RESEARCH ARTICLE

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The Predictors of Liver Fluke Infection-Preventive Behaviors, Khon Kaen Province: A Structural Equation Model

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Abstract

Background: Liver fluke infection is a public health problem and the main cause of cholangiocarcinoma in northeastern Thailand, especially in Khon Kaen Province. This study aimed to determine the prevalence and predictors of liver fluke infection-preventive behaviors, using the Health Belief Model (HBM) and Structural Equation Modeling (SEM) among adults living in Khon Kaen Province. **Methods:** This analytical cross-sectional study utilized secondary data. A stratified cluster multi-stage sampling technique, proportional to size, was used to select a provincially representative sample of the Khon Kaen adult population. The participants responded via interview. HBM scale, demographic and environmental factors, knowledge, health behaviors, and information on preventive behaviors (avoidance of consuming various types of uncooked freshwater fish and five personal hygiene practices) were measured. The hypothesized causal path models were examined using SEM analysis. **Results:** Among the 980 adult participants, the prevalence of non-consumption of raw freshwater fish and the practice of good hygiene during the past month was 2.9% (95% CI: 2.0, 4.1). The final structural model demonstrated a good fit. The predictors explained 25.7% of the variance in preventive behaviors. The model indicated that the total effect of perceived susceptibility had the strongest correlation with liver fluke infection-preventive behaviors ($\beta = 0.34$, $p < 0.001$), followed by perceived severity ($\beta = 0.31$, $p < 0.001$), having a family member who did not consume raw fish ($\beta = 0.27$, $p < 0.001$), education ($\beta = 0.14$, $p < 0.001$), self-efficacy ($\beta = 0.13$, $p < 0.001$), perceived benefit ($\beta = 0.13$, $p < 0.001$), knowledge ($\beta = 0.10$, $p < 0.001$), non-smoking ($\beta = 0.09$, $p < 0.05$), age ($\beta = –0.08$, $p < 0.05$), cue to action ($\beta = 0.06$, $p < 0.05$), and perceived barriers ($\beta = –0.05$, $p < 0.05$). **Conclusion:** Our study showed that significant predictors of preventive behaviors included the HBM constructs, age, education, knowledge, non-smoking, and living with family members who do not consume raw fish. Public health campaigns should focus on strengthening HBM constructs and knowledge with particular attention to older adults, smokers, less-educated individuals, and households in which family members consume raw fish.

Keywords: Liver fluke infection-preventive behaviors- health belief model- structural equation model- Thailand

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Introduction

Infection with the liver fluke Opisthorchis viverrini (O. viverrini) is a serious public health

problem and the main cause of cholangiocarcinoma (CCA) throughout the Mekong Basin in Southeast Asia, where more than 10 million people are infected particularly in Thailand, Laos, Cambodia, Myanmar, and Vietnam [1–3] Each year, 20,000 people develop CCA in Thailand alone, the majority of whom are from northeastern Thailand [4]. The primary route of *O. viverrini* infection is the consumption of raw or undercooked fish, a practice deeply embedded in the culture and dietary traditions of people in this region [5-7]. In addition, individuals infected with *O. viverrini* excrete the parasite eggs into natural water sources due to poor sanitation and wastewater infrastructure. The eggs are subsequently ingested by the first intermediate host, Bithynia snails, where they hatch into miracidia and develop sequentially into sporocysts, rediae, and free-swimming cercariae. These cercariae then penetrate the tissue of cyprinoid fish the second intermediate host and encyst as fully infective metacercariae. When humans eat raw or undercooked freshwater fish containing these metacercariae, they can get infected [8].

