

## Preplanned Studies

# Knowledge, Attitudes, and Practices of Dog Owners Toward a Smart Health Education Pillbox for Controlling Echinococcosis — Western China, 2023–2024

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## Summary

### What is already known about this topic?

Echinococcosis remains a critical public health challenge in western China. Conventional routine health education (RHE) strategies have consistently proven insufficient in achieving the sustained behavioral modifications necessary to reduce disease transmission and burden.

### What is added by this report?

This study provides the first large-scale experimental evidence that a Smart Health Education Pillbox (SHEP) significantly enhances knowledge, corrects misconceptions, and improves practice conversion efficiency regarding echinococcosis control among dog owners in endemic pastoral areas. These findings demonstrate the substantial value of precise, automated health education tools in controlling zoonotic diseases.

### What are the implications for public health practice?

The SHEP represents a scalable, precise health education tool that effectively bridges the knowledge-practice gap in resource-limited settings. Its demonstrated efficacy supports integration into national echinococcosis control programs as a cost-effective digital intervention that promotes sustainable behavior change and reduces zoonotic disease transmission.

## ABSTRACT

**Introduction:** Echinococcosis, a neglected zoonotic disease, imposes a substantial global health burden. Enhancing health literacy and facilitating practice changes among pastoral communities through innovative technological interventions are essential for reducing disease transmission and impact. We evaluated the effectiveness of the Smart Health Education Pillbox (SHEP) on the knowledge,

attitudes, and practices (KAP) of dog owners in controlling echinococcosis.

**Methods:** We conducted a cluster-randomized trial among 2,700 dog owners across nine endemic counties in western China, selecting two townships per county. Within each township, 150 enrolled dog owners were randomly allocated in equal numbers to either the Smart Health Education Pillbox (SHEP) or routine health education (RHE) group. Data were collected through a validated online questionnaire (Cronbach's  $\alpha = 0.85$ ) distributed via the Wenjuanxing platform. Primary outcomes included knowledge, attitude, and practice rates, as well as practice conversion efficiency. Statistical analyses were performed to calculate absolute risk reduction (ARR), relative risk (RR), relative risk reduction (RRR), protective efficacy ( $1/RR$ ), and conversion efficiency index ( $\eta$ ).

**Results:** Implementation of the SHEP significantly enhanced dog owners' knowledge, attitudes, and practices by 6.78%, 3.30%, and 7.50%, respectively, while reducing misconceptions, negative attitudes, and improper practices by 43.92%, 28.60%, and 13.74% compared to RHE (all  $P < 0.001$ ). The intervention demonstrated protective efficacy ratios of 1.82, 1.40, and 1.16 across these domains and increased the overall conversion efficiency index by 7.88% (all  $P < 0.001$ ).

**Conclusion:** The SHEP represents a superior intervention for improving echinococcosis-related knowledge, attitudes, and practices (KAP), demonstrating particular strength in enhancing knowledge-to-practice conversion. As an innovative solution addressing health education challenges in plateau pastoral areas, the SHEP is recommended for integration into the national echinococcosis control program.

Echinococcosis, a neglected tropical zoonosis with cross-species transmission potential, manifests primarily as cystic echinococcosis (CE) and alveolar echinococcosis (AE), caused by *Echinococcus granulosus sensu lato* and *E. multilocularis*, respectively. These forms are endemic across 370 counties in northwestern China, with 115 experiencing co-endemicity (1). Annually, CE accounts for approximately 18,800 new cases and 1 million disability-adjusted life years (DALYs), with China bearing 40% of this global burden. AE is responsible for an estimated 18,200 cases and 666,000 DALYs annually, over 90% occurring within China. The combined annual economic burden reaches approximately 3 billion US dollar (USD), predominantly borne by China (2–3). Consequently, echinococcosis has been designated a priority infectious disease for control within China’s One Health framework (4).

Health education represents a cost-effective foundational intervention for echinococcosis control. New Zealand achieved elimination through legislative measures enforcing “canine management+public health education.” South American nations including Argentina and Chile achieved human incidence reductions exceeding 60% through sustained “dog deworming+community education” campaigns (5). In

China, the National Echinococcosis Control Program (2010–2015) and subsequent implementation plan (2024–2030) emphasize integrated strategies combining source control, health education, intermediate host management, and case treatment, prioritizing culturally tailored health materials for pastoral areas (6). After two decades of sustained efforts, improvements in knowledge, attitudes, and practices (KAP) among residents have contributed to reduced transmission (7–8). However, conventional health education approaches — including pamphlets, lectures, social media, and targeted training — face persistent challenges from low literacy levels, linguistic diversity, sporadic outreach, and coverage disparities (6,9). Lower awareness of echinococcosis control ( $P<0.01$ ) was observed among high-altitude pastoral residents compared to urban/peri-urban residents (9). Addressing these gaps requires smart, precise, digitalized health education tools ensuring sustainable, equitable, and effective delivery of control messages to reduce disease burden.

Between 2021 and 2023, we developed an AI and IoT-enabled SHEP with a dedicated anthelmintic bait compartment, two reminder lights, a liquid-crystal display, six function buttons, and an integrated speaker and charging port (Figure 1). Core functions include



FIGURE 1. Structure and functionalities of Smart Health Education Pillbox. Abbreviation: SHEP=Smart Health Education Pillbox.

automated deworming reminders and delivery of at least three daily health education broadcasts per household. We conducted a 12-month cluster-randomized trial from 2023 to 2024 across nine endemic counties (10). Within each county, two townships were randomly assigned to intervention arms using a computer-generated random number table. The SHEP group received automated intervention with digitized core knowledge delivery, while the routine health education (RHE) group received standard health education through pamphlets, WeChat, and conventional methods. Sample size calculations determined that 150 eligible dog owners per township would provide 90% power to detect significant differences at the two-sided 5% significance level.

A baseline survey was conducted in 2023 using a questionnaire with satisfactory internal consistency (Cronbach's  $\alpha=0.85$ ) through face-to-face, in-home interviews with all 2,700 eligible dog owners. One year later, a follow-up assessment was administered to both randomized groups of 1,350 participants each. Data were collected using a validated online questionnaire on the Wenjuanxing platform, capturing demographic characteristics, socioeconomic status, and KAP related to echinococcosis. A pilot survey was conducted and multilingual versions were provided to ensure data quality. Blinding was maintained through separate surveyors for each group and independent WeChat groups for survey administration.

Data from the Wenjuanxing platform were entered into MS-Excel and analyzed using SPSS software (version 27.0, IBM Corp., NY, USA). Categorical variables were reported as counts ( $n$ ) and percentages (%). Primary outcomes included knowledge, attitude, and practice rates related to echinococcosis control, and conversion efficiency. These were assessed using absolute risk reduction (ARR), relative risk (RR), relative risk reduction (RRR), protective efficacy (1/RR), and conversion efficiency index ( $\eta$ ). Between-group comparisons used the chi-square test or Fisher's exact test, with two-tailed testing and statistical significance at  $P<0.05$ .

At baseline, all 2,700 dog owners completed the survey. At one-year follow-up, retention rates were 75.63% ( $n=1,021$ ) in SHEPG and 68.89% ( $n=930$ ) in RHEG. The survey employed a nine-item knowledge questionnaire across five domains: basic knowledge, policy awareness, transmission routes, key practices, and livestock management. The knowledge rate in SHEPG reached 91.35%, significantly exceeding both

RHEG and baseline by 6.78% [ARR=6.78%; 95% confidence interval (CI): 5.95, 7.61;  $P<0.001$ ] and 6.50% (ARR=6.50%; 95% CI: 5.71, 7.29;  $P<0.001$ ), respectively. SHEP intervention substantially reduced the risk of knowledge gaps and misconceptions compared to both groups. The relative risk reduction was 43.92% (RRR, 95% CI: 40.23, 47.61;  $P<0.001$ ) versus RHEG and 42.97% (RRR, 95% CI: 39.38, 46.56;  $P<0.001$ ) versus Baseline. Relative probabilities of incomplete or incorrect knowledge were reduced to 0.55 times RHEG (RR, 95% CI: 0.51, 0.59;  $P<0.001$ ) and 0.57 times Baseline (RR, 95% CI: 0.53, 0.61;  $P<0.001$ ). SHEP demonstrated protective efficacy of 1.82-fold against knowledge inaccuracies relative to RHE (1/RR, 95% CI: 1.70, 1.96;  $P<0.001$ ) and 1.75-fold relative to Baseline (1/RR, 95% CI: 1.64, 1.88;  $P<0.001$ ) (Table 1; Supplementary Table S1, available at <https://weekly.chinacdc.cn/>). RHEG showed marginal, non-significant decrease in knowledge rate versus Baseline (ARR=-1.85; 95% CI: -8.32 to 4.62;  $P=0.575$ ; RR=1.02; 95% CI: 0.96-1.08;  $P=0.569$ ) (Supplementary Table S2, available at <https://weekly.chinacdc.cn/>). Detailed knowledge rates and response frequencies for questions 1-9 are in Table 1 and Supplementary Tables S1-S2.

The attitude questionnaire evaluated participants' willingness to adopt eight key control measures: handwashing, dog tethering, deworming, safe fecal disposal, centralized slaughtering, abstaining from feeding viscera to dogs, lamb vaccination, and health screening. Participants demonstrated overwhelmingly positive attitudes at all time points (Baseline: 89.97%; SHEPG: 91.76%; RHEG: 88.46%). One year post-initiation, SHEPG showed substantial improvements versus both controls. The absolute risk reduction was 3.30% (95% CI: 2.28-4.32;  $P<0.001$ ) versus RHEG and 1.79% (95% CI: 0.95-2.63;  $P<0.0001$ ) versus Baseline. These improvements corresponded to meaningful reductions in negative attitudes: RRR was 28.60% (95% CI: 19.76-37.38;  $P<0.001$ ) versus RHEG and 17.85% (95% CI: 9.48-26.22;  $P<0.0001$ ) versus Baseline. The RR of negative attitudes decreased to 0.71 (95% CI: 0.65-0.78;  $P<0.001$ ) versus RHEG and 0.82 (95% CI: 0.76-0.89;  $P<0.0001$ ) versus Baseline. Consequently, SHEP provided protective effects against unfavorable attitudes that were 1.40-fold (1/RR, 95% CI: 1.28-1.54;  $P<0.001$ ) and 1.22-fold (1/RR, 95% CI: 1.12-1.32;  $P<0.0001$ ) stronger than RHEG and Baseline, respectively (Table 2 and Supplementary Table S3, available at <https://weekly.chinacdc.cn/>). Conversely, RHEG

TABLE 1. Knowledge rates from Baseline, SHEPG, and RHEG; ARR, RRR, RR, and 1/RR between SHEPG and RHEG after the 12-month follow-up, 2023–2024.

