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Evaluating adherence to COVID-19 quarantine protocols at two international ground crossings in Savannakhet Province, Lao PDR

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Abstract

Background Border surveillance measures, including health screening and mandatory quarantine for travelers, are critical components of global pandemic response strategies. In Lao PDR, however, no known study has assessed the performance of the quarantine system, which was designed to protect the health of both citizens and incoming travelers, particularly during the COVID-19 pandemic and in preparation for future outbreaks. This study therefore evaluates adherence to the national COVID-19 quarantine protocols at two ground crossings (Vietnam–Laos and Thailand–Laos) in Savannakhet Province during the COVID-19 pandemic.

Methods A retrospective cross-sectional study was conducted among 380 registered adult incoming travelers who entered Lao PDR via Dansavanh–Lao Bao border or Second Thai–Lao Friendship Bridge between April 2020 and March 2021. Data were extracted from point-of-entry registers, provincial hospital records, and quarantine facility registers. Overall quarantine performance (OQP) was defined as completion of the Lao PDR national quarantine protocol. Binary logistic regression was employed to identify the factors associated with OQP completion.

Results Of the 380 incoming travelers, 277 (72.9%; 95%CI 68.2–77.1) completed the full quarantine procedures. Body temperature screening was conducted for 348 individuals (91.6%), with 13 (3.7%) presenting with fever ≥ 37.5 °C and referred for further screening. Among 335 incoming travelers directed to quarantine facilities, 264 (78.8%) completed the 14-day quarantine. Multivariate analysis revealed that female incoming travelers were significantly more likely to complete quarantine procedure than males (aOR: 1.84; 95%CI 1.14–2.96; p = 0.013). Those who traveled into the provinces other than Savannakhet had higher odds of quarantine completion (aOR: 1.78; 95%CI 1.49–3.26; p = 0.042).

Conclusion Based on locally defined indicators, the quarantine system achieved OQP rate of 72.9% which reflects an acceptable level of compliance. Gender and destination province were significant predictors of adherence. Enhancing communication strategies and standardizing strict quarantine procedures could improve border surveillance and preparedness for future public health emergencies.

Keywords Border crossing, COVID-19, Ground crossing, Lao PDR, Pandemic preparedness, Quarantine, Surveillance

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Background

Coronavirus disease 2019 (COVID-19) pandemic prompted countries worldwide to implement stringent border control measures to prevent virus transmission. Border surveillance systems, including health screening and mandatory quarantine for incoming travelers, became critical components of national pandemic response strategies [1, 2]. The World Health Organization (WHO) emphasized the importance of robust quarantine and surveillance systems at points of entry (POEs) as part of comprehensive public health measures [2, 3].

Despite the widespread implementation of border surveillance measures globally, there is limited empirical evidence on their actual performance and effectiveness, particularly in low-and-middle income countries (LMICs) [4, 5]. Most studies focused on the theoretical effectiveness of screening measures rather than real-world implementation outcomes [4]. Anearlier study reported that COVID-19 prevention measures taken for incoming and outgoing air passengers and airlines staff members had variable effectiveness depending on implementation context [6]. Understanding the performance of quarantine systems and factors influencing compliance is crucial for improving current measures and preparing for future health emergencies [7]. Body temperature screening, while commonly used, has limitations due to the high proportion of asymptomatic COVID-19 cases and the virus's incubation period [8]. Some earlier studies reported that about 30% of COVID-19 cases were asymptomatic [4, 9], while another research indicates the rates as high as 51.7% [9], making temperature screening alone insufficient for effective detection. The median incubation period of 5.1 days further complicates early detection efforts [8].

According to WHO, as of August 2023, over 760 million confirmed cases of COVID-19 and more than 6.9 million deaths associated with COVID-19 were reported globally, presenting an unprecedented public health challenge, while 13 billion vaccine doses had been administered [10]. The government of Lao PDR, a landlocked country in Southeast Asia, implemented strict border controls during the pandemic, including mandatory quarantine for all incoming travelers. The country's strategic location, bordering five countries (Cambodia, China, Myanmar, Thailand, and Vietnam) makes it a crucial transit point for regional trade and travel [11]. Savannakhet Province, with its two major international ground crossings, serves as a vital gateway connecting Lao PDR with Thailand and Vietnam. Lao PDR was the last country in Southeast Asia to report a confirmed case of COVID-19, announcing its first case on 24 March 2020. By May 2023, the country documented 218,227 cases and 671 associated-deaths whereas 86% of the population were vaccinated [12]. Savannakhet Province having the second largest territory in Lao PDR, played a pivotal role during the pandemic as it has two major ground (land) border crossings, which incessantly experiences a high volume of incoming and outgoing travelers throughout the year. Given the Province-specific context, it is essential to evaluate the performance of quarantine measures implemented at these borders, for the purpose of mitigating the spread of COVID-19 and safeguarding the health of incoming travelers. Such an evaluation provides the government with valuable insights for informing national strategies aimed at strengthening health security and enhancing community resilience against future epidemics [13].

This study therefore aimed to evaluate the performance of the quarantine system at two major ground crossings in Savannakhet Province, Lao PDR, and to further identify the factors associated with successful completion of quarantine procedures. The findings will be conducive to making policy recommendations for improving border surveillance systems in Lao PDR and provide the insights applicable to similar settings in other LMICs.

Methods

Study design

A retrospective cross-sectional study was conducted to assess the performance of the quarantine system at the POEs for two ground crossings in Savannakhet Province, Lao PDR, during the period from April 2020 to March 2021. The study followed the STROBE checklist [14, 15] of reporting (Supplemental 1).

Study setting

The study was conducted at two ground crossings in Savannakhet Province, the second-largest of the 18 provinces in Lao PDR. Savannakhet borders Khammouan Province to the north, Quang Tri and Thua Thien Hue Provinces of Vietnam to the east, Salavan Province to the south, and Nakhon Phanom and Mukdahan Provinces of Thailand to the west. The two ground crossings studied were: (i) the Second Thai–Lao Friendship Bridge over the Mekong River, connecting Mukdahan Province in Thailand with Savannakhet Province; and (ii) the Dansavanh–Lao Bao border crossing, linking Dansavanh in Lao PDR with Vietnam (Fig. 1). In 2019, a total of 907,000 incoming travelers entered Lao PDR through these two ground crossings, indicating Savannakhet as a vital trading hub between Lao PDR and Thailand, and between Lao PDR and Vietnam [16–18]. Furthermore, Savannakhet Province recorded a total of 17,092 confirmed cases of COVID-19, accompanied by 40 documented mortality cases in the year 2023 [12].