The Thai Ministry of Public Health has implemented extensive national liver fluke control campaigns for decades, including health education, regular surveillance of intermediate hosts to reduce transmission of opisthorchiasis, treatment, and improved personal hygiene

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and sanitation. A particular emphasis has been placed on promoting self-preventive behaviors against *O. viverrini* infection, such as avoiding the consumption of various types of raw freshwater fish, properly disposing of food waste made from raw fish, washing hands, and practicing sanitary defecation [9]. Moreover, institutions or centers were established to eliminate liver fluke disease and reduce the incidence of CCA among the northeastern population such as a Coordination Centre for Liver Fluke Disease and Cholangiocarcinoma, and the Cholangiocarcinoma Screening and Care Program (CASCAP) at Khon Kaen University [10, 11]. One of the most successful liver fluke control programs implemented in Thailand was the Lawa model, which integrates the EcoHealth and One Health approaches to address *O. viverrini* transmission [12]. A decline in liver fluke infections has been achieved through the combined efforts of government policies and non-government organizations. Therefore, the prevalence of liver fluke infections among Thai people decreased from 16.3% in 2016 to 3.2% in 2021 [13]. However, the reduction has not been as successful as expected in certain areas. Data from the Isan Cohort database also showed that the prevalence of liver fluke infections among people living in Khon Kaen province increased from 5.6% in 2020 to 25.5% in 2022 [14]. Many communities in the northeastern region have a well-established cultural practice. People believed in the efficacy of putting lime or red ants in Koi pla (raw fish salad) or eating Koi pla with white whiskey to kill parasites, and early-stage CCA can be cured. However, 41% and 57%, respectively, were more likely to be infected with O. viverrine

[15, 16]. A national survey conducted in 2023 reported that the highest consumption of raw freshwater fish in Thailand was in Khon Kaen province (23.8%), which is located in the northeastern region, where the overall consumption rate was 18.7% [17]. In addition, reinfection rates of O. viverrine have been high, with cumulative rates ranging from 10.9% to 51.5% over the past year, primarily due to the consumption of improperly prepared raw freshwater fish [18, 19].

A systematic review showed that factors associated with *O. viverrini* infection include demographic, environmental, and geographic factors, health behaviors or hygiene, treatment with praziquantel, a history of *O. viverrini* infection, and health policy [5] Additionally, other predictors (e.g., structural or psychosocial factors) may be associated with beliefs and indirectly health behaviors. Rosenstock (1974) demonstrated that education can indirectly influence behaviors by altering perceived susceptibility, severity, benefits, and barriers. To predict people's behaviors, it is necessary to consider how factors influence and interact with one another; thus, health behavior theory is needed to explain changes in health behavior [20].

The Health Belief Model (HBM) has been widely used to explain changes in health-related behaviors, as demonstrated in previous studies. Ilias Mahmud, et al. concluded that individuals who agreed with perceived susceptibility, perceived severity, perceived benefits, and cues to action were more likely to take the COVID-19 vaccine compared to those who did not. On the other hand, individuals who disagreed with perceived barriers were more likely to take the vaccine than those who agreed [21]. Similarly, the study by Hui Liu, et al. found that perceived susceptibility, perceived benefits, self-efficacy, and cues to action were significantly positively linked to HIV-preventive behaviors [22]. However, relatively few studies account for all variables needed to explain the complexity of predictors on preventive behaviors. Structural Equation Modeling (SEM) analysis is useful for revealing complex relationships (direct, indirect, and total standardized effects). The study of Wang, et al. used an extended HBM to predict healthy eating intentions and behaviors in Chinese residents showing that perceived susceptibility, severity, and benefits had indirectly influenced healthy eating behaviors through healthy eating intentions, stronger than their direct effects on the eating behavior (.248 >.014, .269 >.012, .300 >.017, respectively). While perceived barriers and self-efficacy had a partial mediating effect on healthy eating intentions and indirect effects are weaker than their direct effects on healthy eating behaviors (.071 < .084, .148 < .398, respectively) [23]. Chamroonsawasdi, et al., conducted protection motivation theory to predict intention of healthy eating to prevent diabetes mellitus in the Thai population, showing that self-efficacy had a direct effect (.048) on the intention to change eating behaviors. While both knowledge of DM and perceived susceptibility had an indirect effect (.138 and .079, respectively) on intention towards healthy eating behaviors. Only perceived severity had both a direct and indirect influence on intention to change eating behaviors (.078 and .039, respectively) [24].