Question	Response	Baseline [% (n/M)]	SHEPG [% (n/M)]	CHEG [% (n/M)]	ARR		RRR		RR		1/RR	
					95% CI	P	95% CI	P	95% CI	P	95% CI	P
Q1. Have you heard of echinococcosis?	Yes (correct)	93.89 (2,535/2,700)	96.87 (989/1,021)	90.97 (846/930)	5.90 (3.56, 8.24)	<0.001	65.33 (39.41, 91.24)	<0.001	0.12 (0.05, 0.28)	<0.001	8.47 (3.57, 20.08)	<0.001
	No	3.96 (107/2,700)	0.59 (6/1,021)	4.95 (46/930)	4.36 (3.07, 5.65)	<0.001	88.08 (72.96, 95.04)	<0.001	0.62 (0.38, 1.02)	0.058	1.61 (0.98, 2.63)	0.058
	Not sure	2.15 (58/2,700)	2.55 (26/1,021)	4.09 (38/930)	1.54 (0.19, 2.89)	0.026	37.65 (3.59, 61.52)	0.026				
Q2. How do people get echinococcosis?	Get infected if they accidentally ingest worm eggs excreted by dogs or foxes (correct)	66.33 (1,791/2,700)	71.69 (732/1,021)	66.92 (615/919)†	4.77 (0.90, 8.64)	0.016	14.43 (2.73, 26.14)	0.016	0.89 (0.78, 1.03)	0.126	1.12 (0.97, 1.28)	0.126
	By eating unclean internal organs of cattle or sheep	29.67 (801/2,700)	27.23 (278/1,021)	30.47 (280/919)†	3.24 (−0.57, 7.05)	0.095	14.43 (2.73, 26.14)	0.016	0.41 (0.21, 0.83)	0.013	2.44 (1.20, 4.76)	0.013
	Human-to-human	4.00 (108/2,700)	1.08 (11/1,021)	2.61 (24/919)†	1.53 (0.41, 2.65)	0.007	58.62 (17.30, 79.86)	0.007				
Q3. How do dogs get infected with <i>Echinococcus</i> ?	By consuming the diseased internal organs of cattle or sheep (correct)	93.03 (1,976/2,124)†	98.53 (1,006/1,021)	96.34 (896/930)	2.19 (0.87, 3.51)	0.001	59.46 (23.64, 95.28)	0.001	0.45 (0.22-0.95)	0.036	2.22 (1.05-4.55)	0.036
	Dog-to-dog	6.50 (138/2,124)†	0.98 (10/1,021)	2.15 (20/930)	1.17 (0.20, 2.14)	0.018	54.42 (5.26-79.63)	0.018	0.32 (0.12, 0.88)	0.028	3.13 (1.14, 8.33)	0.028
	Human-to-dog	0.47 (10/2,124)†	0.49 (5/1,021)	1.51 (14/930)	1.02 (0.22, 1.82)	0.012	67.55 (12.33, 87.80)	0.012				
Q4. Are you aware of the national policies for echinococcosis patients?	Fully aware (correct)	43.85 (1,184/2,700)	73.16 (747/1,021)	49.13 (450/916)†	24.03 (20.32, 27.74)	<0.001	47.30 (39.98, 54.61)	<0.001	0.62 (0.55, 0.71)	<0.001	1.60 (1.41, 1.82)	<0.001
	Partially aware	46.33 (1,251/2,700)	25.86 (264/1,021)	41.48 (380/916)†	15.62 (11.48, 19.76)	<0.001	37.66 (27.68, 47.63)	<0.001	0.10 (0.05, 0.20)	<0.001	9.58 (5.01, 18.33)	<0.001
	Not aware	9.81 (265/2,700)	0.98 (10/1,021)	9.39 (86/916)†	8.41 (6.73, 10.09)	<0.001	89.56 (82.71, 94.99)	<0.001				

Question	Response	Baseline [% (n/M)]	SHEPG [% (n/M)]	CHEG [% (n/M)]	ARR		RRR		RR		1/RR	
					95% CI	P	95% CI	P	95% CI	P	95% CI	P
Q5. Is deworming dogs a preventive measure for echinococcosis?	Yes (correct)	96.96 (2,618/2,700)	99.80 (1,019/1,021)	95.46 (799/837)†	4.34 (2.92, 5.76)	<0.001	95.45 (64.10, 126.80)	<0.001	0.05 (0.00, 0.79)*	0.033	19.61 (1.27, ∞)*	0.033
	No	1.56 (42/2,700)	0.00 (0/1,021)	2.03 (17/837)†	2.03 (1.01, 3.05)	<0.001	100.00 (58.04, 100.00)*	<0.001	0.08 (0.02, 0.33)	<0.001	12.82 (3.03, 50.00)	<0.001
	Not sure	1.48 (40/2,700)	0.20 (2/1,021)	2.51 (21/837)†	2.31 (1.30, 3.32)	<0.001	92.03 (67.18, 98.48)	<0.001				
Q6. Is the safe disposal (deep burial) of dog feces a preventive measure for echinococcosis?	Yes (correct)	90.70 (2,449/2,700)	93.83 (958/1,021)	89.35 (831/930)	4.48 (2.16, 6.80)	<0.001	42.11 (20.32, 63.90)	<0.001	1.15 (0.77, 1.71)	0.498	0.87 (0.58, 1.30)	0.498
	No	5.15 (139/2,700)	4.80 (49/1,021)	4.19 (39/930)	-0.61 (-2.46, 1.24)	0.518	-14.56 (-71.49, 42.37)	0.518	0.21 (0.12, 0.37)	<0.001	4.76 (2.70, 8.33)	<0.001
	Not sure	4.15 (112/2,700)	1.37 (14/1,021)	6.45 (60/930)	5.08 (3.55, 6.61)	<0.001	78.76 (63.45, 88.12)	<0.001				
Q7. Is not feeding raw livestock internal organs to dogs a preventive measure for echinococcosis?	Yes (correct)	90.74 (2,450/2,700)	92.26 (942/1,021)	86.56 (805/930)	5.70 (3.10, 8.30)	<0.001	42.54 (23.13, 61.94)	<0.001	1.15 (0.77, 1.71, 0.498)	0.498	0.87 (0.58, 1.30)	0.498
	No	6.26 (169/2,700)	6.95 (71/1,021)	6.02 (56/930)	-0.93 (-3.24, 1.38)	0.430	-15.45 (-53.76, 22.86)	0.430	0.11 (0.05, 0.22)	<0.001	9.09 (4.55, 20.00)	<0.001
	Not sure	3.00 (81/2,700)	0.78 (8/1,021)	7.42 (69/930)	6.64 (4.96, 8.32)	<0.001	89.49 (78.22, 94.97)	<0.001				
Q8. Is not playing with dogs a preventive measure for echinococcosis?	Yes (correct)	93.30 (2,519/2,700)	96.57 (986/1,021)	90.32 (840/930)	6.25 (4.17, 8.33)	<0.001	64.52 (43.02, 86.02)	<0.001	0.59 (0.38, 0.91)	0.018	1.70 (1.10, 2.63)	0.018
	No	4.04 (109/2,700)	2.84 (29/1,021)	4.84 (45/930)	2.00 (0.41, 3.59)	0.014	41.32 (8.97, 62.45)	0.014	0.12 (0.05, 0.27)	<0.001	8.26 (3.70, 20.00)	<0.001
	Not sure	2.67 (72/2,700)	0.59 (6/1,021)	4.84 (45/930)	4.25 (2.85, 5.65)	<0.001	87.81 (71.43, 94.74)	<0.001				

Question	Response	Baseline [% (n/M)]	SHEPG [% (n/M)]	CHEG [% (n/M)]	ARR		RRR		RR		1/RR	
					95% CI	P	95% CI	P	95% CI	P	95% CI	P
Q9. Is washing hands before meals a preventive measure for echinococcosis?	Yes (correct)	96.56 (2,607/2,700)	99.41 (1,015/1,021)	90.65 (843/930)	8.76 (6.92, 10.60)	<0.001	93.75 (74.07, 113.44)	<0.001	0.09 (0.04, 0.23)	<0.001	11.11 (4.35, 25.00)	<0.001
	No	1.22 (33/2,700)	0.49 (5/1,021)	5.16 (48/930)	4.67 (3.22, 6.12)	<0.001	90.50 (77.91, 96.15)	<0.001	0.02 (0.00, 0.15)	<0.001	50.00 (6.67, ∞)*	<0.001
Total (Q1–Q9)	Yes (correct)	84.85 (20,129/23,724)	91.35 (8,394/9,189)	84.57 (6,925/8,252)	6.78 (5.95, 7.61)	<0.001	43.92 (40.23, 47.61)	<0.001	0.55 (0.51, 0.59)	<0.001	1.82 (1.70, 1.96)	<0.001
	Other responses (incorrect)	15.15 (3,595/23,724)	8.65 (795/9,189)	15.43 (1,327/8,252)	6.78 (5.95, 7.61)	<0.002	43.92 (40.23, 47.61)	<0.001				

Abbreviation: ARR=absolute risk reduction; RR=relative risk; RRR=relative risk reduction; 1/RR=protective efficacy; CI=confidence interval; SHEPG=smart health education pillbox group; RHEG =routine health education group.

\*For cells containing zero counts (Q5-No, Q9-Not sure), the Haldane-Anscombe correction was implemented by adding 0.5 to each cell. The RRR for Q5-No was set at 100% when the intervention group risk equaled 0; the corresponding CI was calculated using this correction.

†All responses were considered valid except for 576 logical errors in Q3 at baseline and 11, 14, and 93 logical errors in Q2, Q4, and Q5 in RHEG, respectively.

Note: Chi-square tests were employed for all comparisons; however, Fisher's exact test was applied when the expected frequency of any cell fell below 5. Blank cells indicate values that were not calculated (with no need for calculation).

TABLE 2. Attitude rates from Baseline, SHEPG, and RHEG; ARR, RRR, RR, and 1/RR between SHEPG and RHEG after the 12-month follow-up, 2023–2024.

Question	Response	Baseline [% (n/M)]	SHEPG [% (n/M)]	CHEG [% (n/M)]	ARR		RRR		RR		1/RR	
					95% CI	P	95% CI	P	95% CI	P	95% CI	P
Q1. Would you like to wash your hands before meals?	Yes	97.30 (2,627/2,700)	98.33 (1,004/1,021)	97.74 (909/930)	0.59 (-0.49, 1.67)	0.288	25.93 (-21.67, 73.52)	0.288	0.74 (0.40, 1.37)	0.336	1.35 (0.73, 2.50)	0.336
	No	2.70 (73/2,700)	1.67 (17/1,021)	2.26 (21/930)	0.59 (-0.49, 1.67)	0.288	26.11 (-21.74, 73.96)	0.288				
Q2. Would you agree to tether all your dogs?	Yes	95.63 (2,582/2,700)	97.16 (992/1,021)	95.94 (803/837)*	1.22 (-0.40, 2.84)	0.137	29.76 (-9.76, 69.29)	0.137	0.70 (0.44, 1.12)	0.139	1.43 (0.89, 2.27)	0.139
	No	4.37 (118/2,700)	2.84 (29/1,021)	4.06 (34/837)*	1.22 (-0.40, 2.84)	0.137	30.05 (-9.85, 69.95)	0.137				
Q3. Would you agree to free regular dog deworming?	Yes	97.22 (2,625/2,700)	98.82 (1,009/1,021)	98.17 (913/930)*	0.65 (-0.47, 1.77)	0.208	35.71 (-25.81, 97.22)	0.208	0.64 (0.32, 1.30)	0.218	1.56 (0.77, 3.13)	0.218
	No	2.78 (75/2,700)	1.18 (12/1,021)	1.83 (17/930)	0.65 (-0.47, 1.77)	0.208	35.52 (-25.81, 97.22)	0.208				
Q4. Would you agree to bury dog waste deeply after deworming?	Yes	92.70 (2,503/2,700)	96.38 (984/1,021)	92.95 (778/837)*	3.43 (1.37, 5.49)	<0.001	48.57 (19.42, 77.72)	<0.001	0.51 (0.35, 0.75)	<0.001	1.96 (1.33, 2.86)	<0.001
	No	7.30 (197/2,700)	3.62 (37/1,021)	7.05 (59/837)*	3.43 (1.37, 5.49)	<0.001	48.65 (19.42, 77.72)	<0.001				
Q5. Would you support centralized slaughter?	Yes	49.74 (939/1,888)*	61.76 (533/863)*	50.32 (419/852)*	11.44 (6.30, 16.58)	<0.001	22.73 (12.52, 32.94)	<0.001	0.77 (0.69, 0.86)	<0.001	1.30 (1.16, 1.45)	<0.001
	No	50.26 (949/1,888)*	38.24 (330/863)*	49.68 (433/852)*	11.44 (6.30, 16.58)	<0.001	23.03 (12.68, 33.33)	<0.001				

