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Risk factors for *Clonorchis sinensis* infection transmission in humans in northern Vietnam: A descriptive and social network analysis study

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Abstract

Clonorchis sinensis is major fish-borne trematode, endemic in North Vietnam. Risk factors described so far include individual eating behaviors and environmental factors. Here, additional to conventional risk factors, we report on socially influenced liver fluke transmission in endemic communities. A cross-sectional study on risk factors and fish sharing networks was conducted in 4 villages of Gia Thinh Commune, Ninh Binh Province. A total of 510 residents in 272 households were recruited for risk factor analysis while 220 households, 28 fishermen and 10 fish-sellers were enrolled for social network study. Fecal examination for *C. sinensis* eggs was performed. Average *C. sinensis* infection rate at Gia Thinh commune was 16.5% (range 2% to 34.4%). Higher infection rates were significantly associated with males, lower educational levels, eating raw fish, and location of the villages. Social network analysis (SNA) showed a strong positive correlation between ego network size (number of households in fish sharing network) and quantity of raw fish consumed ($r=0.603$, $P<0.05$). The infection rate in people who ate raw-fish caught from a nearby river was significantly higher than those who consumed fish taken from farmed ponds ($P<0.05$). The amount of raw-fish meal consumed per resident/year was significantly higher in villages that had a strong network of sharing raw-fish food ($P<0.001$). This study reports for the first time on fish-food sharing among neighbors, proximity to water bodies, frequency of eating raw fish from

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natural water bodies and low education were key risk factors in *C. sinensis* infection transmission in northern Vietnam.

Keywords

Clonorchiasis; *Clonorchis sinensis*; risk factors; social network analysis; SNA; Vietnam

1. Introduction

Liver flukes of the family Opisthorchidae (class Trematoda), particularly the species *Opisthorchis viverrini*, *Opisthorchis felinus*, and *Clonorchis sinensis*, pose a major public health burden in Southeast Asia [1, 2]. *Clonorchis sinensis* is endemic in Southeast and East Asia including China, North Vietnam, South Korea and Eastern Russia with approximately 15–20 million infected and over 200 million are at risk [3, 4]. Eating raw freshwater fish containing *C. sinensis* metacercariae is the main source of human infection [1]. Chronic liver fluke infection can lead to a range of liver and bile duct diseases including cholangiocarcinoma, a malignant and generally fatal cancer [1]. Due to the strong association between liver fluke infection and cholangiocarcinoma, the World Health Organization International Agency for Research on Cancer (IARC) has classified *C. sinensis* as Group 1 human biological carcinogens [3].

In Vietnam, it has been reported that clonorchiasis and opisthorchiasis coexist [5] with an estimate of 1 million infected with *C. sinensis* in 1995 [6] and 33 million at risk [7]. Latest data show that clonorchiasis is endemic in 21 northern provinces and its prevalence varies from 0.2% to 40.1% [8]. Similar to other liver fluke infections, key risk factors are due to local habit of eating raw or undercooked fish [9, 10], and the rapid growth of freshwater fish production [11]. Several investigations have been conducted to examine factors associated with *C. sinensis* infection such as raw fish consuming behavior and gender, occupation, education level. [12–15]. However, to our knowledge, no attempt has been made to apply social network analysis to analyzing fish distribution networks, and raw-fish-eating behaviors associated with *C. sinensis* transmission in humans.

Social Network Analysis (SNA) is the study of patterns in health risk behaviors influenced by peer or social contexts [12]. It provides in-depth understanding of various risk behaviors that can be affected by other people [12, 13]. Network information can be used to accelerate behavior change or reduce negative consequences that occur when bad and unhealthy behaviors spread [14]. Network data can also be used to find bridges that may be responsible for spreading diseases or behaviors between groups. Ego network is a part of social network analysis that focuses on an individual node. It can provide insights into individual perception, identity and behaviors that differ from others [15].