Nevertheless, no study has applied the HBM to predict liver fluke infection-preventive behaviors, especially in high endemic areas. Moreover, no study has examined the complex relationships between HBM constructs including self-efficacy and preventive behaviors of liver fluke infection in Khon Kaen, Thailand. Therefore, this study aimed to determine the prevalence and prediction of the liver fluke infection-preventive behaviors, using the HBM and SEM among adults living in Khon Kaen province, Thailand.

Materials and Methods

Study design

This study was a secondary analysis of the data originally collected from a survey previously published [25]. Briefly, the survey aimed to investigate the factors influencing the avoidance of eating raw freshwater fish. As described in detail elsewhere, a stratified multi-stage cluster sampling method was used during September to December 2024 in Khon Kaen Province, Thailand [25].

Population and sample

A sample size of 980 was determined a priori using the sample size calculator for structural equation models according to Soper (2021) [26]. The data were collected in Khon Kaen province, where the sample was randomly selected to represent the Khon Kaen population aged 18 years and older. The sampling was performed proportionally to the size of the population and stratified by

gender, age, and risk area. Age was categorized into five groups: 18-30, 31–40, 41–50, 51–60, and > 60 years. Risk areas were classified into three zones—low, moderate, and high—based on the prevalence of *O. viverrini* infection diagnosed during the past year: ≤ 1%, 1.1%–3.2%, and ≥3.3%, resulting in 30 strata (ranging from 23 to 46 participants in each stratum). Participants (i.e., citizens who had lived in Khon Kaen for at least one year and were aged 18 years or older) were invited to participate by the original research team. Written informed consent was obtained before enrollment in the survey, after which interviews were conducted to collect participants' information.

Variables

The variables are classified into four categories namely endogenous, exogenous, latent, and observed variables. In this regard, liver fluke infection-preventive behaviors and HBM constructs were latent endogenous variables, and all indicators that are used to measure each construct of the HBM and preventive behaviors were observed endogenous variables. Modifying factors were defined as demographic factors, health behavior factors, environmental factors, and knowledge were observed exogenous variables.

Demographic factors: sex, age, income, occupation, and education

Health behaviors: alcohol consumption, cigarette smoking, experience or family consumption and social influence regarding raw fish consumption, participation in health education, liver fluke screening, medical history, praziquantel treatment and health policy about liver fluke disease.

Environmental factors: type of area included living in rural or municipal areas, the risk zone and having a residence near a source of freshwater fish.

Knowledge encompassed an understanding of liver fluke disease: liver fluke infection, symptoms, treatment, and hygiene such as washing hands before and after preparing freshwater fish and specific methods and time period to kill liver fluke.

HBM constructs: perceived susceptibility, perceived severity, perceived benefits, perceived barriers, self-efficacy, and cues to action, all of which were examined in relation to liver fluke infection–preventive behaviors.

Liver fluke infection preventive behaviors were defined as the avoidance of consuming various kinds of raw or undercooked freshwater fish and always good personal hygiene practices, including the proper disposal of food waste made from raw fish, hand washing, and sanitary defecation in the past month.

Ethical Consideration

The study was reviewed and approved by the Ethical Review Committee for Research in Human Subjects of the Faculty of Public Health, Mahidol University (MUPH 128/2024).