Fig. 1 Ground crossings at Savannakhet Province, Lao PDR (study site)

Study population

The study targeted adult incoming travelers who entered Lao PDR either through Dansavanh–Lao Bao border or through the Second Thai–Lao Friendship Bridge in Savannakhet Province, between 1st April 2020 and 31st March 2021. Truck drivers were excluded from the study due to a separate quarantine system applied to them at the POEs. Outgoing travelers were also excluded because (i) the study focused exclusively on inbound cases to assess the effectiveness of national containment measures, and (ii) they were not subject to the same quarantine protocols as incoming travelers.

Sample size and sampling

To estimate the proportion of incoming travelers who fully completed OQP process, the sample size (n) was calculated, by using the Cochran formula (19), $n = \frac{Z^2 P_o(1-P_o)}{d^2}$. Given the lack of available data from previous studies on adherence to COVID-19 quarantine protocols among incoming travelers, a conservative population proportion ($P_o = 0.50$) was adopted. The sample size calculation further employed a standard normal variate at 95% confidence ($Z^2_{\alpha/2} = 1.96$) and a precision level of 5% ($d = 0.05$). As a result, 384 incoming travelers were determined as the sample size for this study.

A total of 384 eligible individuals were selected through probability proportional to size sampling at the two international ground crossings in Savannakhet Province. At the POE of each ground crossing, proportionate random sampling was initially employed to determine the sample sizes for each month from April 2020 to March 2021 (see Table 1). Then, systematic random sampling was conducted to select the 384 participants.

Lao PDR national quarantine protocol

All travelers entering Lao PDR were subject to mandatory health screening procedures upon arrival. This began with the submission of a health declaration form and body temperature screening. Travelers presenting with a body temperature ≥ 37.5 °C were referred for polymerase chain reaction (PCR) testing to determine potential COVID-19 infection. Those who tested positive were placed under medical quarantine at designated provincial hospitals. Conversely, individuals who tested negative were directed to quarantine at approved government or private facilities. Travelers whose body temperature was < 37.5 °C were not required to undergo PCR testing but still completed a quarantine period at either government-designated facilities or authorized private accommodations, such as hotels. In Savannakhet Province, the approved quarantine facilities included Buasavanh, Philavanh, Phaemai, and Tondou hotels. Government quarantine sites were also designated within two primary schools and a sports stadium, repurposed to support public health containment efforts. The visual representation of the quarantine protocol is shown in Fig. 2.

Data collection

A structured questionnaire (Supplemental 2) was developed to collect the data on eligible incoming travelers from quarantine-related registers through document review at the two ground crossings. Three trained research assistants were recruited to extract data from

Table 1 Description of estimated border sample size at Savannakhet Province

Month and year	Second Thai–Lao Friendship Bridge border			Dansavanh–Lao Bao Border		
	Incoming travelers (X_1)	Coverage ($Y_1 = X_1/16{,}283$)	Participants sampled ($Z_1 = Y_1 \times 384$)	Incoming travelers (X_2)	Coverage ($Y_2 = X_2/16{,}283$)	Participants sampled ($Z_2 = Y_2 \times 384$)
April 2020	807	5.0%	19	37	0.2%	1
May 2020	124	0.8%	3	42	0.3%	1
June 2020	2006	12.3%	47	35	0.2%	1
July 2020	2169	13.3%	51	106	0.7%	3
August 2020	1424	8.7%	34	65	0.4%	2
September 2020	1913	11.8%	45	332	2.0%	7
October 2020	969	6.0%	23	416	2.6%	10
November 2020	682	4.1%	16	602	3.7%	14
December 2020	559	3.4%	13	593	3.6%	13
January 2021	506	3.1%	12	142	0.9%	4
February 2021	821	5.0%	19	59	0.4%	2
March 2021	1616	10.0%	38	258	1.5%	6
Sub-total	13,596	83.5%	320	2687	16.5%	64
Total	$(X_1 + X_2)$	$(Y_1 + Y_2)$	$(Z_1 + Z_2)$			
	16,283	100%	384			

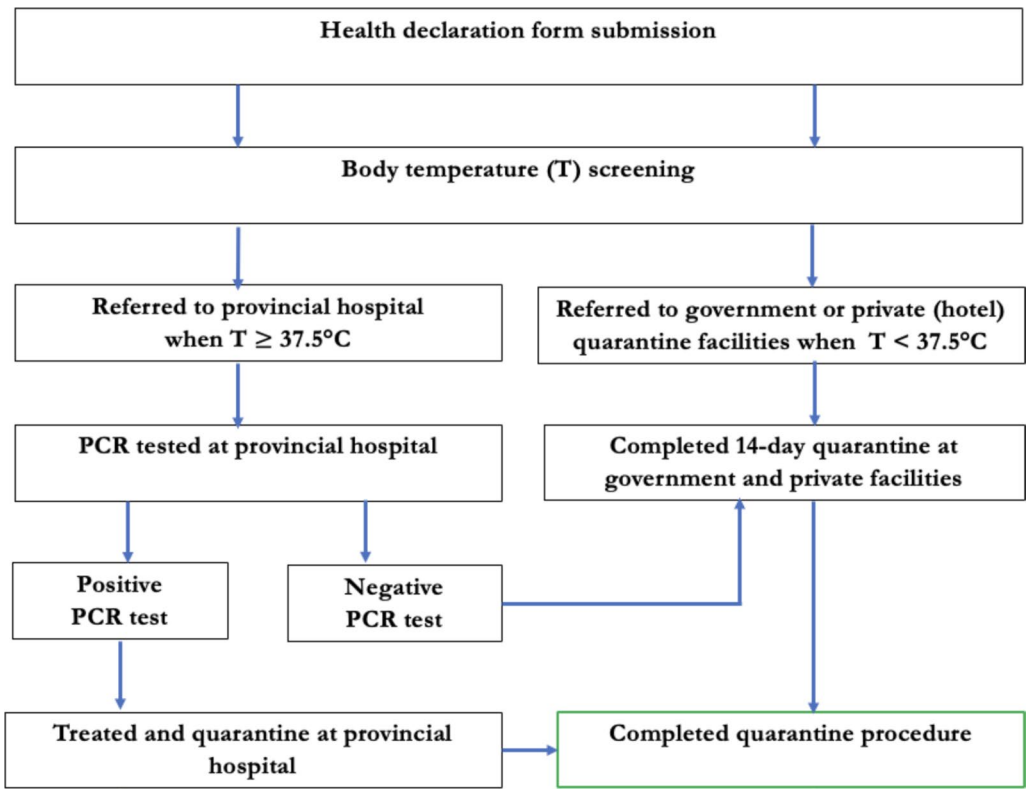

Fig. 2 COVID-19 quarantine protocol in Lao PDR (Savannakhet border crossings)

paper-based registers between 1st April and 31st May 2022. Data were collected from three sources: (i) POE registers at the ground crossings; (ii) Savannakhet Provincial Hospital registers to track recruited referral travelers for PCR testing; and (iii) quarantine facility registers to monitor recruited referral travelers for completion of the 14-day quarantine period. Three government quarantine facilities (two schools and one stadium) and four private or hotel quarantine facilities (namely Buasavanh, Philavanh, Phaemai, and Tondou hotels) were utilised during this period.

