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Digital dashboards as tools for regional influenza monitoring

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Yearly seasonal epidemics of influenza, an acute viral respiratory disease, pose a substantial health burden on all age groups worldwide.[1] In addition, zoonotic influenza viruses circulating in animal populations cause occasional infections in humans. Influenza is a priority disease for regional surveillance in the World Health Organization (WHO) Western Pacific Region, where several zoonotic influenza viruses have infected humans in recent years.[2] Effective risk assessment for influenza is supported through the use of multiple sources of surveillance information. However, bringing together different streams of data and information for analysis can be challenging. Online visualization and analytics tools help to synthesize and disseminate various data sources for risk assessment and public health action. Herein we describe digital dashboards built by the WHO Regional Office for the Western Pacific to share regional influenza data.

Surveillance systems for influenza are well established in many high-income countries, allowing for continuous epidemiological and virological characterization of circulating viruses.[3] Data from these systems are routinely analysed to monitor trends, assess risk, plan interventions and allocate resources.[4] In recent years, many lower- and middle-income countries have established syndromic surveillance systems for influenza that are also generating repositories of epidemiological and virological data.[5]

WHO's Global Influenza Surveillance and Response System (GISRS) collects and collates data on circulating strains of influenza viruses to inform vaccine composition recommendations, conduct risk assessments and monitor antiviral susceptibility.[6] In the Western Pacific Region, GISRS includes 21 National Influenza Centres (NICs) in 15 countries and areas that receive respiratory specimens from a range of sources in their respective countries. NICs upload virologic data to FluNET, a publicly available web-based tool for influenza virological surveillance launched by WHO in 1997. Recently, WHO established FluMART, a global data-sharing platform that links national influenza epidemiological data with virological FluNET data in a single global database. Further efforts are needed to analyse and disseminate these routinely collected data to inform policy and stimulate public health action.

Interactive, web-based surveillance reporting platforms allow users to access timely disease information collected by national surveillance systems and view these data in a dynamic manner to meet their particular needs.[7] Several agencies, including various WHO offices and the United States Centers for Disease Control and Prevention, have developed platforms to disseminate influenza surveillance information.[8–10] To enhance regional information-sharing and the use of multiple sources of information for risk assessment under the Asia Pacific Strategy for Emerging Diseases and Public Health Emergencies,[11] and to further global collaboration under the Pandemic Influenza Preparedness Framework Partnership Contribution Implementation Plan, the WHO Regional Office for the Western Pacific has developed a set of online interactive influenza dashboards.[12] The dashboards summarize overall influenza activity and surveillance capacity in the Region by bringing together laboratory and epidemiological data; national surveillance system information; and data on human infections with avian influenza viruses A(H5N1), A(H5N6) and A(H7N9) notified under the International Health Regulations (IHR) (**Fig. 1**). The site is publicly accessible, allowing communication with various audiences at the national, regional and global levels. Disseminating these data supports risk assessments, thereby narrowing the gap between surveillance and public health action.

To develop the dashboards, a proof of concept prototype using simulated data and designed with Tableau 9.0 (Tableau Software, Seattle, Washington)