Statistical analysis

Descriptive statistics, including means, standard deviations, median, interquartile range, frequency, and percentage, were used to summarize sample characteristics. In developing the SEM, the following steps were performed: Normality test and descriptive statistics of latent variables: HBM constructs and prevention behaviors variables. The multivariate normality was verified through skewness (≤3) and kurtosis (≤10), which all are continuous variables such as HBM constructs and prevention behaviors, etc., were normally distributed [27]. Pearson's correlation was employed to assess the statistically significant relationships among latent variables ($p < 0.05$). Parameter estimation was conducted using the Maximum Likelihood Estimation (MLE) method. Lastly, Confirmatory Factor Analysis (CFA) was performed to evaluate the measurement model, which comprised seven latent variables, including the HBM constructs and preventive behaviors, to ensure that all items within each construct demonstrated statistically significant factor loadings ($p < 0.05$). The initial model was specified based on the original HBM by Rosenstock (1974) [20]. In this study, modifying factors were defined as demographic factors, health behavior factors, environmental factors, and knowledge. The six constructs of the HBM were treated as mediators. To evaluate the model fit, several indices were used: Chi-square (χ^2), Root Mean Square Error of Approximation (RMSEA), Standardized Root Mean Square Residual (SRMR), Comparative Fit Index (CFI), and Tucker–Lewis Index (TLI). Model fit was considered acceptable when χ^2 p-value > 0.05, RMSEA < 0.08, SRMR < 0.08, CFI ≥ 0.90, and TLI ≥ 0.95 [28] The level of significance was 0.05. All analyses were performed using STATA® (Version 18, 2023, Stata Corp., College Station, Texas, USA).

Results

General characteristics

A total of 980 participants were included in this study. The general characteristics of participants are shown in Table 1. The median age of the participants were 47 years (Interquartile range (IQR): 33-59); majority of participants were 51 – 60 years old (21.7%), followed by 18-30 years (21.4%) and completed primary school education (38.2%). The median monthly household income was 5,000 Thai Baht (THB, IQR: 3,500 - 10,000). More than half were female (51.0%), agriculturists (53.2%), not consuming alcohol (55.9%), and had seen a social influencer consuming uncooked fish (55.6%). Nearly three-quarters of participants were non-smokers of cigarettes (76.1%) and had family members that consumed uncooked fish (70.1%). The majority never received health education about liver fluke (64.9%). The prevalence of liver fluke infection-preventive behaviors was 2.9% (95% CI: 20, 4.1).

SEM initial model

The initial model, based on the original HBM and its modifying factors, did not meet the recommended thresholds for most model fit indices, except for the RMSEA (χ^2, $p < 0.001$; TLI = 0.598; CFI = 0.623; RMSEA = 0.072; SRMR = 0.106).

Table 1. General characteristics of Participants (n = 980)

Characteristics	Number	%	Median (IQR)
Gender			
Male	480	48.98	
Female	500	51.02	
Age (years)			47 (33, 59)
Age group (years)			
18-30	210	21.43	
31-40	170	17.35	
41-50	185	18.88	
51-60	213	21.73	
> 60	202	20.61	
Risk areas			
Zone1 (≤1%)	278	28.36	
Zone2 (1.1%–3.2%)	403	241.1	
Zone3 (≥3.3%)	299	30.51	
Occupation			
Unemployment	81	8.27	
Agriculturist	521	53.16	
Trading	54	5.51	
Daily laborer	232	23.67	
Civil officer	30	3.06	
Students	47	4.8	
Private sector employee	6	0.61	
Others	9	0.92	
Education complete			
No school	12	1.22	
Primary school	374	38.16	
Junior high school	238	24.29	
Senior high school/Vocational	246	25.1	
High vocational certificate	56	5.71	
Bachelor's degrees	46	4.69	
Higher than bachelor's degree	8	0.82	
Monthly household income (THB)			5,000 (3,500-10,000)
Alcohol consumption			
Yes	380	38.78	
No	548	55.92	
Stop drinking	52	5.31	
Cigarettes smoking			
Yes	200	20.41	
No	746	76.12	
Stop smoking	34	3.47	
Experience social influencer consumes uncooked fish			
Yes	545	55.61	
No	435	44.39	
Experience family members consume uncooked fish			
Yes	687	70.1	
No	293	29.9	
Ever joined health education about liver fluke			
Yes	344	35.1	
No	636	64.9	
Unconsumed raw fish during last month and practiced good hygiene			
Yes	28	2.86	
No	952	97.14	

SEM final model

Subsequently, the model was refined by eliminating statistically insignificant variables, modifying the structural paths, and adjusting the covariance structure of the model. The final structural model demonstrated acceptable fit across all indices (χ^2, $p = 0.096$; TLI = 0.996; CFI = 0.998; RMSEA = 0.008; SRMR = 0.037), suggesting its suitability for predicting liver fluke infection-preventive behaviors (Figure 1).

