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Field investigations on epidemiology and control of fish-borne parasites in Korea*

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Summary Helmithiases have long been recognized as an important cause of endemic disease in Korea. Consumption of undercooked or raw fish has played an increasingly important role in their transmission in recent years. The important organisms associated with fresh-water, brackish water and marine fish species are described, their relative significance assessed and strategies for their control described.

Keywords Cestodes, helminths, nematodes, parasitoses, public health, trematodes.

Introduction

Various helminthiases have been recognized as important endemic diseases in Korea for many years. In the past, the traditional application of night soil to vegetable gardens resulted in a wide-spread parasitism with a variety of helminths found in Korea. In addition, the practice of consumption of raw vegetables, fish, crustaceans and mammals provides a means of transmission of helminths.

The most common and important parasites were mainly soil-transmitted helminths, e.g. *Ascaris lumbricoides*, *Trichuris trichiura* and hookworms. The control of *A. lumbricoides* and other soil-transmitted nematodes has been conducted by mass chemotherapy since 1969, chiefly by the Korea Association of Parasite Eradication (KAPE), the predecessor of the present Korea Association of Health. The egg-positive rate of *A. lumbricoides* in inhabitants nation-wide was over 80% until the end of 1950s but has decreased markedly since the 1970s. The nation-wide prevalence was estimated by KAPE to be 54.9% in 1971, 41.0% in 1976, 13.0% in 1981, 2.1% in 1986 and 0.3% in 1992. The incidence of hookworm infections has been improved since the 1970s – 2.2% in 1976, 0.5% in 1981, 0.1% in 1986 and 0.01% in 1992. The infection rate of *T. trichiura* was estimated to be 65.4% in 1971, 42.0% in 1976, 23.4% in 1981, 4.8% in 1986 and 0.2% in 1992. From the above results, it is clear that the prevalence of soil-transmitted helminths has decreased remarkably during the last 30 years.

However, food-borne parasitic infections seem to be quite different in their pattern of prevalence, unlike that of soil-transmitted nematodiases, clonorchiasis, paragonimiasis and metagonimiasis are still regarded as major trematode infections of medical importance in Korea. These trematode infections are significantly related to human behavioural patterns based on socioeconomic and cultural conditions, and are linked with the local biological and physical environments. Infection by *Clonorchis sinensis* is caused by the consumption of raw or undercooked cyprinid fishes that harbour the metacercariae. According to nation-wide survey results, the incidence of *C. sinensis* infection was 4.6% in 1971, 1.8% in 1976, 2.6% in 1981, 1.7% in 1986 and 2.1% in 1992. Therefore, the infection status of *C. sinensis* has remained essentially unchanged over 25 years, despite the development of effective anthelminthics such as praziquantel. Owing to difficulties in the diagnosis of paragonimiasis caused by *Paragonimus westermani*, few data have been available on its nation-wide prevalence, although it is believed to have been quite high in

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the past and has been decreasing significantly. The nation-wide egg-positive rate of *Metagonimus yokogawai* was 1.2% in 1981, 1.0% in 1986 and 0.3% in 1992, showing a decreasing tendency.

The incidence of other intestinal trematodiases such as heterophyiasis (*Heterophyes nocens*) and echinostomiasis (*Echinostoma hortense*, *E. cinetorchis* and *Echinochasmus japonicus*) are reported to be steady or even increasing. A considerable numbers of infections with *Pygidiopsis summa*, *Heterophyopsis continua*, *Stellantchasmus falcatus*, *Centrocestus armatus*, *Stictodora fuscatum* and *Neodiplostomum seoulense* (syn. *Fibricola seoulensis*), etc. have been reported from humans by identification of the adult worms. A new intestinal fluke, *Gymnophalloides seoi*, transmitted by oysters, has been found prevalent in some coastal areas. On the other hand, only five cases of biliary or ectopic infections with *Fasciola hepatica* have been reported.

Of the other fish-borne parasitic infections, a total of 161 cases of anisakiasis mostly due to *Anisakis* type I larvae have been reported in the literature. Cases are increasingly being reported nowadays. A total of 28 worm-proven cases of *Diphyllobothrium latum* have been reported in the literature since the first case report of 1971. A case of *D. yonagoense* infection has also been proved by recovery of an adult worm.

At present, it is obvious that the general status of parasitic infections in Korea has shown a marked decrease, particularly in soil-transmitted helminthic infections. However, in terms of prevalence and distribution, as well as the difficulties associated with changing the habit of eating raw fish, clonorchiasis and metagonimiasis and other fish-borne parasitic infections are currently major parasitoses of public health importance in Korea. Our current understanding of the distribution, epidemiological characteristics and pathology of fish-borne parasitic infections other than *C. sinensis* and *M. yokogawai* is generally based on individual case reports rather than on systematic investigations in the populations.