Question	Response	Baseline [% (n/M)]	SHEPG [% (n/M)]	CHEG [% (n/M)]	ARR		RRR		RR		1/RR	
					95% CI	P	95% CI	P	95% CI	P	95% CI	P
Q6. Would you agree to free lamb vaccination?	Yes	87.16 (1, 147/1, 316)*	88.02 (507/576)*	86.81 (553/637)*	1.21 (-2.78, 5.20)	0.490	8.75 (-20.08, 37.58)	0.490	0.91 (0.68, 1.21)	0.509	1.10 (0.83, 1.47)	0.509
	No	12.84 (169/1, 316)*	11.98 (69/576)*	13.19 (84/637)*	1.21 (-2.78, 5.20)	0.490	9.17 (-21.08, 39.42)	0.490				
Q7. Would you avoid feeding dogs raw livestock organs?	Yes	86.86 (1, 342/1, 545)*	90.70 (634/699)*	85.53 (668/781)*	5.17 (1.66, 8.68)	0.001	35.71 (11.46, 59.96)	0.001	0.64 (0.49, 0.84)	0.001	1.56 (1.19, 2.04)	0.001
	No	13.14 (203/1, 545)*	9.30 (65/699)*	14.47 (113/781)*	5.17 (1.66, 8.68)	0.001	35.73 (11.46, 59.96)	0.001				
Q8. Would you agree to free regular check-ups (screening)?	Yes	98.26 (2, 653/2,700)	98.33 (1, 004/1,021)	98.28 (914/930)	0.05 (-0.91, 1.01)	0.901	2.78 (-50.00, 55.56)	0.901	N/A	N/A	N/A	N/A
	No	1.74 (47/2,700)	1.67 (17/1,021)	1.72 (16/930)	0.05 (-0.91, 1.01)	0.901	2.91 (-55.56, 55.56)	0.901	0.97 (0.50, 1.88)	0.929	1.03 (0.53, 1.99)	0.929
Q9. Would you use our Smart Health Education Pillbox?	Yes	N/A	89.72 (916/1,021)**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	No	N/A	10.28 (105/1,021)**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total (Q1-8)	Yes	89.97 (16, 418/18, 249)	91.76 (7, 583/8, 264)	88.46 (5, 957/6, 734)	3.30 (2.28, 4.32)	<0.001	28.57 (19.76, 37.38)	<0.001	0.71 (0.65, 0.78)	<0.001	1.40 (1.28, 1.54)	<0.001
	No	10.03 (1, 831/18, 249)	8.24 (68/18, 264)	11.54 (777/6, 734)	3.30 (2.28, 4.32)	<0.001	28.60 (19.76, 37.38)	<0.001				

Abbreviation: ARR=absolute risk reduction; RRR=relative risk reduction; 1/RR=protective efficacy; CI=confidence interval; SHEPG=smart health education pillbox group; RHEG=routine health education group; N/A=not applicable.

\*N=2,700 at baseline. At the one-year follow-up, SHEPG (N=1,021) and RHEG (N=930). Valid response counts in RHEG for Q2 and Q4 totaled 837. For Q5, valid response counts among households raising livestock were 1,888,863, and 852 across the three groups, respectively; for Q6, among households raising sheep, counts were 1,316,576, and 637, respectively; for Q7, among households raising livestock, counts were 1,545,699, and 781, respectively.

\*\*The attitude survey regarding SHEP usage was administered exclusively in the SHEPG.

Note: Chi-square tests were applied for all comparisons; however, Fisher's exact test was employed when the expected frequency of any cell fell below 5. Blank cells indicate "not calculated (with no need for calculation)".

TABLE 3. Practice rates from Baseline, SHEPG, and RHEG; ARR, RRR, RR, and 1/RR between SHEPG and RHEG after the 12-month follow-up, 2023–2024.

Question	Response	Baseline [% (n/M)]	SHEPG [% (n/M)]	CHEG [% (n/M)]	ARR		RRR		RR		1/RR	
					95% CI	P	95% CI	P	95% CI	P	95% CI	P
1. Do you wash your hands before meals?	Three times a day or more (correct)	53.89 (1, 455/2,700)	59.94 (612/1,021)	54.73 (509/930)	5.21 (1.37, 9.05)	0.015	11.52 (3.03, 20.01)	0.015	1.09 (0.94, 1.26)	0.250	0.92 (0.79, 1.07)	0.250
	1-2 times a day (partly)	23.96 (6, 47/2,700)	27.13 (277/1,021)	24.95 (232/930)	-2.18 (-6.35, 1.99)	0.250	-8.74 (-25.45, 7.97)	0.250	0.64 (0.52-0.78, P<0.001)	<0.001	1.57 (1.28, 1.92)	<0.001
2. How is your dog typically restrained?	Occasionally (incorrect)	22.15 (598/2,700)	12.93 (132/1,021)	20.32 (189/930)	7.39 (4.35, 10.43)	<0.001	36.36 (21.41, 51.33)	<0.001	0.89 (0.72, 1.11)	0.330	1.12 (0.90, 1.39)	0.300
	Always tethered (correct)	27.89 (753/2,700)	31.73 (324/1,021)	28.84 (265/919)	2.89 (-0.97, 6.75)	0.150	4.06 (-1.36, 9.49)	0.150	0.99 (0.90, 1.10)	0.900	1.01 (0.91, 1.11)	0.900
3. Do you often pet or hug your dog?	Tethered during the day, free at night (partly)	14.96 (404/2,700)	13.22 (135/1,021)	14.79 (136/919)	1.57 (-2.18, 5.32)	0.330	10.62 (-14.74, 35.97)	0.330	0.87 (0.65, 1.18)	0.400	1.15 (0.85, 1.55)	0.380
	settlements, free during migration (partly)	47.78 (1, 290/2,700)	48.09 (491/1,021)	48.42 (445/919)	0.33 (-3.69, 4.35)	0.900	0.68 (-7.62, 8.98)	0.900	0.98 (0.87, 1.11)	0.750	1.02 (0.90, 1.15)	0.750
4. Do you deworm your dog regularly?	Never tethered (incorrect)	9.37 (253/2,700)	6.95 (71/1,021)	7.94 (73/919)	0.99 (-1.30, 3.28)	0.400	12.47 (-16.37, 41.31)	0.400	0.99 (0.91, 1.09)	0.880	1.01 (0.92, 1.10)	0.880
	Never (correct)	8.24 (175/2, 124)	10.19 (104/1,021)	9.25 (86/930)	0.94 (-1.96, 3.84)	0.480	1.04 (-2.16, 4.23)	0.480	0.98 (0.87, 1.11)	0.750	1.02 (0.90, 1.15)	0.750
5. Do you properly dispose of your dog's waste after deworming?	Occasionally (partly)	53.95 (1, 146/2, 124)	52.69 (538/1,021)	53.01 (493/930)	0.32 (-3.71, 4.35)	0.880	0.60 (-7.00, 8.21)	0.880	0.44 (0.34, 0.57)	<0.001	2.27 (1.75, 2.94)	<0.001
	Often (incorrect)	37.81 (803/2, 124)	37.12 (379/1,021)	37.74 (351/930)	0.62 (-3.73, 4.97)	0.750	1.64 (-9.88, 13.17)	0.750	0.03 (0.02, 0.07)	<0.001	33.33 (14.29, 50.00)	<0.001
4. Do you deworm your dog regularly?	Yes (correct; 9-12 times/yr)	61.00 (1, 647/2,700)	91.38 (933/1,021)	59.89 (557/930)	31.49 (28.17, 34.81)	<0.001	78.57 (70.15, 86.99)	<0.001	0.44 (0.34, 0.57)	<0.001	2.27 (1.75, 2.94)	<0.001
	Frequently (4-8 times/yr) (partly)	18.11 (489/2,700)	7.44 (76/1,021)	16.88 (157/930)	9.44 (6.67-12.21, P)	<0.001	55.92 (39.51, 72.34)	<0.001	0.03 (0.02, 0.07)	<0.001	33.33 (14.29, 50.00)	<0.001
5. Do you properly dispose of your dog's waste after deworming?	Occasionally (1-3 times/year) (partly)	17.19 (464/2,700)	0.69 (7/1,021)	20.65 (192/930)	19.96 (18.06, 21.86)	<0.001	96.66 (87.48, 105.83)	<0.001	0.19 (0.07, 0.50)	<0.001	5.26 (2.00, 14.29)	<0.001
	Never dewormed (incorrect)	3.70 (100/2,700)	0.49 (5/1,021)	2.58 (24/930)	2.09 (1.10, 3.08)	<0.001	81.01 (42.64, 119.38)	<0.001	0.18 (0.052, 1.00)	0.052	0.85 (0.72, 1.00)	0.052
5. Do you properly dispose of your dog's waste after deworming?	Yes (correct; deep burial)	51.04 (1, 378/2,700)	54.65 (558/1,021)	51.73 (433/837)	2.92 (-1.34, 7.18)	0.180	6.06 (-2.78, 14.91)	0.180	1.18 (1.00, 1.39)	0.052	0.75 (0.64, 0.88)	<0.001
	Occasionally (partly)	21.81 (589/2,700)	25.17 (257/1,021)	21.39 (179/837)	-3.78 (-7.80, 0.24)	0.052	-17.67 (-36.46, 1.12)	0.052	0.75 (0.64, 0.88)	<0.001	1.33 (1.14, 1.56)	<0.001
5. Do you properly dispose of your dog's waste after deworming?	Untreated (incorrect)	27.15 (733/2,700)	20.18 (206/1,021)	26.88 (225/837)	6.70 (2.51, 10.89)	<0.001	24.93 (9.34, 40.52)	<0.001	0.75 (0.64, 0.88)	<0.001	1.33 (1.14, 1.56)	<0.001

Question	Response	Baseline [% (n/N)]	SHEPG [% (n/N)]	CHEG [% (n/N)]	ARR		RRR		RR		1/RR	
					95% CI	P	95% CI	P	95% CI	P	95% CI	P
6. Do you often slaughter cattle and sheep at home?	No (correct)	18.17 (343/1,888)*	19.00 (164/863)*	17.72 (151/852)*	1.28 (-2.97, 5.53)	0.480	7.22 (-16.76, 31.21)	0.480	0.98 (0.94, 1.03)	0.480	1.02 (0.97, 1.06)	0.480
	Yes (incorrect)	81.83 (1,545/1,888)*	81.00 (699/863)*	82.28 (701/852)*	1.28 (-2.97, 5.53)	0.480	1.56 (-3.61, 6.72)	0.480				
7. Do you feed the internal organs of the cattle and sheep to dogs?	Never (correct)	61.04 (943/1,545)*	67.81 (474/699)*	60.95 (476/781)*	6.86 (2.06, 11.66)	0.006	17.62 (5.29, 29.95)	0.006				
	Occasionally (partly)	25.18 (389/1,545)*	22.03 (154/699)*	25.74 (201/781)*	3.71 (-0.70, 8.12)	0.100	14.41 (-2.72, 31.54)	0.100	0.86 (0.71, 1.03)	0.100	1.17 (0.97, 1.41)	0.100
	Frequently (incorrect)	13.79 (213/1,545)*	10.16 (71/699)*	13.32 (104/781)*	3.16 (-0.63, 6.95)	0.064	23.72 (-4.73, 52.18)	0.064	0.76 (0.58, 1.01)	0.058	1.32 (0.99, 1.72)	0.058
	Regularly (correct)	55.02 (724/1,316)*	55.21 (318/576)*	54.79 (349/637)*	0.42 (-4.86, 5.70)	0.890	0.93 (-10.71, 12.57)	0.890				
8. Are your lambs vaccinated regularly?	Irregularly (partly)	25.23 (332/1,316)*	27.60 (159/576)*	26.06 (166/637)*	-1.54 (-6.66, 3.58)	0.560	-5.91 (-25.56, 13.74)	0.560	1.06 (0.88, 1.27)	0.560	0.94 (0.79, 1.14)	0.560
	No (incorrect)	19.76 (260/1,316)*	17.19 (99/576)*	19.15 (122/637)*	1.96 (-2.38, 6.30)	0.37	10.24 (-12.43, 32.91)	0.37	0.90 (0.71, 1.14)	0.37	1.11 (0.88, 1.41)	0.37
9. Do you regularly participate in echinococcosis screening?	Regularly (correct)	73.30 (1,979/2,700)	86.68 (885/1,021)	74.30 (691/930)	12.38 (9.16, 15.60)	<0.001	48.15 (35.67, 60.63)	<0.001				
	Irregularly (partly)	24.04 (649/2,700)	12.83 (131/1,021)	24.84 (231/930)	12.01 (8.81, 15.21)	<0.001	48.35 (35.47, 61.23)	<0.001	0.52 (0.43, 0.62)	<0.001	1.92 (1.61, 2.33)	<0.001
	No (incorrect)	2.67 (72/2,700)	0.49 (5/1,021)	0.86 (8/930)	0.37 (-0.37, 1.11)	0.32	43.02 (-43.02, 129.07)	0.320	0.57 (0.19, 1.71)	0.320	1.75 (0.59, 5.26)	0.320
Total (Q1-9)	Correct	46.12 (9,397/20,373)	52.90 (4,264)	45.40 (3,746)	7.50 (5.96, 9.04)	<0.001	13.74 (10.91, 16.56)	<0.001				
	Partly correct+incorrect	53.88 (10,976/20,373)	47.10 (3,264)	54.60 (4,746)	7.50 (5.96, 9.04)	<0.001	13.74 (10.91, 16.56)	<0.001	0.86 (0.84, 0.89)	<0.001	1.16 (1.14, 1.19)	<0.001

Note: Chi-square tests were applied for all comparisons; however, Fisher's exact test was employed when the expected frequency of any cell fell below 5. Blank cells indicate "not calculated (with no need for calculation)".