Therefore, this study was designed to explore factors associated with *C. sinensis* infection, and social networking activities relating to fresh water fish sharing and raw fish recipes in addition to conventional epidemiology. Specifically, the study investigated likely socio-cultural behavioral patterns relating to fish sharing and raw fish eating associated with *C. sinensis* infection in 4 communities from a heavily endemic area in northern Vietnam.

2. Materials and methods

2.1 Study site

This study was conducted in Gia Thinh community, Gia Vien district, Ninh Binh Province of Vietnam. The communes were known as heavily clonorchiasis-endemic areas in northern Vietnam. Gia Thinh Commune consisted of 4 villages (Lien Huy, Trinh Phu, Dong Chua, and Kenh Ga) comprising 2,247 households with a total population of 8,113. Most of the residents were rice agriculturists; however, some farmers also relied on cage fish farming for livelihood in the Hoang Long River. Three villages (Lien Huy, Trinh Phu, and Dong Chua) are bordered by a dike near the river (Figure 1). Kenh Ga Village is located in front of the dike next to the Hoang Long River, so those villagers living along the river experience flooding annually in rainy season.

2.2 Research design

A cross-sectional study was conducted to determine social network structure and its association between fish sharing and *C. sinensis* infection status as well as factors associated with the infection among households in the Gia Thinh community.

2.3 Baseline survey and demographic data

The baseline survey was conducted in April 2015 with 510 residents and 272 households in the 4 villages of Gia Thinh Commune. The commune is known as heavily clonorchiasis-endemic areas in Northern Vietnam.

Demographic characteristics including age, gender, education, occupation, etc. and fecal samples were collected. Formalin-ethyl acetate concentration technique (FECT) was used to examine helminth eggs. Numbers of households/participants categorized by village are Lien Huy 103/187, Trinh Phu 26/50, Dong Chua 68/142, and Kenh Ga 75/131. All participants were randomly selected.

2.4 Social network analysis (SNA)

A second survey for social network analysis was done in 108 ego households for sociodemographic data, their raw fish eating and sharing network behaviors (Definition: *ego* in this context refers to a household sharing fish to other households (*alters*) in a village). A clonorchiasis positive household is defined as having at least one individual with positive *Clonorchis* eggs upon stool examination. Consumer questionnaires were also applied in 112 households (alter households). The ego network of fresh water fish sharing was carried out with 112 consumers, 28 fishermen and 10 fish sellers. All fishermen and fish-traders around the communes were surveyed on their fish catching, purchasing and selling behaviors. Fecal examination was performed in both egos and alters.

2.4.1 Questionnaires for SNA data collection—Five different questionnaires were applied to obtain the data for social network analysis including 1) household questionnaire for demographic data of the household, sources of fish, and access to “information, education and communication” (IEC) information 2) individual questionnaire for individual demographic data, source of fish access, behavior of eating raw fish and their knowledge

about small liver flukes 3) questionnaire for consumers was used to explore information of people in each household, who was infected with *C. sinensis* regarding to demographic information, behavior of raw fish eating and sharing, source of fish access, and network information 4) fish trader questionnaire was devised to collect trader demographic information as well as the source of their freshwater fish such as where and from whom they bought and also on-sold fish to, and 5) fishermen questionnaire including demographic information, their fishing sites and wholesale fish buyers they sell fish to.

2.4.2 Indicators in measuring social network

Centrality: This study focused on the three most common degree centrality measures developed by [16] and ego network size. When network visualization is shown, nodes located in the center are frequently focused. Central nodes often occupy important position of the network field, and attract critical attention. The important node could be identified by centrality.

Degree centrality: It is defined as the number of links incident upon a node (i.e. number of ties that a node has). It shows number of links that a node has. The degree usually separates into 2 measures, in-degree and out-degree. In this work in-degree means receiving raw fish from alters and out-degree means sharing it to them.

Ego network size: It is the number of alters. In this study is number of households which sharing and receiving raw fish with ego households.