Field investigations of fish-borne parasites in Korea

Freshwater fish are most frequently the hosts of metacercaria of digenetic trematodes belonging to the families of Opisthorchiidae, Heterophyidae, Echinostomatidae and Clinostomidae. Brackish water fishes serve as hosts for the metacercaria of many trematodes belonging to the family Heterophyidae. Anisakid larvae have been reported from the flesh and abdominal cavities of marine fishes.

In Korea, field investigations of the presence of metacercaria of *Clonorchis sinensis*, *Metagonimus yokogawai* and other species of trematodes in many different species of freshwater fishes have been undertaken by numerous workers since the 1960s. The study of the metacercaria harboured in brackish water fishes has been carried out since the 1980s, mostly by Seo, Lee and Chai. They have detected many different metacercaria in mullet (*Mugil cephalus*) and other brackish water fishes. They have found many fishes harbouring the metacercaria, and human infections by *Heterophyes nocens*, *Heterophyopsis continua*, *Pygidiopsis summa*, *Stellantchasmus falcatus* and *Stictodora fuscatum* have been confirmed by both feeding experiments and finding of adult worms from stools after treatment. Other kinds of metacercaria have been reported from marine-water fishes, but have not yet been confirmed as causing human infection. Since 1971, when the first case of anisakiasis was reported, anisakid larvae have been found in many kinds of marine fishes in Korea. The cestode *Diphyllobothrium latum* is distributed world-wide but is not a common parasite of humans in Korea. However, with the increasing popularity of eating raw marine fishes, such as salmon, trout and perch, this tapeworm infection tends to be increasing in Korea.

The examination of encysted metacercaria of flukes or anisakid larvae and of the plerocercoid of *D. latum* should be made on the living specimens. For detection of metacercariae, a specimen of flesh from fish is taken between two slide glasses, pressed and examined under a stereomicroscope with 20- to 100-fold magnification. To isolate metacercariae from the flesh of fish, small pieces of flesh are minced and mixed with artificial gastric juice (0.6% HCl and 1% pepsin in distilled water) and incubated at 37°C for 3–4 h with occasional shaking. For the detailed observation of the morphology of metacercariae, it is necessary to liberate them from the cysts. When the cyst layer is very thin, metacercariae can easily be liberated without injury by slight pressure on the cover glass. When the cyst layer is thick and elastic, they cannot be so easily liberated, and liberation of metacercariae by successive treatment with artificial gastric and intestinal juice (0.5 g of trypsin, 0.2 g of sodium bicarbonate in 50 mL of water) is recommended.

The species of encysted larvae (metacercariae) are differentiated morphologically by examining the size and shape of the cysts and the characteristic features of the internal organs. The usual form of the metacercaria is flat and elliptical in shape, but frequently it can be oval, flask-shaped or cylindrical. The length of the body ranges from 0.2 to 1.0 mm and is rarely over 1.0 mm. The size of the body varies in living specimens according to its contraction and extension. The body in the cyst is usually transparent and colourless but can appear pink, yellow-brown or dark in colour owing to the distribution of the pigment or pigment granules in the body.

Anisakis third-stage larvae in the fish host grow to a relatively large size, usually 2–3 cm long but often more than 3 cm long and up to 1 mm wide. Usually they are colourless and are normally tightly coiled in a spiral some 3 mm in diameter, which makes them extremely difficult to find within the flesh. However, the larvae are easily detected by the compression of musculature between two glass plates over a ground-glass screen illuminated from below by a fluorescent light. Candling of fish fillets in this way can be used to detect plerocercoid larva of *D. latum*.

The occurrence and epidemiology of fish-borne parasites in Korea

Species of fish-borne parasites that have been reported as infecting humans in Korea are listed in Table 1.

Freshwater fish

Clonorchis sinensis *(Cobbold, 1875) (Looss, 1907)*

C. sinensis, a liver fluke, has been known as a parasite of major public health importance in Korea and also in several South-east Asian countries.