Information gathered included incoming travelers' characteristics (gender, age, occupation, nationality, and presentation of COVID-19 symptoms) and quarantine system-related details (POE, day type at POE, quarantine facilities, and completion of the quarantine procedures). The dependent variable was the overall quarantine performance (OQP), coded as "1 = completion of OQP" and "0 = incompletion of OQP." The OQP measures the completion of the quarantine procedure which is described in Fig. 2. A total completion of the prescribed quarantine procedures, representing acceptable compliance denotes full adherence while incomplete fulfillment of the quarantine period or failure to meet required procedures indicates partial or non-adherence [20, 21]. The independent variables included incoming travelers' characteristics and other quarantine system–related factors. These variables are further described in Table 2.

Data analysis

The data was analyzed using STATA version 18.0 (Stata Corporation, Texas, USA) [22]. Descriptive statistics were conducted to determine the prevalence of OQP and to summarize the exposure variables (such as background characteristics of the incoming travelers). Logistic regression analyses were employed to identify the factors associated with OQP rate. Multicollinearity among the independent variables (potential factors associated with OQP) was examined prior to multivariate analysis using the variance inflation factor (VIF). As all independent variables had VIF values less than 10, they were all included in the multivariate analysis. Multiple binary logistic regression was then performed to identify factors associated with OQP by utilizing simultaneous variable entry at 95% confidence interval.

Ethical approval and consent to participate

Ethical approvals were obtained for the study from two ethics committees: (i) School of Tropical Medicine and Global Health, Nagasaki University (TMGH/NU) Institutional Review Board (approval number: *NU_TMGH_2021_189_1*); and (ii) National Ethics Committee for Health Research (NECHR) in Lao PDR (approval number: *03/NECHR*). The study was performed in accordance with regulations and guidelines under the Declaration of Helsinki. In addition, the research permission was granted by three organizations: (i) Savannakhet Provincial Health Office; (ii) Savannakhet Provincial Hospital; and (iii) Savannakhet quarantine facilities. Informed consent was not required from participants, as the study involved a review of existing secondary data and documents related to the COVID-19 quarantine system.

Results

Sociodemographic characteristics of incoming travelers

Table 3 presents the sociodemographic characteristics of incoming travelers at Lao-PDR borders. Complete datasets were available for 380 (99%) out of the 384 initially enrolled participants. Hence four incomplete datasets were excluded during data analysis. Of 380 incoming travelers selected, 62 (16.3%) entered at Dansavanh–Lao Bao ground crossing, whereas the remaining 318 (83.7%) entered through the Second Thai–Lao Friendship Bridge. The travelers had a mean age of 28.6 (SD = 9.5) years. More than half of these travelers were between 18 and 29 years of age (56.5%), and 51.6% were male. A majority of the incoming travelers were employees who worked in non-technical areas (289; 76.0%) and identified as Laotian nationals (362; 95.3%). More than two-thirds of the incoming travelers traveled for employment purposes (306; 80.5%) and also indicated Savannakhet Province as their intended destination (287; 75.5%). All incoming travelers submitted their health declaration forms, of which 226 (59.5%) were fully completed. Lastly, 274 travelers (72.1%) arrived in the country on weekdays.

OQP of incoming travelers

Table 4 outlines the outcomes related to quarantine performance among the incoming travelers. A descriptive and diagrammatic presentation for quarantine process flow are further described in Fig. 3. All the 380 incoming travelers submitted their health declaration forms at the POEs. Body temperature screening was conducted for 348 incoming travelers (91.6%), of whom 13 individuals (3.7%) presented with a fever of ≥ 37.5 °C. These 13 incoming travelers were subsequently referred to Savannakhet Provincial Hospital for PCR testing and quarantine procedures. Of the 335 individuals referred to designated quarantine facilities, 264 (78.8%) successfully completed the full 14-day quarantine period.

In total, 277 out of 380 incoming travelers (72.9%; 95%CI 68.2–77.1) completed all required (overall) quarantine procedures. With respect to the location of quarantine facilities among those who completed the procedures, 248 incoming travelers (65.3%) were accommodated in government-operated facilities, 16 (4.2%)

Table 2 Description and measurement of study variables

Variable	Variable type	Description (definition)	Categories
Overall quarantine performance (OQP)	Binary	The incoming travelers who completed or did not complete all necessary criteria of the quarantine procedure A total completion of the prescribed quarantine procedures, representing acceptable compliance denotes Full adherence whilst incomplete fulfillment of the quarantine period or failure to meet required procedures indicates Partial or Non-adherence	Completion of OQP; Incompletion of OQP
Point of entry (POE)	Binary	The kind of ground or land border where incoming travelers legally entered Lao PDR	Lao-Thai border (Second Thai-Lao Friendship Bridge); Lao-Vietnam border (Dansavanh–Lao Bao)
Day type at POE	Binary	The type of day (either weekend or weekday) where incoming travelers legally entered Lao PDR	Weekday; Weekend
Purpose/Reason for entry	Categorical	The purpose or intend behind incoming travelers' visit to Lao PDR	Business/trading purposes; Studies (students); Medical treatment (patients); Tourism
Completion of health declaration form	Binary	The process of providing personal, travel, and health-related information before entering a country, often as part of border control or quarantine procedures	Complete; Incomplete
COVID-19 Symptoms reported on health declaration form	Categorical	The immediate, common and frequent symptoms (fever: temperature ≥ 37.5 °C, headache, cough, sore throat, runny nose, shortness of breath) of COVID-19 documented on health declaration form at POE	Symptoms present; Symptoms absent; Not checked/reported
Referral quarantine facility type based on temperature (T) check at POE	Categorical	The kind of quarantine health facility used to contain referred travelers based on temperature results at POE	Government quarantine facility (T < 37.5 °C); Private/hotel quarantine facility (T < 37.5 °C); Savannakhet provincial hospital (T ≥ 37.5 °C); Unknown
Referral quarantine facility type based on overall quarantine procedure	Categorical	The kind of quarantine health facility used to contain the recruited travelers based on quarantine procedures and performance	Government quarantine facility; Private/hotel quarantine facility; Savannakhet provincial hospital; Unknown
Destination province	Binary	The specific province in Lao PDR an incoming traveler intends to move or travel to	Savannakhet province; Other provinces
Issuance of Certificate of Completion	Binary	The issue of certificate to incoming travelers who completed the 14-day quarantine without registering symptoms of COVID-19 or tested negative (PCR) for COVID-19	Received; Not received
Age	Categorical	The age category (in years) of incoming travelers	0–17 years; 18–29 years; 30–39 years; 40 years and above
Gender	Binary	Socially constructed identity of incoming travelers categorized into male or female	Male; Female
Nationality	Categorical	The legal status of belonging to a particular country	Laotian; Vietnamese; Thai; Others
Occupational status	Categorical	The regular employment status (job or profession) of incoming travelers	Non-technical (labor); Technical (professional); Students

