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A new method for estimating the prevalence of clonorchiasis in Korea

A proposal to replace arbitrary riverside sampling

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Abstract

South Korea presently uses an arbitrary sampling method to monitor the prevalence of *Clonorchis sinensis* infection in the endemic areas of the country. However, the present method is not standardized and focuses primarily on individuals who reside nearest to the mainstream river. We propose a new sampling method that combines cluster sampling with proportionate quota sampling to ensure that the entire endemic area is accurately represented. We tested the new method in Okcheon-gun, South Korea, and determined that the *C sinensis* infection prevalence (8.9%) in 2013 was higher than that (6.9%) estimated in 2012 when the arbitrary method was used. Additionally, no difference was observed in the prevalence based on the distance from the riverside areas, including branches and creeks, between the areas <1 and >1 km away from the riversides. Therefore, health authorities should place equal emphasis on all regions within the endemic areas. Based on the findings, we recommend the following: the clonorchiasis prevalence rate must be measured using probability sampling, (clear guidelines on survey coverage should be provided to include the riverside areas and all areas nearby branch streams, and regional cohorts should be created for continuous monitoring of prevalence rates across the region.

Abbreviations: CEP = Clonorchiasis Eradication Program, KCDC = Korea Centers for Disease Control and Prevention, MoHW = Ministry of Health and Welfare.

Keywords: *Clonorchis sinensis*, incidence, prevalence, sampling study

1. Introduction

The Korean government has been conducting the "National Survey of Intestinal Parasite Infection" every 5 to 7 years since 1971 to estimate the prevalence of parasitic infection and evaluate the effect of antiparasitic infection programs.[1,2] As a result, soil-transmitted helminths in Korea have been almost eradicated.[3] However, clonorchiasis still comprises a major percentage of all parasitic diseases in Korea, although its infection rate has decreased over the recent decades.[4]

Clonorchiasis in humans is acquired by ingesting undercooked freshwater fish infected with the metacercariae of *Clonorchis sinensis*. Some riverside dwellers near the 5 major rivers in Korea have traditionally consumed raw freshwater fish; therefore, careful monitoring of these individuals for clonorchiasis is important.[5] Although clinical symptoms are rare in the early infection stage, special and close attention is needed because of the risk of severe complications, such as cholangitis, biliary cirrhosis, and cholangiocarcinoma.[6–10] To solve the clonorchiasis problem, the Ministry of Health and Welfare (MoHW) and the Korea Centers for Disease Control and Prevention (KCDC) launched the Clonorchiasis Eradication Program (CEP) in 2005 with the goal of reducing the infection rate by diagnosing, treating, and educating residents in endemic areas.[11,12] However, the *C sinensis* infection prevalence rate among inhabitants near the riverside is still ~4.6 times (11.05%) higher than the average infection rate (2.40%) across the country, although this rate has gradually declined.[13,14]

To eradicate or control *C sinensis*, the health authority must establish an accurate prevalence rate. Accurate information on regional prevalence can help policymakers prioritize and allocate resources efficiently and implement CEP successfully. As mentioned, the MoHW and KCDC annually analyze the prevalence rates of infection among people who live in the mainstream basin of the 5 major rivers. However, KCDC does not use a standardized sampling method and has not developed guidelines for sampling area determination. Therefore, the annual prevalence estimates vary depending on the procedures selected by individual program coordinators, which may potentially misrepresent the true results of the eradication

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efforts. In some cases, increased prevalence rates have been observed even after the implementation of substantial efforts to reduce the prevalence.[15–17]

We address 3 issues regarding the present method of estimating the prevalence rate of C. *sinensis* infection. The first issue is defining mainstream. We believe that distinguishing the mainstream of a major river from its creeks and streams is difficult. We searched for relevant studies, and no clear criteria have been established in Korea to distinguish between the mainstream river, creek, and stream.[18–23] Additionally, we hypothesize that no significant difference exists in the prevalence based on the proximity of the location where an individual lives from a waterbody in an endemic area because fish are not necessarily consumed where they are caught. We believe that all areas of the region should be investigated because infected fish from any of the waterbodies can easily be transported to other areas of the region for consumption. The second issue is determining which people live in the mainstream basin of the 5 major rivers. In other words, the question on how should riverside dwellers be selected should be answered. Many studies selected riverside areas based on distance, such as those <1, 2, or 5 km. However, the standards used for distance varied among researchers.[18–23] The last issue is changing the present arbitrary sampling method. Until now, the sampling has been arbitrarily established. Unfortunately, many related studies have used the arbitrary sampling method to select residents in riverside areas.[11,18–21] Improving the existing method of measuring the prevalence rates of C *sinensis* infection is necessary. In this study, we propose an alternative method using clustered quota sampling by eup (town) and myeon (village) based on ban (cluster) to measure the prevalence rate of C *sinensis* infection in Okcheon-gun, which is one of the endemic areas in Korea.