Table 1 Fish-borne parasites of man in Korea

Name of parasites	Sources of infection	Distribution
Liver fluke		
Clonorchis sinensis	Freshwater fish	Whole country
Intestinal flukes		
Metagonimus yokogawai	Freshwater fish	South and eastern coast
Metagonimus takahashii (including *M. Miyata* type)	Freshwater fish	Inland of whole country
Centrocestus armatus	Freshwater fish	Whole country
Echinostoma hortense	Freshwater fish	South-eastern part of Korea
Echinostoma cinetorchis	Freshwater fish	In several localities
Echinochasmus japonicus	Freshwater fish	South-eastern part of Korea
Clinostomum complanatum	Freshwater fish	Uisong-gun, Kyungpuk-do
Heterophyes nocens	Brackish water fish	Southern coast area
Heterophyopsis continua	Brackish water fish	West and southern coast
Pygidiopsis summa	Brackish water fish	Western coast area
Stellantchasmus falcatus	Brackish water fish	Southern coast area
Stictodora fuscatum	Brackish water fish	Southern coast area
Anisakis nematodes larvae		
Anisaskis simplex	Marine fish	West, south, eastern sea
Anisakis physeteris	Marine fish	West, south, eastern sea
Pseudoterranova decipiens	Marine fish	West, south, eastern sea
Contracaecum osculatum	Marine fish	West, south, eastern sea
Intestinal tapeworms		
Diphyllobothrium latum	Marine fish	East sea
Diphyllobothrium yonagoensis	Marine fish	East sea

Early light infections in humans are usually asymptomatic, whereas chronic infections cause damage to the bile duct epithelium, eliciting gastrointestinal symptoms, jaundice, cholangitis, biliary stones and possibly cholangiocarcinoma.

The geographical distribution of clonorchiasis closely parallels the distribution of the intermediate host, particularly the snail, *Parafossarulus manchouricus*, although infected fish can be found far away from the location of the snail's habitat. This snail is the only known molluscan host for *C. sinensis* in Korea.

Numerous species of freshwater fish serve as the second intermediate hosts of *C. sinensis*. Approximately 36 species of freshwater fish have been found to serve as second intermediate hosts in Korea. The majority of these fish belong to the family Cyprinidae. Among these, the infection of *Clonorchis* metacercariae is found most frequently in *Pseudorasbora parva*, *Sarcocheilichthys sinensis*, *Hemibarbus labeo*, *Acanthorhodeus gracilis*, *A. taenianalis*, *Puntungia herzi*, *Pseudogobio esosinus*, *Gnathopogon* spp. and *Acheilognathus limbata*. *P. parva* shows an extremely high degree of infection, usually hundreds to thousands of the metacrcariae in a fish, with a maximum of 31 516 having been found. In the lower basins of the Nakdong river, the mean number of metacercariae per gram of flesh of *P. parva* ranged from 46.7 to 3189.4 in different localities.

According to reports summarized by KAPE in 1978, the most frequently infested fish was *P. parva* 90.3%, followed by *S. sinensis* 78.0%, *H. labeo* 68.2%, *P. herzi* 50.9%, *P. esocinus* 47.5%, *Gnathopogon* sp. 44.4%, *Cultriculus kneri* 38.5% and *A. taenianalis* 29.5%.

Clonorchis infection is acquired by eating uncooked fish containing infectious metacercariae, and the intensity of human infection is dependent upon the eating habits of the population. It is well known that the Korean people have a custom of eating raw fish at drinking parties. Therefore, in endemic areas, more men are infected than women. The incidence in children is low, but from 20 years of age onwards the incidence increases, being the highest at 40–50 years of age. The large fish, *Cyprinus carpio* and *Carassius carassius*, which are frequently eaten by the inhabitants in endemic areas, have low rates of infestation. However, repeated consumption of the raw fish may lead to heavy infections and high incidence. On the other hand, heavily infected small fish are not generally eaten raw, but they may be undercooked and still transmit infection (Rim, 1986).

The metacercaria of *C. sinensis* is oval in shape, measuring about 135–145 μm by 90–100 μm. A true cyst wall about 2 μm thick, an outer and an inner hyaline wall, is formed by the larva, and an additional capsule outside the true cyst wall develops as a result of local tissue reaction of the fish. Within the cyst the metacercaria moves its body freely, the suckers are of approximately equal size and a thick-walled ovoid excretory vesicle is filled with many excretory corpuscles.

According to Rhee *et al.* (1982), a large number of clavate cells were found in the epidermis of *Misgurnus anguillicaudatus*, *Parasilurus asotus*, *C. carpio* and *C. carassius*, which are not suitable as the second intermediate hosts for *C. sinensis*, whereas clavate cells were not found in *P. parva*, *Zacco platypus*, *Microphysogobio koreensis* etc., which are known as second intermediate hosts. From these results, he suggested that the degree of infection of *C. sinensis* metacercariae would be closely related to the occurrence of clavate cells in epidermis of freshwater fish.

Metagonimus yokogawai *(Katsurada, 1912)*

M. yokogawai is the most prevalent of all intestinal trematode species reported from humans in Korea. This fluke is also known to be distributed in Japan, China and Taiwan. The worms are found in the middle part of the small intestine within the crypts of Lieberkuhn at early stages of infection, or between the villi at later stages. The most frequent symptoms complained of by the patients were abdominal pain, diarrhoea and lethargy, and the degree of symptoms seems to be related to the individual worm burden. However, even the most heavily infected case in the literature, a man residing in the Tamjin river basin and harbouring as many as 63 587 worms at one time (Seo *et al.*, 1985a), complained of only minor troubles such as mild indigestion and epigastric pain.