2.5 Data analysis

Questionnaire data were entered into Excel 2010 and EpiData 3.1. Analysis was conducted by using STATA/SE for Windows (v10.2, StataCorp LP, College Station, TX). Network data was analyzed by UCINETsoftware(v 6.575.[17]).

2.6 Human Ethics

This study was reviewed and approved by the Ethical Committee of Vietnam National Institute of Malaria Parasitology and Entomology (NIMPE) (Approval No.: 157/2015/NIMPE).

3. Results

3.1 Demographic data, prevalence and factors associated with *C. sinensis* infection

Study population demographics and the likelihood of *C. sinensis* infection across demographic and behavioral risk factors are shown in Table 1. Fecal examination showed overall mean prevalence of *C. sinensis* infection in the four villages was 16.47%. Kanh Ga village had the highest *C. sinensis* infection rate of 34.35% with Dong Chua, Lien Huy and Trinh Phu villages at 15.49%, 8.56 and 2%, respectively.

Univariate analysis revealed *C. sinensis* infection risk for males was 2.33 times higher than for females (95% CI=1.37–3.61, $P < 0.001$). Overall, people with higher education had much lower risk of *C. sinensis* infection. Those who completed secondary school had less

chance of infection (OR=0.63; 95% CI=0.38–1.05) than those with primary school education or less (OR 1). Farmers (OR=4.05; 95% CI=1.59–10.32) were much more likely to be infected than non-farmers. Those who had eaten raw fish over the last 5 years had much higher infection risk (OR=9.06; 95% CI=4.36 – 18.83) than those who never ate raw fish. People who ate raw fish with alcohol had 1.97 times (95% CI=1.03–3.74) higher risk of infection than those eating raw fish dish without alcohol. Table 2 shows gender differences in raw-fish eating behaviors. Males showed significantly higher frequency in eating raw fish dish (67.41%) than females (32.59%)($P < 0.0001$). Similarly, males had higher rate of eating raw fish dishes with alcohol (88%) than females (12%) ($P < 0.0001$).

3.2 Source of fish and raw fish sharing network

3.2.1 Source of fish and their distribution networks—Sources of fish were categorized into 1) from their own/family pond, 2) from neighboring pond, 3) from River/canal, and 4) from market in community. Among the four sources of fresh water fish for raw consumption, there was no significantly different in *Clonorchis* infection rates between people who ate raw fish dishes prepared from fish obtained from their own ponds or fish from the market. However, there was a significant different in *C. sinensis* infection rates between people who ate raw fish caught from rivers and canals compared to fish from other sources (31.86% vs. 19.5%, $p = 0.014$) and fish from ponds of their neighbors ($p = 0.032$) (Table 3). No significant difference in the infection rate was found between people eating fish buying from a market (26.67% vs. 19.49%)(Table 3).

Network analysis for freshwater fish sources for making traditional raw fish salad in Gia Thinh commune is shown in Figure 2. The habitants in Trinh Phu village mostly used fish from their own ponds and their neighbors' ponds for preparing raw fish dishes. On the other hands, villagers lived in Kenh Ga village preferred wild caught fish from river or canal (Fig. 2). The prevalence of *C. sinensis* from Trinh Phu is lower than that of whom having raw fish dish prepared from fish caught in the river or bought from local fishmonger.

All fishermen were interviewed by using questionnaires and the results revealed that 100% of fishermen sold their fish, 85.1% partly used for their household consumption, and only 7.14% shared the fish with others. Most fishermen (89.29%) sold their fish at the fish market at Kenh Ga village. The market chain of fish caught by the fishermen found to be sold within the Kenh Ga market (21.43%), 35.71% sold to other markets out of the village, and 32.14% sold to markets out of the commune. Ten fishmongers were interviewed to identify who they sold the fish to in this commune. The results revealed that 67.8% of fishmongers sold the fish to Kenh Ga villagers, 13.57% sold the fish to Dong Chua villagers, and 18.55% sold the fish to Lien Huy villagers. Fish cultured in ponds in each community was the most favorite fish for fishmongers.

