Outbreak, Surveillance, Investigation & Response (OSIR) Journal
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Investigation of a COVID-19 Cluster in a Football Academy of Buri Ram, October 2021

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Received: 20 Jul 2022; Revised: 31 Jan 2023; Accepted: 31 Mar 2023
https://doi.org/10.59096/osir.v16i2.263761

Abstract

A COVID-19 cluster in a football academy, Buri Ram, Thailand, was notified in October 2021. We aimed to characterize the outbreak, identify the source of disease and risk factors for infection, and give recommendations for preventive measures. We conducted a descriptive study by interviewing cases and academy participants, and assessed ventilation measures at the academy via an environmental survey. We performed a retrospective cohort study among football players using Poisson regression to identify risk factors of COVID-19 infection presenting adjusted incidence rate ratios (AIRR) and 95% confidence intervals (CI). The attack rate was 22.4% (48/214). The median age was 14 years and 77.1% of patients had mild illnesses. All examined environmental surfaces tested negative for SARS-CoV-2. The bedroom density had a strong relationship with attack rates among female bedrooms. Risk factors for infection were being high-risk close contact with the primary case (AIRR 5.4, 95% CI 2.2–12.9) and sleeping in crowded bedrooms (AIRR 2.42, 95% CI 1.14–5.15). Mask-wearing was a protective factor (AIRR 0.32, 95% CI 0.13–0.80). We recommend sports academies and schools encourage mask-wearing during an outbreak, provide living areas that conform to recommended density guidelines, and prepare an isolation or quarantine room for infected students.

Keywords: COVID-19, football academy, risk factors, school

Background

Thailand began experiencing a sharp rise in coronavirus disease 2019 (COVID-19) cases in April 2021, with a peak number reported on 13 Aug 2021.[1] The Thai government used a variety of control strategies, including promoting global COVID-19 prevention measures, limiting group activities, closing high-risk areas and buildings, limiting mobility, and implementing control measures tailored to particular risk areas. Every school closed down and implemented online learning.[2] Consequently, the number of cases fell from September to October 2021.[1] COVID-19 immunization for adolescents (ages 12 to 18 years) began in October 2021, and classes resumed in early November 2021.[3,4] Thailand provided recommendations for re-opening schools and sports venues.[5–7] Before October 2021, there were three COVID-19 outbreaks in sports schools but no outbreak in sports facilities.[8] However, there has been no previous study exploring risk factors for COVID-19 outbreaks in schools or sports facilities in Thailand.

The proportion of asymptomatic COVID-19 infections among children and adolescents ranges from 15–42%.[9]

Among symptomatic cases, fever and cough were the most common symptoms. Other symptoms, including rhinorrhea, sore throat, diarrhea, and vomiting, are less common. Disease is rarely severe and the mortality rate is low.[10] Higher transmission rates are observed in older children (ages 10–19 years) compared with younger children (<10 years).[11] COVID-19 transmission rates in schools are low.[11,12] Lack of masking, staff-to-staff dining, and team sports or other types of group extracurricular activities are risk factors for in-school transmission.[13–15] Group living environment and poor ventilation are environmental risk factors for COVID-19.[16,17]

On 13 Oct 2021, Buri Ram Provincial Health Office notified the joint investigation team of the Office of Disease Prevention and Control Region 9 Nakhon Ratchasima about a COVID-19 cluster in a football academy at a secondary school in Nai Mueang Subdistrict of Mueang Buri Ram District, Buri Ram Province, Thailand. An investigation was conducted aiming to describe epidemiological characteristics of the outbreak, identify potential sources of disease transmission, identify risk factors of COVID-19 infection, and recommend preventive measures.

Methods

An investigation was conducted at school M, Muang District, Buri Ram Province, between 14 Oct and 7 Nov 2021, by a joint investigation team that included officers from the Office of Disease Prevention and Control Region 9 Nakhon Ratchasima, Buriram Hospital, Buri Ram Provincial Health Office, and the Division of Epidemiology.

A descriptive study was performed by reviewing Novelcorona-3 form (Thailand's COVID-19 patient summary report form), field hospital records and laboratory data, and interviewing football players, coaches, and directors. Contact tracing, active case finding, and laboratory testing was also performed.

A confirmed case of COVID-19 was defined as a person who lived in school M and had a positive result for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) by real-time reverse transcription–polymerase chain reaction (RT-PCR) method at Buriram Hospital between 23 Sep and 7 Nov 2021.