Abbreviation: ARR=absolute risk reduction; RRR=relative risk reduction; RR=relative risk; 1/RR=protective efficacy; CI=confidence interval; SHEPG=smart health education pillbox group; RHEG=routine health education group.

\* N=2,700 at Baseline. At the one-year follow-up, SHEPG (N=1,021) and RHEG (N=930). Valid response counts for Q2 in RHEG totaled 919; for Q3 in Baseline, 2, 124; for Q5 in RHEG, 837. For Q6, among households raising livestock, counts across the three groups were 1, 888, 863, and 852, respectively; for Q7, among households raising livestock, counts were 1, 545, 699, and 781, respectively; for Q8, among households raising sheep, counts across the three groups were 1, 316, 576, and 637, respectively.

showed significant decline in positive attitudes ( $ARR=-1.51$ ; 95%  $CI$ :  $-2.31$  to  $-0.71$ ;  $P=0.0002$ ) with increased  $RR$  of 1.15 (95%  $CI$ :  $1.07-1.24$ ;  $P<0.0001$ ) (Supplementary Table S4, available at <https://weekly.chinacdc.cn/>). SHEP acceptability among dog owners was high at 89.72% (916/1,021) (Q9, Table 2). Detailed attitude data for questions 1–8 are presented in Table 2 and Supplementary Tables S3–S4.

The questionnaire evaluated dog owners' adoption of recommended echinococcosis control practices. Correct practice rates remained low across all groups (SHEPG: 52.90%; RHEG: 45.40%; Baseline: 46.12%). SHEP intervention achieved significant improvements, with absolute increases of 7.50% over RHEG ( $ARR=7.50\%$ , 95%  $CI$ :  $5.96-9.04$ ;  $P<0.001$ ) and 6.78% over Baseline ( $ARR=6.78\%$ , 95%  $CI$ :  $5.35-8.21$ ;  $P<0.001$ ). These corresponded to relative reductions in incomplete compliance of 13.74% versus RHEG ( $RRR=13.74\%$ , 95%  $CI$ :  $10.91-16.56$ ;  $P<0.001$ ) and 12.58% versus Baseline ( $RRR=12.58\%$ , 95%  $CI$ :  $9.92-15.24$ ;  $P<0.001$ ).  $RR$  of “partly correct+incorrect” practices was significantly lower in SHEPG versus RHEG ( $RR=0.86$ , 95%  $CI$ :  $0.84-0.89$ ;  $P<0.001$ ) and Baseline ( $RR=0.87$ , 95%  $CI$ :  $0.85-0.90$ ;  $P<0.001$ ). SHEP participants were 1.16 times more likely to adopt correct practices than RHEG ( $1/RR=1.16$ , 95%  $CI$ :  $1.14-1.19$ ;  $P<0.001$ ) and 1.15 times more likely than Baseline ( $1/RR=1.15$ , 95%  $CI$ :  $1.11-1.18$ ;  $P<0.001$ ) (Table 3; Supplementary Table S5, available at <https://weekly.chinacdc.cn/>). RHEG showed no significant changes versus Baseline ( $ARR=-0.72\%$ , 95%  $CI$ :  $-1.70$  to  $0.26$ ;  $P=0.150$ ;  $RR=1.01$ , 95%  $CI$ :  $0.99-1.04$ ;  $P=0.180$ ). Detailed responses are in Table 3 and Supplementary Table S5–6 (available at <https://weekly.chinacdc.cn/>).

To quantitatively elucidate the knowledge-to-practice conversion mechanism, we developed a path model positing that knowledge (K) influences attitude (A), which shapes practices (P). Three parameters were defined:  $\alpha$  (knowledge-to-attitude coefficient), representing attitude generated per unit knowledge ( $\alpha=A/K$ );  $\beta$  (attitude-to-practice coefficient), representing practice generated per unit attitude ( $\beta=P/A$ ); and  $\eta$  (conversion efficiency index), representing overall knowledge-to-practice efficiency ( $\eta=P/K=\alpha\times\beta$ ). The derived formulae are:  $A=\alpha\times K$ ,  $P=\beta\times A=\beta\times\alpha\times K$ . Results demonstrated superior attitude-to-practice conversion in SHEPG, with  $\beta=0.5765$  (95%  $CI$ :  $0.5642-0.5888$ ) significantly exceeding RHEG ( $0.5132$ , 95%  $CI$ :  $0.4999-0.5265$ )

and Baseline ( $0.5126$ , 95%  $CI$ :  $0.5046-0.5206$ ). The  $\beta$  differences were substantial:  $\Delta\beta=0.0633$  for SHEPG versus RHEG and  $\Delta\beta=0.0639$  for SHEPG versus Baseline (all  $P<0.0001$ ). SHEPG achieved relative increases in conversion efficiency of 7.88% ( $0.0423/0.5368$ ) versus RHEG and 6.55% ( $0.0356/0.5435$ ) versus Baseline, demonstrating greater overall efficiency in translating knowledge into practice (all  $P<0.0001$ ) (Table 4–5). Conversely, RHEG showed only a 1.23% ( $0.0067/0.5435$ ) increase in conversion efficiency versus Baseline, which was not statistically significant ( $Z=0.799$ ,  $P=0.424$ ) (Table 4–5).

## DISCUSSION

The SHEP represents an innovative integration of artificial intelligence and Internet of Things technologies for echinococcosis control, transitioning from RHE to precision-targeted interventions. Its core functionalities include: 1) Systematic Knowledge Delivery: Pre-recorded messages broadcast at predetermined intervals (at least three times daily, exceeding 1,095 times annually) strengthen policy comprehension and promote sustained behavioral change. 2) Automated Deworming Reminders: Audio and visual alerts prompt dog owners on scheduled deworming days, enhancing compliance and reducing missed treatments. 3) Precision Targeting: Distribution specifically to dog owners — the primary target population — enables efficient, focused educational outreach and practice promotion. 4) Cultural Adaptability: Multilingual modules (Standard Chinese, Tibetan, Uyghur, Kazakh, and others) ensure accessibility across diverse endemic regions, overcoming literacy barriers through audio-based communication. 5) Technical Reliability: With six-month battery life, compact design, and portability, the platform supports continuous education during pastoral migrations and in remote pasturages, addressing “last-mile” challenges in disease control programs. 6) Dedicated Bait Storage: A secure compartment protects anthelmintic baits, resolving storage challenges.

The 12-month SHEP implementation resulted in substantial improvements in echinococcosis-related knowledge. The SHEPG demonstrated significantly higher overall correct response rates compared to both RHEG and Baseline (Table 1 and Supplementary Table S1). These enhancements were particularly notable across key knowledge domains, validating

SHEP's effectiveness as a persistent, interactive tool that reinforces essential health messages and surpasses the less engaging, one-time RHE. The intervention effectively dispelled misconceptions and reduced uncertainty (Table 1 and Supplementary Table S1). Additionally, SHEP demonstrated significant protective value by countering the observed decline in correct response rates on several crucial questions (e.g., Q7, Q8, Q9) within the RHEG, preventing knowledge deterioration and emergence of new misconceptions over time (Table 1 and Supplementary Table S1). Comparison of RHEG to Baseline revealed minimal knowledge improvement; the overall knowledge rate showed no statistically significant change (Table 1 and Supplementary Table S2). These findings suggest that routine, one-time health education is inadequate for consolidating and retaining complex knowledge over time and may prove ineffective against knowledge erosion or misinformation spread without sustained, reinforced messaging.

The SHEP intervention notably influenced dog owners' attitudes, as evidenced in Table 2 and Supplementary Table S3. The 3.30% increase in ARR confirmed SHEP's effectiveness in disseminating information and positively shaping behavioral intentions. The 28.57% reduction in risk of negative attitudes demonstrated that the intervention strengthened positive intentions while mitigating resistance and hesitancy ( $P < 0.001$ ). Significant improvements were observed in key practice-related attitudes, including proper burial of dog waste (Q4), support for centralized slaughter (Q5), and avoidance

of feeding raw viscera to dogs (Q7). All changes were statistically significant ( $P < 0.001$ ) and critical for interrupting the parasite's transmission cycle (Table 2). Furthermore, 89.72% of SHEPG participants expressed willingness to use the smart pillbox (Q9), indicating high acceptability of this innovative technology and promising potential for large-scale implementation.

The ultimate measure of an intervention's effectiveness lies in its capacity to transform knowledge and attitudes into meaningful behavioral change. Our analysis of conversion efficiency quantified the SHEP's impact across the knowledge-attitude-practice pathway (Table 4). This study revealed a persistent disconnect between high knowledge levels (Table 1) and positive attitudes (SHEPG, 91.76%; RHEG, 88.46%; Baseline, 89.97%; Table 2), contrasted with substantially lower adoption of recommended practices (SHEPG, 52.90%; RHEG, 45.40%; Baseline, 46.12%; Table 3). This pattern underscores the challenge of bridging the *knowledge-attitude-practice gap* in health education interventions. The SHEP intervention successfully addressed this challenge, markedly enhancing participants' ability to translate positive attitudes into concrete actions. The device functioned as a behavioral facilitator, narrowing the *knowledge-attitude-practice gap* by delivering timely cues and reminders while simplifying execution of desired practices, such as adherence to deworming schedules.

This study has limitations warranting consideration. The 1-year follow-up period is brief for evaluating long-term sustainability of behavioral changes. The

TABLE 4. The K, A, P,  $\alpha$ ,  $\beta$ , and  $\eta$  across SHEPG, RHEG, and Baseline after the 12-month follow-up, 2023–2024.

Group	K	A	P	$\alpha$ (95% CI)	$\beta$ (95% CI)	$\eta$ (95% CI)
SHEPG	0.9135	0.9176	0.5290	1.0045 (0.9954, 1.0136)	0.5765 (0.5642, 0.5888)	0.5791 (0.5668, 0.5914)
RHEG	0.8457	0.8846	0.4540	1.046 (1.0328, 1.0592)	0.5132 (0.4999, 0.5265)	0.5368 (0.5228, 0.5508)
Baseline	0.8485	0.8997	0.4612	1.0603 (1.0526, 1.0680)	0.5126 (0.5046, 0.5206)	0.5435 (0.5349, 0.5521)

Abbreviation: K=knowledge; A=attitude; P=practice;  $\alpha$ =knowledge-to-attitude coefficient;  $\beta$ =attitude-to-practice coefficient;  $\eta$ =conversion efficiency index; CI=confidence interval; SHEPG=smart health education pillbox group; RHEG=routine health education group.

TABLE 5. The  $\Delta\alpha$ ,  $\Delta\beta$ , and  $\Delta\eta$  across SHEPG, RHEG, and Baseline after the 12-month follow-up, 2023–2024.

Group	$\Delta\alpha$	Z (P)	$\Delta\beta$	Z (P)	$\Delta\eta$	Z (P)
SHEPG vs. RHEG	-0.0415	-5.08 (<0.001)	0.0633	6.85 ( $P < 0.001$ )	0.0423	5.32 (<0.001)
SHEPG vs. Baseline	-0.0558	-9.21 (<0.001)	0.0639	8.53 (<0.001)	0.0356	4.87 (<0.001)
RHEG vs. Baseline	0.0143	1.835 (0.067)	-0.0006	-0.0758 (0.940)	0.0067	0.799 (0.424)

Note: To maintain consistency across all comparisons, data in this table are retained to four decimal places because  $\Delta\beta$  in RHEG versus Baseline equals -0.0006.

