Optimization of surveillance effectiveness for smart attendance based all-cause absenteeism: a longitudinal study, China, September 2021 to June 2022

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Research Article

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Abstract

Background

Although smart attendance can only collect all-cause-absenteeism, which is conductive to the modernization of syndromic surveillance system (SSS). It is of great significance to optimize all-cause-absenteeism. The aim of this study was to choose appropriate standard for absenteeism and effective indicators for the face-recognition-based SSS (FRSSS).

Methods

Two primary schools in Hangzhou, China participated in this study. Grades 1-2 (DARL), 3-6 (DARH), and school-wide (DARX) all-cause-absenteeism reported by FRSSS, and all-cause (DARY) and sickness absenteeism (DARZ) reported by school physicians, were daily collected from September, 2021, to June, 2022, and their surveillance effectiveness were compared by by correlations, time series, and control charts.

Results

The time standard of absenteeism was "$\geq 24$ hours" for DARY and DARZ, while "$\geq$ one hour" for DARX, DARL and DARH. DARY and DARZ were 32.6% and 25.2% of DARX. The correlation between DARY and DARZ was 0.843 ($P<0.001$) in school A and 0.933 ($P<0.001$) in school B. Yoden indexes of DARL, DARH, DARX, DARY and DARZ were 83.0%, 85.0%, 80.6%, 78.2% and 80.4% in school A, and 89.3%, 91.0%, 83.9%, 76.8% and 81.0% in school B, respectively.

Conclusions

The surveillance effectiveness of all-cause-absenteeism could be raised to considerable level by setting reasonable standard and adopting multi-level indicators. It is feasible and effective to popularize smart attendance in school-oriented SSSs.

Background

Absenteeism is a core indicator in the school-oriented infectious disease syndromic surveillance system (SSS). Since Peterson et al. [1] revealed in 1979 that absenteeism is closely related to levels of influenza activity, the absenteeism-based SSS has been popularized around the world due to its non-invasiveness, low cost, high sensitivity, and ability to promote effective collaboration between the education and health sectors [1-5]. Absenteeism can be classified into all-cause, sickness and syndrome-specific absenteeism [6]. Generally, the latter two are more specific for infectious disease surveillance, while all-cause absenteeism is only considered as an alternative option when resources are insufficient [6,7].
In China, the absenteeism-based SSS was established in 2006 first [8], with the pandemic of new H1N1 promoting further popularization of this system. The existing absenteeism-based SSSs are nearly all based on sickness or syndrome-specific absenteeism reported by school physicians. However, with the penetration of about 33.1% of school physicians [9], it is difficult to support the effective operation of this system. Meanwhile, homogeneity in standard implementation is difficult to maintain with manual collection of absenteeism. The existing absenteeism-based SSSs have exposed many data quality problems, such as missing data, misreporting and concealment of data [10]. As Baer et al. [11] pointed out, absenteeism-based SSSs should balance specificity and burden, otherwise the quality of data collection cannot be effectively guaranteed. Consequently, replacing manual absenteeism collection of school physicians with innovative methods is crucial.

Two technical paths for replacement have been explored. One is the crowd-sourcing method, such as inviting parents or students to report absenteeism online to disperse the burden of school [12,13]. However, this method is difficult to constraint reporters’ behavior and control the data quality. The other is to utilize intelligent attendance technology, such as fingerprint [14], smart card [15], or face recognition [16] to automate the data collections. Only all-cause absenteeism could be collected by these techniques currently, but they enable the data collection to be uniform in standards, rich in dimensions, and objective in contents. Although studies have suggested that all-cause absenteeism is less specific than sickness and syndrome-specific absenteeism in epidemic surveillance, their conclusions are not based on the similar time standard of absenteeism [6]. Actually, if loss in effectiveness is acceptable, the surveillance based on all-cause absenteeism with automation will have better value of application.

Our team piloted a facial-recognition-based SSS (FRSSS) in March, 2021, and demonstrated that the completeness and accuracy of the data collected by FRSSS was reliable [16]. This study addressed two issues: (1) How to choose an appropriate time standard for absenteeism; (2) How to construct the indicator system for FRSSS with the best outbreak detection. Two primary schools in Zhejiang Province, China were selected as surveillance population. Absenteeism of the two schools reported by school physicians and FRSSS was collected from September 2021 to June 2022, and the effectiveness of epidemic detection for five indicators with different time standard and attributes was compared. Our work would lay a foundation for the modernization of SSS.