A close contact was defined as a person who came into contact with a confirmed case or talked to a confirmed case within a distance of one meter for at least five minutes, or was exposed to the secretion of a confirmed case, or stayed in a closed environment with a confirmed case for at least 30 minutes, and came into contact with the case between two days before the case's onset date and the date of their isolation. The date of contact or exposure must have occurred between 23 Sep and 7 Nov 2021. If a confirmed case was asymptomatic, we used the detected date as the onset date. A high-risk close contact was defined as a close contact who did not wear proper personal protective equipment or was a roommate of a confirmed case, otherwise, the person was defined as a low-risk close contact.

Nasopharyngeal swabs were collected from all students in the football academy, basketball academy and personnel in school M for active case finding. The specimens were sent to the certified laboratory of Buriram Hospital. We recorded the cycle threshold level of the RNA-dependent RNA polymerase (RdRp) gene, nucleocapsid (N) gene, and envelope (E) gene.

The environmental study was conducted in the football academy via a walk-through survey to determine possible transmission locations. We interviewed cases, football coaches, and football players to describe risky behaviors, risky activities, and any COVID-19 preventive measures that were implemented. We swabbed environmental surfaces at common contact points, toilets, and dormitories, and submitted the specimens to Nakhon Ratchasima Medical Sciences Center for RT-PCR testing. We measured the dimensions of the academy to estimate the crowd density using a laser distance meter. We measured the airflow rate in air changes per hour (ACH) using a hot-wire anemometer, the air direction using a smoke tube, and the ventilation size of football players' bedrooms.[18] We fit a linear regression model to the attack rate in bedrooms to identify associated environmental factors.

A retrospective cohort study was conducted to identify risk factors of being a COVID-19 case in the football academy. The study population consisted of all football players who lived in school M between 23 Sep and 7 Nov 2021 and had no evidence of COVID-19 infection (RT-PCR or antigen test kit results) before the study period and responded to a survey via Google Forms. We elicited participant's age, gender, underlying disease, vaccine history, and behaviors through a structured questionnaire. Answers to the behavior questions were "always", "sometimes", and "never". We classified those who responded "always" or "sometimes" as the exposure group and "never" as the non-exposure group. We defined the cohort beginning on 7 October since this was the onset date of the primary case, and we followed up participants until 4 Nov 2021 (14 days after the last case was detected).

For the descriptive analysis, we present median and interquartile range for continuous variables and

frequency and percentage for categorical variables. Microsoft Excel 365 was used for data management. We performed univariate analysis using Poisson regression and multivariate analysis using a backward stepwise method by including variables with a *p*-value <0.2 from the univariate analysis. A variable with a *p*-value <0.05 was considered statistically significant. We calculated person-time from the cohort beginning from being a COVID-19 case until the end of the study period. For those who had no person-time defined, we used a value of 0.5 person-days. STATA version 16.0 was used for all statistical analyses.

Ethics

Participants gave their verbal consent to join the study. The participants' names were not recorded to ensure anonymity. This study was conducted as part of an emergency public health response. There were no invasive procedures in this investigation.

Results

School M is a public school catering for primary and secondary students. Football and basketball are the two-sport academies in this school. During the outbreak, all classes were closed. At the time of our investigation, the school housed 214 people including 59 female and 120 male football players, 18 female basketball players, and 17 staff (15 football staff, 2 basketball staff). Teachers at the school had no contact with the sports academy. Both sports academies were separated from each other and neither students nor staff communicated with those from the other academy. On 13 Oct 2021, 16 confirmed COVID-19 cases were detected (15 female football player and one male football player) from 194 persons who were in the football academy. The joint investigation team started investigating the outbreak on 14 Oct 2021. The remaining 163 football players and 15 football staff were defined as high-risk close contacts. RT-PCR tests for SARS-CoV-2 were performed on days 0, 7, 14, and 21 after the investigation. We conducted active case findings on the female basketball players, staff, administrative officers, and teachers. The outbreak was monitored for 14 days after the last case was reported.

The distribution of COVID-19 cases by date of onset in the football academy is shown in Figure 1. During 23–30 Sep 2021, all players went back to their homes. On 1 October they returned to the academy where they were screened for SARS-CoV-2 using antigen test kits, of which all results were negative. On 5 October, all players received their first dose of the COVID-19 vaccine (BNT162b2) at Buriram Hospital. The primary case was a 15-year-old female who developed symptoms on 7 October. She went to a coffee shop with her family on 30 September before returning to the academy on 30 September and developed a fever on 7 October. Her entire family was not infected with COVID-19. Because the staff assumed that her symptoms were side effects from the vaccination, they did not consider that she had COVID-19 and did not isolate her. Five female football players developed symptoms a few days later. On 12 October, staff transported ten female football players to Buriram Hospital, of which eight tested positive for SARS-CoV-2. The field investigation began on 14 October. The football academy implemented group quarantine for all high-risk contacts on 15 October and the number of cases reported each day began to decrease. The last case was reported on 24 Oct 2021.