3.2.2 Fresh water fish sharing networks

3.2.2.1 Overall of ego networks of fresh water fish sharing: Ego networks were conducted in 3 villages of Gia Thinh Commune: Kenh Ga, Lien Huy and Dong Chua. In this context, ego includes fish consumers, fishermen and fishmongers. The tie represents both sharing and trading freshwater fish between egos and other nodes or alters. Direction of

sending or receiving is indicated by out-degree or in-degree respectively. Size of nodes indicates the number of degrees that link between each pair of nodes. The sociogram of overall data shows the differences between 3 villages, the families live in Kenh Ga village (square) are big with multiple ties binding each other clustering in the center. Alternately the households in Lien Huy (rhombus) and Dong Chua (circle) villages are smaller in size, no hub of sharing and located more sparsely at the edge of the network. Considering *C. sinensis* infection in the commune, Kenh Ga village has highest number of positive households than the other 2 villages. This suggests that households in Kenh Ga villages have more infected households and more raw fish sharing comparing to other villages (Fig. 3).

3.2.2.2 Kenh Ga social network: When extracting Kenh Ga network from the commune social network, the network pattern looks similar but different from the other two villages (Figure 4). The sociogram comprises 4 components and 2 isolates lining in central clustering with periphery. The biggest component linked most numbers of egos together. The density of connection for fish sharing among nodes, and social network data are concordance with the information from questionnaires. It reveals that Kenh Ga village is the important fish market in this commune. Moreover, most of *C. sinensis* infected households locate in the biggest component. Big red square nodes reflect the sharing mostly from smaller red square nodes. However, there is no data from the biggest blue square that has high out-degree.

3.2.2.3 Dong Chua social network: The sociogram shows sparse pattern of 13 components and 14 isolators. The network composed of medium sized cluster having positive household sharing raw fish (red circle) and scattered small nodes. There is no hub of raw fish sharing. Pattern of sharing is branched. It could be influenced by geographical location and/or culture of food sharing. The positive households mainly locate in the medium-sized hub with peripheral isolators (Figure 5).

3.2.2.4 Lien Huysocial network: The network is similar to Dong Chua village but less isolator. The sociogram shows 6 components and 3 isolates which the biggest components comprised of 39 nodes (Figure 6). There are 2 medium hubs of sharing.

3.2.2.4 Ego network parameter: Focusing on the raw fish eating habit through the characteristics of ego networks, the amount of raw fish consumption per households per year, ego size and degree were calculated. There are significant differences in number of degree ($P = 0.001$), ego size ($P = 0.001$), and quantity of raw fish consumption among 3 villages ($P = 0.001$). Averaged consuming raw fish mass of a person in Gia Thinh commune is 3.07 ± 4.57 kg per year. The inhabitants lived in Kenh Ga village consuming the biggest raw fish mass, estimated 5.07 ± 5.53 kg/person/year. While, villagers of Dong Chua village consume the lowest raw fish mass, estimated at 0.88 ± 1.22 kg/person/year.

Ego size is the number of households that sharing fish to with particular ego. Overall, ego size for sharing fish is 3.28 ± 3.0 . The highest ego size is 4.69 ± 3.61 in Kenh Ga village, and the lowest ego size was 1.66 ± 1.66 in Dong Chua village. The average degree of Kenh Ga, Lien Huy and Dong Chua village are 1.85 ± 1.24 , 0.95 ± 0.68 and 0.56 ± 0.48 respectively (Table 4).

Correlation of ego size and raw fish consumption were tested. The result showed that there are positive correlations between ego size and amount of raw fish consumption ($r=0.603$). This revealed the fact that, the more sharing and receiving activities they did, the more raw fish mass they consumed (Figure 5). This means that for the families having sharing and receiving raw fish dish with other families, the more sharing and receiving activities they do, the more raw fish mass they consumed.