The results showed that several factors had significant effects on liver fluke infection-preventive behaviors. Three factors had only direct effects on liver fluke infection-preventive behaviors. Both perceived susceptibility and self-efficacy had a significant positive direct effect ($\beta = 0.34$, $p < 0.001$, $\beta = 0.13$, $p < 0.05$, respectively). In contrast, age exhibited a significant negative direct effect ($\beta = –0.08$, $p < 0.05$). In terms of indirect effects, perceived severity had a positive indirect effect ($\beta = 0.31$, $p < 0.001$) through perceived susceptibility, perceived barriers, and self-efficacy. Perceived benefit had a positive indirect effect ($\beta = 0.13$, $p < 0.001$) through perceived susceptibility, perceived severity, perceived barriers, and self-efficacy. Knowledge showed a positive indirect effect ($\beta = 0.10$, $p < 0.001$) through all HBM constructs, except cue to action. In addition, four factors had both direct and indirect effects. Individuals living in family that did not consume raw fish had a total positive effect on preventive behaviors ($\beta = 0.27$, $p < 0.001$), consisting of a direct effect of 0.21 ($p < 0.001$) and an indirect effect of 0.06 ($p < 0.001$) through all HBM constructs. Higher than compulsory education level had an indirect effect ($\beta = 0.03$, $p > 0.05$) on preventive behaviors through perceived barriers and self-efficacy marking the total effect (sum of direct and indirect effect) of ($\beta = 0.14$, $p < 0.001$). Non-smoking individuals had a total positive effect ($\beta = 0.09$, $p < 0.05$), with a direct effect of 0.05 ($p < 0.05$) and an indirect effect of 0.04 ($p < 0.05$) mediated by perceived susceptibility, severity, barriers, and self-efficacy. Moreover, cues to action had a total positive effect ($\beta = 0.06$, $p < 0.05$), composed of a negative direct effect ($\beta = –0.13$, $p < 0.05$) and a positive indirect effect ($\beta = 0.19$, $p < 0.001$) through all HBM constructs, as shown in Figure 1 and Table 2.

Discussion

In this study, we used SEM to analyze the predictors of liver fluke infection-preventive behaviors by utilizing constructs of HBM, along with demographic factors, knowledge, health behaviors factors, and environment factors among participants in Khon Kaen province. The study showed significant relationships between liver fluke infection-preventive behaviors and predictors such as older adults, non-smokers, less-educated individuals, and family member in household's non-consumption of raw fish, knowledge, and HBM constructs.

Age had a negative direct effect on liver fluke infection-preventive behaviors. These results were described as that increasing age is associated with a decline in liver fluke infection-preventive behaviors. Several studies similarly indicated older people had higher risk

Table 2. Effect Size of Demographic Factors, Health Behaviors Factors, Environment Factors, Knowledge, and HBM on Liver Fluke Infection-Preventive Behaviors

Independent Variable	HBM Construct											
	Perceived Susceptibility (β)			Perceived Severity (β)			Perceived Benefit (β)			Perceived Barrier (β)		
	DE	IE	TE	DE	IE	TE	DE	IE	TE	DE	IE	TE
Age	-	-	-	-	-	-	-	-	-	-	-	-
Knowledge	-	0.25**	0.25**	0.25**	0.06**	0.31**	0.15**	-	0.15**	-	-0.24**	-0.24**
Education	-	-	-	-	-	-	-	-	-	-0.07*	-	-0.07*
Smoking	-	0.07*	0.07*	0.09*	-	0.09*	-	-	-	-	-0.07*	-0.07*
Family influence	-	0.16**	0.16**	0.18**	0.02*	0.20**	-	0.05*	0.05*	-	-0.15**	-0.15**
Perceived Susceptibility	-	-	-	-	-	-	-	-	-	-	-	-
Perceived Severity	0.8**	-	0.8**	-	-	-	-	-	-	-0.76**	-	-0.76**
Perceived Benefit	-	0.33**	0.33**	0.42**	-	0.42**	-	-	-	-	-0.32**	-0.32**
Perceived Barriers	-	-	-	-	-	-	-	-	-	-	-	-
Cue to action	-	0.30**	0.30**	-	0.37**	0.37**	0.89**	-	0.89**	-	-0.28**	-0.28**
Self-efficacy	-	-	-	-	-	-	-	-	-	-	-	-
R^2			0.643			0.313			0.605			0.595