## Methods

**The FRSSS**

FRSSS is based on an application named *Xiaolianxing*. The data flow of FRSSS is as follows: First, under the school administration, parents download the application on Alipay with smart phones, register a free account and input information such as the identity and face image of the child into the account. Second, the service provider builds the student identity information base at different levels: individual, class, grade and school. Then, the service personnel install the face recognition instrument (Identification accuracy ≥ 99.99%, Sunmi Technology Group Co., Ltd.) to the school gate, and students are tested daily...
under the supervision of a duty officer. Finally, the data such as whether to test and test time are uploaded to the data processing center immediately, and the center assesses the attendance status of students on that day and creates statistics according to different levels. These results will be fed back to users in real time. Absenteeism-based surveillance may serve various objectives, including those related to a given affected school or to the broader community [17], and the FRSSS orients to the former.

**Surveillance population**

Two primary schools in Hangzhou, Zhejiang Province, China were selected as the study population. Schools A and B are located in Xiaoshan and Binjiang District, respectively. The study spanned the 2021 to 2022 academic year. In semester one, the total number of students was 3111, of which 3110 registered in FRSSS, with a registration rate of 99.96%. In semester two, the total number was 3118, of which 3118 students registered in FRSSS, with a registration rate of 100% (Table 1). The number of students in a class ranged from 40 to 45, with an average of 42 students per class in this academic year.

| Table 1 Composition of students from grades 1-6 in schools A and B. |

**Data collection**

In semester one, the effective surveillance time of school A was 92 days (September 1, 2021 to January 14, 2022), and that of school B was 77 days (September 22, 2021 to January 14, 2022); in semester two (February 21, 2022 to June 24, 2022), the effective time was 86 days in school A and 82 days in school B. Data included:

1. Daily absenteeism reported by FRSSS. The data, which was exported from the FRSSS background, includes information such as class, grade, school and time of day of the students who are absent each day. If a student is not tested within one hour of the scheduled arrival time for each school, FASSS will consider them absent. Both schools are voluntarily using FRSSS for COVID-19 prevention and control.

2. Daily absenteeism reported by school physicians. This absenteeism was manually collected by school physicians and included information such as class, grade, school and detailed reasons for absence. The standard of absence reported by the school physicians was "the student is not in school all day". Based on the information provided by school physicians on the reasons for absences, absences were classified as all-cause and sickness. A student identified as sickness absence was reported to have a diagnosis of a medical condition or a symptom (i.e., fever, cough, diarrhea, fatigue), not because he was absent due to personal leave or unintentional injury. The school physician's reporting of absenteeism was mandatory by the local government.

**Data analysis**

First, the total daily all-cause absence rate (DARX) and the absenteeism for six grades (DAR1-DAR6) of the two schools were calculated based on the information reported by FRSSS. According to the factor
analysis results, DAR1-DAR6 was divided into two levels: grades 1-2 (DARL) and grades 3-6 (DARH). Simultaneously, the total daily all-cause (DARY) and sickness absenteeism (DARZ) for the two schools were calculated based on school physicians' collection (Table 2). The formulas were as follows:

\[
DARX = \frac{\text{Number of absent students reported daily by FASSS}}{\text{Number of students registered in FASSS}} \times 100%
\]

\[
DARY = \frac{\text{Number of absent students reported daily by school physicians}}{\text{Total number of students in the school}} \times 100%
\]

\[
DARZ = \frac{\text{Number of sickness absence reported daily by school physicians}}{\text{Total number of students in the school}} \times 100%
\]

Second, correlations between DARX, DARY and DARZ were analyzed, and the consistency of variables such as DARL, DARH, DARX, DARY and DARZ was examined using time series (Figure 1). Finally, three indicators (i.e., sensitivity, specificity and Youden index) of DARL, DARH, DARX, DARY, and DARZ were analyzed to epidemic detection (Table 3), in combination with quality control charts (Figure 2-4) and epidemic outbreak investigation. Sensitivity is defined as the proportion of alerts that the system sends out that are true outbreaks, specificity refers to the proportion of events that the system evaluates to be non-outbreak in routine epidemic level surveillance data for infectious diseases, and Youden index is equal to sensitivity plus specificity minus 100% [18]. According to the information provided by school physicians, an outbreak would be considered if the number of absent students in a day reached the following standard: (1) More than one newly confirmed infectious disease case; (2) Number of students with similar epidemiologically relevant symptoms (ERSs) ≥ 4 within a class; (3) Number of students with ERSs ≥ 19 in school A or ≥ 10 in school B. ERSs include fever, cough, headache, sore throat, enlarged parotid gland, abdominal pain, diarrhea, vomiting, rash, dizziness, weakness and conjunctival congestion [19].