In Korea, almost all the large and small streams in eastern and southern coastal areas are endemic foci of metagonimiasis. In most endemic villages, 10–20% or higher egg-positive rates were reported in the Sumjin, Tamjin and Boseong rivers (Chai & Lee, 1990).

The metacercariae are disc-shaped, 140–160 μm in diameter, or elliptical, 170–180 by 130–140 μm. Within the cyst the metacercaria moves its body freely, and a prominent oral sucker is larger than acetabrium. The yellow-brownish pigment granules are scattered in the area of the intestinal bifurcation, and excretory granules with variable size, but smaller than those of *Clonorchis*, fill an ovoid excretory vesicle.

Human infection is attributed primarily to eating raw or undercooked freshwater fish, the sweet fish (*P. lecoglossus altivelis*), dace (*Tribolodon taczanowskii*) and perch (*Lateolabrax japonicus*). The molluscan intermediate host is a freshwater snail, *Semisulcospira coreana* or *S. libertina*. According to Chai *et al.*, 1991, metacercariae of *M. yokogawai* were isolated from various body parts (scale, muscle, fin, head and gill, and viscera) of dace, *T. taczanowskii*, that had been caught in the Sumjin river. The total number of metacercariae collected from 15 fish was 8767, therefore the average metacercarial density per fish was 584. The majority (8062; 92.0%) were recovered from scales.

Metagonimus takahashii *(Suzuki, 1939, including the so-called* M. Miyata *type; Saito, 1984)*

M. takahashii was first found by Takahashi (1929) in Japan in dogs experimentally fed the *Metagonimus* metacercariae encysted in several kinds of freshwater fish other than the sweetfish. *M. takahashii* is distinguished easily from *M. yokogawai* by the different location and arrangement of two testes and the different size of the eggs (Saito, 1984). The *Metagonimus* Miyata type has been recognized as the intermediate form between the above two species. Chai *et al.* (1991) obtained three morphological types of *Metagonimus* metacercariae – *M. yokogawai, M. takahashii* and the *Metagonimus* Miyata type – encysted in the dace, *T. taczanowskii*, caught in the Sumjin River. It was reported that 9.7% and 48.1% of the inhabitants were infected in some villages along the upper reaches of the Namhan River (Chai *et al.*, 1993). Later, many human cases were reported from various other localities. (Ahn, 1993; Park *et al.*, 1993; Son *et al.*, 1994). From the above reports it is generally acknowledged that, unlike *M. yokogawai*, *M. takahashii* and the *Metagonimus* Miyata type are distributed along relatively small streams, rather than large rivers, in inland areas of Korea.

The snail host involved is *Semisulcospira coreana* or *Koreanomelania nodifila* (Cho *et al.*, 1984), and the fish host is *C. carassius*, *C. carpio*, *P. parva*, *Z. platypus* and *T. taczanowskii*. Rim *et al.* (1996) recently investigated the metacercariae in various freshwater fish species collected from different localities in Korea and experimentally fed to golden hamsters. Their observations of recovered adult worms showed that *Plecoglossus altivelis* was infected with metacercariae of both *M. yokogawai* and *M. takahashii*. *Carassius auratus* was infected with metacercariae of *M. takahashii*, and *Z. platypus*, *Z. temminckii* and *Opsariichthys bidens* were infected only with metacercariae of the *Metagonimus* Miyata type.

Centrocestus armatus *(Tanabe, 1922) Price*

Like *M. yokogawai*, *C. armatus* belongs to the family Heterophyidae, and its metacercarial stage has been found in freshwater fish such as the sweetfish and carp. A natural human infection case was recently reported in Korea (Hong *et al.*, 1988). The first intermediate host is known to be *Semisulcospira* sp. in Japan, but it has not yet been studied in Korea. In Korea freshwater fish such as *Z. platypus*, *Rhodeus ocellatus*, *Gobius similis*, *P. parva*, *Pelteobagrus fulvidraco* and several other species have been reported to harbour the metacercariae of *C. armatus* (J. K. Lee *et al.*, 1983, 1984). A recent field survey on metacercarial infection of the fish host revealed that *Z. platypus* and *Z. temminckii* caught in five large rivers of South Korea were heavily infected with this fluke (Hong *et al.*, 1989). According to Rim *et al.* (1996), the metacercariae of *C. armatus* occurred mostly in flesh, but the internal organs, especially the intestinal outer membrane, were the favourite habitat for *C. armatus* metacercariae.