Abbreviation:  $\Delta\alpha$ =difference in knowledge-to-attitude conversion coefficients between groups;  $\Delta\beta$ =difference in attitude-to-practice conversion coefficients between groups;  $\Delta\eta$ =difference in conversion efficiency index between groups; Z=Z-test statistic; SHEPG=smart health education pillbox group; RHEG=routine health education group.

outcomes relied on self-reported data, susceptible to social desirability bias, recall bias, and cultural influences. Additionally, SHEP effectiveness may be constrained by inadequate internet connectivity in remote pastoral areas. Future research should prioritize scaling up the SHEP intervention and integrating it with complementary veterinary and public health measures to achieve synergistic effects in echinococcosis control.

In conclusion, the SHEP's demonstrated efficacy and high acceptability among dog owners support its integration into national public health strategies for sustainable control of echinococcosis and other zoonotic diseases.

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## SUPPLEMENTARY MATERIALS

SUPPLEMENTARY TABLE S1. Knowledge rates, ARR, RRR, RR, and 1/RR comparing SHEPG with Baseline after 12-month follow-up, 2023-2024.

Question	Response	Baseline [% (n/N)]	SHEPG [% (n/N)]	ARR		RRR		RR		1/RR	
				95% CI	P	95% CI	P	95% CI	P	95% CI	P
Q1. Have you heard of echinococcosis?	Yes (correct)	93.89 (2,535/2,700)	96.87 (989/1,021)	2.98 (1.33, 4.63)	<0.001	49.02 (21.87, 76.16)	<0.001				
	No	3.96 (107/2,700)	0.59 (6/1,021)	3.37 (2.40, 4.34)	<0.001	85.10 (73.89, 96.31)	<0.001	0.15 (0.07, 0.33)	<0.001	6.76 (3.03, 15.09)	<0.001
	Not sure	2.15 (58/2,700)	2.55 (26/1,021)	-0.40 (-1.48, 0.68)	0.466	-18.60 (-68.84, 31.63)	0.466	1.19 (0.74, 1.89)	0.481	0.84 (0.53, 1.35)	0.481
Q2. How do people get echinococcosis?	Get infected if they accidentally ingest worm eggs excreted by dogs or foxes (correct)	66.33 (1,791/2,700)	71.69 (732/1,021)	5.36 (2.29, 8.43)	<0.001	15.94 (6.81, 25.07)	<0.001				
	By eating unclean internal organs of cattle or sheep	29.67 (801/2,700)	27.23 (278/1,021)	2.44 (0.60, 5.48)	0.116	8.22 (2.02, 18.43)	0.116	0.92 (0.82, 1.03)	0.144	0.92 (0.82, 1.03)	0.144
	Human-to-human	4.00 (108/2,700)	1.08 (11/1,021)	2.92 (1.93, 3.91)	<0.001	73.00 (48.25, 97.75)	<0.001	0.27 (0.15, 0.50)	<0.001	3.70 (2.00, 6.67)	<0.001
Q3. How do dogs get infected with echinococcosis?	By consuming the diseased internal organs of cattle or sheep (correct)	93.03 (1976/2,124)**	98.53 (1006/1,021)	5.50 (3.87, 7.13)	<0.001	78.57 (55.29, 101.86)	<0.001				
	Dog-to-dog	6.50 (138/2,124)**	0.98 (10/1,021)	5.52 (4.41, 6.63)	<0.001	84.92 (67.92, 101.92)	<0.001	0.15 (0.08, 0.29)	<0.001	6.67 (3.45, 12.82)	<0.001
	Human-to-dog	0.47 (10/2,124)**	0.49 (5/1,021)	-0.02 (-0.69, 0.65)	0.951	-4.26 (-138.30, 146.81)	0.951	1.04 (0.36, 3.03)	0.943	0.96 (0.33, 2.78)	0.943
Q4. Are you aware of the national policies for echinococcosis patients?	Fully aware (correct)	43.85 (1,184/2,700)	73.16 (747/1,021)	29.31 (25.87-32.75, )	<0.001	52.20 (46.11-58.30, )	<0.001				
	Partially aware	46.33 (1,251/2,700)	25.86 (264/1,021)	20.47 (16.93, 24.01)	<0.001	44.18 (36.54, 51.82)	<0.001	0.56 (0.50, 0.62)	<0.001	1.79 (1.61, 1.99)	<0.001
	Not aware	9.81 (265/2,700)	0.98 (10/1,021)	8.83 (7.28, 10.38)	<0.001	90.01 (84.13, 95.89)	<0.001	0.10 (0.05, 0.19)	<0.001	10.01 (5.26, 19.05)	<0.001
Q5. Is deworming dogs a preventive measure for echinococcosis?	Yes (correct)	96.96 (2,618/2,700)	99.80 (1,019/1,021)	2.84 (1.73, 3.95)	<0.001	91.18 (55.91, 126.45)	<0.001				
	No	1.56 (42/2,700)	0.00 (0/1,021)	1.56 (0.79, 2.33)	<0.001	100.00 (58.04, 100.00)*	<0.001	0.05 (0.00, 0.79)*	0.033	19.61 (1.27, ∞)*	0.033
	Not sure	1.48 (40/2,700)	0.20 (2/1,021)	1.28 (0.68, 1.88)	P<0.001	86.49 (45.95, 100.00)	<0.001	0.13 (0.03, 0.54)	0.005	7.69 (1.85, 33.33)	0.005

Continued

Question	Response	Baseline [% (n/N)]	SHEPG [% (n/N)]	ARR		RRR		RR		1/RR	
				95% CI	P	95% CI	P	95% CI	P	95% CI	P
Q6. Is the safe disposal (deep burial) of dog feces a preventive measure for echinococcosis?	Yes (correct)	90.70 (2,449/2,700)	93.83 (958/1,021)	3.13 (1.29, 4.97)	<0.001	33.69 (13.89, 53.49)	<0.001				
	No	5.15 (139/2,700)	4.80 (49/1,021)	0.35 (-1.02, 1.72)	0.616	6.80 (-46.61, 33.01)	0.616	0.93 (0.68, 1.28)	0.674	1.08 (0.78, 1.48)	0.674
	Not sure	4.15 (112/2,700)	1.37 (14/1,021)	2.78 (1.83, 3.73)	<0.001	66.99 (44.10, 89.88)	<0.001	0.33 (0.19, 0.57)	<0.001	3.03 (1.75, 5.26)	<0.001
Q7. Is not feeding raw livestock internal organs to dogs a preventive measure for echinococcosis?	Yes (correct)	90.74 (2,450/2,700)	92.26 (942/1,021)	1.52 (-0.47, 3.51)	0.134	16.36 (-5.06, 37.78)	0.134				
	No	6.26 (169/2,700)	6.95 (71/1,021)	-0.69 (-2.48, 1.10)	0.450	-11.02 (-17.58, 39.62)	0.450	1.11 (0.85, 1.45)	0.442	0.90 (0.69, 1.18)	0.442
	Not sure	3.00 (81/2,700)	0.78 (8/1,021)	2.22 (1.37, 3.07)	<0.001	74.00 (45.67, 100.00)	<0.001	0.26 (0.13, 0.52)	<0.001	3.85 (1.92, 7.69)	<0.001
Q8. Is not playing with dogs a preventive measure for echinococcosis?	Yes (correct)	93.30 (2,519/2,700)	96.57 (986/1,021)	3.27 (1.79-4.75, P)	<0.001	48.96 (26.79-71.13, P)	<0.001				
	No	4.04 (109/2,700)	2.84 (29/1,021)	1.20 (0.08, 2.32)	0.036	29.70 (1.98, 57.42)	0.036	0.70 (0.47, 1.05)	0.084	1.42 (0.95, 2.13)	0.084
	Not sure	2.67 (72/2,700)	0.59 (6/1,021)	2.08 (1.29, 2.87)	<0.001	77.90 (48.31, 100.00)	<0.001	0.22 (0.10, 0.49)	<0.001	4.55 (2.04, 10.00)	<0.001
Q9. Is washing hands before meals a preventive measure for echinococcosis?	Yes (correct)	96.56 (2,607/2,700)	99.41 (1,015/1,021)	2.85 (1.73, 3.97)	<0.001	81.82 (49.72, 113.92)	<0.001				
	No	1.22 (33/2,700)	0.49 (5/1,021)	0.73 (0.08, 1.38)	0.028	59.84 (6.56, 100.00)	0.028	0.40 (0.16, 1.02)	0.055	2.50 (0.98, 6.25)	0.055
	Not sure	2.22 (60/2,700)	0.10 (1/1,021)	2.12 (1.48, 2.76)	<0.001	95.50 (66.67, 100.00)	<0.001	0.04 (0.01, 0.29)	<0.001	25.00 (3.45, 100.00)*	<0.001
Total (Q1-9)	Yes (correct)	84.85 (20,129/23,724)	91.35 (8,394/9,189)	6.50 (5.71, 7.29)	<0.001	42.97 (39.38, 46.56)	<0.001				
	Other responses (incorrect)	15.15 (3,595/23,724)	8.65 (795/9,189)	6.50 (5.71, 7.29)	<0.001	42.97 (39.38, 46.56)	<0.001	0.57 (0.53, 0.61)	<0.001	1.75 (1.64, 1.88)	<0.001

Note: Chi-square tests were applied for all comparisons; however, Fisher's exact test was substituted when the expected frequency in any cell fell below 5. Blank cells denote "not calculated (unnecessary)".

\*For cells containing zero counts (Q5-No, Q9-Not sure), the Haldane-Anscombe correction was implemented by adding 0.5 to each cell. The *RRR* for Q5-No is designated as 100% when intervention group risk equals zero; the *CI* was computed using this correction.

\*\*All responses were valid except for 576 logical errors identified in Q3 at Baseline.

Abbreviation: *ARR*=absolute risk reduction; *RR*=relative risk; *RRR*=relative risk reduction; *1/RR*=protective efficacy; *CI*=confidence interval; SHEPG=smart health education pillbox group; RHEG=routine health education group.

SUPPLEMENTARY TABLE S2. Knowledge rates, *ARR*, *RRR*, *RR*, and *1/RR* comparing RHEG with Baseline after 12-month follow-up, 2023-2024.

Question	Response	Baseline [% (n/N)]	SHEPG [% (n/N)]	ARR		RRR		RR		1/RR	
				95% CI	P	95% CI	P	95% CI	P	95% CI	P
Q1. Have you heard of echinococcosis?	Yes (correct)	93.89 (2,535/2,700)	90.97 (846/930)	-2.92 (-4.67, -1.17)	0.001	-47.33 (-75.66, -18.99)	0.001				
	No	3.96 (107/2,700)	4.95 (46/930)	-0.99 (-2.40, 0.42)	0.169	-25.00 (-88.10, 38.10)	0.169	1.25 (0.89, 1.75)	0.201	0.80 (0.57, 1.12)	0.201
	Not sure	2.15 (58/2,700)	4.09 (38/930)	-1.94 (-3.23, -0.65)	0.003	-90.23 (-150.70, -29.77)	0.003	1.90 (1.28, 2.83)	0.001	0.53 (0.35, 0.78)	0.001
Q2. How do people get echinococcosis?	Get infected if they accidentally ingest worm eggs excreted by dogs or foxes (correct)	66.33 (1,791/2,700)	66.92 (615/919)*	0.59 (-2.76, 3.94)	0.730	1.75 (-8.20, 11.70)	0.730				
	By eating unclean internal organs of cattle or sheep	29.67 (801/2,700)	30.47 (280/919)*	-0.80 (-3.75, 2.15)	0.595	-2.70 (-12.64, 7.24)	0.595	1.03 (0.91, 1.16)	0.642	0.97 (0.86, 1.10)	0.642
	Human-to-human	4.00 (108/2,700)	2.61 (24/919)*	1.39 (0.17, 2.61)	0.026	34.75 (4.25, 65.25)	0.026	0.65 (0.42, 1.01)	0.055	1.54 (0.99, 2.38)	0.055
Q3. How do dogs get infected with echinococcus?	By consuming the diseased internal organs of cattle or sheep (correct)	93.03 (1,976/2,124)*	96.34 (896/930)	3.31 (1.86, 4.76)	<0.001	47.29 (26.57, 68.00)	<0.001				
	Dog-to-dog	6.50 (138/2,124)*	2.15 (20/930)	4.35 (3.00, 5.70)	<0.001	66.92 (46.15, 87.69)	<0.001	0.33 (0.21, 0.52)	<0.001	3.03 (1.92, 4.76)	<0.001
	Human-to-dog	0.47 (10/2,124)*	1.51 (14/930)	-1.04 (-1.79, -0.29)	0.007	-221.28 (-380.85, -61.70)	0.007	3.21 (1.45, 7.12)	0.004	0.31 (0.14, 0.69)	0.004
Q4. Are you aware of the national policies for echinococcosis patients?	Fully aware (correct)	43.85 (1,184/2,700)	49.13 (450/916)*	5.28 (2.29, 8.27)	<0.001	9.41 (4.08, 14.74)	<0.001				
	Partially aware	46.33 (1,251/2,700)	41.48 (380/916)*	4.85 (1.32, 8.38)	0.007	10.46 (2.85, 18.08)	0.007	0.90 (0.82, 0.98)	0.012	1.12 (1.02, 1.22)	0.012
	Not aware	9.81 (265/2,700)	9.39 (86/916)*	0.42 (-1.68, 2.52)	0.696	4.28 (-34.15, 25.58)	0.696	0.96 (0.76, 1.21)	0.714	1.04 (0.83, 1.32)	0.714