Independent Variable	HBM Construct						Preventive Behaviors (β)		
	Cue to action (β)			Self-efficacy (β)					
	DE	IE	TE	DE	IE	TE	DE	IE	TE
Age	-	-	-	-	-	-	-0.08*	-	-0.08*
Knowledge	-	-	-	-	0.10**	0.10**	-	0.10**	0.10**
Education	-	-	-	-	0.03*	0.03*	0.13**	0.003	0.14**
Smoking	-	-	-	0.06*	0.03*	0.09*	0.05*	0.04*	0.09*
Family influence	0.06**	-	0.06*	-	0.09*	0.09**	0.21**	0.06**	0.27**
Perceived Susceptibility	-	-	-	-	-	-	0.34**	-	0.34**
Perceived Severity	-	-	-	-	0.28**	0.28**	-	0.31**	0.31**
Perceived Benefit	-	-	-	-	0.12**	0.12**	-	0.13**	0.13**
Perceived Barriers	-	-	-	-0.36**	-	-0.36**	-	-0.05*	-0.05*
Cue to action	-	-	-	0.6**	0.10**	0.70**	-0.13*	0.19**	0.06*
Self-efficacy	-	-	-	-	-	-	0.13*	-	0.13*
R^2			0.004			0.546			0.257

*p<0.05; **p<0.001; DE, Direct effect; IE, Indirect effect; TE, Total effect

factors for *O.viverrini* infection than younger age-groups due to the continued consumption of raw fish [5, 18, 29]. This might be because older people have the habit of consuming raw fish, deeply ingrained in their local culture, which is difficult to change. Therefore, older adults are a high-risk group of acquiring *O. viverrini* infection and

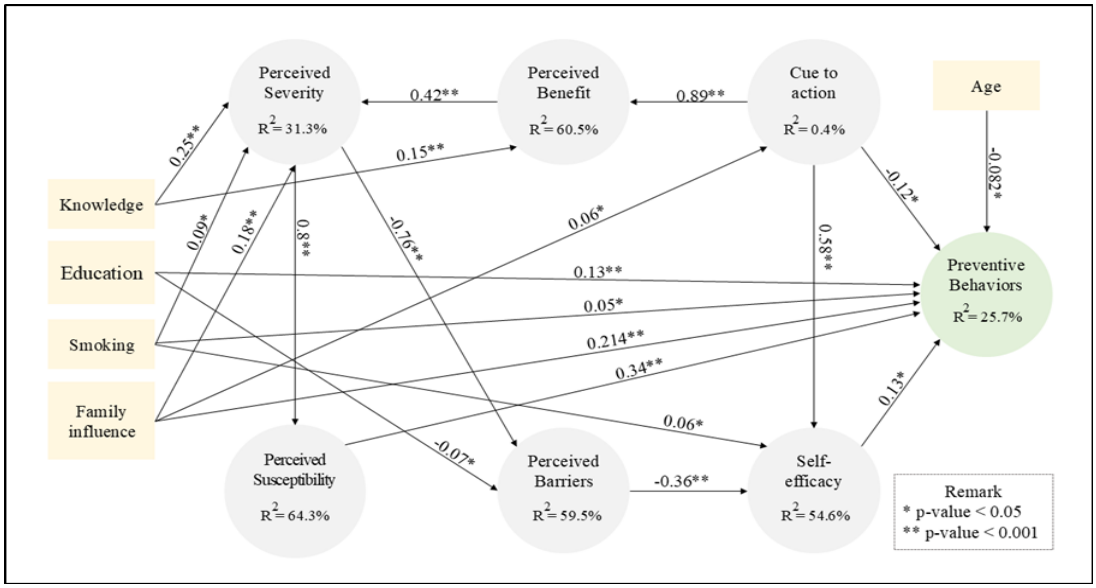

Figure 1. The Final Model of Liver Fluke Infection-Preventive Behaviors

reinfections after treatment. A health education about methods of cooking freshwater fish until it is cooked and good hygiene practices that promotes gradual change and interventions are keys to encouraging older people to select safer food products and washing hands before meals for healthier eating habits.

