africa, Europe and South America.

	Gilan province	Nile Delta	Fango Delta Corsica	Mérida	Cotopaxi	Cajamarca	Puno	Northern Altiplano	VIIth Region
	Iran	Egypt	France	Venezuela	Ecuador	Peru	Peru	Bolivia	Chile
Human disease situation	Large epidemics	Hyperendemic	Lowly hypoendemic	Hypoendemic	Mesoendemic	Highly hyperendemic	Highly hyperendemic	Higly hyperendemic	Hypoendemic
Description	Agricultural plain beside the Caspian sea	Large delta transformed into agricultural plain	Flooding river mouth in Mediterranean island	Andean valley located at high altitude	Andean valley located at high altitude	Andean valley located at medium altitude	Andean altiplano located at high altitude	Andean altiplano located at high altitude	Valley located at the foot of the Andes
Irrigation	Natural and artificial, from a lagoon and near mountains	Artificial, with main large and smaller secondary canals	Natural, seasonal, after river water level increases	Natural, from streams of the thaw of the near by mountains	Natural, from streams of the thaw of the near by mountains	Natural, from streams of the thaw of the near by mountains	Artificial, from lagoon, with small main and little secondary canals	Natural, rivers and subsoil effluences from nearby mountain thaw	Natural and artificial, from water collections of the Andes
Reference station	Bandar-e Anzali (Rasht)	Damanhour and Tahrir (Behera)	Ajaccio	Paramo Mucuchies	Cuturivi Grande	Cajamarca	Chuquibambilla (Asillo/Azángaro)	Huacullani	Talca
Hemisphere	North	North	North	North	South	South	South	South	South
Lat./Long.	37° N/49° E	30–31° N/30° E	41° N/8° E	8° N/70–71° W	0°/78° W	7° S/78° W	14–15° S/70° W	16° S/68° W	35° S/71° W
Altitude	− 27 to +23 m	0–15 m	0–5 m	2500–4200 m	2500–3500 m	2600–3200 m	3800–4000 m	3800–4100 m	100–600 m
Mean annual temperature and monthly range	16.0°C 7.0°C/Feb 25.5°C/Jul	20.7°C 13.1°C/Jan 27.0°C/Aug	14.7°C 8.1°C/Jan 22.2°C/Jul & Aug	6.1°C 5.0°C/Jan 6.6°C/Sept	7.8°C 7.4°C/Jun & Jul 8.1°C/Mar	15.3°C 14.3°C/Jun 15.7°C/Nov	7.0°C 3.6°C/Jul 8.8°C/Dec	7.9°C 4.2°C/Jul 10.3°C/Feb	14.7°C 8.3°C/Jul 21.9°C/Jan
Total annual rainfall and monthly range	1780 mm 44 mm/May 304 mm/Oct	99 mm 0 mm/Jun-Sept 24 mm/Jan	639 mm 10 mm/Jul 94 mm/Nov	871 mm 10 mm/Jan 153 mm/Jul	1084 mm 31 mm/Aug 139 mm/Apr	769 mm 6 mm/Jul 107 mm/Oct	778 mm 1 mm/Jun 154 mm/Dec	774 mm 2 mm/Jun 168 mm/Jan	737 mm 7 mm/Jan-Feb 190 mm/Jun
Mean annual potential evapotranspiration and monthly range	65 mm 44 mm/May 304 mm/Oct	144 mm 71 mm/Jan 216 mm/Jun	71 mm 15 mm/Dec 159 mm/Jul	45 mm 38 mm/Jan 50 mm/May	60 mm 52 mm/Jun 64 mm/Oct	99 mm 84 mm/Apr-May 109 mm/Dec	72 mm 45 mm/Jun 94 mm/Nov	(no data) (134 mm of total yearly evaporation)	84 mm 14 mm/Jun 175 mm/Jan
Dry period	–	Jan to Dec	Sept to May	Dec to Mar	Aug	May to Sept	May to Sept	May to Aug	Oct to Mar
Wet period	Jan to Dec	–	Jun to Aug	Apr to Nov	Sept to Jul	Oct to Apr	Oct to Apr	Sept to Apr	Apr to Sept

distributed and linked to the presence of appropriate water collections, and human prevalences in schoolchildren appear to be related to the distance to water bodies presenting lymnaeids (Mas-Coma *et al.*, 1999c).

From results obtained in the human endemic areas of Europe, South America, Africa and Asia, it may be concluded that well-known epidemiological patterns of fascioliasis may not always explain the transmission characteristics in a given area. This means that when dealing with an endemic zone not previously studied, known epidemiological patterns of fascioliasis must always be taken into account merely as the starting base, before control measures can be considered in the zone concerned.

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