4. Discussion

This is the first social network analysis study on raw fish sharing behavior in endemic North Vietnamese areas for clonorchiasis. This study elucidates key factors and their relationship in spreading this disease through food sharing. Our results could have useful application in development of *C. sinensis* infection prevention and control programs.

4.1 What factors are associated with *C. sinensis* infection?

In the present study, many factors were found to influence *C. sinensis* infection rate in Gia Thinh commune. Some earlier studies have shown higher infection rates for males compared to females [11, 18, 19]. Our study corroborated these results finding that 22.27% male and 11.4% female participants were infected with the *C. sinensis* ($P=0.001$). Alcohol and raw fish consumption were also found to be positive factors for *C. sinensis* infection in the present study. The infection rate for those drinking alcohol was 27.11%, significantly higher than that in the non-drinking alcohol participants ($P=0.037$), also found in the studies in China and Korea [18–21].

Univariate analysis showed that farmers had 4.05 times higher risk of infection with *C. sinensis* than non-famer groups (95% CI=1.59–10.32). Similarly in the Northeast of Thailand, research has shown evidence of a relationship between *O. viverrini* infection rate and different occupational groups. In all cases, people who worked in agriculture had 2.3 times the risk of *O. viverrini* infection than other groups (95% CI=1.41–3.9) [22].

People who had never consumed raw fish were also infected with the worm. However, the prevalence of infection was 4.57%, much lower than in who ate raw fish. The infection rate increased for those who had eaten raw fish more than 5 years ago (12.04%). In people who have eaten raw fish within the last 5 year the infection rate soared up to 30.24%. The difference in the prevalence among these 3 group was statistically significant ($P=0.000$).

We also found that clear relationships between gender and consumption of raw fish together and with drinking alcohol. The infection rate of male participants who ate raw fish was 67.41% compared to 32.59% in the female counterparts. Also, more males (88%) drank while eating raw fish in the comparison with female (12%, $P=0.000$). This reflects Vietnamese culture in which it is more common for men to drink than woman. When drinking, men usually find food to eat, and raw fish is one of the favorites. Many people mistakenly think that alcoholic drink can kill bacteria and parasites in the food, and so they are not afraid of being infected by pathogens from the potentially contaminated food. Moreover, some people are influenced by the behaviors of drinking-mates, or are even compulsorily encouraged to drink and to eat the risky food. Consequently, men had higher

risk of being infected with *C. sinensis* than women, and prevalence of *C. sinensis* infection in men was significantly higher than that in women in this study. Similar results were shown in other studies [18, 21]. In the cross-sectional study conducted in Keollabuk province, Korea by [19], the rates of drinking in men and women were 56.1% and 20.8% respectively. They also found that more men ate raw fish than women (77.2% versus 46.6%).

In this study, education level also affected the rate of *C. sinensis* infection. The higher the education participants received, the lower risk of infection of *C. sinensis* they had. People who had secondary education tend to have lower risk of *C. sinensis* infection (OR=0.63, 95% CI=0.38–1.05) than primary school and people who graduated from high school had only 0.152 times risk of *C. sinensis* infection (95% CI=0.003–0.443). All 14 participants who attend colleges and university were not infected by the worm in this study. In other studies, the associations between the infection rate of worm and education level have also been documented [19, 20, 23]. Similar result was found from in the Northeast of Thailand, where people who had graduated secondary school had lower risk (OR=0.38, 95% CI=0.16–0.91) of infection with *O. viverrini* (an helminth that has a similar life cycle to that of *C. sinensis*), compared to the people who had only primary education [24]. About the harm caused by *C. sinensis* to the health in the community was still limited. The rates of people who did not know about *C. sinensis*, and who did not know how the *C. sinensis* infection transmitted were 71.57% and 69.02% respectively. This means that the need for programs educating the understanding in *C. sinensis*, and the harm from eating raw fish behavior is essential.