Based on the following hypotheses, we will prove that the present arbitrary riverside sampling method should be changed: first, in the case of endemic areas, distinguishing between the mainstream and river branches is not necessary because the infection rates of all regions in endemic areas are higher compared with the average rate in the country. If this is proved, the present standard should be abolished. Second, all endemic areas have significantly higher prevalence rates than the rest of the country, and these areas are not limited to those immediately surrounding the river bank. Policymakers should place equal emphasis on all regions within endemic areas. Third, the results from the proposed quota and cluster sampling method differ from those obtained using the present arbitrary sampling method. If so, further analysis should be performed to identify whether the new method is more accurate than the present method.

2. Methods

2.1. Study area and subjects

Okcheon-*gun*, which is located in the middle of South Korea, was selected as the study area because it is a clonorchiasis-endemic area, and the Geum River (1 of the 5 major rivers in Korea) runs through the middle of this area. A *gun* is an administrative unit that is comparable to a *county* in the United States. A typical *gun* consists of a couple of *eups* (towns) and several *myeons* (villages). Additionally, each *eup* or *myeon* has several *ris* (blocks), which are further divided into *bans* (clusters). *Ban* is the smallest unit of measurement and consists of several families with up to 50 individual members. Okcheon-gun has 1 eup and 8 myeons that together contain a total of 375 ris and 964 bans. As of 2013, 53,244 residents are living in Okcheon-gun (Table 1).

2.2. Geographical location of each eup and myeon in Okcheon-gun

Gunbuk-myeon and Dongi-myeon have the largest area along the mainstream of the Geum River. Other myeons also have at least some areas touching the mainstream. On the contrary, Cheongsan-myeon and Gunseo-myeon do not touch the mainstream of the Geum River at all (Figs. 1 and 2). However, creeks and streams

Table 1

Participants of the present study and information on Okcheon-gun population and reference data.

Region			Total population in 2013 (%), n = 53,244		Sampled population in 2013 (present study) (%) n = 1000 (100.0)		Sampled population in 2012 (reference data) (%), n = 2133 (100.0)	
			Male	Female	Male	Female	Male	Female
Okcheon-gun (total)	Subtotal		26,784 (50.3)	26,460 (49.7)	368 (36.8)	632 (63.2)	749 (35.1)	1384 (64.9)
	Age, y	<20	4887 (18.3)	4460 (16.9)	1 (0.3)	1 (0.2)	9 (1.2)	5 (0.4)
		20–29	2917 (10.9)	2306 (8.7)	5 (1.4)	3 (0.5)	3 (0.4)	13 (0.9)
		30–39	3412 (12.7)	2814 (10.6)	13 (3.5)	7 (1.1)	16 (2.1)	21 (1.5)
		40–49	4080 (15.2)	3402 (12.9)	26 (7.1)	18 (2.8)	53 (7.1)	67 (4.8)
		50–59	4793 (17.9)	4499 (17.0)	42 (11.4)	59 (9.3)	139 (18.6)	238 (17.2)
		60–69	3261 (12.2)	3421 (12.9)	75 (20.3)	148 (23.4)	189 (25.2)	334 (24.2)
		≥70	3434 (12.8)	5558 (21.0)	206 (56.0)	396 (62.7)	340 (45.4)	706 (51.0)
Okcheon-eup	Subtotal		15,140 (50.5)	14,860 (49.5)	204 (36.2)	259 (63.8)	49 (52.7)	44 (47.3)
	Age, y	<20	3624 (23.9)	3308 (22.3)	1 (0.5)	0 (0.0)	0 (0.0)	6 (12.2)
		20–29	1821 (12.0)	1484 (10.0)	2 (1.0)	1 (0.3)	1 (2.3)	1 (2.0)
		30–39	2301 (15.2)	2139 (14.4)	7 (3.4)	4 (1.1)	6 (13.6)	7 (14.3)
		40–49	2490 (16.5)	2277 (15.3)	14 (6.9)	7 (1.9)	10 (22.7)	8 (16.3)
		50–59	2376 (15.7)	2348 (15.8)	26 (12.7)	29 (8.1)	7 (15.9)	9 (18.4)
		60–69	1412 (9.3)	1488 (10.0)	36 (17.6)	85 (23.7)	9 (20.5)	9 (18.4)
		≥70	1116 (7.4)	1816 (12.2)	118 (57.9)	233 (64.9)	11 (25.0)	9 (18.4)
Dongi-myeon	Subtotal		1731 (51.3)	1644 (48.7)	25 (39.7)	38 (60.3)	86 (42.2)	118 (57.8)
	Age, y	<20	199 (11.5)	170 (10.3)	0 (0.0)	0 (0.0)	2 (2.3)	0 (0.0)
		20–29	170 (9.8)	127 (7.7)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
		30–39	163 (9.4)	116 (7.1)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.8)

(*continued*)

Table 1

(continued).