Continued

Question	Response	Baseline [% (n/N)]	SHEPG [% (n/N)]	ARR		RRR		RR		1/RR	
				95% CI	P	95% CI	P	95% CI	P	95% CI	P
Q5. Is deworming dogs a preventive measure for echinococcosis?	Yes (correct)	96.96 (2,618/2,700)	95.46 (799/837)*	-1.50 (-2.72, 0.28)	0.016	-48.39 (-87.10, 9.68)	0.016				
	No	1.56 (42/2,700)	2.03 (17/837)*	-0.47 (-1.52, 0.58)	0.379	-30.13 (-97.26, 37.00)	0.379	1.30 (0.74, 2.29)	0.361	0.77 (0.44, 1.35)	0.361
	Not sure	1.48 (40/2,700)	2.51 (21/837)*	-1.03 (-1.96, 0.10)	0.030	-69.59 (-132.43, -6.76)	0.030	1.70 (1.01, 2.85)	0.045	0.59 (0.35, 1.00)	0.045
Q6. Is the safe disposal (deep burial) of dog feces a preventive measure for echinococcosis?	Yes (correct)	90.70 (2449/2,700)	89.35 (831/930)	-1.35 (-3.29, 0.59)	0.173	-14.88 (-36.27, 6.52)	0.173				
	No	5.15 (139/2,700)	4.19 (39/930)	0.96 (-0.46, 2.38)	0.185	18.64 (-8.94, 46.22)	0.185	0.81 (0.58, 1.14)	0.230	1.23 (0.88, 1.72)	0.230
	Not sure	4.15 (112/2,700)	6.45 (60/930)	-2.30 (-3.85, 0.75)	0.004	-55.42 (-92.77, 18.07)	0.004	1.55 (1.16, 2.08)	0.003	0.64 (0.48, 0.86)	0.003
Q7. Is not feeding raw livestock internal organs to dogs a preventive measure for echinococcosis?	Yes (correct)	90.74 (2,450/2,700)	86.56 (805/930)	-4.18 (-6.68, 1.68)	0.001	-45.11 (-72.07, 18.15)	0.001				
	No	6.26 (169/2,700)	6.02 (56/930)	0.24 (-1.41, 1.89)	0.775	3.83 (-37.86, 30.19)	0.775	0.96 (0.72, 1.28)	0.778	1.04 (0.78, 1.39)	0.778
	Not sure	3.00 (81/2,700)	7.42 (69/930)	-4.42 (-5.98, 2.86)	<0.001	-147.33 (-199.33, -95.33)	<0.001	2.47 (1.84, 3.32)	<0.001	0.40 (0.30, 0.54)	<0.001
Q8. Is not playing with dogs a preventive measure for echinococcosis?	Yes (correct)	93.30 (2519/2,700)	90.32 (840/930)	-2.98 (-4.83, 1.13)	0.002	-44.48 (-72.09, 16.87)	0.002				
	No	4.04 (109/2,700)	4.84 (45/930)	-0.80 (-2.22, 0.62)	0.270	-19.80 (-73.27, 33.66)	0.270	1.20 (0.86, 1.67)	0.289	0.83 (0.60, 1.16)	0.289
	Not sure	2.67 (72/2,700)	4.84 (45/930)	-2.17 (-3.53, 0.81)	0.002	-81.27 (-132.21, -30.34)	0.002	1.81 (1.27, 2.58)	0.001	0.55 (0.39, 0.79)	0.001
Q9. Is washing hands before meals a preventive measure for echinococcosis?	Yes (correct)	96.56 (2,607/2,700)	90.65 (843/930)	-5.91 (-7.72, 4.10)	<0.001	-168.86 (-220.00, -117.71)	<0.001				
	No	1.22 (33/2,700)	5.16 (48/930)	-3.94 (-5.32, 2.56)	<0.001	-322.95 (-436.07, -209.84)	<0.001	4.23 (2.76, 6.48)	<0.001	0.24 (0.15, 0.36)	<0.001
	Not sure	2.22 (60/2,700)	4.19 (39/930)	-1.97 (-3.32, 0.62)	0.004	-88.74 (-149.55, -27.93)	0.004	1.89 (1.28, 2.78)	0.001	0.53 (0.36, 0.78)	0.001
Total (Q1-9)	Yes (correct)	84.85 (20,129/23,724)	84.57 (6,925/8,187)	-1.85 (-8.32, 4.62)	0.575	-1.84 (-10.89, 7.21)	0.691				
	Other responses (incorrect)	15.15 (3,595/23,724)	15.43 (1,263/8,187)	-0.28 (-1.26, 0.70)	0.575	-1.85 (-8.32, 4.62)	0.575	1.02 (0.96, 1.08)	0.569	0.98 (0.93, 1.04)	0.569

Abbreviation: ARR=absolute risk reduction; RR=relative risk; RRR=relative risk reduction; 1/RR=protective efficacy; CI=confidence interval; SHEPG=smart health education pillbox group; RHEG=routine health education group.

\* All responses were valid except for 576, 11, 14, and 93 logical errors identified in Q3 at Baseline and Q2, Q4, and Q5 in RHEG, respectively.

Note: Chi-square tests were employed for all comparisons; however, Fisher's exact test was applied when the expected frequency of any cell fell below 5. Blank cells denote "not calculated (with no need for)".

SUPPLEMENTARY TABLE S3. Attitude rates, ARR, RRR, RR, and 1/RR comparing SHEPG with Baseline after the 12-month follow-up, 2023-2024.

Question	Response	Baseline [% (n/N)]	SHEPG [% (n/N)]	ARR		RRR		RR		1/RR	
				95% CI	P	95% CI	P	95% CI	P	95% CI	P
Q1. Would you like to wash your hands before meals?	Yes	97.30 (2, 627/2,700)	98.33 (1, 004/1,021)	1.03 (0.04, 2.02)	0.042	38.10 (1.48, 74.72)	0.042				
	No	2.70 (73/2,700)	1.67 (17/1,021)	1.03 (0.04, 2.02)	0.042	38.15 (1.48, 74.81)	0.042	0.62 (0.37, 1.04)	0.072	1.62 (0.96, 2.72)	0.072
Q2. Would you agree to tether all your dogs?	Yes	95.63 (2, 582/2,700)	97.16 (992/1,021)	1.53 (0.25, 2.81)	0.019	35.11 (5.73, 64.49)	0.019				
	No	4.37 (118/2,700)	2.84 (29/1,021)	1.53 (0.25, 2.81)	0.019	35.01 (5.72, 64.30)	0.019	0.65 (0.44, 0.97)	0.035	1.54 (1.03, 2.29)	0.035
Q3. Would you agree to free regular dog deworming?	Yes	97.22 (2, 625/2,700)	98.82 (1, 009/1,021)	1.60 (0.64, 2.56)	<0.001	57.14 (22.92, 91.36)	<0.001				
	No	2.78 (75/2,700)	1.18 (12/1,021)	1.60 (0.64, 2.56)	<0.001	57.55 (23.02, 92.08)	<0.001	0.42 (0.24, 0.75)	0.003	2.36 (1.33, 4.20)	0.003
Q4. Would you agree to bury dog waste deeply after deworming?	Yes	92.70 (2, 503/2,700)	96.38 (984/1,021)	3.68 (1.92, 5.44)	<0.001	50.00 (26.09, 73.91)	<0.001				
	No	7.30 (197/2,700)	3.62 (37/1,021)	3.68 (1.92, 5.44)	<0.001	50.41 (26.30, 74.52)	<0.001	0.50 (0.35, 0.69)	<0.001	2.02 (1.44, 2.82)	<0.001
Q5. Would you support centralized slaughter?	Yes	49.74 (939/1,888)*	61.76 (533/863)*	12.02 (7.68, 16.36)	<0.001	23.94 (15.29, 32.59)	<0.001				
	No	50.26 (949/1,888)*	38.24 (330/863)*	12.02 (7.68, 16.36)	<0.001	23.92 (15.28, 32.56)	<0.001	0.76 (0.69, 0.84)	<0.001	1.31 (1.19, 1.45)	<0.001
Q6. Would you agree to free lamb vaccination?	Yes	87.16 (1, 147/1, 316)*	88.02 (507/576)*	0.86 (-3.14, 4.86)	0.700	6.73 (-24.61, 38.07)	0.700				
	No	12.84 (169/1, 316)*	11.98 (69/576)*	0.86 (-3.14, 4.86)	0.70	6.70 (-24.45, 37.85)	0.70	0.93 (0.72, 1.21)	0.60	1.07 (0.83, 1.39)	0.60
Q7. Would you avoid feeding dogs raw livestock organs?	Yes	86.86 (1, 342/1,545)*	90.70 (634/699)*	3.84 (1.27, 6.41)	0.003	29.20 (9.66, 48.74)	0.003				
	No	13.14 (203/1,545)*	9.30 (65/699)*	3.84 (1.27, 6.41)	0.003	29.22 (9.66, 48.78)	0.003	0.71 (0.54, 0.92)	0.010	1.41 (1.08, 1.84)	0.010
Q8. Would you agree to free regular check-ups (screening)?	Yes	98.26 (2, 653/2,700)	98.33 (1, 004/1,021)	0.07 (-0.85, 0.99)	0.94	4.00 (-48.00, 56.00)	0.94				
	No	1.74 (47/2,700)	1.67 (17/1,021)	0.07 (-0.85, 0.99)	0.94	4.02 (-48.28, 56.32)	0.94	0.96 (0.55, 1.68)	0.88	1.04 (0.60, 1.82)	0.88
Q9. Would you use our Smart Health Education Pillbox?	Yes	N/A	89.72 (916/1,021)†	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	No	N/A	10.28 (105/1,021)†	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total (Q1-8)	Yes	89.97 (16, 418/18, 249)	91.76 (7, 583/8, 264)	1.79 (0.95, 2.63)	<0.001	17.86 (9.49, 26.23)	<0.001				
	No	10.03 (1, 831/18, 249)	8.24 (681/8, 264)	1.79 (0.95, 2.63)	<0.001	17.85 (9.48, 26.22)	<0.001	0.82 (0.76, 0.89)	<0.001	1.22 (1.12, 1.32)	<0.001

**Abbreviation:** ARR=absolute risk reduction; RR=relative risk; RRR=relative risk reduction; 1/RR=protective efficacy; CI=confidence interval; SHEPG=smart health education pillbox group; RHEG=routine health education group; N/A=not applicable.

\*At baseline (N=2,700) and one-year follow-up in the SHEPG (N=1,021), the numbers of valid responses to Q5 among households raising livestock were 1,888 and 863, respectively; for Q6 among households raising sheep, 1, 316 and 576, respectively; and for Q7 among households raising livestock, 1,545 and 699, respectively †The attitude survey regarding SHEP usage was conducted exclusively in the SHEPG.

**Note:** Chi-square tests were employed for all comparisons; however, Fisher's exact test was applied when the expected frequency of any cell fell below 5. Blank cells denote "not calculated (with no need for)".