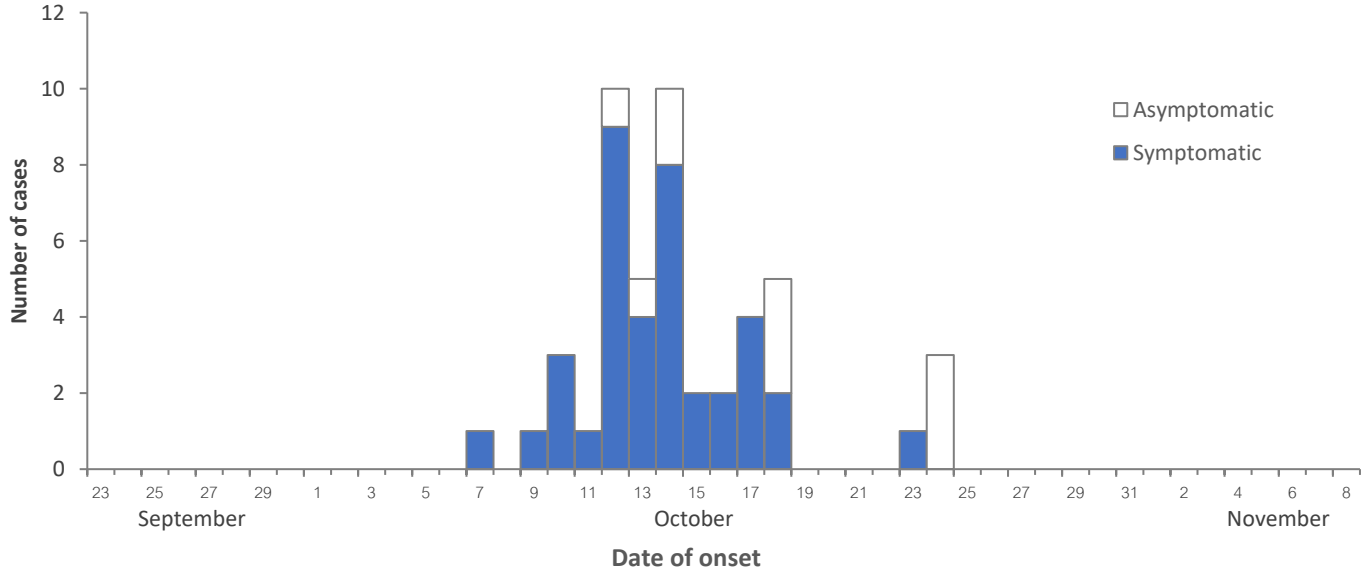


Figure 1. Distribution of COVID-19 cases by onset/detected date in a football academy from 23 Sep–7 Nov 2021 (n=48)

Epidemiological Characteristics of the Outbreak

From September to November 2021, there were 48 confirmed COVID-19 cases in school M giving an overall attack rate of 22.4% (48/214). Table 1 presents demographic and clinical characteristics of the cases. The median age was 14 years (interquartile range (IQR) 12–17 years) and the female to male ratio was 1.29:1. One case had an underlying disease (glucose-6-phosphate dehydrogenase deficiency). The cases consisted of 27 female and 21 male football players. No case was detected among coaches, staff, basketball players, teachers, nor administrative officers. The gender-specific attack rate was 45.8% in female football players (27/59) and 17.5% in male football players (21/120).

Table 1. Demographic and clinical characteristics of COVID-19 cases (n=48)

Characteristics	n (%)
Age group (years)	
12–14	25 (52.1%)
15–17	23 (47.9%)
Median age (IQR)	**14 (12–17)**
Gender	
Female	27 (56.2%)
Male	21 (43.8%)
Female to male ratio	**1.29:1**
Underlying disease	
Yes	1 (2.1%)
No	47 (97.9%)

IQR: interquartile range

Most (77.1%) cases were symptomatic with the main symptoms being cough (62.2%), sore throat (56.8%), fever (40.5%), rhinorrhea (35.9%), and headache (33.3%). Other symptoms included secretions, anosmia, ageusia and myalgia. All cases were taken to a field hospital. There were no severe cases and no deaths reported. The median cycle threshold level for the RdRp gene was 21.59 (IQR 14.70–27.67) and for the N and E genes was 23.48 (IQR 16.39–29.07), and 22.64 (IQR 15.58–28.01), respectively.[21] On 5 Oct 2021, all 48 cases received a single dose of the BNT162b2 vaccine, with 16, 26, and four developing symptoms or vaccine side effects between 0–7 days, 8–14 days, and 15–21 days after vaccination, respectively.