Region			Total population in 2013 (%), n=53,244		Sampled population in 2013 (present study) (%) n=1000 (100.0)		Sampled population in 2012 (reference data) (%), n=2133 (100.0)	
			Male	Female	Male	Female	Male	Female
		40–49	249 (14.4)	176 (10.7)	2 (8.0)	2 (5.3)	8 (9.3)	5 (4.3)
		50–59	365 (21.1)	314 (19.1)	2 (8.0)	2 (5.3)	18 (20.9)	25 (21.2)
		60–69	240 (13.9)	253 (15.4)	5 (20.0)	8 (21.1)	14 (16.3)	25 (21.2)
		≥70	345 (19.9)	488 (29.7)	16 (64.0)	26 (68.3)	44 (51.2)	62 (52.5)
Annam-myeon	Subtotal		729 (49.1)	757 (50.9)	8 (28.6)	20 (71.4)	29 (31.2)	64 (68.8)
	Age, y	<20	77 (10.6)	67 (8.9)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
		20–29	72 (9.9)	44 (5.8)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
		30–39	64 (8.8)	42 (5.5)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.5)
		40–49	90 (12.3)	72 (9.5)	1 (12.5)	0 (0.0)	0 (0.0)	1 (1.5)
		50–59	147 (20.2)	124 (16.4)	1 (12.5)	3 (15.0)	4 (13.8)	4 (6.3)
		60–69	117 (16.0)	127 (16.8)	3 (37.5)	6 (30.0)	8 (27.6)	14 (21.9)
		≥70	162 (22.2)	281 (37.1)	3 (37.5)	11 (55.0)	17 (58.6)	44 (68.8)
Anne-myeon	Subtotal		1070 (50.0)	1069 (50.0)	18 (45.0)	22 (55.0)	40 (44.9)	49 (55.1)
	Age, y	<20	95 (8.9)	95 (8.9)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
		20–29	94 (8.8)	68 (6.4)	0 (0.0)	0 (0.0)	1 (2.5)	0 (0.0)
		30–39	98 (9.2)	46 (4.6)	0 (0.0)	0 (0.0)	1 (2.5)	0 (0.0)
		40–49	155 (14.5)	96 (9.0)	3 (16.7)	4 (18.2)	3 (7.5)	2 (4.1)
		50–59	231 (21.6)	207 (19.3)	0 (0.0)	1 (4.5)	6 (15.0)	7 (14.3)
		60–69	176 (16.4)	172 (16.1)	7 (38.9)	4 (18.2)	9 (22.5)	12 (24.5)
		≥70	221 (20.6)	385 (36.0)	8 (44.4)	13 (59.1)	20 (50.0)	28 (57.1)
Cheongseong-myeon	Subtotal		1253 (49.5)	1279 (50.5)	16 (33.3)	32 (66.7)	56 (12.9)	379 (87.1)
	Age, y	<20	104 (8.3)	79 (6.2)	0 (0.0)	0 (0.0)	1 (1.8)	5 (1.3)
		20–29	98 (7.8)	73 (5.7)	0 (0.0)	0 (0.0)	0 (0.0)	8 (2.1)
		30–39	100 (8.0)	50 (3.9)	0 (0.0)	0 (0.0)	1 (1.8)	4 (1.1)
		40–49	147 (11.7)	101 (7.9)	0 (0.0)	0 (0.0)	3 (5.4)	17 (4.5)
		50–59	258 (20.6)	228 (17.8)	0 (0.0)	1 (3.1)	9 (16.1)	79 (20.8)
		60–69	215 (17.2)	233 (18.2)	1 (6.3)	11 (34.4)	13 (23.2)	101 (26.6)
		≥70	331 (26.4)	515 (40.3)	15 (94.7)	20 (62.5)	29 (51.7)	165 (43.6)
Cheongsan-myeon	Subtotal		1664 (47.5)	1842 (52.5)	19 (28.8)	47 (71.2)	166 (36.4)	290 (63.6)
	Age, y	<20	190 (11.4)	195 (10.6)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
		20–29	145 (8.7)	121 (6.6)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
		30–39	142 (8.5)	101 (5.5)	1 (5.3)	1 (2.1)	1 (0.6)	2 (0.7)
		40–49	205 (12.3)	160 (8.7)	1 (5.3)	0 (0.0)	5 (3.0)	10 (3.4)
		50–59	348 (20.9)	321 (17.4)	1 (5.3)	5 (10.6)	29 (17.5)	44 (15.2)
		60–69	272 (16.4)	318 (17.2)	6 (31.6)	14 (29.8)	42 (25.3)	64 (22.1)
		≥70	362 (21.8)	626 (34.0)	10 (52.5)	27 (57.5)	89 (53.6)	170 (58.6)
Iwon-myeon	Subtotal		2365 (50.4)	2324 (49.6)	41 (46.6)	47 (53.4)	205 (41.3)	291 (58.7)
	Age, y	<20	298 (12.6)	270 (11.6)	0 (0.0)	1 (2.1)	0 (0.0)	0 (0.0)
		20–29	241 (10.2)	165 (7.1)	1 (2.4)	1 (2.1)	1 (0.5)	4 (1.4)
		30–39	244 (10.3)	149 (6.4)	2 (4.9)	1 (2.1)	5 (2.4)	5 (1.7)
		40–49	340 (14.4)	249 (10.7)	2 (4.9)	1 (2.1)	15 (7.4)	17 (5.8)
		50–59	464 (19.6)	418 (18.0)	8 (19.5)	10 (21.3)	41 (20.0)	44 (15.1)
		60–69	373 (15.8)	378 (16.3)	11 (26.8)	12 (25.5)	56 (27.3)	69 (23.7)
		≥70	405 (17.1)	695 (29.9)	17 (41.5)	21 (44.8)	87 (42.4)	152 (52.3)
Gunseo-myeon	Subtotal		1220 (51.5)	1164 (48.5)	10 (22.2)	35 (77.8)	43 (45.3)	52 (54.7)
	Age, y	<20	126 (10.3)	113 (9.7)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
		20–29	124 (10.2)	101 (8.7)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
		30–39	125 (10.2)	59 (5.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.9)
		40–49	157 (12.9)	101 (8.7)	0 (0.0)	0 (0.0)	6 (4.0)	2 (3.8)
		50–59	257 (21.1)	213 (18.3)	1 (10.0)	3 (8.6)	10 (23.2)	17 (32.7)
		60–69	198 (16.2)	205 (17.6)	1 (10.0)	2 (5.7)	19 (44.2)	12 (23.1)
		≥70	233 (19.1)	372 (32.0)	8 (80.0)	30 (85.7)	8 (18.6)	20 (38.5)
Gunbuk-myeon	Subtotal		1612 (51.5)	1521 (48.5)	27 (45.8)	32 (54.2)	75 (43.6)	97 (56.4)
	Age, y	<20	174 (10.8)	163 (10.7)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
		20–29	152 (9.4)	123 (8.1)	2 (7.4)	1 (3.1)	0 (0.0)	0 (0.0)
		30–39	175 (10.9)	112 (7.4)	3 (11.1)	1 (3.1)	1 (1.3)	1 (1.0)
		40–49	247 (15.3)	170 (11.2)	3 (11.1)	4 (12.5)	5 (6.7)	3 (3.1)
		50–59	347 (21.5)	326 (21.4)	3 (11.1)	5 (15.6)	13 (17.3)	11 (11.3)
		60–69	258 (16.0)	247 (16.2)	5 (18.5)	6 (18.8)	19 (25.3)	28 (28.9)
		≥70	259 (16.1)	380 (25.0)	11 (40.8)	15 (46.9)	37 (49.3)	54 (55.7)