The commune Gia Thinh consists of 4 villages Dong Chua, Lien Huy, Trinh Phu and Kenh Ga, out of which 3 former villages are surrounded by dykes. Kenh Ga village is located outside dykes and annually affected by floods. Interestingly, the rate of infection of *C. sinensis* in people at Kenh Ga (34.35%) was significantly higher than those in other villages (2.00% to 15.49%). It is possible that contaminated feces in the open environment were spread during the flood period, leading to more contact between fish in open waters and cercariae and metacercariae. Other studies in Laos and Thailand have also found similar results [24, 25].

4.2 Who are key players in fish distribution network and raw fish sharing network?

4.2.1 Fish distribution network—Gia Thinh Commune has two main fish distribution sources; the first is from fish sellers at local markets and the second source is directly from fishermen. Residents can also buy fish from a bigger market at a town about 1.5 km away. Most fishermen fish in the Hoang Long River which runs across Gia Thinh commune. Only some fishermen catch fish from other communes.

In the present study, a strong relationship between the fish source and human *C. sinensis* infection was detected. The infection rate in people who eat raw fish from rivers and canals was significantly higher (31.86%) than for those from other sources (19.5%). Furthermore, people who eat raw fish from their own or neighbors' ponds had much less infection risk compared with those who had fish from other sources.

In this study, the infection rate in Kenh Ga village was significantly higher than the other three villages. Interestingly, all of the fishermen were residents at Kenh Ga village. The

majority of fishermen (89%) sold fish to people at Kenh Ga village, only 35%, 32.14% and 21.43% sold fish at other villages in Gia Thinh Commune, other communes, and fish traders respectively. The sources of fish for daily consumption were different. At Kenh Ga village, most of villagers bought fish from fishermen who caught them from rivers while most of villagers in Dong Chua bought fish caught from ponds. Alternately, villagers from Lien Huy mostly bought fish from local markets.

Hung, Dung do, Lan Anh, Van, Thanh, Van Ha, Van Hien and Canh le [26] found the infection rate of foodborne zoonotic trematodiasis in Gia Thinh commune was much higher in wild-caught-fish (59.6%) compared to cultivated fish (1.8%). Sharpbelly fish (*Hemiculter leucisculus*), a native living fish in Hoang Long River, had a high infection rate of 12.8%. As mentioned above, people residing at Gia Thinh commune knew little about *C. sinensis* and its transmission route. In addition,, they mistakenly believed that eating raw fish made them healthier, and *C. sinensis* metacercaria could not survive after raw-fish food preparation process. Many people thought that drinking alcohol with food would kill any parasites that might persist in the food. These findings suggest the importance of the community health education about clonorchiasis prevention and control.

4.2.2 Fresh water fish sharing network—Normally, key players in social networks are the persons who are the most trusted for receiving/sharing information from other people. The most important index to determinate key players is in-degree centrality [27]. Determining key players is extremely important in social network analysis because key players are individuals who can limit or influence the spread of behavior [28]. The results from the ego network of overall data showed that almost all nodes linked together. Kenh Ga social network showed the most clustered pattern and had high number of degrees of concordance with the numbers of bigger ego sizes in sociogram. So the ego network approach was applied to identified the important nodes of sharing fish among 3 categories; consumers, fishermen and fishmongers. The sociogram of each village showed both similar and different characters. They were similar in terms of the nodes with *C. sinensis* positive were the high degree nodes in fish sharing network, but the number of degree were totally different between Kenh Ga and the other 2 villages. There were also nodes having no raw fish sharing with others. They were households located in isolated areas and far from other households so had less chance for sharing fish with others and are therefore less important nodes in the network. While raw fish sharing patterns influence *C. sinensis* transmission between households, the parasite contaminated dish is most important in the process. Regardless of whether the sharing households are infected or uninfected the receivers could become infected. Interventions, therefore, should be focused on the nodes which showed higher number of degree or ego size.