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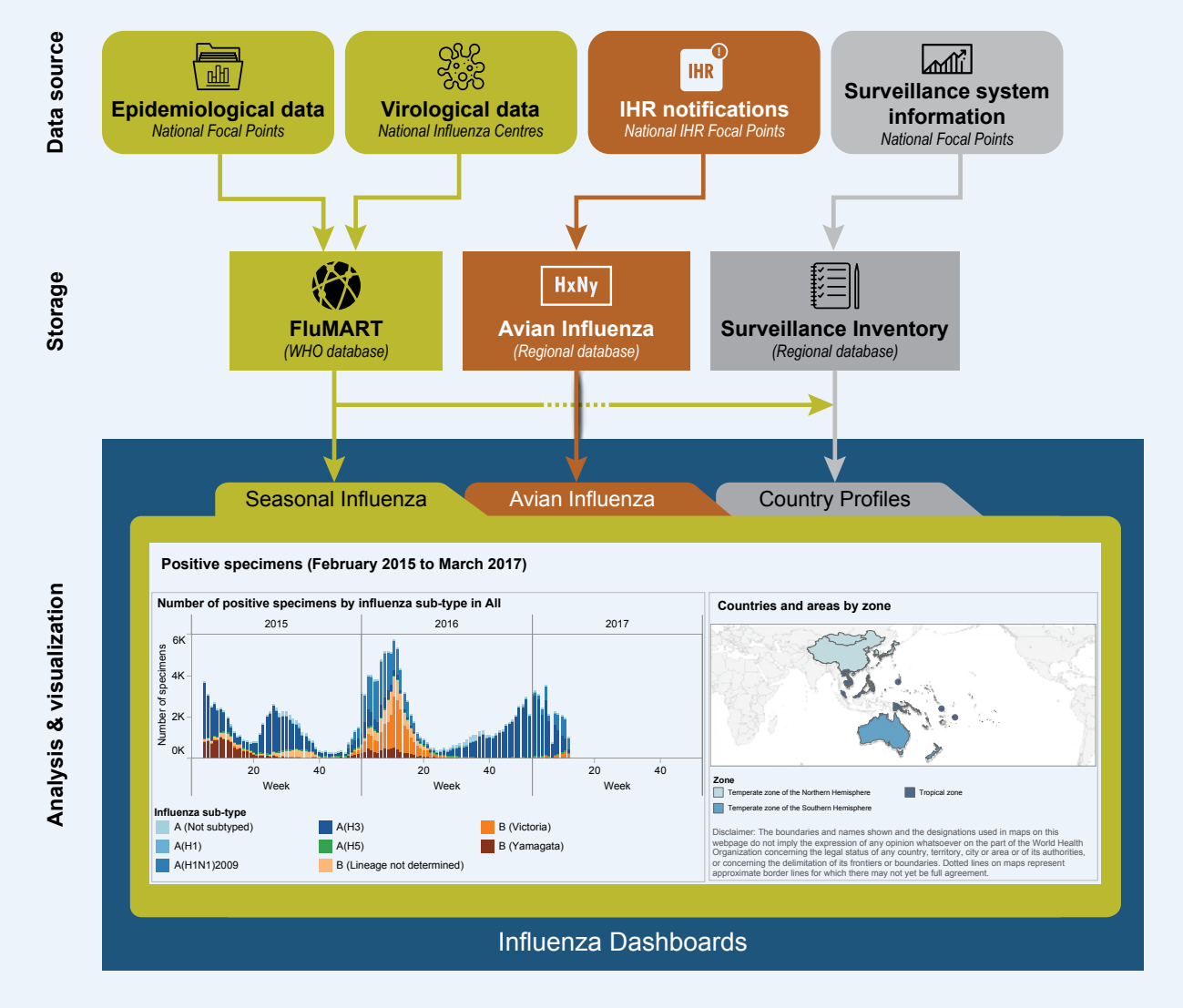
Fig. 1. **Schematic diagram of data sources and flow for regional influenza dashboards**



This figure shows the four sources and contributors of data to the regional influenza dashboards, where these data are stored and on which dashboards they are displayed. National epidemiological and virological data are stored in a global WHO database (FluMART) and displayed on the Seasonal Influenza and Country Profiles dashboards. Human infections with novel influenza viruses are reported by Member States under the IHR, stored in a regional WHO database and displayed on the Avian Influenza dashboards. National surveillance system information reported by individual Member States through a questionnaire is stored in a regional database and displayed on the Country Profiles dashboards.

was shared for feedback with potential stakeholders through an online questionnaire and discussions at a regional influenza forum in August 2015. Revisions were made accordingly and a single data request was sent to countries to gather national surveillance system information and epidemiological data for inclusion in WHO databases. This collaborative effort resulted in a pilot site that was presented to key stakeholders in 2016, before launching publicly.

The regional influenza dashboards include individual dashboards that display seasonal and avian influenza data through interactive maps, graphs and tables (**Fig. 1**). Surveillance system information is currently provided for 35 countries and areas, virological data for 15 countries and areas and epidemiological data for 28 countries and areas. Basic epidemiological data on human infections with avian influenza A(H5N1), A(H5N6) and A(H7N9) viruses are also displayed. The platform facilitates creation of graphics that can be tailored to meet specific needs and downloaded directly. For example, users can compare measures of seasonal influenza activity, including counts of influenza-like illness or severe acute respiratory infection cases, number of deaths and number of positive

virological specimens between different time periods within the same country or between different countries within the Region. Additionally, users can map human infections with avian influenza viruses at the provincial level for specified time periods to visualize the spread of infections over time. Links directing users to national surveillance information and an archive of biweekly regional reports are also available.

Still in the early stages of production, the dashboards have some limitations. Tableau software is compatible with newer versions of web browsers so computers running older versions, such as Internet Explorer 8, 9 and 10, may not display the dashboards. Due to differences between countries in reporting frequency, surveillance methodology, case definitions and continuity of reporting by individual surveillance sites caution must be taken when comparing across years or between countries and areas. Sustainability is also a concern in the adoption of new and innovative technologies. However, steps to address this concern have been taken and include the efficient leveraging of existing global and regional databases that link to the dashboards without duplicate data entry by WHO Member States.

The Western Pacific regional influenza dashboards will facilitate the use of a growing amount of virological and epidemiological surveillance data as a basis for public health action. Not only do they present regional data, but they also support countries with limited capacity to maintain national reporting platforms. By linking different information sources, they support a regional system that can serve as an operational hub to inform risk assessment and decision-making. In the face of a pandemic, regional dashboards could provide both baseline and real-time surveillance information for risk assessment. Moving forward, it will be useful to incorporate animal sector data and information from vaccination surveys such as the WHO-UNICEF Joint Reporting Form to bring together disparate information sources in a single platform for better informed regional risk assessments. Regional monitoring and assessment of other priority diseases could be enhanced by developing similar dashboards. In the future, linkages between focused disease-specific platforms could yield comprehensive overviews of national and regional public health.