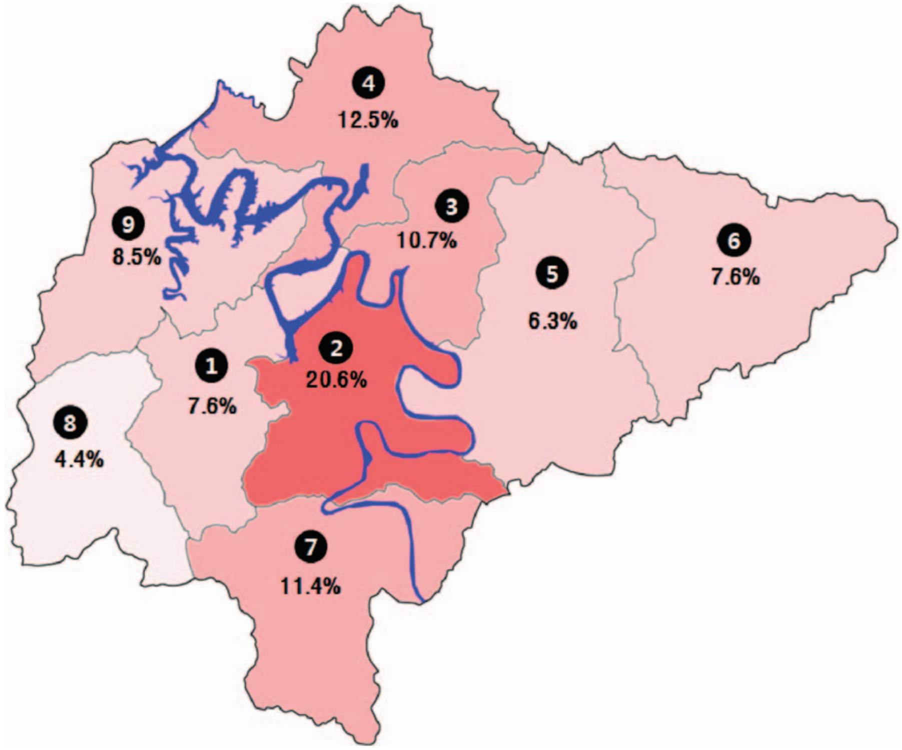

Figure 1. Prevalence of clonorchiasis in Okcheon-gun based on each eup and myeon, ① Okcheon-eup, ② Dongi-myeon, ③ Annam-myeon, ④ Anne-myeon, ⑤ Cheonseong-myeon, ⑥ Cheongsan-myeon, ⑦ Iwon-myeon, ⑧ Gunseo-myeon, ⑨ and Gunbuk-myeon.