Table 3 Sociodemographic characteristics of incoming travelers (N = 380)

Variables	Frequency (n)	Proportion (%)
Age		
< 18 years	12	3.2
18 – 29 years	215	56.5
30 – 39 years	112	29.5
≥ 40 years	41	10.8
Mean (SD): 28.6 (9.5)		
Gender		
Male	196	51.6
Female	184	48.4
Occupation		
Non-technical (labor job)	289	76.0
Technical	17	4.5
Students	40	10.5
Unknown	34	9.0
Nationality of incoming traveler		
Lao	362	95.3
Vietnamese and Thai	18	4.7
Purpose of entry into Lao PDR		
Job (work) purpose	306	80.5
Studies	40	10.5
Tourism	27	7.1
Medical purpose	7	1.9
Destination province in Lao PDR		
Savannakhet province	287	75.5
Other provinces	93	24.5
Completion of health declaration form		
Complete	226	59.5
Incomplete	154	40.5
Point of entry (POE)		
Second Thai-Lao Friendship Bridge (Lao—Thai) border	318	83.7
Dansavanh-Lao Bao (Lao—Vietnam) border	62	16.3
Day type at POE		
Weekday	274	72.1
Weekend	106	27.9

in private or hotel quarantine facilities, and 13 (3.4%) in hospital settings.

Trend of COVID-19 cases among incoming travelers

Figure 4 illustrates the temporal trend of COVID-19 cases during the quarantine period. A total of 264 incoming travelers were placed in quarantine facilities (government centers or private hotels), while 13 were referred to the Provincial hospital for PCR testing.

Of these 13 travelers, 3 tested positive for COVID-19 and were admitted for treatment and monitoring at the hospital. The remaining 10, who tested negative, were transferred to quarantine facilities for self-assessment and close monitoring. During the 13-day quarantine period, all 13 travelers underwent further medical evaluation and repeat PCR testing, which confirmed no additional infections. The 264 travelers in quarantine facilities were self-monitored daily through temperature checks and symptom screening (fever, headache, cough, sore throat, runny nose, and shortness of breath). At the end of the 13-day period, medical officers declared them free of COVID-19 following thorough assessment.

Consequently, the number of confirmed cases decreased from three to zero. In total, all 277 travelers (264 in facilities, 3 initially positive, and 10 initially

Table 4 Descriptive analysis of quarantine performance (N = 380)

Variable	Frequency (n)	Proportion (%)
Criteria of quarantine procedure		
Body temperature measurement at POE		
Measured	348	91.6
Not measured (documented)	32	8.4
Referral status and quarantine facility based on the temperature measured at POE (N = 348)		
Referred to the provincial hospital when ≥ 37.5 °C	13	3.7
Referred to the quarantine facilities when < 37.5 °C	335	96.3
PCR test and quarantine completion status for referral incoming travelers to provincial hospital (N = 13)		
PCR tested and completed quarantine process	13	100
Not tested	0	0.0
Quarantine completion status based on referral to non-hospital quarantine facilities (N = 335)		
Completed 14-day quarantine	264	78.8
Not completed 14-day quarantine	71	21.2
Referral quarantine facility type based on overall completed quarantine procedure		
Government quarantine facility	248	65.3
Private quarantine facility	16	4.2
Provincial hospital	13	3.4
Unknown	103	27.1
Issuance of Certificate of completion to incoming travelers		
Received	277	72.9
Not received	103	27.1
Overall quarantine procedures/performance (OQP)	**n**	**% (95%CI)**
Completion of overall quarantine procedures	277	72.9 (68.2–77.1)
Incompletion of overall quarantine procedures	103	27.1 (22.9–31.8)

negative) received Certificates of Completion at the end of quarantine.

Factors associated with the overall quarantine performance

Table 5 presents the results of descriptive and multivariate analyses conducted for identifying the factors associated with whether OQP was adhered to. The results of descriptive (univariate) analysis showed statistically significant associations between OQP completion (dependent variable) and five independent variables (i.e. gender, occupation, purpose of entry, destination province, and point of entry) ($p < 0.05$). However, the results of multiple binary logistic regression indicated that, only gender and destination province of the five independent variables produced significant adjusted odds ratio (aOR).

Specifically, female incoming travelers were significantly 1.84 times more likely to complete OQP compared to male incoming travelers (aOR = 1.84; 95%CI 1.14–2.96; $p = 0.013$). Those whose destination provinces were beyond Savannakhet (i.e. Champasak, Khammouan, and Vientiane Provinces) were 1.78 times more likely to complete OQP than those remaining in Savannakhet (aOR = 1.78; 95% CI 1.49–3.26; $p = 0.042$).

Discussion

This study is the first systematic assessment of adherence to COVID-19 quarantine system at ground crossings during its pandemic not only in Lao PDR but globally, too.