Ethics approval

Data used in this study were anonymized, so the Jingganshan University Review Board classified this study as nonhuman subject research, and it was exempted from approval.

Results

Characteristics of different absenteeism

Results showed that the dynamic trend of absenteeism versus grade decreased first and then increased. DAR1 was the highest in both schools, and the lowest absenteeism was DAR4 in school A and DAR5 in school B (Table 2).

Table 2 Descriptive statistics of daily absence rates reported by FRSSS and school physicians.
Among the six pair differences in absenteeism between school A and B, differences in grade three and four were the most prominent, and each exceeding one percentage point. The two schools were relatively close in DARX, separated by 0.3 percentage points ($t=2.503$, $P=0.013$), however, the gaps of DARY and DARZ between school A and B were larger, with the values of school B being more than twice that of school A.

According to the correlation matrix of absenteeism in six grades, factor analysis was performed by the principal component method, and the factor rotation method was maximal variance rotation. Two factors (i.e., grades 1-2 and 3-6) could be selected from this analysis in school A, which explained 62.2% of the total variation. Two factors (i.e., grades 1-2 and 3-6) could also be selected from this analysis in school B, which explained 64.4% of the total variation. Considering that the human immune system approaches maturation at about 8 years old [20], students at this age are in grade 3 in China. Therefore, absenteeism reported by FRSSS for the six grades can be divided into two levels: grades 1-2 and grades 3-6. The former was recorded as DARL, and the latter was recorded as DARH. Whether in school A ($t=10.466$, $P<0.001$) or B ($t=5.731$, $P<0.001$), DARL was significantly higher than DARH.

**Correlation of different absenteeism**

For school A, there were 9466 all-cause absences reported by FRSSS and 2609 all-cause absences reported by school physicians (of which 1811 were due to sickness). Accordingly, DARY and DARZ were 27.5% and 19.1% of DARX, respectively, while DARZ was 70.5% of DARY. For school B, FRSSS reported 6787 all-cause absences and school physicians reported 2652 all-cause absences (of which 2278 were due to sickness). Accordingly, DARY and DARZ accounted for 39.5% and 33.6% of DARX, respectively, while DARZ for 84.9% of DARY. Combined, DARY and DARZ were 32.6% and 25.2% of DARX, respectively, while DARZ was 77.3% of DARY.

For school A, DARX and DARY ($r=0.398$, $P<0.001$), DARX and DARZ ($r=0.225$, $P<0.001$), and DARY and DARZ ($r=0.843$, $P<0.001$) were all significantly correlated. For school B, DARX and DARY ($r=0.486$, $P<0.001$), DARX and DARZ ($r=0.483$, $P<0.001$), and DARY and DARZ ($r=0.933$, $P<0.001$) were also significantly correlated. Between school A and B, the correlations of two DARLs ($r=0.148$, $P=0.115$), DARXs ($r=0.079$, $P=0.296$) and DARZs ($r=0.103$, $P=0.197$) were not significant, while the correlations of two DARHs ($r=0.464$, $P<0.001$) and DARYs ($r=0.321$, $P<0.001$) were significant. Data showed a clear gap between school A and B in the trend of five indicators (DARL, DARH, DARX, DARY, and DARZ) over time (Figure 1); however, the time series of these five indicators were relatively consistent in the same school.

For school A, it could be observed that there was an obvious divergence between the time-series of indicators reported by FRSSS (DARL, DARH and DARX) and those reported by school physicians (DARY and DARZ) during May 2022. For school B, a similar divergence took place during November 2021. According to the information provided by school physicians, we investigated that there was a severe influenza outbreak in school B during November 2021 and a serious pertussis epidemic in school A during May 2022. After excluding the data from these two periods, DARX’s correlation with DARY and
DARZ significantly increased: two coefficients were 0.672 (P<0.001) and 0.443 (P<0.001) for school A, and 0.910 (P<0.001) and 0.914 (P<0.001) for school B.

Comparison of surveillance effectiveness among indicators

For school A, the effective surveillance time was 178 days, of which 49 days (39 days for grades 1-2 and 27 days for grades 3-6) showed infectious disease outbreaks. According to the control charts of DARX, DARY and DARZ (Figure 2), the days to meet the warning standard (i.e., three standard deviations above the average) were 18 days, 13 days, and 10 days, respectively. Meanwhile, the time when the above three indicators sent out the warning signal simultaneously was only four days.