Education, consumption of raw fish of family members, and smoking were identified as modifying factors of HBM constructs on liver fluke infection-preventive behaviors [20]. Our study had similar results as other studies that higher education and individuals living in a family that do not consume raw freshwater fish were more likely to practice better preventive behaviors compared to those who completed lower education and those in families that consumed raw fish, respectively [5, 30]. This might be that education and attitudes within a family can greatly influence individual behaviors related to food choices. Moreover, higher educated people and families that avoid raw fish might have a higher awareness of the health risks such as likelihood of contracting liver fluke infection, afraid of CCA, etc. leading to more preventive behaviors. Similarly, non-smokers tended to have higher levels of preventive behaviors. Health campaigns and education programs can help shift attitudes towards raw fish consumption and promoted preventive behaviors. Therefore, public health campaigns need to focus on individuals who have low education, live in a family that consumes raw fish, and smoke.

Knowledge had only an indirect effect on liver fluke infection-preventive behaviors positively through the mediators were perceived severity, susceptibility, benefit, barriers, and self-efficacy. These results indicate that individuals with higher levels of knowledge tend to exhibit increased perceived severity, susceptibility, benefit, and self-efficacy, while perceived barriers decrease, ultimately leading to higher liver fluke infection-preventive behaviors. This finding is consistent with the study of Jadgal, et al. [31], which concluded that knowledge plays a role in predicting preventive behaviors through HBM constructs. Likewise, the result research of Hajian-Tilaki [32] showed HBM constructs were mediators between knowledge and preventive behaviors. These finding might contrast the belief of some public health officers in Thailand, who often believe that knowledge is not necessary for improving preventive behaviors. However, based on the above empirical evidence and a study of Sornlorm et al. [6], improving knowledge about liver fluke disease—including its infection, symptoms, treatment, and preventive behaviors—is a key strategy for promoting behavior change.

All HBM constructs had significant effects on the prevention behaviors. These findings demonstrate the usefulness of HBM constructs on the beliefs of individuals in understanding liver fluke infection-preventive behaviors.

Perceived susceptibility was found to be a significant predictor of liver fluke infection-preventive behaviors. This finding contrasts with previous studies, which reported that the perception of susceptibility had no link to the prevention of behaviors for COVID-19 [33-35]. While this result is consistent with the study of Park and Oh [36], who concluded that perceived susceptibility, was a key internal factor in promoting COVID-19 preventive behaviors. This present study showed perceived susceptibility was the strongest predictor of the prevention behaviors. If individuals perceive themselves to be at high risk of liver fluke infection—due to consuming raw freshwater fish or practicing poor personal hygiene (e.g., defecation outside toilet, not washing hands before or after? meal, etc.). Their perceived susceptibility will increase and may lead to improve the preventive behaviors.

Perceived severity was defined as an individual's belief about the seriousness of liver fluke infection. This study showed that perceived severity had only an indirect effect on prevention behaviors positively through the mediators namely perceived susceptibility, barriers, and self-efficacy. These results were described as high perceived severity will reduce perceived barriers, while increasing perceived susceptibility and self-efficacy, which in turn leads to greater prevention behaviors. This pattern is consistent with previous researches [37, 38]. This may be very useful for health education programs to change risk liver fluke infection behaviors, even though perceived severity only had indirect effects.