Echinostoma hortense *(Asada, 1926)*

The presence of *E. hortense* in Korea was first described by Park (1938) in rats in Seoul. The first human case was reported by Seo *et al.* (1983). Since then, a total of 79 egg- or worm-proven cases have been reported in Korea (S. K. Lee et al., 1988; Ryang, 1990). In particular, Cheongsong-gun, an inland area located in south-eastern part of Korea, was found to be a highly endemic area of human echinostomiasis (*E. hortense*), with 22.4% of the villagers infected (S. K. Lee *et al.*, 1988). The first intermediate hosts reported in Korea are freshwater snails such as *Lymnaea pervia* or *Radix auriculata coreana* (Ahn & Kang, 1988). The fish second intermediate hosts are *Misgurnus anguillicaudatus*, *M. mizolepis*, *Odontobutis obscura interrupta*, *Moroco oxycephalus*, *Coreoperca kawamebari*, *Squalidus coreanus* (Chai & Lee, 1990). However, Rim *et al.* (1996) reported that the metacercariae of *E. hortense* were found only in the gills of *Rhinogobius brunneus* and *Acanthorhodeus macropterus* from the Hyongsang river.

The metacercariae are elliptical, 167 × 130 μm in average size with double layers of 3–4 μm thickness. The body is covered with minute cuticular spines, and the head collar is covered with 28 head spines, arranged in a row, including four end-group spines on both sides.

Intestinal pathology due to *E. hortense* infection was studied in experimental rats. It was revealed that the worms dwell in the lumen of the upper small intestine, and pathological changes were chiefly confined to the mucosal layer accompanying noticeable destruction of villi and loss of mucosal integrity (S. H. Lee *et al.*, 1990a).

Echinostoma cinetorchis *(Ando & Ozaki, 1923)*

In Korea *E. cinetorchis* was first reported in rats (Seo *et al.*, 1964). Also, four cases of human infection have been reported in the literature. Studies on the life cycle in Korea have revealed that *Hippeutis cantori*, the freshwater snail, was experimentally confirmed as the first as well as the second intermediate host of *E. cinetorchis* (S. H. Lee *et al.*, 1990b). Other freshwater snails such as *Radix auricularia coreanus*, *Physa acuta* and *Cipangopaludina* sp. or freshwater fish such as *Misgurnus anguillicaudatus* have been shown to carry the metacercarial stage of *E. cinetorchis* (Chai *et al.*, 1990). The metacercariae were round to elliptical and 139 × 134 μm in average diameter. The refractile excretory granules and two suckers were easily recognized under the light microscope, but it was hard to identify their head crown and collar spines.

Echinochasmus japonicus *(Tanabe, 1926)*

E. japonicus is known to be distributed chiefly in Far-Eastern countries. Natural human infection in Korea was reported by Seo *et al.* (1985b). The metacercarial stage of this fluke was found from various kinds of fresh water fish (J. K. Lee *et al.*, 1983). The first intermediate host in Korea is *Parafossalurus manchouricus*. The second intermediate hosts are 18 species of freshwater fish, including *P. parva*, *Hypomesus olidus*, *Gnathopogon strigatus*, *Rhodeus uyekii*, *Z. platypus*, *C. auratus*, *Pseudogobio esocinus* and *Silurus asotus*. The metacercaria of this fluke is elliptical and smaller in size (77–80 × 54–60 μm) with transparent and hyaline elastic double layers. The metacercariae of *E. japonicus* were found only in the gills of various fish hosts, but the infestation rates and densities of this metacercariae were highest in *P. parva* (Rim *et al.*, 1996). Natural infection of the avian hosts such as chickens and ducks has been confirmed by the recovery of adult worms from their small intestine (Eom & Rim, 1984).

The echinostomatid metacercariae were elliptical, golden-yellow, 73–78 μm long and 54–65 μm wide. Their head portions were characterized by the presence of a head crown armed with collar spines, twenty-four in number, and interrupted at the mid-dorsal side of the oral sucker.

Clinostomum complanatum (Rudolphi, 1814)

C. complanatum is a digenetic trematode that naturally parasitizes the throat and oesophagus of piscivorous birds (Yamaguti, 1958). Sometimes, the fluke causes pharyngitis in human beings. In Korea, the first human case of infection by *C. complanatum* was reported by Chung *et al.* (1995a). Chung *et al.* (1995b) recently recovered the metacercariae mainly from muscles, tissues around gills, and fins of the freshwater fishes *Acheilognathus koreensis*, *Microphysogobio yaluensis*, *Rhodeus uyckii*, *Squalidus chankaensis tsuchigae* and *S. gracilis majimae*, which were collected from ponds and rivers in Uisong-gun, Kyongsangbuk-do in Korea.