For school B, the effective surveillance time was 159 days, of which 44 days (34 days for grades 1-2 and 28 days for grades 3-6) showed outbreaks. According to the charts of DARX, DARY and DARZ (Figure 3), the days to meet the warning standard were 22 days, 16 days and 17 days, respectively. Meanwhile, the time when the above three indicators sent out the warning signal simultaneously was 15 days. There was only one day (December 14, 2021) when DARX, DARY and DARZ from both schools issued the warning signal simultaneously. After splitting DARX into DARL and DARH, the time for these two indicators to meet the warning standard was 20 and 14 days at school A, 19 and 15 days at school B, respectively. Either at school A (14-17, December, 2021) or B (November 15, December 13, 14, 17, 2021), the time when DARL and DARH issued outbreak signal simultaneously was four days (Figure 4).

According to the detailed information reported by school physicians, all dates of infectious disease outbreaks in school A and B were identified from September 1, 2021 to June 24, 2022. Then, based on the warning dates shown in Figures 2-4, the surveillance accuracy of DARL, DARH, DARX, DARY and DARZ was calculated for the detecting of infectious disease outbreak in the two schools. Whether in school A or B, the data showed that indicators reported by FRSSS (DARX) outperformed indicators reported by school physicians (DARY and DARZ) in the accuracy of infectious disease surveillance, meanwhile the separation of DARX into DARL and DARH resulted in a significant increase in the specificity and Youden index (Table 3).

Table 3 Infectious disease surveillance effectiveness of different absenteeism indicators.

Discussion

This study resulted in three major findings: (1) When the time standard for absenteeism was set as "≥ 24 hours", DARZ was 77.3% of DARY, the two were highly positively correlated, and their surveillance effectiveness was very close; (2) Adjust the standard from "≥ 24 hours" to "≥ one hour", DARY was 32.6% of DARX, the two were moderately correlated, but DARX's surveillance accuracy was better; (3) After DARX being divided into DARL and DARH, the surveillance accuracy and timeliness of the latter two were higher than that of DARX.
By definition, DARZ was a subset of DARY. The data revealed that DARZ accounted for 77.3% of DARY, and their correlation were as high as 0.843 in school A and 0.933 in school B, respectively. This means that there is a high overlap between all-cause and sickness absenteeism with the time standard being set as \( \geq 24 \text{ hours} \) within primary schools in China. Theoretically, the specificity of all-cause absenteeism is weaker than that of sickness absenteeism. However, some studies agree with this [6,7], others disagree [21]. All-cause absenteeism is easy to obtain the high-quality data for its simplicity, but it is difficult to guarantee the data quality of sickness absenteeism for its complicated record and heavy workload. Therefore, the effectiveness of all-cause absenteeism is not necessarily weaker than that of sickness absenteeism in practice. From the investigation, it could be speculated that the school physician has experienced some interference during data reporting, and similar findings were found in both schools, so we can find that the accuracy of epidemic surveillance was close between DARY and DARZ. As a consequence, we can infer that, when the time standard of absenteeism was set as \( \geq 24 \text{ hours} \), the accuracy of outbreak detection between all-cause and sickness absenteeism was nearly equivalent.

For the time standard of absenteeism, there is no consensus among studies, and no consensus on which standard is superior [6]. By definition, DARY was a subset of DARX. Results revealed that DARX was approximately 3 times DARY, which means two-thirds of the absent students were absent for less than 24 hours, and these results were consistent with the findings of Pan et al. [22]. The sensitivity of surveillance can fall into case detection, epidemic detection and case definition [23]. With wider case coverage, DARX has higher sensitivity of case detection than DARY, which leads to higher sensitivity of epidemic detection. Most Chinese parents attach great importance to studies and do not let their children be absent from school for a longer time than necessary. Consequently, children are less likely to take personal leave and will still go to school when their symptoms are not too severe or return to school after treatment. This could partly explain why DARX did not include more bias when it expanded its case coverage. Another reason may be the automation of absenteeism collection. Absenteeism collected by the FRSSS is less subject to human interference, which makes its data standards more uniform and its data content more objective. In summary, adjusting the standard from \( \geq 24 \text{ hours} \) to \( \geq \text{ one hour} \) may significantly improve the case detection and outbreak detection sensitivity of all-cause absenteeism.