SUPPLEMENTARY TABLE S4. Attitude rates, ARR, RRR, RR, and 1/RR comparing RHEG with Baseline after the 12-month follow-up, 2023-2024.

Question	Response	Baseline [% (n/N)]	SHEPG [% (n/N)]	ARR		RRR		RR		1/RR	
				95% CI	P	95% CI	P	95% CI	P	95% CI	P
Q1. Would you like to wash your hands before meals?	Yes	97.30 (2, 627/2,700)	97.74 (909/930)	0.44 (-0.73, 1.61)	0.450	16.30 (-27.04, 59.63)	0.450				
	No	2.70 (73/2,700)	2.26 (21/930)	0.44 (-0.73, 1.61)	0.450	16.30 (-27.04, 59.63)	0.450	0.84 (0.52, 1.35)	0.470	1.19 (0.74, 1.91)	0.470
Q2. Would you agree to tether all your dogs?	Yes	95.63 (2, 582/2,700)	95.94 (803/837)*	0.31 (-1.54, 2.16)	0.740	7.14 (-35.38, 49.66)	0.740				
	No	4.37 (118/2,700)	4.06 (34/837)*	0.31 (-1.54, 2.16)	0.740	7.09 (-35.24, 49.43)	0.740	0.93 (0.64, 1.35)	0.700	1.08 (0.74, 1.56)	0.700
Q3. Would you agree to free regular dog deworming?	Yes	97.22 (2, 625/2,700)	98.17 (913/930)	0.95 (-0.02, 1.92)	0.055	34.48 (-0.72, 69.68)	0.055				
	No	2.78 (75/2,700)	1.83 (17/930)	0.95 (-0.02, 1.92)	0.055	34.17 (-0.72, 69.06)	0.055	0.66 (0.39, 1.11)	0.120	1.52 (0.90, 2.57)	0.120
Q4. Would you agree to bury dog waste deeply after deworming?	Yes	92.70 (2, 503/2,700)	92.95 (778/837)*	0.25 (-1.45, 1.95)	0.770	3.45 (-19.83, 26.72)	0.770				
	No	7.30 (197/2,700)	7.05 (59/837)*	0.25 (-1.45, 1.95)	0.770	3.42 (-19.86, 26.71)	0.770	0.97 (0.73, 1.28)	0.820	1.03 (0.78, 1.37)	0.820
Q5. Would you support centralized slaughter?	Yes	49.74 (939/1,888)*	50.36 (419/852)*	0.62 (-3.58, 4.82)	0.770	1.23 (-7.08, 9.54)	0.770				
	No	50.26 (949/1,888)*	49.64 (433/852)*	0.62 (-3.58, 4.82)	0.770	1.23 (-7.12, 9.58)	0.770	0.99 (0.90, 1.09)	0.810	1.01 (0.92, 1.11)	0.810
Q6. Would you agree to free lamb vaccination?	Yes	87.16 (1, 147/1, 316)*	86.81 (553/637)*	-0.35 (-4.31, 3.61)	0.860	-2.73 (-33.59, 28.13)	0.860				
	No	12.84 (169/1, 316)*	13.19 (84/637)*	-0.35 (-4.31, 3.61)	0.860	-2.73 (-33.56, 28.10)	0.860	1.03 (0.80, 1.32)	0.830	0.97 (0.76, 1.25)	0.83
Q7. Would you avoid feeding dogs raw livestock organs?	Yes	86.86 (1, 342/1,545)*	85.53 (668/781)*	-1.33 (-4.74, 2.08)	0.440	-10.14 (-36.15, 15.87)	0.440				
	No	13.14 (203/1,545)*	14.47 (113/781)*	-1.33 (-4.74, 2.08)	0.440	-10.12 (-36.07, 15.82)	0.440	1.10 (0.89, 1.36)	0.380	0.91 (0.74, 1.12)	0.380
Q8. Would you agree to free regular check-ups (screening)?	Yes	98.26 (2, 653/2,700)	98.28 (914/930)	0.02 (-0.85, 0.89)	0.97	1.15 (-48.98, 51.28)	0.970				
	No	1.74 (47/2,700)	1.72 (16/930)	0.02 (-0.89, 0.85)	0.970	1.15 (-51.28, 48.98)	0.970	0.99 (0.56, 1.74)	0.970	1.01 (0.57, 1.78)	0.970
Total (Q1-8)	Yes	89.97 (16, 418/18, 249)	88.46 (5, 957/6, 734)	-1.51 (-2.31, -0.71)	<0.001	-15.00 (-22.96, -7.04)	<0.001				
	No	10.03 (1, 831/18, 249)	11.54 (777/6, 734)	-1.51 (-2.31, -0.71)	<0.001	-15.06 (-23.04, -7.08)	<0.001	1.15 (1.07, 1.24)	<0.001	0.87 (0.81, 0.93)	<0.001

Abbreviation: ARR=absolute risk reduction; RR=relative risk; RRR=relative risk reduction; 1/RR=protective efficacy; CI=confidence interval; SHEPG=smart health education pillbox group; RHEG=routine health education group.

\*At Baseline (N=2,700) and at the one-year follow-up in the RHEG (N=1,021), the distribution of valid responses varied by question. For questions 2 and 4 in the RHEG, 837 valid responses were recorded. For question 5, which was restricted to households raising livestock, valid responses totaled 1,888 at Baseline and 852 in the RHEG. For question 6, limited to households raising sheep, valid responses numbered 1, 316 at Baseline and 637 in the RHEG. For question 7, again restricted to households raising livestock, valid responses were 1,545 at Baseline and 781 in the RHEG.

Note: Chi-square tests were employed for all statistical comparisons; however, Fisher's exact test was applied when the expected frequency of any cell fell below 5. Blank cells indicate values that were not calculated (and not required).

SUPPLEMENTARY TABLE S5. Practice rates, ARR, RRR, RR, 1/RR between SHEPG and Baseline after the 12-month follow-up, 2023-2024.

Question	Response	Baseline [% (n/N)]	SHEPG [% (n/N)]	ARR		RRR		RR		1/RR	
				95% CI	P	95% CI	P	95% CI	P	95% CI	P
1. Do you wash your hands before meals?	Three times a day or more (correct)	53.89 (1,455/2,700)	59.94 (612/1,021)	6.05 (3.15, 8.95)	<0.001	13.12 (6.83, 19.41)	<0.001				
	1-2 times a day (partly)	23.96 (647/2,700)	27.13 (277/1,021)	-3.17 (-7.35, 1.01)	0.041	-13.23 (-30.68, 4.22)	0.041	1.13 (1.00, 1.28)	0.041	0.88 (0.78, 1.00)	0.041
	Occasionally (incorrect)	22.15 (598/2,700)	12.93 (132/1,021)	9.22 (6.18, 12.26)	<0.001	41.63 (27.90, 55.36)	<0.001	0.58 (0.49, 0.69)	<0.001	1.71 (1.45, 2.04)	<0.001
2. How is your dog typically restrained?	Always tethered (correct)	27.89 (753/2,700)	31.73 (324/1,021)	3.84 (0.77, 6.91)	0.015	5.32 (1.07, 9.58)	0.015				
	Tethered during the day, free at night (partly)	14.96 (404/2,700)	13.22 (135/1,021)	1.74 (-0.81, 4.29)	0.18	11.63 (-5.41, 28.67)	0.18	0.88 (0.74, 1.06)	0.18	1.14 (0.94, 1.35)	0.18
	Tethered in settlements, free during migration (partly)	47.78 (1,290/2,700)	48.09 (491/1,021)	-0.31 (-3.95, 3.33)	0.87	-0.65 (-8.27, 6.97)	0.87	1.01 (0.93, 1.09)	0.87	0.99 (0.92, 1.08)	0.87
	Never tethered (incorrect)	9.37 (253/2,700)	6.95 (71/1,021)	2.42 (0.42, 4.42)	0.019	25.83 (4.48, 47.18)	0.019	0.74 (0.58, 0.95)	0.019	1.35 (1.05, 1.72)	0.019
3. Do you often pet or hug your dog?	Never (correct)	8.24 (175/2,124)*	10.19 (104/1,021)	1.95 (-0.11, 4.01)	0.063	2.13 (-0.12, 4.37)	0.063				
	Occasionally (partly)	53.95 (1,146/2,124)*	52.69 (538/1,021)	1.26 (-2.54, 5.06)	0.500	2.34 (-4.71, 9.38)	0.500	0.98 (0.91, 1.05)	0.500	1.02 (0.95, 1.10)	0.500
	Often (incorrect)	37.81 (803/2,124)*	37.12 (379/1,021)	0.69 (-3.24, 4.62)	0.730	1.82 (-8.57, 12.21)	0.730	0.98 (0.88, 1.09)	0.730	1.02 (0.92, 1.14)	0.730
4. Do you deworm your dog regularly?	Yes (correct; 9-12 times/yr)	61.00 (1,647/2,700)	91.38 (933/1,021)	30.38 (27.06, 33.70)	<0.001	77.90 (69.38, 86.41)	<0.001				
	Frequently (4-8 times/yr) (partly)	18.11 (489/2,700)	7.44 (76/1,021)	10.67 (7.90, 13.44)	<0.001	58.92 (43.62, 74.22)	<0.001	0.41 (0.33, 0.52)	<0.001	2.44 (1.92, 3.03)	<0.001
	Occasionally (1-3 times/yr) (partly)	17.19 (464/2,700)	0.69 (7/1,021)	16.50 (14.60, 18.40)	<0.001	95.99 (84.93, 107.05)	<0.001	0.04 (0.02, 0.08)	<0.001	25.00 (12.50, 50.00)	<0.001
	Never dewormed (incorrect)	3.70 (100/2,700)	0.49 (5/1,021)	3.21 (2.22, 4.20)	<0.001	86.76 (60.00, 113.51)	<0.001	0.13 (0.05, 0.32)	<0.001	7.69 (3.13, 20.00)	<0.001
5. Do you properly dispose of your dog's waste after deworming?	Yes (correct; deep burial)	51.04 (1,378/2,700)	54.65 (558/1,021)	3.61 (0.19, 7.03)	0.039	7.37 (0.39, 14.35)	0.039				
	Occasionally (partly)	21.81 (589/2,700)	25.17 (257/1,021)	-3.36 (-7.38, 0.66)	0.031	-15.41 (-33.84, 3.02)	0.031	1.15 (1.01, 1.31)	0.031	0.87 (0.76, 0.99)	0.031
	Untreated (incorrect)	27.15 (733/2,700)	20.18 (206/1,021)	6.97 (3.82, 10.12)	<0.001	25.67 (14.07, 37.27)	<0.001	0.74 (0.65, 0.85)	<0.001	1.35 (1.18, 1.54)	<0.001