Body temperature screening was successfully conducted for 91.6% of incoming travelers, aligning with international public health recommendations that advocate fever screening as a primary surveillance tool at POEs [2, 4]. Despite this high coverage, only 3.7% of incoming travelers were identified having fever ≥ 37.5 °C, revealing the inherent limitations of temperature-based screening. This finding is particularly salient given that a substantial proportion of COVID-19 cases are asymptomatic. Several previous studies estimated asymptomatic rates at 31% [8, 9], with systematic reviews suggesting figures as high as 52% [9]. These reports highlight the inadequacy of relying solely on body temperature checks at international ground crossings. This calls for the need to integrate complementary screening strategies such as

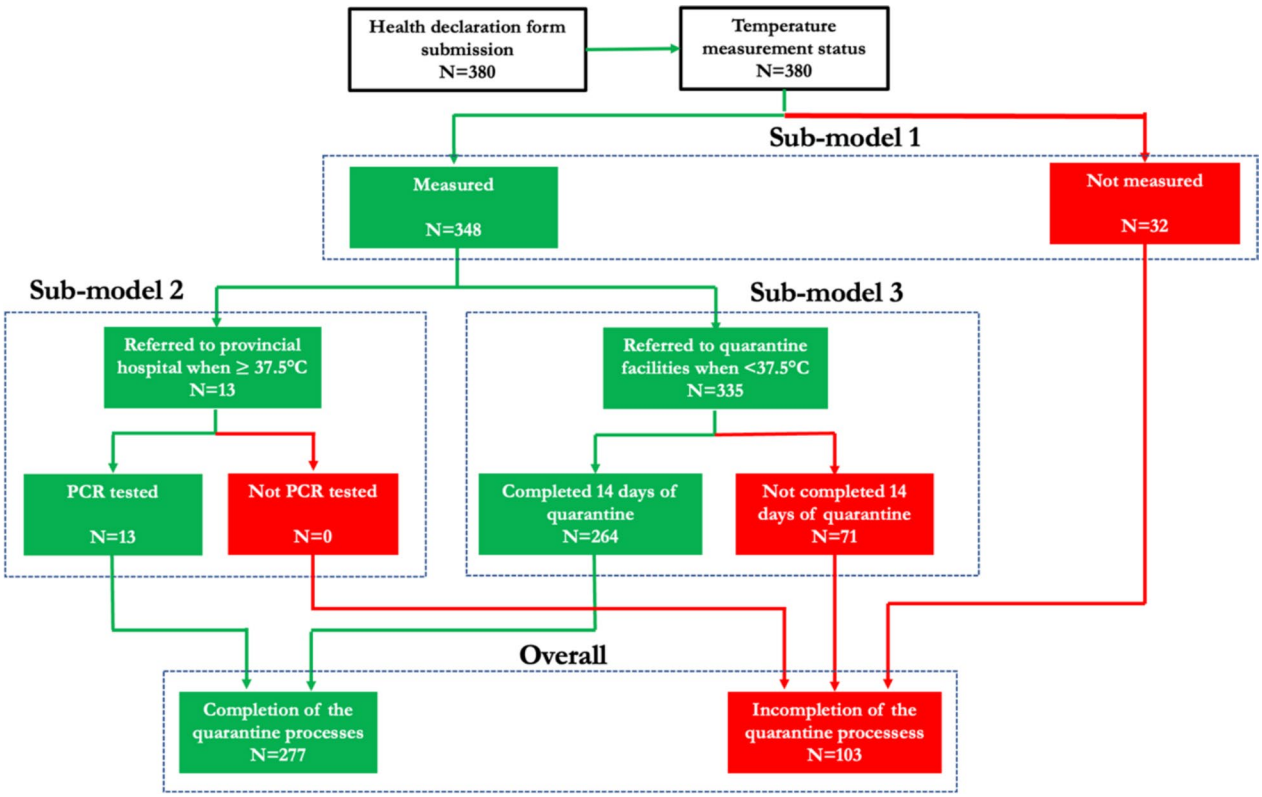

Fig. 3 Quarantine adherence and process flow at Savannakhet border crossings

symptom questionnaires, rapid antigen testing, and digital contact tracing to enhance the sensitivity and specificity of border surveillance systems [1, 4, 7].

Among the 335 incoming travelers referred to quarantine facilities due to not having fever ≥ 37.5 °C, only 78.8% completed the full 14-day quarantine period. Psychological distress could be a significant driver to this quarantine incompletion, as prolonged isolation from family and social support networks often lead to heightened anxiety, loneliness, and emotional fatigue [3]. Economic hardship also played a critical role as travelers facing financial instability were compelled to abandon quarantine prematurely in order to resume work and secure income, particularly in contexts where social safety nets are limited or unavailable. Inadequate supervision, lack of monitoring infrastructure, and insufficient personnel to oversee quarantine facilities allowed some incoming travelers to evade restrictions [1, 2]. These challenges reflect a broader spectrum of practical, emotional, and societal pressures that undermined public health efforts and highlight the need for more holistic, supportive, and enforceable quarantine systems in future health emergencies.

On the other hand, the findings from temporal trend analysis of COVID-19 cases highlight the effectiveness of a structured quarantine and monitoring system in preventing the spread of COVID-19 among incoming travelers. Although three individuals initially tested positive, prompt isolation, treatment, and continuous monitoring ensured that no secondary infections occurred. The negative results from repeat PCR testing and medical assessments confirm that the quarantine measures successfully contained potential transmission risks. Daily symptom screening and temperature checks among the larger group of 264 travelers further reinforced early detection and prevention strategies. By the end of the 13-day quarantine period, all 277 travelers were declared free of infection, underscoring the importance of rigorous entry screening, hospital referral for suspected cases, and consistent follow-up testing. This outcome demonstrates that coordinated quarantine protocols [21] can reduce confirmed cases to zero and provide assurance of safe reintegration of travelers into the community [20, 23].

As a result, the OQP was estimated at 72.9% (95% CI: 68.2–77.1) at the two major ground crossing borders in Lao PDR. It implies that nearly three-quarters of incoming travelers entering through these borders successfully completed their mandated quarantine period. While this may indicate a reasonably acceptable compliance to public health protocols during the