Environmental Study

All football players and staff were living in the football academy at school M. Every morning, staff would screen the players for signs of fever and respiratory symptoms. If someone showed symptoms, staff would transport them to a hospital for further investigations.

Daily activities at the academy included two hours of group exercise per day, two hours of football practicing per day, and six hours of online studying per day. Players did not wear masks during group exercises or football practice. Inactive players gathered in groups on the sidelines.

At the academy, common areas have multipurpose tables, water dispensers, and toilets. The multipurpose tables are used for dining, studying, and relaxing (such as group conversations and playing cellphone games). During meal times the players are closely seated at the dining table. Separate times are allocated for males and females and the table is cleaned after use with alcohol spray. The press botton of the water dispenser and the drinking glasses are shared. There are separate toilets for males and females but there are no private bathrooms. Almost all bathrooms have a water retainer, bowl, faucet, and water closet. The bathrooms are cleaned twice a week.

There are 12 shared bedrooms, of which five are designated for females (8–15 per room) and seven for males (12–24 per room). All bedrooms contain air conditioners and the spacing between the beds ranges from 0–0.5 meters. The air-conditioning is usually on while the players are in their bedrooms. A mop with floor cleanser is used to clean the bedroom floors daily. There are no isolation or quarantine rooms at the academy.

On the investigation day, we collected 28 samples from surface areas for RT-PCR testing for SARS-CoV-2. All samples were collected before cleaning the areas. We selected three bedrooms (two females, one male) based on the ones with the highest attack rates on the investigation day. We collected five samples from each of the bedrooms; one each from a light switch, floor, bedrail, doorknob, and air-conditioning outlet. We collected nine samples from three of the toilets (two females, one male); three each from the toilet bowls, faucet handles, and seat cover surfaces. We collected four samples from two side table surfaces and the press buttons from two water dispensers. All specimens tested negative for SARS-CoV-2.

Table 2 provides detailed characteristics of each of the 12 bedrooms at the academy. The median (IQR) density was 1.5 (1.3–1.6), air changes per hour (ACH) was 7.33 (2.05–21.19), and the attack rate was 19.5% (6.6–39.4).

Table 2. Characteristics of bedrooms in the football academy

Room	Area (m^2)	Volume (m^3)	Airflow rate (m^3/hr)	Ventilation rate (m^3/hr/person)	ACH (L/hr)	Crowd density (person/4 m^2)	Specific attack Rate (%)
1F	48.0	132.1	2,592	216.00	19.62	1.00	16.67 (2/12)
2F	38.6	109.5	3,924	301.85	35.83	1.35	53.85 (7/13)
3F	40.2	108.4	252	16.80	2.32	1.49	86.67 (13/15)
4F	28.1	75.6	2,556	232.36	33.79	1.56	45.45 (5/11)
5F	28.1	75.6	1,692	211.50	22.39	1.14	0.00 (0/8)
1M	48.0	102.6	756	63.00	7.37	1.42	33.33 (4/12)
2M	37.1	112.9	144	12.00	1.28	2.37	18.18 (4/22)
3M	37.1	102.6	2,052	136.80	19.99	1.63	13.33 (2/15)
4M	44.8	137.6	396	19.80	2.88	1.79	30.00 (6/20)
5M	36.7	123.9	180	12.86	1.45	1.53	0.00 (0/14)
6M	39.2	118.4	864	66.46	7.30	1.33	0.00 (0/13)
7M	60.0	160.7	288	12.00	1.79	1.60	20.83 (5/24)
Median	38.9	111.2	810	64.73	7.33	1.51	19.50
(IQR)	(36.9–46.4)	(102.6–128)	(270–2340)	(14.83–213.8)	(2.05–21.19)	(1.34–1.62)	(6.66–39.39)

M: male, F: female, ACH: air changes per hour

There was no association between any of the bedroom characteristics and bedroom-specific attack rates. However, among female bedrooms, the density had a positive linear relationship (r=0.77) with the specific attack rate. From the linear regression the relationship was not statistically significant (regression coefficient 109.96, *p*-value 0.130) (Figure 2).