The metacercaria is encysted within a very thin cyst wall, so that the larva liberates easily in process of collection. According to Chung *et al.* (1995b), the encysted metacercariae are tongue shaped, slightly attenuated at the post-acetabular level and measured 3.28–4.27 mm in length by 0.94–1.46 mm in width. The infection rate ranged from 1.6% (*Z. temminckii*) to 88.9% (*A. rhombea* and *M. yaluensis*). The intensity was highest in *A. rhombea*.

Brackish water fish

Heterophyes nocens *(Onji & Nishio, 1916)*

In Korea, the metacercariae of *H. nocens* were first found in 1978 from mullet (*M. cephalus*) captured in the three southern coastal areas (Seo *et al.*, 1980). The metacercariae are round or slightly ellipsoid measuring 155–198 μm by 131–190 μm. The metacercarial wall is 3.0–4.4 μm thick and surrounded by muscular tissue of the mullet in compressed preparations. The excretory bladder was bluish-black or dark-pinkish in colour and was filled with many granular excretory corpuscles. There were three prominent, muscular suckers, one at the anterior end and the outer two at the middle portion of the body. Before 1990, human infections with this fluke had been verified in 13 cases from scattered areas. In April 1990, however, a highly endemic area of *H. nocens* infection was discovered in a south-western coastal island, where as many as 43% (42 cases) of the population examined were found infected (Chai & Lee, 1990).

The first intermediate host is supposed to be a brackish water snail; this, however, has still to be identidied. The second intermediate hosts were reported to be brackish water fish such as the mullet or goby (*Acanthogobius flavimanus*). Domestic cats were found naturally infected with this fluke (Eom *et al.*, 1985).

Heterophyopsis continua *(Onji & Nichio, 1916) (Yamaguti, 1958)*

H. continua has been reported to be prevalent in Korea, Japan and China. The presence of *H. continua* in Korea was first verified by Chun (1960), who observed the metacercariae in the flesh of the perch (*L. japonicus*) and goby (*A. flavimanus*), and obtained adult worms after an experimental infection. Two cases of human infection with this fluke were reported in Korea by Seo *et al.* (1984b) and two further cases by Hong & Han (1989).

The first intermediate host is not yet known in Korea. The second intermediate hosts are the perch, goby, shad (*Clupanodon punctatus*) (Chun, 1960) and the sweetfish (*Plecoglossus altivelis*) (Cho & Kim, 1985). Domestic cats were reported to be naturally infected (Eom *et al.*, 1985).

Pygidiopsis summa *(Onji & Hishio, 1916)*

The presence of *P. summa* in Korea was first described by Chun (1963), who observed the metacercariae from the gill and muscle of the mullet. Human infection was first reported in eight cases by the recovery of adult worms after chemotherapy from persons who were living in a salt farm village and were habitually eating the raw flesh of the mullet (Seo *et al.*, 1981). Seo *et al.* (1986) found a further nine egg-positive cases of *P. summa* during the faecal examination of some sea-shore villagers, from whom adult worms were recovered later (Chai *et al.*, 1990)

The first intermediate host in Korea is *Cerithidea* (=*Tympanotonus*) sp. The second intermediate host is the mullet or goby (*A. flavimanus*) (Seo *et al.*, 1981). In experimental rats and mice, the worms caused severe villous atrophy and crypt hyperplasia with inflammation of the mucosa (Seo *et al.*, 1986).

Stellantchasmus falcatus *(Onji & Nishio, 1916)*

In Hawaii, the first intermediate host is known to be *Stenomelania newcombi* or *Thiara granifera* (Noda, 1959), but it is not yet known in Korea. Some of the mullet in Korea were shown to harbour the metacercariae of *S. falcatus* (Chai & Sohn, 1988).

The metacercaria of *S. falcatus* is elliptical 150–200 × 130–150 μm, with cysts being enveloped by cysts of host origin. The metacercaria is morphologically characterized by a submedially located ventral sucker and elongated seminal vesicle.

The human infections were reported by Seo *et al.* (1984a) and Hong *et al.* (1986). Chai & Sohn (1988) identified *S. falcatus* by the morphology of adult worms obtained from rat experimentally given metacercariae encysted in the flesh of mullet. They confirmed that mullets serve as a second intermediate host of this heterophyid fluke in Korea.

Stictodora fuscatum *(Onji & Nishio, 1916) (Yamaguti, 1958)*

A case of human infection with *Stictodora* sp. (*S. fuscatum*) was recently reported from a young

Korean who was fond of eating raw mullet or goby (Chai & Sohn, 1988). Thirteen additional human cases were found in a sea-shore village in a south-western coastal area of Korea (J. Y. Chai, 1997, personal communication).

The metacercaria is long and elliptical, 190 by 160 μm in diameter. Brackish water fishes, probably mullet, are known to harbour the metacercariae of *Stictodora* sp., but no report is available on intermediate hosts in Korea.