Some studies adopt the total indicator (i.e., school-wide absenteeism) [1-4,6,7,10-16], others choose multi-level indicators (i.e., absenteeism of different grades) [5], but few indicate which approach works better. However, this study suggested that the effectiveness could be improved significantly after the DARX being divided into DARL and DARH. Studies have confirmed significant differences in absenteeism among grades [3-5], and which was verified by this study. More than that, we believed that there was a striking gap in the characteristics between the low-grade (grades 1-2) and high-grade (grades 3-6) absenteeism. Both DARL and DARH had higher sensitivity, specificity and Yoden index than DARX. Meanwhile, combining the information of DARL and DARH could detect epidemic outbreaks earlier than DARX. We think that these results could be attributed to the development of the immune system in children. In general, the immune system reaches maturation at about 8 years old [20], which happens to be the third grade in China. This study also found the evidence as follows: there were differences in the
types, time and intensity of epidemic between students of 1-2 grades and 3-6 grades. Therefore, multi-level absenteeism may have better ability of epidemic awareness than total absenteeism.

Two limitations must be pointed out. First, during the implementation of this study, participating schools were always facing great pressure of COVID-19 prevention. Although which may provide us with a rare opportunity to investigate the characteristics of absenteeism in the context of pandemic, it may have also made the conclusions of this study can not be applicable to common situations. Conclusions of this study still need to be verified on a wider population and extended time periods. Secondly, this study judged the outbreak of infectious diseases based on the data reported by school physicians, but did not investigate the quality of the data itself. The physician's reporting of data is a government-mandated act. Still, the ratio of student physicians at both schools is well above the national standard of 600:1, and the resulting high workload may interfere with the effective reporting of information by school physicians. This is especially true for the physician of school A, because the number of students at A school is 1.7 times that of B school.

**Conclusions**

When the time standard was set as "≥ 24 hours", there was a large overlap between all-cause and sickness absenteeism within primary schools, and their accuracy of epidemic surveillance was similar. If the time standard is adjusted to "≥ one hour", the new-standard-based absenteeism could expand the coverage of cases about three times compared with the original-standard-based absenteeism, and its accuracy of outbreak detection could be significantly improved, too. Under the premise that the standard was "≥ one hour", the total absenteeism could be divided into two secondary indicators with different characteristics: the low-grade (grades 1-2) and high-grade (grades 3-6) absenteeism. The accuracy and timeliness of outbreak detection of these two secondary indicators were superior to those of the total indicator, respectively. It followed that the effectiveness of epidemic surveillance for automatic all-cause absenteeism could be raised to a level close to that of manual sickness absenteeism by setting reasonable time standard and adopting multilevel indicators.

**Abbreviations**

DAR: Daily Absence Rate

DARH: Daily Absence Rate of Grades 1-2 all-cause absenteeism reported by the new system

DARL: Daily Absence Rate of Grades 3-6 all-cause absenteeism reported by the new system

DARX: Daily Absence Rate of school wide all-cause absenteeism reported by the new system

DARY: Daily Absence Rate of all-cause absenteeism reported by school physician

DARZ: Daily Absence Rate of Sickness Absenteeism Reported by School Physician
Declarations

Ethics approval and consent to participate

Data used in this study were anonymized, so the Jinggangshan University Review Board classified this study as nonhuman subject research, and it was exempted from approval.

Consent for publication

Not applicable.

Competing interests

No competing interests in this study.

Funding

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Authors’ contributions

All authors participated in the design of the study. WY W was responsible for the design of the study, carried out the statistical analysis, composed the draft, and was responsible for the subsequent revision of each version. XL H made important contributions to the determination of the research direction, the selection of research methods and the structure of the discussion. Z Y was responsible for the application of research funds, the development of research proposals, the coordination of work with relevant partners, and the revision and finalization of the manuscript. The final manuscript was read and approved by all authors.

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References


## Tables

**Table 1** Composition of students from grades 1-6 in schools A and B.

<table>
<thead>
<tr>
<th>School</th>
<th>Grade</th>
<th>The first semester</th>
<th>The second semester</th>
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<tr>
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<td>Registration</td>
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<tr>
<td></td>
<td>Six</td>
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<td></td>
<td>Six</td>
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<td></td>
<td>Total of school B</td>
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**Table 2** Descriptive statistics of daily absence rates reported by FRSSS and school physicians.
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<th>School B (%)</th>
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<td></td>
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Table 3 Infectious disease surveillance effectiveness of different absenteeism indicators.

<table>
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<th>School</th>
<th>Surveillance indexes</th>
<th>Accuracy of infectious disease surveillance</th>
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<td></td>
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<td></td>
<td>DARZ</td>
<td>100</td>
</tr>
</tbody>
</table>

Figures
Figure 1

Time-series of DARL, DARH, DARX, DARY and DARZ at two schools.
Figure 2
The control charts of DARX, DARY and DARZ for school A.

Figure 3
The control charts of DARX, DARY and DARZ for school B.
Figure 4

The control charts of DARL, DARH for school A and B.