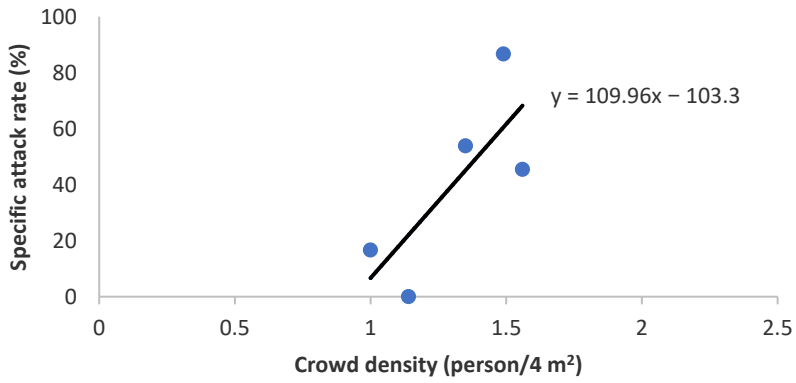


Figure 2. Scatter plot showing the relationship between crowd density and specific attack rate among female bedrooms. The black line represents fitted values from a linear regression model (n=5)

Risk Factors of Being a COVID-19 Case in the Football Academy

Of all 179 football players at the academy, 176 responded to the online survey and none reported ever being infected with COVID-19. Overall, 48 (27.3%) players were infected with COVID-19. Univariate analysis showed that factors associated with being a COVID-19 case were female gender (incidence rate ratios (IRR) 3.57, 95% CI 2.01–6.31), being a high-risk close contact of the primary case (IRR 7.85, 95% CI 4.42–13.93), and mask-wearing (IRR 0.40, 95% CI 0.17–0.93).

Results of the multivariate analysis are shown in Table 3. Significant factors associated with being a case were being a high-risk close contact of the primary case (adjusted incidence rate ratios (AIRR) 5.36, 95% CI 2.22–12.94), bedroom density (AIRR 2.42, 95% CI 1.14–5.15), and wearing a face mask (AIRR 0.32, 95% CI 0.13–0.80).

Table 3. Risk factors of being a COVID-19 case in the football academy (Poisson regression)

Factors	Exposure		Non-exposure		IRR (95% CI)	AIRR (95% CI)
	cases	non-cases	cases	non-cases		
Female	27	32	21	96	3.57 (2.01–6.31)	2.57 (0.99–6.72)
Age >15 years	13	43	35	85	0.74 (0.39–1.41)	-
High-risk close contact of the primary case	20	8	28	120	7.85 (4.42–13.93)	5.36 (2.22–12.94)
Bedroom density >1.45 person/4 m^2	35	97	13	31	0.74 (0.33–1.68)	2.42 (1.14–5.15)
Wearing a face mask	42	122	6	6	0.40 (0.17–0.93)	0.32 (0.13–0.80)
Distancing	47	125	1	3	1.10 (0.15–7.95)	-
Hand washing before touching environment and others	45	124	3	4	0.52 (0.16–1.67)	-
Hand washing after touching environment and others	46	123	3	6	0.77 (0.24–2.47)	-
Dining with others	31	78	15	49	1.31 (0.71–2.43)	-
Sharing drinking glasses	32	67	16	61	1.73 (0.95–3.16)	1.78 (0.95–3.34)
Sharing spoon and folk	15	33	33	95	1.29 (0.70–2.38)	-
Buying delivery food	34	74	12	53	1.92 (0.99–3.70)	-
Go outside training camp	8	16	40	112	1.35 (0.63–2.89)	-

IRR: incidence rate ratios, AIRR: adjusted incidence rate ratios

Discussion

A cluster of COVID-19 cases in a football academy at a school in Buri Ram Province was confirmed. The overall attack rate was 22.4%. All cases were football players and the median age was 14 years. Females had a higher specific attack rate than males (45.8% versus 17.5%). A previous study showed no significant gender differences in susceptibility to COVID-19 infection.[19] Our study found that females had a higher specific attack rate, which was likely because the initial infection occurred among the female football players. Additionally, we investigated and provided control measures when the disease initially spread among the males.

Most cases were symptomatic; the most common symptoms being cough, sore throat, and fever. Symptoms of COVID-19 differ between studies.[9,20,21] The proportion of asymptomatic children and young people ranges from 14.6% to 42% based on a systematic review, and the most common symptoms are fever (46–64.2%) and cough (32–55.9%) with sore throat being less common.[9] A study from the United Kingdom reported that the most common symptoms in children aged 12–17 years were headache (65.9%), fatigue (60.7%), sore throat (51.0%), anosmia (48.3%), and fever (34.6%).[20]