This study also pointed out that there was a strong positive correlation between ego network size and consumption of raw fish ($r=0.603$). In other words, households who shared more raw fish would also consume more raw fish. Interestingly, although raw-fish recipes are traditional food at Gia Thinh commune, there are no restaurants or shops selling this food. This showed the importance of the household and family in preparation and sharing of these traditional raw fish meals in the community. It also indicated that interventions should include understandings of the local raw-fish preparation traditions and sharing networks.

The mean rate of *C. sinensis* infection in these communities was 16.47%. The highest infection rates were found in persons with lowest educational levels. Eating raw fish from the river increased risk of *C. sinensis* infection rather than fish from fishery ponds. The fishermen, who all came from the village closest to the river, also contributed to concentrating *C. sinensis* infection in this village by selling their fish mostly in this village.

This study provides clearer overview information and more details on the fish distribution and fish sharing networks in endemic areas. Therefore, we can determinate more precisely relative risk factors in the transmission cycle of this fatal worm. Our study has implications for all clonorchiasis endemic areas in North Vietnam. Its data would make useful contributions to developing culturally suitable and effective clonorchiasis prevention and control campaigns for hi-infection risk areas.

In conclusion, a range of *C. sinensis* risk factors was found including being male, working in agriculture, consuming alcohol with raw fish eating, and having low education levels. The highest infection rates were found in persons having lowest educational level. Eating raw fish sourced from the river rather than fish farmed ponds also noticeably increased *C. sinensis* infection risk. Fish sourcing and distribution factors appear to affect the transmission of the *C. sinensis* in these communities. Infection risk prevention interventions, including education for the residents and particularly key players in the networks should be carried out to reduce raw fish consumption behavior among communities.

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Figure 1. Map of 4 study site-villages (Lien Huy, Trinh Phu, Dong Chua and Kenh Ga villages) in Gia Thinh Commune (white boundary line), Ninh Binh Province (inset). Green arrowhead = dyke lane.

Figure 2.

Network of fish sources for making raw fish salad in Gia Thinh commune. Blue down triangle nodes indicate fish origin. Note: white nodes indicate households with no *C. sinensis* infection, red nodes indicate households with *C. sinensis* positive. Node shapes indicate to resident population from different villages: square nodes indicate Kenh Ga village, up triangle nodes indicate Lien Huy village, circle nodes indicate Dong Chua village and the box nodes indicate Trinh Phu village.

Figure 3.

Raw fish sharing network in Gia Thinh Commune. The square nodes indicated households in Kenh Ga village. The rhombus nodes indicated households in Lien Huy village. The circle nodes indicated the households in Dong Chua village, and the triangle nodes indicated the households with no information about resident place. The color of nodes indicated *C. sinensis* infection: red indicated positive cases, white indicated negative cases, and blue indicated cases have no information.

Figure 4.

Raw fish sharing network *according to* degree centrality attribute in Kanh Ga village. The families in the raw fish sharing network have trend forward gathering each other into a central network with a lots of big nodes (families sharing raw fish dish with so many other families in the village). Only few families locate sparsely at the edge of the network.

Figure 5.

Raw fish sharing network *indicated* by size of egos in Dong Chua village. Different sizes of nodes indicated by degree. The color of nodes indicates *C. sinensis* infection: red indicated positive cases, white indicated negative cases, and blue indicate to cases with no information.

Figure 6. Raw fish sharing network *according to* degree centrality attribute in Lien Huy village. Different sizes of nodes indicate by degree. The color of nodes indicates *C. sinensis* infection: red indicated positive cases, white indicated negative cases, and blue indicate to cases with no information.

Figure 7.
Correlation between ego size and amount of raw fish consumption among households in 3 villages of Gia Thinh commune, egsize = Ego size.