Perceived benefit had only an indirect effect on liver fluke infection-preventive behaviors positively through the mediators were perceived susceptibility, severity, barriers, and self-efficacy. The result was similarly described as that people who had high perceived benefit, they will have high perceived susceptibility, severity, and self-efficacy, then their liver fluke preventive-behaviors will increase accordingly [39-41]. On the other hand, if people had high perceived benefit and perceived barriers decreased, then their prevention behaviors increased [42, 43]. Encouraging the perception of benefit about the preventive behaviors should focus on increasing awareness of the advantages of parasitic egg detection, handwashing, avoidance of consuming various kinds of uncooked freshwater fish, proper disposal of raw fish scraps, and practicing hygienic defecation.

Self-efficacy had a direct and positive effect on liver fluke infection-preventive behaviors. Likewise, some studies indicated that self-efficacy is one of the important variables for predicting preventive behaviors [23, 44-46]. Self-efficacy refers to an individual's belief in their ability to prevent behaviors of liver fluke infection. It serves as a key mediating component between perceived barriers, cue to action and preventive behaviors [22,47]. Therefore, the researchers believe that improving self-efficacy can significantly enhance the liver fluke infection-preventive behaviors among individuals living in Khon Kaen province, Thailand.

Cues to action refers to external factors that trigger preventive behaviors, such as local policies or measures, family/public health officers/village health volunteers' support, and online and traditional media. The result of this study was similarly positively associated with liver fluke infection-preventive behaviors [48-50]. Cues to action had an indirect positive effect on prevention behaviors through the mediators namely perceived susceptibility, severity, benefit, barriers, and self-efficacy

[37, 51]. In the other words, if individuals have high cues to action, their perceived susceptibility, severity, benefit, self-efficacy would increase, perceived barriers would decrease, and their liver fluke preventive-behaviors would also improve. However, when considering only the direct effect, it was surprising to find that cues to action had negative direct effects on prevention behaviors [52]. These results might be explained by the presence of negative external cues to action, such as living in a family that consumes uncooked fish (70.1%) or observing influencers consuming uncooked fish through online media (55.6%). Even though the effect of cues to action on preventive behaviors was small, its effects on perceived susceptibility, severity, benefit, barriers, and self-efficacy were substantial. Therefore, it remains an important factor to focus on.

Perceived barriers had only an indirect negative effect on prevention behaviors when the mediator was self-efficacy, similar to previous studies [23, 45]. While the finding contrasts with some studies that concluded that the perception of barriers had no link to the prevention behaviors [44, 53]. This result may describe that individuals with low perceived barriers tend to have higher self-efficacy, which subsequently leads to increased liver fluke infection-preventive behaviors. Therefore, this alternative pathway can enhance self-efficacy, then leads to improve preventive behaviors.

Advantages and Disadvantages of the study

Advantages

The present study had several strengths. First, the sample size was relatively large and representativeness, enhancing the statistical power of the analysis and precision of the prevalence of liver fluke infection-preventive behaviors. Second, liver fluke infection–preventive behaviors were defined not only by the avoidance of consuming various kinds of raw or undercooked freshwater fish but also personal hygiene practices. Last, Structural Equation Modeling (SEM) based on covariance structure analysis was employed. This advanced analytical method addresses limitations of basic models such as linear regression and logistic regression, and is capable of capturing complex relationships, including direct, indirect, and total effects.

Disadvantages

This study utilized secondary data, which imposed certain limitations on the ability to explore additional variables of interest.

In conclusion, these results indicate that health education, communication programs and activities developed as part of this study were effective in changing the consumption of uncooked fish and low personal hygiene practices. In addition, guidelines for modifying and developing health behavior program emphasis strengthen all constructs of HBM. Appling a combination of various communication channels such as social media, health volunteers or community influencers that are appropriate and effective in encouraging preventive behaviors among high-risk groups. Particular attention should be given to older adults, smokers, lower educated individuals, and those living in households where raw fish is consumed to control the O.viverrini infection and its subsequent CCA.

Author Contribution Statement

The concept for research was developed by WR, PS, SK, JS, and PK. PS was principal investigators. PS and SK provided advice on study design. PK and JS provided advice on statistical analyses. WR conducted statistical analyses and wrote the first draft. All authors contributed and approved the final version.

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Competing interests

The authors declare that they have no conflicts of interest.

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