The primary case was a female football player who developed symptoms on 7 October, two days before any other players became symptomatic. The source of infection for this local outbreak was unknown. Two asymptomatic cases had COVID-19 detected with a high cycle threshold value after the primary case was detected. We only used a single RT-PCR for diagnosis testing; therefore, we could not be certain that they had a prior or recent infection.[22] The serial trend of cycle threshold values can predict likely individual infectiousness.[23]

The lack of staff awareness contributed to the delay in outbreak detection and control. Additionally, we found that this cohort had close physical activities with each other, and personal protective equipments were not used, which may have contributed to disease spread.[24] Environmental factors may also have contributed to the spread of disease since the bedrooms were poorly ventilated and over-crowded.[16,17,25] The football academy did not follow the Department of Health's recommended measures for schools[5] or sports venues.[6,7] All bedrooms were over-crowded due to their crowd density more than one person per four square meters (m^2).[26] We found that among female bedrooms, density was positively related to the attack rate. Airflow rate, ventilation rate, and ACH were not associated with attack rate in this study, probably because we measured these parameters when all bedrooms were ventilated. Usually, the bedrooms at this academy were closed with no air ventilation, although air-conditioners would be operating, therefore ventilation rate and air change rate per hour was very low. We recommended to the staff at the academy that the ACH

value should be at least 4.0 and the air ventilation rate should be more than 10 liters/second/person (36 m^3/hr per person).[26,27] Because all bedrooms had a density of more than the recommended value (less than 1 person/4 m^2), we defined a crowded bedroom as a bedroom that had a density of more than 1.45 person/4 m^2 for determination of risk factors.[26] The operative cut-off value was designed to find a recommended value that could be applied in this or similar settings.

Risk factors of being a COVID-19 case in the football academy on multivariate analysis were being a high-risk close contact of the primary case, bedroom density (>1.45 person/4 m^2), and lack of mask-wearing. A previous cohort study identified a higher secondary clinical attack rate and seroprevalence in household contacts than workplace contacts and social connections.[28] In this academy, football players lived in shared bedrooms, which were more like household settings. Also, close physical proximity is a known risk factor for SARS-CoV-2 transmission. In the bedrooms, the distance between beds was less than 0.5 meters, making it difficult to adhere to physical distancing and avoid direct conversation. Among the mask-wearing group, mask-wearing reduced 68% of COVID-19 cases that would occur if those did not wear masks.[29] Non-N95 type masks can also reduce the risk of infection and disease.[30]

Limitations

Our study has a few limitations. First, behavior and risk factor information was self-reported, which can introduce information bias. Second, ventilation measures did not suit this outbreak situation; thus, we could not provide more details about the association between air ventilation and COVID-19 infection in this outbreak. Third, confirmed cases with high cycle threshold levels (>30) diagnosed early in the outbreak did not receive a follow-up test, therefore we could not differentiate between prior and recent infection. Lastly, we did not identify the virus variants.

Recommendations

Sports academies and schools should encourage mask-wearing during an outbreak, ensure that rooms, especially bedrooms, have a density of less than 1.45 person/4 m^2, and provide isolation or quarantine rooms.

Conclusion

We report a cluster of COVID-19 cases in a football academy at a school in Buri Ram Province, Thailand, between September and November 2021, comprised of 48 confirmed cases (attack rate 22.4%). The source of this outbreak could not be identified. The risk factors of being a case were being a high-risk close contact of the primary case and over-crowded bedrooms. Mask-wearing was a protective factor.

Acknowledgment

We would like to thank the health team from Buriram Hospital, Buri Ram Town Municipality, Buri Ram Provincial Health Office, Office of Disease Prevention and Control 9, and the football coaches and players of the investigated academy.

Suggested Citation

Sornsurin W, Boonrampai K, Srisopha R, Sophon P, Porntanakulapat S, Saisood J, et al. Investigation of a COVID-19 cluster in a football academy of Buri Ram, October 2021. OSIR. 2023 Mar;16(2):63–71. doi:10.59096/osir.v16i2.263761.