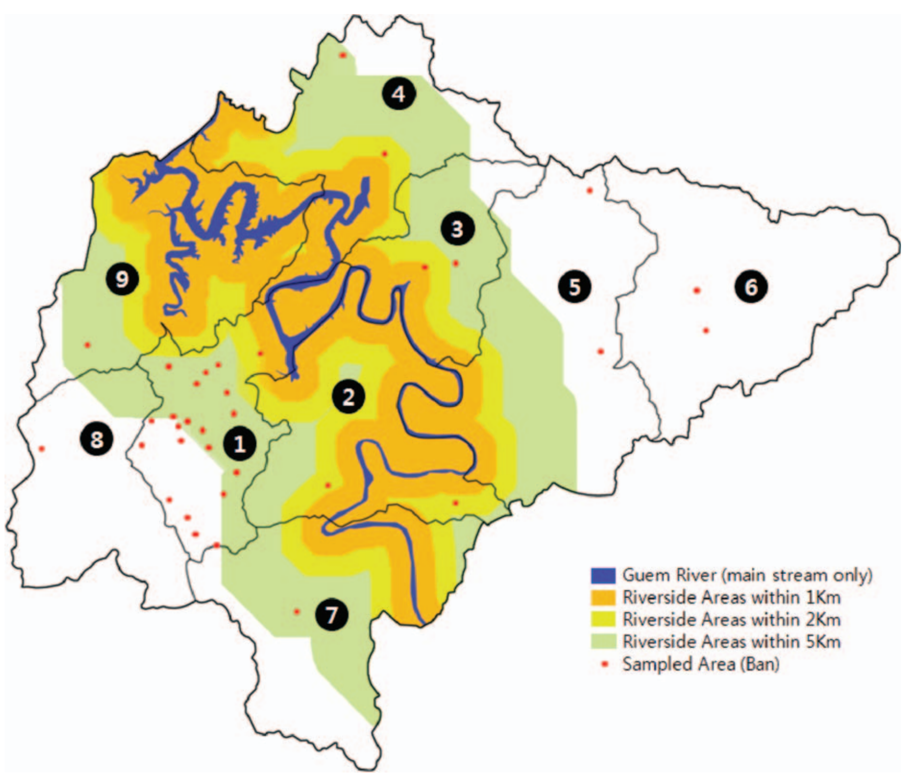

Figure 2. Riverside areas based on the distance from the mainstream of Geum River and the locations of sampled bans, ① Okcheon-eup, ② Dongi-myeon, ③ Annam-myeon, ④ Anne-myeon, ⑤ Cheongseong-myeon, ⑥ Cheongsan-myeon, ⑦ Iwon-myeon, ⑧ Gunseo-myeon, ⑨ and Gunbuk-myeon.

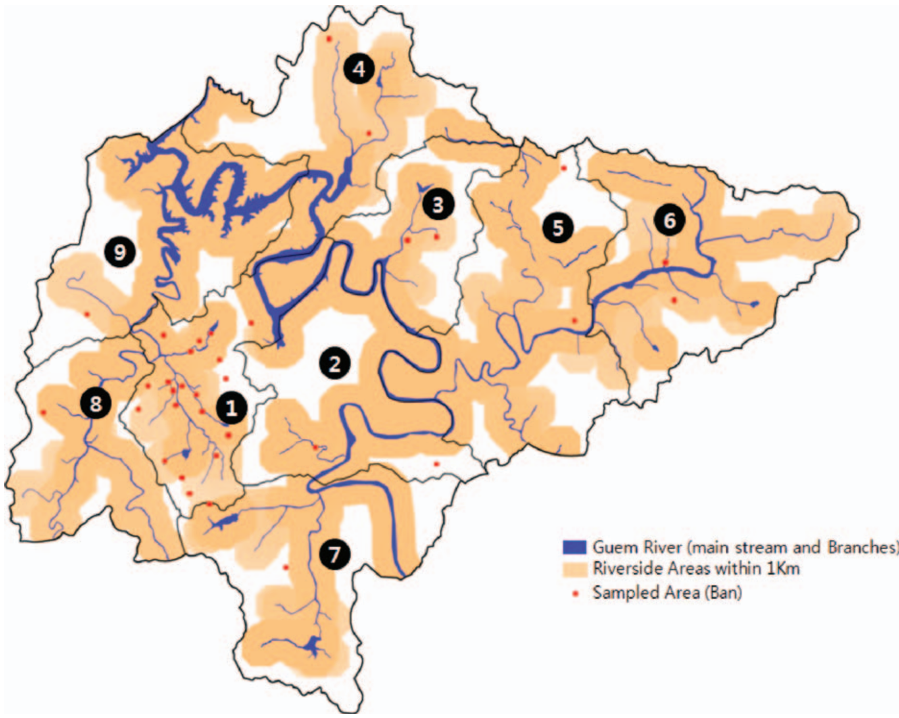

Figure 3. Riverside areas based on the distance from the branches and creeks of Geum River and the locations of sampled bans, ① Okcheon-eup, ② Dongi-myeon, ③ Annam-myeon, ④ Anne-myeon, ⑤ Cheonseong-myeon, ⑥ Cheongsan-myeon, ⑦ Iwon-myeon, ⑧ Gunseo-myeon, ⑨ and Gunbuk-myeon.

from the Geum River run through the eup and all myeons in Okcheon-gun (Fig. 3).

2.3. Sampling

We used cluster sampling combined with proportionate quota sampling to ensure that every eup and myeon was fully represented. The target sample population was set at 1000 residents aged ≥19 years (adults in Korea). The target sample of 1000 people was then divided among each eup and myeon based on the proportion of the population that live in each of these administrative areas. For example, Okcheon-*eup* was assigned 563 samples because its population occupied 56.3% (30,000 dwellers) of the total population in Okcheon-gun. Furthermore, Annam-myeon was assigned 28 persons based on the same methodology (Table 1).