Marine fish

Nematodes

Human anisakiasis may occur after ingestion of raw marine fish infected with nematode larvae of Anisakidae. Since the first Korean case of *Anisakis* larval infection in the left tonsil was reported by Kim *et al.* (1971), more than 241 cases of gastrointestinal anisakiasis have been reported (Im *et al.*, 1990, 1995). Reported cases of anisakiasis have increased recently because of wide use of gastrofibreoscopy for diagnosis. However, the incidence of human anisakiasis appears to be low when compared with the amount of marine fish consumed in Korea and the high infection rates of *Anisakis* sp. larvae in marine fish.

According to Im *et al.* (1995), 90 larvae removed from the stomach were referred to a parasitological laboratory in Cheju-do during 1989–92; among them 82 larvae were identified as *Anisakis* type I (larva of *Anisakis simplex*), five larvae were *Anisakis* type II (larva of *Anisakis physeteris*), two larvae of *Terranova* type A (*Pseudoterranova decipiens* larva) and one larva was *Contracaecum* type A (*Contracaecum osculatum* larva). Therefore, the larva of *Anisakis simplex* was the most prevalent species. They also analysed the important species of marine fish from which the patients became infected by the yellow corvina (*Pseudoscianena manchurica*), namely sea eel, ling, yellowtail, cuttle fish, scabbard fish, flatfish, etc.

Seven human cases were confirmed by several investigators as infection by *P. decipiens* larva (*Terranova* type A). However, the larvae have never been recovered or described from the fish host. Chai *et al.* (1995) have reported recently the third larvae of *P. decipiens* from the liver and stomach of the codfish (*Notothenia neglecta*) caught in the Antarctic Ocean, South Pole, where the Polar Research Centre of the Korea Ocean Research and Development Institute is operating.

Larval anisakids found in the yellow corvina, a marine fish caught in the Yellow sea, were identified by Chai *et al.* (1986). A total of 1068 anisakid larvae were collected from 30 fish examined, with the average number per fish of 35.6. The encapsulated nematode larvae were isolated from the liver, stomach, intestine, air bladder and from their walls, such as the liver capsule, omentum, anterior and posterior abdominal walls. Among the larval anisakids, the most frequent type was *Anisakis* type I larvae (80.4%), and the others in the decreasing order were *Contracaecum* type D′, *Contracaecum* type C′ (5.1%), *Contracaecum* type D (1.7%), *Contracaecum* type A (1.2%), *Contracaecum* type V (0.28%) and *Raphidascaris* sp. larva (0.09%).

Kim *et al.* (1990) examined the infection state of anisakid larvae from seven salmon (*Oncorhynchus keta*) purchased directly from Taep'o port, Sokcho City, in the coastal area of the East Sea. From seven salmon, 202 anisakid larvae were found, and the mean infection number of anisakid larvae per individual salmon was 28.86. Among them, 98% of larvae were found in the muscle of salmon, but larvae in the intestine were extremely rare compared with muscle. They identified three types of anisakid larvae: *Anisakis* type I., *Contracaecum* type B and *Contracaecum* type D. However, the larvae of *Contracaecum* were found only in the intestine.

Diphyllobothrium latum *(Linnaeus, 1758)*

Human diphyllobothriasis is chiefly caused by infection with *D. latum* by eating raw or inadequately cooked fish, predominantly salmon, trout and perch. A considerable amount of work on *Diphyllobothrium* has been carried out in Japan. It was recently clarified that the tapeworm previously regarded as *D. latum* in Japan was a different species, and a new specific name, *D. nihonkaiense*, was proposed (Miyazaki, 1991). Several species other than *D. latum* have also been reported as causing human infections in many countries, e.g. Japan and Korea, including *D. yonagoense* (S. H. Lee *et al.*, 1989), *D. pacificum*, *D. cameroni*, *D. scoticum* and *D. hians*.

In Korea, the first worm-proven case of *D. latum* infection was reported by Cho *et al.* (1971), and to date a total of 29 cases have been reported in the available literature (S. H. Lee *et al.*, 1983, 1989; Min., 1990). However, with the increasing popularity of eating raw salmon, trout and perch, infection by this tapeworm is tending to increase in Korea. Five cases of *D. latum* were proved by collection of worms after treatment with bithionol, niclosamide or praziquantel during 1975–83. (S. H. Lee *et al.*, 1983). All affected persons recalled eating several kinds of raw marine fish, including perch (*L. japonicus*).

The second intermediate hosts of *Diphyllobothrium* sp. in Japan and Korea are fishes of the family Salmonidae, the most common being *O. masou* (trout) and *O. gorbuscha* (Saghalien trout), *O. keta* (salmon) and *O. nerka* (red trout). The incidence of the plerocercoid in the second intermediate hosts has not yet been reported in Korea.