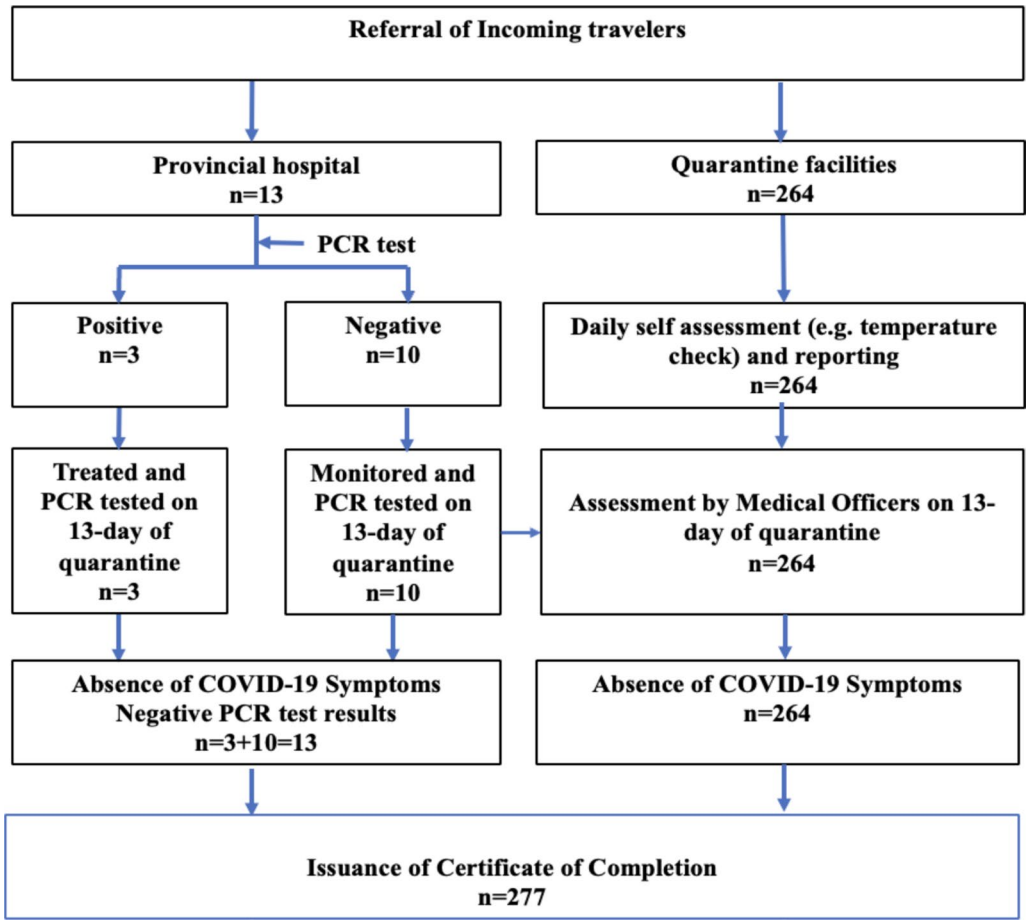

Fig. 4 Trend of COVID-19 cases among incoming travelers

COVID-19 pandemic [21], it remains a cause for concern given the rapid transmission of the virus within a densely populated setting [23, 24]. This OQP attrition rate (27.1%) suggests the challenges in sustaining compliance over extended isolation durations. Several contributing factors may explain this trend. Socioeconomic barriers were likely influential, as incoming travelers were responsible for covering the costs of PCR testing and private quarantine accommodations, whereas government facilities were provided at no charge. This financial burden may have disproportionately affected lower-income incoming travelers, leading to premature departures or avoidance of formal quarantine procedures [1, 25, 26]. Additionally, deficiencies in record-keeping and security mechanisms may have facilitated non-adherence, with some incoming travelers reportedly leaving facilities before completing the mandated isolation period. Accordingly, it is imperative to conduct thorough assessments and reinforce national health security systems, with particular emphasis on quarantine protocols during pandemics [26, 27].

Gender emerged as a significant predictor of quarantine completion, with female incoming travelers being 1.84 times more likely to adhere to procedures compared to males. This observation is consistent with broader epidemiological patterns observed during pandemics, wherein women have demonstrated higher levels of health-seeking behaviour and adherence to preventive measures [28, 29]. Although gender-based differences in quarantine compliance have not been extensively explored in border contexts, existing literature on COVID-19-related behaviours supports the notion that women are generally more compliant with public health guidelines, including mask-wearing, social distancing, and vaccination uptake [3, 10].

The association between destination province and quarantine completion further illuminates the influence of local sociocultural dynamics on compliance. Incoming travelers whose destinations were outside Savannakhet, specifically Champasak, Khammouan and Vientiane, were significantly more likely to complete quarantine procedures. In contrast, those remaining in Savannakhet exhibited lower completion rates, potentially due to

Table 5 Associated factors of overall quarantine performance

Variables	OQP		Logistic regression analyses			
	Completion	Incompletion	Univariate analysis		Multivariate analysis	
	n (%)	n (%)	cOR (95%CI)	p-value	aOR (95%CI)	p-value
Age						
< 18 years	8 (2.9)	4 (3.9)	Ref			
18 – 29 years	158 (57.0)	57 (55.3)	1.39 (0.40–4.78)	0.605		
30 – 39 years	79 (28.5)	33 (32.1)	1.20 (0.34–4.25)	0.781		
≥ 40 years	32 (11.6)	9 (8.7)	1.78 (0.43–7.28)	0.424		
Gender						
Male	133 (48.0)	63 (61.2)	Ref		Ref	
Female	144 (52.0)	40 (38.8)	1.71 (1.08–2.70)	0.023*	**1.84 (1.14–2.96)**	**0.013***
Occupation						
Non-technical (labour)	196 (70.8)	93 (90.3)	Ref		Ref	
Technical	15 (5.4)	2 (1.9)	3.56 (0.80–5.88)	0.096	3.03 (0.07–4.41)	0.566
Students	35 (12.6)	5 (4.9)	3.32 (1.26–8.75)	0.015*	2.69 (0.08–7.58)	0.578
Unknown	31 (11.2)	3 (2.9)	4.90 (1.46–6.45)	0.010*	1.39 (0.26–4.76)	0.698
Nationality of incoming traveler						
Lao	261 (94.2)	101 (98.1)	Ref			
Vietnamese and Thai	16 (5.8)	2 (1.9)	3.10 (0.70–3.71)	0.137		
Purpose of entry into Lao PDR						
Job (work) purpose	211 (76.2)	95 (92.2)	Ref		Ref	
Studies	35 (12.6)	5 (4.9)	3.15 (1.20–8.30)	0.020*	2.22 (0.74–7.82)	0.274
Tourism	27 (9.4)	1 (1.0)	11.7 (9.57–13.5)	0.017*	8.06 (0.54–11.1)	0.129
Medical purpose	5 (1.8)	2 (1.9)	1.13 (0.21–5.91)	0.889	1.41 (0.19–3.99)	0.740
Destination province in Lao PDR						
Savannakhet province	201 (71.6)	86 (83.5)	Ref		Ref	
Other provinces	76 (27.4)	17 (16.5)	1.91 (1.07–3.43)	0.029*	**1.78 (1.49–3.26)**	**0.042***
Completion of health declaration form						
Complete	111 (40.1)	43 (41.8)	Ref			
Incomplete	166 (59.9)	60 (58.2)	1.07 (0.68–1.70)	0.767		
Point of entry (POE)						
Second Thai-Lao Bridge	222 (80.1)	96 (93.2)	Ref		Ref	
Dansavanh-Lao Bao	55 (19.9)	7 (6.8)	3.40 (1.49–7.73)	0.004*	1.22 (0.04–3.97)	0.909
Day type at POE						
Weekday	206 (74.4)	68 (66.0)	Ref			
Weekend	71 (25.6)	35 (34.0)	0.70 (0.41–1.10)	0.108		

* *p-value < 0.05, AOR: Adjusted odds ratio, COR: Crude odds ratio, OQP: Overall quarantine performance, Ref: Reference, Bold AOR, 95%CI, p-value: significant values for associated factors*

proximity to family homes, familiar environments, and more lenient enforcement practices within their home Province. These findings suggest that geographic and social proximity may undermine the perceived necessity of quarantine, thereby reducing adherence [23, 30]. Prior research has demonstrated that mobility patterns and social networks play a critical role in shaping compliance with health interventions, particularly in contexts where enforcement is decentralized or inconsistently applied [31, 32].