After assigning the sample sizes, we used random sampling to designate numbers to all the 964 bans in Okcheon-gun to select our sample. This selection was performed using the RANDOM function in Microsoft Excel. We then began collecting data starting from the ban that was randomly assigned as ban 1, and the data collection continued in chronological order until we reached a sample size of 1000 people. We made every possible attempt to invite every adult in the selected bans to participate in the study. We moved on to the next ban once the data collection was completed for 50 persons in a ban (average population in each ban). If the number of respondents was less or respondents refused to participate in the study, additional participants were selected from the next ban until a total of 50 people were included.

2.4. Survey

All adult dwellers in the selected bans were invited to participate in the survey. Between January and April 2013, personal interviews were conducted, and stool samples were collected from all adults who provided informed consent. When the target number of individuals was not reached in a ban, we surveyed residents who lived in one of the alternative bans that had previously been selected using the RAND function in Microsoft Excel.

2.5. Analytical method

The prevalence data from 2012 in Okcheon-gun was used as a reference to compare the results of the present study (Table 2).[16] To prove hypotheses 1 and 2, we created 2 maps. The first one only contained the mainstream of the Geum River with red dots representing the randomly selected bans and color coding based on the distance from the mainstream. The other map includes branches and creeks of the Geum River with red dots and color coding (Figs. 1 and 2). Lastly, after receiving the test results from KCDC, we marked the prevalence rates on another map based on each eup and myeon to clearly identify the subregional variations (Fig. 3).

2.6. Stool examination

To investigate the clonorchiasis prevalence rate, the stool samples were sent to the Division of Malaria and Parasite of KCDC. The formalin–ether sedimentation technique was used to examine helminth eggs, larvae, and protozoan cysts.

2.7. Statistical analysis

We analyzed the data using SPSS (SPSS Win, version 18.0K, SPSS Inc.). The regional infection rate of C *sinensis* was analyzed in frequencies and percentages. Pearson's chi-square test was conducted to identify any difference in prevalence rates based

Table 2

The prevalence of clonorchiasis in Okcheon-gun based on subregional areas using arbitrary convenience sampling method in 2012 (reference data).

Region	Total population (%)	Sampled population (%)	Clonorchiasis positive (persons)	Prevalence (%)
Okcheon-gun (total)	53,496 (100.0)	2133 (100.0)	148	6.9
Okcheon-eup	30,021 (56.1)	97 (4.5)	2	2.1
Dongi-myeon	3376 (6.3)	188 (8.8)	24	12.8
Annam-myeon	1517 (2.8)	108 (5.1)	14	13.0
Anne-myeon	2138 (4.0)	89 (4.2)	13	14.6
Cheongseong-myeon	2558 (4.8)	432 (20.3)	29	6.7
Cheongsan-myeon	3544 (6.6)	459 (21.5)	26	5.7
Iwon-myeon	4726 (8.8)	495 (23.2)	22	4.4
Gunseo-myeon	2420 (4.5)	95 (4.5)	9	9.5
Gunbuk-myeon	3196 (6.0)	170 (8.0)	9	5.3

on the residential distance from the river. The level of significance in this study was set at 0.05.

2.8. Ethics statement

This study was approved by the Institutional Review Board of KCDC (IRB No. 2012-04EXP-04-3C).

3. Results

3.1. The composition of present study participants

Table 1 shows the composition of study participants based on subregions by sex and age group. The population data of the present study showed that participants were skewed to females and the elderlies compared with that of Okcheon-gun. However, these data were similar to that of the reference study of 2012.

3.2. Clonorchiasis prevalence in Okcheon-gun in 2013

The overall clonorchiasis prevalence rate in Okcheon-gun was 8.9% (89 out of 1000 cases). With regard to subregions, Dongi-myeon had the highest infection rate (20.6%), followed by Anne-myeon (12.5%), Iwon-myeon (11.4%), Annam-myeon (10.7%), Gunbuk-myeon (8.5%), Okcheon-eup and Cheongsan-myeon (7.6%), Cheonseong-myeon (6.3%), and Gunseo-myeon (4.4%) (Table 3, Fig. 1). Although Gunseo-myeon had the lowest infection rate in Okcheon-gun, its *C sinensis* infection rate is still 2 times higher than the national average rate.

3.3. Prevalence rate based on the distance from the mainstream, branches, and creeks

We investigated the infection rate in areas within 1, 1–2, and 2–5, and >5 km to determine the prevalence based on the residential distance from the mainstream of the Geum River, which is the most commonly used method. The corresponding infection rates were 16.5%, 9.6%, 7.1%, and 9.3%, respectively ($P=0.013$). Noteworthy, the infection rate was 9.3% in residential areas >5 km from the mainstream, which is ~4.5 times higher than the national average rate (Table 4, Fig. 2). Additionally, when branches and creeks were included, no statistically significant difference was observed in the prevalence based on distance. The infection rates were 8.8% (<1 km) and 9.5% (>1 km). Furthermore, we found that almost 90% of areas in Okcheon-gun are <1 km from the river when we included the branches and creeks (Table 4, Fig. 3).