References

1. Department of Disease Control. DDC coronavirus disease (COVID-19) dashboard [Internet]. Nonthaburi: Department of Disease Control (TH); 2021 [cited 2022 Feb 19]. <https://ddc.moph.go.th/covid19-dashboard/>. Thai.
2. Regulation. Issued under Section 9 of the Emergency Decree on Public Administration in Emergency Situations B.E. 2548 (2005) (Number 32). Royal Thai Government Gazette Volume 138, Section 170 D, special (dated 28 August B.E. 2564)
3. Bureau of Risk Communication and Health Behavior Development. The Department of Disease Control is ready to support COVID-19 vaccines for students starting this October [Internet]. Nonthaburi: Department of Disease Control, Ministry of Public Health (TH); 2021 Sep 13 [cited 2022 Feb 19]. <https://ddc.moph.go.th/brc/news.php?news=20605&deptcode=brc&news_views=24549> Thai.
4. Wichanon A. The Ministry of Education of Thailand announced the reopening of schools on May 1st. [Internet]. Bangkok: Ministry of Education (TH); 2021 Oct 28 [cited 2022 Feb 19]. <https://moe360.blog/2021/10/28/open-semester-1nov/>. Thai.
5. Criteria for opening a school or educational institution. Regulation. Issued under Section 9 of the Emergency Decree on Public Administration in Emergency Situations B.E. 2548 (2005) (Number 32 section 5(1)). Ministry of Education, Thailand. (dated 20 September B.E. 2564)

6. Ministry of Public Health. COVID Free Setting for Indoor stadium and gym [Internet]. Nonthaburi: Department of Health, Ministry of Public Health (TH); 2021 Sep 27 [cited 2021 Feb 19]. 2 p. <https://covid19.anamai.moph.go.th/web-upload/2xdccaaf3d7f6ae30ba6ae1459eaf3dd66/m_document/6740/35258/file_download/90bcdad99a1f20c8838099fab2d81150.pdf>. Thai.

7. Department of Health, Ministry of Public Health. COVID Free Setting for outdoor sports and park [Internet]. Nonthaburi: Department of Health, Ministry of Public Health (TH); 2021 Aug 31 [cited 2021 Feb 19]. 2 p. <https://covid19.anamai.moph.go.th/web-upload/2xdccaaf3d7f6ae30ba6ae1459eaf3dd66/m_document/6740/35248/file_download/8bd8caa6c11897f8db89e24868f78eed.pdf>. Thai.

8. Operational Data Team, Division of Epidemiology, Department of Disease Control (TH). COVID-19 cluster situation. Nonthaburi: Department of Disease Control, Ministry of Public Health (TH); 2021. Unpublished internal organization report.

9. Viner R, Ward J, Hudson L, Ashe M, Patel S, Hargreaves D, et al. Systematic review of reviews of symptoms and signs of COVID-19 in children and adolescents. Arch Dis Child. 2020 Dec 17;106(8):802–7. doi:10.1136/archdischild-2020-320972.

10. MCRI COVID 19 Governance Group. Research brief: COVID-19 and child and adolescent health [Internet]. Victoria (AU): Murdoch Children's Research Institute; 2021 Sep 13 [cited 2022 Feb 9]. 6 p. <https://www.mcri.edu.au/sites/default/files/media/documents/covid-19-and-child-and-adolescent-health-140921.pdf>

11. Siebach MK, Piedimonte G, Ley SH. COVID-19 in childhood: transmission, clinical presentation, complications and risk factors. Pediatr Pulmonol. 2021 Jun;56(6):1342–56. doi:10.1002/ppul.25344.

12. Katz SE, McHenry R, Mauer LG, Chappell JD, Stewart LS, Schmitz JW, et al. Low in-school COVID-19 transmission and asymptomatic infection despite high community prevalence. J Pediatr. 2021 Oct;237:302-306.e1. doi:10.1016/j.jpeds.2021.06.015.

13. Nelson S, Dugdale C, Bilinski A, Cosar D, Pollock N, Ciaranello A. Prevalence and risk factors for in-school transmission of SARS-CoV-2 in Massachusetts K-12 public schools, 2020-2021. medRxiv [Preprint]. 2021 Sep 26 [cited 2022 Feb 19]. <https://doi.org/10.1101/2021.09.22.21263900>

14. National Center for Immunization and Respiratory Diseases, Division of Viral Diseases. Schools and childcare programs [Internet]. Atlanta (GA): Centers for Disease Control and Prevention (US); 2022 [updated 2023 Apr 13, cited 2023 Jun 13]. <https://www.cdc.gov/coronavirus/2019-ncov/science/science-briefs/transmission_k_12_schools.html>

15. Boutzoukas AE, Zimmerman KO, Benjamin DK, DeMuri GP, Kalu IC, Smith MJ, et al. Secondary transmission of COVID-19 in K–12 schools: findings from 2 states. Pediatrics. 2022 Feb 1;149(12 Suppl 2):e2021054268K. doi:10.1542/peds.2021-054268K.

16. Akaishi T, Kushimoto S, Katori Y, Kure S, Igarashi K, Takayama S, et al. COVID-19 transmission in group living environments and households. Sci Rep. 2021 Jun 2;11(1):11616. doi: 10.1038/s41598-021-91220-4.