Univariate analysis for *C. sinensis* being detected in stools according to selected risk factors

Table 1

Characteristic	n	Positive No. (%)	Univariate analysis OR (95 % CI)	P value
Gender				0.001
Male	238	53 (22.27)	2.23 (1.37 – 3.61)	
Female	272	31 (11.40)	1	
Education level				0.002
Primary school (under grades 6)	120	29 (24.17)	1	
Secondary school (grades 6–9)	310	52 (16.77)	0.63 (0.38–1.05)	
High school (grades 10–12)	65	3 (4.62)	0.152 (0.042 – 0.543)	
University	15	0 (0.00)	-	
Occupation				0.002
Non-Farmers	92	5 (5.43)	1	
Farmers	418	79 (18.90)	4.05 (1.59 – 10.32)	
Alcohol drinking when eating raw fish				0.037
No	88	14 (15.91)	1	
Yes	225	61 (27.11)	1.97 (1.03–3.74)	
Raw fish consumption				0.000
Never	197	9 (4.57)	1	
Yes but not for the past 5 years	108	13 (12.04)	2.86 (1.18 – 6.93)	
Yes, still eating in the past 5 years	205	62 (30.24)	9.06 (4.36 – 18.83)	
Raw fish consumption for last year				0.013
At least once a week	5	1 (20.00)	1	
At least once a month	42	13 (30.95)	1.79 (0.18 – 17.65)	
At least once in last year	126	39 (30.95)	1.79 (0.19 – 16.57)	
Have not eat raw fish in last year	140	22 (15.71)	0.75 (0.80 – 7.00)	

Table 2

Differences in behavioral characteristics according to gender.

Characteristics	Male N (%)	Female N (%)	Total N (%)	P-value
Raw fish consumption (n=510)				0.000
No	27 (13.61)	170 (86.29)	197 (100)	
Yes	211 (67.41)	102 (32.59)	313 (100)	
Alcohol consumption with raw fish (n=313)				0.000
No	13 (14.77)	75 (85.23)	88 (100)	
Yes	198 (88.0)	27 (12.0)	225 (100)	

Table 3

Association between sources of fish for raw fish dishes and *Clonorchis sinensis* egg-positive rates in the participants.

Characteristic	Negative (%)	Positive (%)	Total (%)	P value
Source of fish (Total = 313)				
<i>Fish from pond of family</i>				
Yes	18 (90.0)	2 (10.0)	20(100)	0.178
No	220 (75.09)	73 (24.91)	293 (100)	
<i>Fish from neighbors' pond</i>				
Yes	35 (89.74)	4 (10.26)	39 (100)	0.032
No	203 (74.09)	71 (25.91)	274(100)	
<i>Fish from river or canal</i>				
Yes	77 (68.14)	36 (31.86)	113(100)	0.014
No	161 (80.5)	39 (19.5)	200(100)	
<i>Fish from market</i>				
Yes	143 (73.33)	52 (26.67)	195(100)	0.15
No	95 (80.51)	23 (19.49)	118(100)	

Table 4
Differences of raw fish consumption and ego network parameters among 3 villages in Gia Thinh commune.

Characteristic	Overall Mean $\pm$ SD	Village			P value
		Dong Chua Mean $\pm$ SD	Kenh Ga Mean $\pm$ SD	Lien Huy Mean $\pm$ SD	
Raw fish consumption (kg/year)	3.07 $\pm$ 4.57	0.88 $\pm$ 1.22	5.07 $\pm$ 5.53	1.63 $\pm$ 3. 05	0.0001
Ego size	3.28 $\pm$ 3. 08	1.66 $\pm$ 1.66	4.69 $\pm$ 3. 61	2.38 $\pm$ 1. 58	0.0001
Degree	1.36 $\pm$ 1. 15	0.56 $\pm$ 0.48	1.85 $\pm$ 1. 24	0.95 $\pm$ 0.68	0.0001