Taken together, these findings underscore the complexity of implementing effective quarantine systems at land borders [27]. While initial screening measures such as temperature checks are widely adopted, their limitations necessitate a more holistic approach to surveillance. Furthermore, socioeconomic and behavioural factors must be considered in the design of quarantine protocols to ensure equitable access and sustained adherence or compliance. Strengthening enforcement mechanisms, improving record-keeping, and subsidizing

quarantine-related costs may enhance adherence and overall system performance (11, 24, 33). Future research should explore the interplay of gender, mobility, and local governance in shaping quarantine outcomes, with the aim of informing more responsive and inclusive public health strategies.

Study limitations

Some limitations warrant consideration. As this represents the inaugural assessment of quarantine system performance, the absence of standardized evaluation tools may have compromised the validity of certain variables. Secondly, the findings may not be readily generalizable to other infectious diseases or epidemiological contexts due to the specificity of the study setting. Thirdly, reliance on secondary data sources precluded the inclusion of critical behavioural determinants, such as incoming travelers' socioeconomic status, knowledge, attitudes, and individual motivations for non-completion of quarantine.

Furthermore, this study could add to past research which indicates that asymptomatic COVID-19 transmission rates exhibit considerable variability across different populations and environmental conditions, which may further influence the interpretation of quarantine effectiveness. Another limitation of the study is that weekly epidemiological trend data on COVID-19 were not documented, which prevented reporting on whether weekly COVID-19 cases increased, decreased, or remained stable. Future studies should consider this context. Nevertheless, certificates of completion were issued to all incoming travelers who successfully completed the 14-day quarantine period, indicating that they remained asymptomatic or tested negative for COVID-19 by PCR. It further suggests that COVID-19 case numbers decreased at the end of the 14-day quarantine period. Ultimately, the absence of predefined cut-off values, national or international benchmarks, or standardized classifications for quarantine adherence made it uneasy to determine standard compliance levels in this study. Therefore, qualitative categorization from prior studies was adopted. Notwithstanding these limitations, this pioneering study in Lao PDR systematically evaluates quarantine performance and offers foundational insights to inform future research.

Policy and future pandemics implications

The observed OQP rate of 72.9% highlights the partial effectiveness of current border health measures and underscores the need for strengthened systems to ensure consistent compliance during future epidemics. To improve quarantine systems, POE personnel should receive training to deliver clear and consistent information on the purpose of quarantine and applicable regulations. Complementary visual aids such as signboards, instructional labels, and social distancing markers, can further support traveler comprehension and adherence.

Providing advance data on anticipated traveler volumes would enable more efficient screening and preparedness of quarantine facilities, supported by robust technological systems to enhance health security. Addressing socioeconomic barriers through free, user-friendly quarantine accommodations and harmonized operational procedures across provinces and/or regions may promote more equitable outcomes. Finally, routine monitoring and evaluation mechanisms are essential and must be instituted to track system performance, assess daily or weekly epidemiological trend of COVID-19 cases at quarantine facilities, and guide strategic improvements during future epidemics.

Conclusion

This study offers the first empirical assessment of quarantine system performance at ground border crossings during a pandemic. A completion rate of 72.9% reflects acceptable COVID-19 quarantine system compliance and effectiveness while underscoring areas requiring improvement. Notably, gender and destination province were significant predictors of adherence, indicating that targeted interventions addressing these factors may enhance overall system performance.

Beyond the immediate context of COVID-19, the findings contribute to the foundational knowledge necessary for designing robust border surveillance systems in future health emergencies. Standardizing evaluation tools and extending assessments to additional points of entry across Lao PDR would further strengthen national preparedness for emerging health threats. The methodology and insights derived from this study may also serve as a valuable reference for similar evaluations and research in other LMICs (particularly Southeast Asia) aiming to reinforce their border health security infrastructure.

Abbreviations

aOR	Adjusted odds ratio
COVID-19	Coronavirus disease 2019
Lao PDR	Lao People's Democratic Republic
LMICs	Low- and -middle income countries
OQP	Overall quarantine performance (procedure)
PCR	Polymerase chain reaction
POE	Point of entry
STATA	Statistics and data
VIF	Variance inflation factor
WHO	World Health Organization

Supplementary Information

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Supplementary Material 1.STROBE checklist

Supplementary Material 2.Study questionnaire

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Author contributions
KX, SAG, KM and HA designed and conceptualized the study. KX, KM and TP carried out the data collection while KX, SAG, TP and HA analyzed and interpreted the data. All authors contributed to drafting the initial manuscript, reviewing and approving the final manuscript.