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Question	Response	Baseline [% (n/N)]	SHEPG [% (n/N)]	ARR		RRR		RR		1/RR	
				95% CI	P	95% CI	P	95% CI	P	95% CI	P
6. Do you often slaughter cattle and sheep at yard?	No (correct)	18.17 (343/1,888)*	19.00 (164/863)*	0.83 (-3.41, 5.07)	0.600	1.02 (-4.17, 6.20)	0.600				
	Yes (incorrect)	81.83 (1,545/1,888)*	81.00 (699/863)*	0.83 (-3.41, 5.07)	0.600	1.01 (-4.17, 6.20)	0.600	0.99 (0.95, 1.03)	0.600	1.01 (0.97, 1.05)	0.600
7. Do you feed the internal organs of the cattle and sheep to dogs?	Never (correct)	61.04 (943/1,545)*	67.81 (474/699)*	6.77 (2.17, 11.37)	0.003	17.38 (5.57, 29.19)	0.003				
	Occasionally (partly)	25.18 (389/1,545)*	22.03 (154/699)*	3.15 (-0.95, 7.25)	0.130	12.51 (-3.77, 28.79)	0.130	0.88 (0.74, 1.04)	0.130	1.14 (0.96, 1.35)	0.130
	Frequently (incorrect)	13.79 (213/1,545)*	10.16 (71/699)*	6.63 (0.63, 11.63)	0.021	48.09 (4.57, 90.61)	0.021	0.74 (0.57, 0.95)	0.021	1.35 (1.05, 1.75)	0.021
8. Are your lambs vaccinated regularly?	Regularly (correct)	55.02 (724/1,316)*	55.21 (318/576)*	0.19 (-4.85, 5.23)	0.940	0.42 (-10.79, 11.63)	0.940				
	Irregularly (partly)	25.23 (332/1,316)*	27.60 (159/576)*	2.63 (-7.37, 2.63)	0.300	10.43 (-29.21, 10.43)	0.300	1.09 (0.93, 1.29)	0.300	0.92 (0.78, 1.08)	0.300
	No (incorrect)	19.76 (260/1,316)*	17.19 (99/576)*	6.72 (-1.58, 6.72)	0.200	34.01 (-8.00, 34.01)	0.200	0.87 (0.70, 1.08)	0.200	1.15 (0.93, 1.43)	0.200
9. Do you regularly participate in echinococcosis screening?	Regularly (correct)	73.30 (1979/2,700)	86.68 (885/1,021)	13.38 (10.16, 16.60)	<0.001	50.11 (38.05, 62.17)	<0.001				
	Irregularly (partly)	24.04 (649/2,700)	12.83 (131/1,021)	11.21 (8.01, 14.41)	<0.001	46.63 (33.32, 59.94)	<0.001	0.53 (0.45, 0.63)	<0.001	1.89 (1.59, 2.22)	<0.001
	No (incorrect)	2.67 (72/2,700)	0.49 (5/1,021)	2.18 (1.20, 3.16)	<0.001	81.65 (44.94, 118.36)	<0.001	0.18 (0.07, 0.45)	<0.001	5.56 (2.22, 14.29)	<0.001
Total (Q1-9)	Correct	46.12 (9,397/20,373)	52.90 (4,372/8,264)	6.78 (5.35, 8.21)	<0.001	12.58 (9.92, 15.24)	<0.001				
	Correct partly+incorrect	53.88 (10,976/20,373)	47.10 (3,892/8,264)	6.78 (5.35, 8.21)	<0.001	12.58 (9.92, 15.24)	<0.001	0.87 (0.85, 0.90)	<0.001	1.15 (1.11, 1.18)	<0.001

Abbreviation: ARR=absolute risk reduction; RR=relative risk reduction; RR= relative risk; 1/RR=protective efficacy; CI=confidence interval; SHEPG=smart health education pillbox group; RHEG=routine health education group.

\*At Baseline (N=2,700), and one-year follow-up in the SHEPG (N=1,021). The numbers of valid responses to Q3 in Baseline were 2, 124; the numbers of valid responses to Q6 based on households raising livestock were 1,888 and 863, respectively; the numbers of valid responses to Q7 based on households raising livestock were 1,545 and 699, respectively; the numbers of valid responses to Q8 based on households raising sheep were 1, 316 and 576, respectively.

Note: The chi-square test was used for all comparisons, but if the expected frequency of any cell was less than 5, Fisher's exact test was used. The blank cells indicate "not calculated (with no need for)".

SUPPLEMENTARY TABLE S6. Practice rates, ARR, RRR, RR, 1/RR between RHEG and Baseline after the 12-month follow-up, 2023-2024.

Question	Response	Baseline [% (n/N)]	SHEPG [% (n/N)]	ARR		RRR		RR		1/RR	
				95% CI	P	95% CI	P	95% CI	P	95% CI	P
1. Do you wash your hands before meals?	Three times a day or more (correct)	53.89 (1,455/2,700)	54.73 (509/930)	0.84 (-2.91, 4.59)	0.660	1.83 (-6.38, 10.04)	0.660				
	1-2 times a day (partly)	23.96 (6,472/2,700)	24.95 (232/930)	0.99 (-4.51, 2.53)	0.580	-4.13 (-18.83, 10.57)	0.580	1.04 (0.91, 1.19)	0.580	0.96 (0.84, 1.10)	0.580
	Occasionally (incorrect)	22.15 (598/2,700)	20.32 (189/930)	1.83 (-1.30, 4.96)	0.250	8.26 (-5.94, 22.46)	0.250	0.92 (0.79, 1.06)	0.250	1.09 (0.94, 1.27)	0.250
2. How is your dog typically restrained?	Always tethered (correct)	27.89 (753/2,700)	28.84 (265/919)*	0.95 (-2.58, 4.48)	0.590	-3.41 (-15.88, 9.06)	0.590				
	Tethered during the day, free at night (partly)	14.96 (404/2,700)	14.79 (136/919)*	0.17 (-2.99, 3.33)	0.880	1.14 (-19.93, 2.21)	0.880	0.99 (0.83, 1.18)	0.880	1.01 (0.85, 1.20)	0.880
	Tethered in settlements, free during migration (partly)	47.78 (1,290/2,700)	48.42 (445/919)*	-0.64 (-4.15, 2.87)	0.720	-1.34 (-9.33, 6.65)	0.720	1.01 (0.94, 1.09)	0.720	0.99 (0.92, 1.07)	0.720
	Never tethered (incorrect)	9.37 (253/2,700)	7.94 (73/919)*	1.43 (-0.77, 3.63)	0.200	15.26 (-7.13, 37.65)	0.170	0.85 (0.67, 1.07)	0.170	1.18 (0.93, 1.49)	0.170
3. Do you often pet or hug your dog?	Never (correct)	8.24 (175/2,124)*	9.25 (86/930)	1.01 (-1.07, 3.09)	0.340	12.26 (-42.96, 18.44)	0.340				
	Occasionally (partly)	53.95 (1,146/2,124)*	53.01 (493/930)	0.94 (-2.72, 4.60)	0.610	1.74 (-6.10, 9.58)	0.610	0.98 (0.91, 1.06)	0.610	1.02 (0.94, 1.10)	0.610
	Often (incorrect)	37.81 (803/2,124)*	37.74 (351/930)	0.07 (-3.69, 3.83)	0.980	0.19 (-10.98, 11.36)	0.980	1.00 (0.90, 1.11)	0.980	1.00 (0.90, 1.11)	0.980
4. Do you deworm your dog regularly?	Yes (correct; 9-12 times/yr)	61.00 (1,647/2,700)	59.89 (557/930)	-1.11 (-4.60, 2.38)	0.530	-2.85 (-11.80, 6.10)	0.530				
	Frequently (4-8 times/yr) (partly)	18.11 (489/2,700)	16.88 (1,57/930)	1.23 (-1.66, 4.12)	0.400	6.79 (-9.17, 22.75)	0.400	0.93 (0.79, 1.10)	0.400	1.08 (0.91, 1.27)	0.400
	Occasionally (1-3 times/yr) (partly)	17.19 (464/2,700)	20.65 (192/930)	-3.46 (-6.31, -0.61)	0.019	-20.13 (-36.71, -3.55)	0.019	1.20 (1.03, 1.40)	0.019	0.83 (0.71, 0.97)	0.019
	Never dewormed (incorrect)	3.70 (100/2,700)	2.58 (24/930)	1.12 (-0.26, 2.50)	0.110	30.27 (-7.03, 67.57)	0.110	0.70 (0.45, 1.08)	0.110	1.43 (0.93, 2.22)	0.110
5. Do you properly dispose of your dog's waste after deworming?	Yes (correct; deep burial)	51.04 (1,378/2,700)	51.73 (433/837)*	0.69 (-3.36, 4.74)	0.740	-1.41 (-10.29, 7.47)	0.740				
	Occasionally (partly)	21.81 (589/2,700)	21.39 (179/837)*	0.42 (-3.09, 3.93)	0.820	1.93 (-14.17, 18.03)	0.820	0.98 (0.84, 1.14)	0.820	1.02 (0.88, 1.19)	0.820
	Untreated (incorrect)	27.15 (733/2,700)	26.88 (225/837)*	0.27 (-3.38, 3.92)	0.880	1.00 (-12.45, 14.45)	0.880	0.99 (0.87, 1.13)	0.880	1.01 (0.88, 1.15)	0.880
6. Do you often slaughter cattle and sheep at yard?	No (correct)	18.17 (343/1,888)*	17.72 (151/852)*	-0.45 (-3.96, 3.06)	0.800	2.48 (-21.77, 26.73)	0.800				
	Yes (incorrect)	81.83 (1,545/1,888)*	82.28 (701/852)*	-0.45 (-3.96, 3.06)	0.800	-0.55 (-4.84, 3.74)	0.800	1.01 (0.97, 1.04)	0.800	0.99 (0.96, 1.03)	0.800

Continued

Question	Response	Baseline [% (n/N)]	SHEPG [% (n/N)]	ARR		RRR		RR		1/RR	
				95% CI	P	95% CI	P	95% CI	P	95% CI	P
7. Do you feed the internal organs of the cattle and sheep to dogs?	Never (correct)	61.04 (943/1,545)*	60.95 (476/781)*	-0.09 (-4.51, 4.33)	0.980	-0.23 (-11.59, 11.13)	0.980				
	Occasionally (partly)	25.18 (389/1,545)*	25.74 (201/781)*	-0.56 (-4.51, 3.39)	0.770	-2.22 (-17.92, 13.48)	0.770	1.02 (0.88, 1.19)	0.770	0.98 (0.84, 1.14)	0.770
	Frequently (incorrect)	13.79 (213/1,545)*	13.32 (104/781)*	0.47 (-2.97, 3.91)	0.770	3.41 (-21.53, 28.35)	0.770	0.97 (0.77, 1.21)	0.770	1.03 (0.83, 1.30)	0.770
8. Are your lambs vaccinated regularly?	Regularly (correct)	55.02 (724/1,316)*	54.79 (349/637)*	-0.23 (-5.18, 4.72)	0.930	-0.51 (-11.52, 10.50)	0.930				
	Irregularly (partly)	25.23 (332/1,316)*	26.06 (166/637)*	-0.83 (-4.78, 3.12)	0.680	-3.29 (-18.95, 12.37)	0.680	1.03 (0.88, 1.22)	0.680	0.97 (0.82, 1.14)	0.680
	No (incorrect)	19.76 (260/1,316)*	19.15 (122/637)*	0.61 (-3.12, 4.34)	0.750	3.09 (-15.78, 21.96)	0.750	0.97 (0.79, 1.19)	0.750	1.03 (0.84, 1.27)	0.750
9. Do you regularly participate in echinococcosis screening?	Regularly (correct)	73.30 (1,979/2,700)	74.30 (691/930)	1.00 (-2.15, 4.15)	0.530	-3.75 (-15.93, 8.43)	0.530				
	Irregularly (partly)	24.04 (649/2,700)	24.84 (231/930)	-0.80 (-4.23, 2.63)	0.650	-3.33 (-17.59, 10.93)	0.650	1.03 (0.91, 1.17)	0.650	0.97 (0.85, 1.10)	0.650
	No (incorrect)	2.67 (72/2,700)	0.86 (8/930)	1.81 (0.67, 2.95)	0.002	67.79 (34.92, 100.66)	0.002	0.32 (0.16, 0.65)	0.002	3.13 (1.54, 6.25)	0.002
Total (Q1-9)	Correct	46.12 (9,397/20,373)	45.40 (3,517/7,746)	-0.72 (-1.70, 0.26)	0.150	-1.34 (-3.16, 0.48)	0.150				
	Partly correct+incorrect	53.88 (10,976/20,373)	54.60 (4,229/7,746)	-0.72 (-1.70, 0.26)	0.150	-1.34 (-3.16, 0.48)	0.150	1.01 (0.99, 1.04)	0.180	0.99 (0.96, 1.01)	0.180

**Abbreviation:** ARR=absolute risk reduction; RR=relative risk reduction; RR=relative risk; 1/RR=protective efficacy; CI=confidence interval; SHEPG=smart health education pillbox group; RHEG=routine health education group.

\*At Baseline (N=2,700), and one-year follow-up in the RHEG (N=930). The numbers of valid responses to Q 2 in RHEG were 919; the numbers of valid responses to Q3 in Baseline were 2, 124; the numbers of valid responses to Q5 in RHEG were 837; the numbers of valid responses to Q6 based on households raising livestock in both group were 1,888 and 852, respectively; the numbers of valid responses to Q7 based on households raising livestock in both group were 1,545 and 781, respectively; the numbers of valid responses to Q8 based on households raising sheep in both group were 1, 316 and 637, respectively.

**Note:** The chi-square test was used for all comparisons, but if the expected frequency of any cell was less than 5, Fisher's exact test was used. The blank cells indicate "not calculated (with no need for)".