3.4. Comparison of the 2013 and 2012 results

Table 3 shows the infection rate of *C sinensis* in 2013 based on the cluster sampling method combined with proportionate quota sampling. It reflects the population in the eup and all the myeons. Additionally, Table 2 presents the infection rate in 2012 based on the arbitrary convenience sampling method. Thus, the new sampling method resulted in different prevalence rates. First, the overall prevalence rate increased from 6.9% in 2012 to 8.9% in 2013. In particular, 4 eups or myeons were recorded to have infection rates that differ by >5%: Dongi-myeon (7.8% in difference, 20.6% vs 12.8%), Iwon-myeon (7.0% in difference, 20.6% vs 12.8%), Okcheon-eup (5.5% in difference, 7.6% vs

Table 3

The prevalence of clonorchiasis in Okcheon-gun based on subregional areas using cluster and quota sampling in 2013.

Region	Total population (%)	Sample population (persons)	Clonorchiasis positive (persons)	Prevalence (%)
Okcheon-gun (total)	53,244 (100.0)	1000	89	8.9
Okcheon-eup	30,000 (56.3)	563	43	7.6
Dongi-myeon	3375 (6.3)	63	13	20.6
Annam-myeon	1486 (2.8)	28	3	10.7
Anne-myeon	2139 (4.0)	40	5	12.5
Cheongseong-myeon	2532 (4.8)	48	3	6.3
Cheongsan-myeon	3506 (6.6)	66	5	7.6
Iwon-myeon	4689 (8.8)	88	10	11.4
Gunseo-myeon	2384 (4.5)	45	2	4.4
Gunbuk-myeon	3133 (5.9)	59	5	8.5

Table 4

Prevalence rate of clonorchiasis based on the distance from the mainstream of Geum River, including the branches (n=1000).

Sampled region	Distance, km	Sampled population, %	Infection test			
			Positive	Negative	Prevalence rate, %	*P*-value
	Total	1000 (100.0)	89 (8.9)	911 (91.1)	8.9	
Distance from the mainstream of Geum River	<1	115 (11.5)	19 (16.5)	96 (83.5)	16.5	0.013*
	1–2	198 (19.8)	19 (9.6)	179 (90.4)	9.6	
	2–5	580 (58.0)	41 (7.1)	539 (92.9)	7.1	
	>5	107 (10.7)	10 (9.3)	97 (90.7)	9.3	
Distance from the mainstream and branches of Geum River	<1	979 (97.9)	87 (8.9)	892 (91.1)	8.9	0.572
	>1	21 (2.1)	2 (9.5)	19 (90.5)	9.5	

* $P<0.05$.

2.1%), and Gunseo-myeon (5.1% in difference, 4.4% vs 9.5%). In 2012, only 4.5% individuals were tested in Okcheon-eup (97 out of 2133 people), although its occupants accounted for >50% of the total population.

4. Discussion

The Korean government launched the CEP in 2005, and Okcheon-gun has been participating in the program since 2011. However, the overall prevalence rate in Okcheon-gun remains unknown because only a pool of arbitrarily selected people was tested for *C sinensis* infection. Moreover, the annual infection rates have substantially fluctuated, and in some cases, the infection rates have even increased over time. Therefore, the actual effectiveness of CEP cannot be evaluated. This problem has been persistent in most regions that adopted CEP. We believe that using the probability sampling method is imperative to improve the calculation of the overall clonorchiasis prevalence rate in the region. The probability sampling method allows us to accurately estimate the population proportion that is clonorchiasis positive and prioritize CEP implementation.

The Geum River runs through the heart of Okcheon-gun, and the river's branches and creeks extend throughout the eup and all myeons of Okcheon-gun. Thus, measuring the prevalence rate of clonorchiasis in the entire region, instead of just the areas nearest to the main river stream, is crucial. This step is also important because *C sinensis* remains in the human body for up to 20 to 30 years, and individuals who once lived near the riverside could now live in other regions of Okcheon-gun.[2] The new sampling method we tested considers the regional characteristics of Okcheon-gun and applies the cluster sampling method combined with proportionate quota sampling. This technique reflects the population of each eup and myeon and, therefore, is better than the arbitrary convenience sampling method used in previous studies. Hence, we believe that the results obtained based on our new method are more accurate than those based on the previous arbitrary sampling method.

Our results showed that 8.9% of the study participants were infected with *C sinensis*, from which we can estimate the overall prevalence rate of *C sinensis* infection in Okcheon-gun to be ~4686 out of 53,2444 people. We can also use these data to estimate the expected prevalence reduction when administering treatments to the infected population. Thus, measuring the clonorchiasis prevalence rate for the entire region is imperative to support the CEP.

Among the eup and myeons of Okcheon-gun, the highest and lowest clonorchiasis prevalence rates observed were 20.6% and 4.4%, respectively, which show a wide variation (Table 3). Okcheon-gun has 8 public subhealth centers and 17 primary healthcare posts. Public servants, working staff, and project managers at these centers are all responsible for implementing the CEP components. Establishing the clonorchiasis prevalence rate at the eup and myeon levels can inform guidelines regarding the amount of CEP resources that need to be allocated in each region. In fact, over the past years, CEP has been implemented in such a way that meet the arbitrarily allocated population set by the program coordinators. Furthermore, in some cases, the test population size varied depending on the interest level of the program coordinators. Hence, accurate measurement of the regional clonorchiasis prevalence rate can facilitate more efficient CEP implementation.