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Data availability
The datasets collected, generated, or analysed during this study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Ethical approvals were obtained for the study from two ethics committees: (i) School of Tropical Medicine and Global Health, Nagasaki University (TMGH/NU) Institutional Review Board (approval number: *NU_TMGH_2021_189_1*); and (ii) National Ethics Committee for Health Research (NECHR) in Lao PDR (approval number: *03/NECHR*). The study was performed in accordance with regulations and guidelines under the Declaration of Helsinki. In addition, the research permission was granted by three organizations: (i) Savannakhet Provincial Health Office; (ii) Savannakhet Provincial Hospital; and (iii) Savannakhet quarantine facilities. Informed consent was not required from participants, as the study involved a review of existing secondary data and documents related to the COVID-19 quarantine system.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. World Health Organization (WHO). WHO policy brief: COVID-19 surveillance. Geneva: WHO; 2024.
2. World Health Organization (WHO). The international health regulations (2005). 3rd ed. Geneva: WHO; 2016.
3. World Health Organization (WHO). From emergency response to long-term COVID-19 disease management: sustaining gains made during the COVID-19 pandemic. Geneva: WHO; 2023.
4. Quilty BJ, Clifford S, Flasche S, Eggo RM. Effectiveness of airport screening at detecting travellers infected with novel coronavirus (2019-nCoV). Euro Surveill. 2020;25(5):1–6. https://doi.org/10.2807/1560-7917.ES.2020.25.5.2000080.
5. Russell TW, Wu JT, Clifford S, Edmunds WJ, Kucharski AJ, Jit M. Effect of internationally imported cases on internal spread of COVID-19: a mathematical modelling study. Lancet Public Heal. 2021;6(1):e12-20. https://doi.org/10.1016/S2468-2667(20)30263-2.
6. Bielecki M, Patel D, Hinkelbein J, Komorowski M, Kester J, Ebrahim S, et al. Air travel and COVID-19 prevention in the pandemic and peri-pandemic period: a narrative review. Travel Med Infect Dis. 2021;39:101915. https://doi.org/10.1016/j.tmaid.2020.101915.
7. Burns J, Movsisyan A, Jm S, Rl B, Coenen M, Kmf E, et al. COVID-19 pandemic : a rapid review (Review). 2021.
8. Lauer SA, Grantz KH, Bi Q, Jones FK, Zheng Q, Meredith HR, et al. The incubation period of coronavirus disease 2019 (CoVID-19) from publicly reported confirmed cases: estimation and application. Ann Intern Med. 2020;172:577–82.
9. Mizumoto K, Kagaya K, Zarebski A, Chowell G. Estimating the asymptomatic proportion of coronavirus disease 2019 (COVID-19) cases on board the Diamond Princess cruise ship, Yokohama, Japan, 2020. Euro Surveill. 2020;25(10):1–5. https://doi.org/10.2807/1560-7917.ES.2020.25.10.2000180.
10. World Health Organization (WHO). Standing recommendions for COVID-19 issued by the Director-General of the World Health Organization (WHO) in accordance with the International Health Regulations (2005) (IHR). Geneva: WHO; 2023.
11. Ministry of Foreign Affairs of Laos. COVID-19 prevention measures at points of entry. Vientiane. 2020. http://www.mofa.gov.la/index.php/legal-documents
12. WHO Country Office. Lao PDR COVID-19 Situation Report number 79. Vientiane - Lao PDR; 2023.
13. Byambasuren O, Cardona M, Bell K, Clark J, McLaws ML, Glasziou P. Estimating the extent of asymptomatic COVID-19 and its potential for community transmission: systematic review and meta-analysis. J Assoc Med Microbiol Infect Dis Can. 2020;5(4):223–34.
14. Cuschieri S. The STROBE guidelines. Saudi J Anaesth. 2019;13(5):S31-34.
15. Vandenbroucke JP, Von EE, Altman DG, Gøtzsche PC, Mulrow CD, Pocock SJ, et al. Strengthening the reporting of observational studies in epidemiology: explanation and elaboration. Epidemiology. 2007;18(6):805–35.
16. Savannakhet Provincial Health Office. Annual Health Report 2020. Savannakhet; 2021.
17. Thai-Lao Friendship Bridge Authority. Getting to know the Thai-Lao Friendship Bridge (Nong Khai - Vientiane): Annual crossing statistics. Bangkok: Thai Ministry of Transport; 2023.
18. Vietnam-Laos Border Management Committee. Vietnam-Laos Border management: Border crossing data. Hanoi; 2022.
19. Cochran WG. Sampling techniques. 3rd ed. Hoboken: Wiley; 1977.
20. Lee K, Williams J, Wu Y, Farwin A, Kim Y, Lee S, et al. The use of quarantine as an international travel measure during the COVID-19 pandemic : a comparative analysis of implementation and equity impacts in five " exemplar " countries. Plos Glob Public Heal. 2025;5(11):1–20. https://doi.org/10.1371/journal.pgph.0005457.
21. Sopory P, Novak JM, Noyes JP. Quarantine acceptance and adherence: qualitative evidence synthesis and conceptual framework. J Public Health. 2022;30:2091–101. https://doi.org/10.1007/s10389-021-01544-8.
22. StataCorp. Stata statistical software: release 17. StataCorp. 2021.
23. Grépin KA, Ho TL, Liu Z, Marion S, Piper J, Worsnop CZ, et al. Evidence of the effectiveness of travel-related measures during the early phase of the

COVID-19 pandemic: a rapid systematic review. BMJ Glob Health. 2021. https://doi.org/10.1136/bmjgh-2020-004537.
24. Clifford S, Quilty BJ, Russell TW, Liu Y, Chan YWD, Pearson CAB, et al. Strategies to reduce the risk of SARS-CoV-2 importation from international travellers: modelling estimations for the United Kingdom. Eurosurveillance. 2021. https://doi.org/10.2807/1560-7917.ES.2021.26.39.2001440.
25. Dickens BL, Koo JR, Wilder-Smith A, Cook AR. Institutional, not home-based, isolation could contain the COVID-19 outbreak. Lancet. 2020;395(10236):1541–2. https://doi.org/10.1016/S0140-6736(20)31016-3.
26. United Nations World Food Programme. WFP food support to returning migrants in Covid-19 quarantine centres in Lao PDR: Building on best practices for future emergencies. Washington DC -USA; 2022.
27. WHO Country Office. Lao PDR builds on efforts to advance national health security through its second Joint External Evaluation. Vientiane - Lao PDR; 2025.
28. Badr HS, Du H, Marshall M, Dong E, Squire MM, Gardner LM. Association between mobility patterns and COVID-19 transmission in the USA: a mathematical modelling study. Lancet Infect Dis. 2020;20(11):1247–54. https://doi.org/10.1016/S1473-3099(20)30553-3.
29. Koh WC, Naing L, Chaw L, Rosledzana MA, Alikhan MF, Jamaludin SA, et al. What do we know about SARS-CoV-2 transmission? A systematic review and meta-analysis of the secondary attack rate and associated risk factors. PLoS One. 2020;15(10):1–23. https://doi.org/10.1371/journal.pone.0240205.
30. Steffen R, Lautenschlager S, Fehr J. Travel restrictions and lockdown during the COVID-19 pandemic—impact on notified infectious diseases in Switzerland. J Travel Med. 2021;27(8):1–3.
31. Linka K, Peirlinck M, Sahli Costabal F, Kuhl E. Outbreak dynamics of COVID-19 in Europe and the effect of travel restrictions. Comput Methods Biomech Biomed Engin. 2020;23(11):710–7. https://doi.org/10.1080/10255842.2020.1759560.
32. Nande A, Adlam B, Sheen J, Levy MZ, Hill AL. Dynamics of COVID-19 under social distancing measures are driven by transmission network structure. PLoS Comput Biol. 2021;17(2):1–26. https://doi.org/10.1371/journal.pcbi.1008684.
33. WHO Regional Office. Lao PDR COVID-19 situation reports. Manila: WHO WPRO; 2025.

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