Prevention and control

In Korea, recent trends of parasitic infections have shown that soil-transmitted helminthiases such as ascariasis, trichuriasis and hookworm infection are decreasing markedly, whereas fish-borne trematode infections such as clonorchiasis, metagonimiasis and other intestinal trematodiases are not showing much reduction in their prevalence. These parasitic diseases are all fish-borne parasitic infections and are acquired by eating raw fish containing infectious metacercariae. This is often significantly related to human behavioural patterns based on socioeconomic and cultural conditions and is linked with the local biological and physical environment. These fish-eating practices in rural areas in Korea are deeply rooted traditional customs and are therefore hard to change among Korean people.

Clonorchiasis is regarded as of considerable public health importance because of its high prevalence in the population, wide geographical distribution, high morbidity and moderate fatality in heavily infected people. In addition, *M. yokogawai* is recognized as endemic in local areas. Since the 1980s, at least 12 different species of intestinal trematodes, other than *M. yokogawai*, have been found causing enteritis in freshwater, brackish- and marine-water zones. They are mostly digeneans of heterophyid and echinostomatid families transmitted by fish.

The control of these trematodes is theoretically very simple, because the infection can only be contracted by ingestion of encysted metacercariae when the raw intermediate host such as freshwater or brackish water fishes is eaten. Therefore, the most practical method of preventing human infection is to avoid eating raw, freshly pickled or imperfectly cooked fish. However, it is exceedingly difficult to carry out such simple measures in the face of centuries-old traditions to which the population clings with great tenacity

In the control of clonorchiasis in Korea, the practical control measures were not attempted until praziquantel was introduced as a safe and effective drug against *C. sinensis* in 1981. Government and parasite control bodies conducted a pilot project of clonorchiasis treatment using praziquantel at a single dose of 40 mg per kg of body weight in 1982. The results showed praziquantel to be highly effective and safe in the treatment of clonorchiasis (Ministry of Health & Social Affairs & Korea Association of Parasite Eradication, 1982). The government launched the mass treatment project of clonorchiasis in 1984. During the 7 years 1984–90, the stools of 3 009 166 people living in endemic areas were examined microscopically using the cellophane faecal thick smear method. All egg-positive cases were treated with praziquantel in a single dose of 40 mg per kg of body weight at local health centres under medical supervision (Ministry of Health & Social Affairs, 1992). After the mass treatment project was begun in 1984 in the endemic areas, the status of clonorchiasis was significantly improved 7 years later. Not only was the infection rate reduced in the previously endemic areas, but also the proportion of the degree of heavy infection in clonorchiasis was lowered from 11.9% to 3.6% in the infected people.

Together with the mass treatment project, voluntary treatment with praziquantel to the infected individuals was popular. In addition to the chemotherapy, reinfection cycle seems blocked in many previous endemic areas because of a changed ecology due to mechanization of farms, urbanization, industrialization, water pollution, reduced population of freshwater fish caused by the use of chemical fertilizers and pesticides, and the resulting attitude changes of the local people towards eating raw freshwater fish. However, many people who enjoy the habit of eating raw fish remain in certain areas in the basins of rivers. Chemotherapy has proved to be a rapid and effective method of control. Therefore, a combination of efforts with major emphasis on health education and mass treatment with praziquantel coupled with governmental aid could reduce the disease.

However, there was not any practical control measures for metagonimiasis and other intestinal trematodes, and for anisakiasis and diphyllobothriasis. Praziquantel is now the most favoured drug against all species of trematodes. In the highly endemic areas of fish-borne parasitic infections, the application of population-based chemotherapy is an important form of control of those infections. For implementation, community participation and drug delivery in co-ordination with primary health care and promotion of diagnostic techniques are essential elements for the success in control measures. Educational process should involve various approaches to change successively knowledge, attitudes, behaviour, habits and customs of their lives. The choice of methods must be directed to the nature of the environment, the habits and customs of the people.

There are a number of public health measures that could contribute to the prevention and control of fish-borne parasitic infections. These measures include:

1. identification of infected individuals and determination of the proportion of infected people in an endemic area (by the promotion of diagnostic technique);
2. community-based treatment (selective treatment in which the prevalence of infection is lower);
3. construction and use of toilets (provision of satisfactory sanitary facilities);
4. disposal and use of excreta, waste water and sewage sludge (environmental control);
5. avoidance of capture, culture, harvest or marketing of fish or shellfish from areas in which the parasites are known to endemic;
6. the application of HACCP (the Hazard Analysis and Critical Control Point) principles;
7. community-based education and mass communication against the consumption of raw or undercooked fish and shellfish, which is widely prevalent around in areas near rivers, lakes, streams and ponds (WHO Study Group, 1995).

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