17. Rashedi J, Mahdavi Poor B, Asgharzadeh V, Pourostadi M, Samadi Kafil H, Vegari A, et al. Risk factors for COVID-19. Infez Med. 2020 Dec 1;28(4):469–74.

18. Bureau of Environmental Health. Operational manuals for indoor air quality assessment [Internet]. Nonthaburi: Bureau of Environmental Health, Department of Health, Ministry of Public Health (TH); 2016 [cited 2021 Feb 19]. 83 p. <https://ghh.anamai.moph.go.th/storage/app/uploads/public/603/b5b/072/603b5b0720697166916487.pdf>. Thai.

19. Mukherjee S, Pahan K. Is COVID-19 gender-sensitive? J Neuroimmune Pharmacol. 2021 Mar;16(1):38–47. doi:10.1007/s11481-020-09974-z.

20. Molteni E, Sudre CH, Canas LS, Bhopal SS, Hughes RC, Antonelli M, et al. Illness duration and symptom profile in symptomatic UK school-aged children tested for SARS-CoV-2. Lancet Child Adolesc Health. 2021 Oct;5(10):708–18. doi:10.1016/S2352-4642(21)00198-X.

21. Christophers B, Gallo Marin B, Oliva R, Powell WT, Savage TJ, Michelow IC. Trends in clinical presentation of children with COVID-19: a systematic review of individual participant data. Pediatr Res. 2022 Feb;91(3):494–501. doi:10.1038/s41390-020-01161-3.

22. Fox-Lewis A, Fox-Lewis S, Beaumont J, Drinkovic D, Harrower J, Howe K, et al. SARS-CoV-2 viral load dynamics and real-time RT-PCR cycle threshold interpretation in symptomatic non-hospitalised individuals in New Zealand: a multicentre cross sectional observational study. Pathology. 2021 Jun;53(4): 530–5. doi:10.1016/j.pathol.2021.01.007.

23. Jefferson T, Spencer EA, Brassey J, Onakpoya IJ, Rosca EC, Pluddemann A, et al. Transmission of severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) from pre and asymptomatic infected individuals: a systematic review. Clin Microbiol Infect. 2022 Feb;28(2):178–89. doi:10.1016/j.cmi.2021.10.015. Epub 2021 Oct 29.

24. Centers for Disease Control and Prevention (US). Coronavirus disease (COVID-19): cleaning and disinfecting your facility [Internet]. Atlanta (GA): Centers for Disease Control and Prevention (US); 2022 [cited 2022 Feb 19]. <https://www.cdc.gov/coronavirus/2019-ncov/community/disinfecting-building-facility.html>

25. World Health Organization. Coronavirus disease (COVID-19): ventilation and air conditioning [Internet]. Geneva: World Health Organization; 2021 Dec 23 [cited 19 Feb 2022]. <https://www.who.int/news-room/questions-and-answers/item/coronavirus-disease-covid-19-ventilation-and-air-conditioning>

26. Department of Health, Ministry of Public Health (TH); Indoor Air Quality Association. Ventilation instructions to prevent the spread of COVID-19 [Internet]. Nonthaburi: Department of Health, Ministry of Public Health (TH); 2021 Jun 1 [cited 2022 Feb 14]. 5 p. <https://covid19.anamai.moph.go.th/web-upload/2xdccaaf3d7f6ae30ba6ae1459eaf3dd6/m_document/6736/35234/file_download/73e5e3a500c252afc224d0b6085c59dd.pdf>. Thai.

27. Allen JG, Ibrahim AM. Indoor air changes and potential implications for SARS-CoV-2 transmission. Jama. 2021 May 25;325(20): 2112–3. doi:10.1001/jama.2021.5053.

28. Ng OT, Marimuthu K, Koh V, Pang J, Linn KZ, Sun J, et al. SARS-CoV-2 seroprevalence and transmission risk factors among high-risk close contacts: a retrospective cohort study. Lancet Infect Dis. 2021 Mar;21(3):333–43. doi:10.1016/S1473-3099(20)30833-1.

29. Shield KD, Parkin DM, Whiteman DC, Rehm J, Viallon V, Micallef CM, et al. Population attributable and preventable fractions: cancer risk factor surveillance, and cancer policy projection. Curr Epidemiol Rep. 2016 Sep;3(3): 201–11. doi:10.1007/s40471-016-0085-5.

30. Hemmer CJ, Hufert F, Siewert S, Reisinger E. Protection from COVID-19: the efficacy of face masks. Dtsch Arztebl Int. 2021 Feb 5;118(5): 59–65. doi:10.3238/arztebl.m2021.0119.