This study provided another insight regarding the measurement of the *C sinensis* infection prevalence rate at the eup and myeon levels. CEP has been primarily implemented in the myeons near the river based on the results of past research. However, our results showed that the clonorchiasis prevalence rate in the eup area is 7.6%. This is the fifth highest prevalence rate among the 9 subregions of Okcheon-gun, which suggests relatively high prevalence among eup residents. However, the past CEP has neglected eup residents. Given the fact that *C sinensis* survives for a period of up to 20 to 30 years once it enters the human body,[2] infection among eup residents could be caused by numerous reasons. For instance, former residents of riverside areas infected with *C sinensis* may have relocated to the eup region. Furthermore, although the main stream of the Geum River does not pass through the eup, the residents near the smaller streams in the eup region may have ingested infected fish. Several restaurants also serve freshwater fish in the area. Considering these factors, we must acknowledge that the residents who live in *C sinensis* contagious regions may be vulnerable to clonorchiasis even if these regions do not have direct proximity to the riverside. Therefore, CEP should use prevalence measurements based on cluster sampling proportional to the population ratios of eup and myeons. Moreover, cohorts should be created for continuous prevalence rate monitoring.

In this research, we also analyzed the prevalence rate of *C sinensis* infection based on the distance from the mainstream of Geum River, similar to the method used in previous studies. Our results showed minimal difference between the areas except for those <1 km of the Geum River. Infection rates were highest in regions closest to the mainstream of the Geum River: 16.5% (<1 km), 9.6% (1–2 km), 7.1% (2–5 km), and 9.3% (>5 km) ($P<0.05$). However, the prevalence rate was 9.3% even in areas >5 km from the mainstream of the Geum River, which is ~4.5 times higher than the national average infection rate (Table 4, Fig. 2). Therefore, we should not neglect these areas.

Additionally, we should reconsider the policy that prioritizes CEP resources based on the distance from the mainstream. For distance away from the riverside areas, including branches and creeks, no difference in prevalence rates was observed between areas <1 and >1 km away from the riversides. Therefore, regardless of the distance from the riverside, all areas should be included from the priority areas of CEP.

Okcheon-gun have 111 small and large branch streams in addition to the main stream of the Geum River. Freshwater fish are present practically everywhere around Okcheon. Although infection rates may vary based on such geographic features, many studies on clonorchiasis prevalence have measured the infection rate <5 km of the river without clear definition of the riverside.[19,21,22] A few studies covered areas <1 km away from the river or its branch.[20] However, measuring the prevalence rate of the entire sample area that covers all branch streams is critical in a region where over 2/3 of its areas are within 5 km or less away from the main river (Fig. 2) and where most of its areas are <1 km or less away from the riverside areas or branch streams, as in the case of Okcheon-gun (Fig. 3).

However, our study has some limitations. First, we applied a probability sampling method based on cluster and proportional quota sampling to obtain more accurate epidemiological data. However, our collected data were not perfectly matched to sex and age structure based on not only the entire Okcheon-gun population but also each eup and myeon (Table 1). Second, we cannot state that our results present more accurate data than the reference data. That is, readers should very carefully interpret our results when comparing these findings with those of the reference data. Third, we did not reflect more detailed demographical factors, such as health behaviors, on our samples. In our study, the total number of participants was 1000. Therefore, we could not perform a subgroup analysis (i.e., although the middle-aged men in Okcheon-gun are more likely to eat raw fish from the river, we could not reflect this factor on the sampling method). To overcome our study limitations, we suggest the following approaches to improve our present method and provide recommendations for further research scheme: first, we must establish more accurate samples using cluster and proportional quota sampling methods. In particular, these samples must be perfectly matched to the population proportion and sex/age structures to reflect those of Okcheon-gun and each eup and myeon. Second, we should consider expanding the sample size from 1000 to 3000. The sample expansion is very important because it will allow us to obtain more in-depth information based on the subgroup or risk group. Lastly, if possible, we should consider the establishment of the cohort panel that can regularly follow-up on the prevalence rate monitoring.

5. Conclusions

Korea has been implementing CEP since 2005, but the infection rate remains high throughout the endemic area.[14,24] Past efforts to measure the prevalence did not provide guidelines on the sampling methods or define the riverside areas. Hence, the results may not be reliable. A guideline must be provided to determine the *C sinensis* infection prevalence in susceptible regions to facilitate effective CEP implementation. This initiative would require explicitly laying out the survey method. Based on the results of this study, we recommend the following: first, the prevalence rate must be representative of the region being studied. Thus, the sample must be selected based on probability sampling. The prevalence rate must also be measured in such a way that it can be used to support CEP in calculating the total patient population and evaluating the program efficacy. Second, clear guidelines on survey coverage should be provided to include the riverside areas and those nearby the branch streams. Lastly, regional cohorts should be created for continuous prevalence rate monitoring across the regions.

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