Conflicts of interest

None.

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High agreement between the new Mongolian electronic immunization register and written immunization records: a health centre based audit

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Introduction: Monitoring of vaccination coverage is vital for the prevention and control of vaccine-preventable diseases. Electronic immunization registers have been increasingly adopted to assist with the monitoring of vaccine coverage; however, there is limited literature about the use of electronic registers in low- and middle-income countries such as Mongolia. We aimed to determine the accuracy and completeness of the newly introduced electronic immunization register for calculating vaccination coverage and determining vaccine effectiveness within two districts in Mongolia in comparison to written health provider records.

Methods: We conducted a cross-sectional record review among children 2–23 months of age vaccinated at immunization clinics within the two districts. We linked data from written records with the electronic immunization register using the national identification number to determine the completeness and accuracy of the electronic register.

Results: Both completeness (90.9%; 95% CI: 88.4–93.4) and accuracy (93.3%; 95% CI: 84.1–97.4) of the electronic immunization register were high when compared to written records. The increase in completeness over time indicated a delay in data entry.

Conclusion: Through this audit, we have demonstrated concordance between a newly introduced electronic register and health provider records in a middle-income country setting. Based on this experience, we recommend that electronic registers be accompanied by routine quality assurance procedures for the monitoring of vaccination programmes in such settings.

Monitoring of vaccination coverage is vital for the prevention and control of vaccine-preventable diseases. Coverage estimates are also an important indicator of health system performance and a benchmark for progress toward reducing child mortality. In countries lacking reliable administrative data on vaccinations, the estimation of vaccination coverage relies on conducting vaccination coverage surveys, which are time-consuming and expensive. In addition, conducting such studies requires expertise to prevent selection or information bias.[1]

To facilitate the monitoring of vaccination coverage, countries around the world are increasingly adopting electronic immunization registers that are defined as computerised, population-based systems that collect individual-level vaccination data.[2] There is strong evidence that the use of immunization registers can increase rates of vaccination.[3] They can have an impact at an individual level, assisting health-care providers to ensure that individuals have received the recommended vaccinations,[4] and at a population level, highlighting undervaccinated groups to guide vaccination policy.[5] Immunization registers are also valuable research tools and can be linked with disease surveillance databases to assess vaccine effectiveness and safety.[6]

The usefulness of an immunization register depends on the completeness and accuracy of the information it contains. Several studies in a range of settings have

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highlighted the potential problem of underreporting of vaccinations,[7–9] leading to systematically lower coverage estimates. One systematic review reported that out of 17 papers using immunization register data to determine vaccine effectiveness, only one addressed the accuracy of information in the register.[6] This highlights the limited literature addressing immunization register data quality despite the need for such studies.

While registers are increasingly widely adopted worldwide, there is limited literature about the use of electronic registers in low- and middle-income country settings such as Mongolia. To coincide with the staged introduction of the 13-valent pneumococcal conjugate vaccine (PCV13), starting with two districts in Mongolia, the national Expanded Programme of Immunizations (EPI) at the Ministry of Health (MoH) developed an electronic immunization register to record PCV13 doses administered. The immunization register allows the EPI team to efficiently monitor vaccination coverage and can be linked with the surveillance system for invasive bacterial and vaccine-preventable diseases (IB-VPD) to monitor vaccine impact. If successful, the MoH plans to expand the immunization register to include all EPI vaccines and to invlove the rest of the country. In this study, we aim to describe the electronic immunization register in Mongolia and determine the completeness and accuracy of PCV13 data to calculate vaccination coverage and determine vaccine effectiveness by comparing electronic records with existing written health provider records.

METHODS

Description of the electronic immunization register

On 6 June 2016, the Mongolian MoH commenced delivery of PCV13 from all 19 immunization clinics in two districts of the capital city Ulaanbaatar. Infants received PCV13 at 2, 4 and 9 months of age. A catch-up campaign for older children was performed; children aged 3–23 months received two doses at one-month intervals. Immunization nurses documented the following in a registration book: name, national identification (ID) number (unique identification number given at birth), age, address, phone number and date of PCV13 administration. This information was entered into a web-based electronic immunization register at the end of each day. The EPI team, responsible for monitoring the introduction of PCV13, is able to access data from the electronic immunization register in real time.

Study design

We conducted a cross-sectional chart audit among children 2–23 months of age vaccinated at immunization clinics within the two districts. The main outcome measures for this audit were (1) completeness: the proportion of written records that were able to be identified on the electronic immunization register; and (2) accuracy: proportion of linked records with matching vaccination dates to within seven days.

We used systematic random sampling, selecting the first 32 entries from registration books from each immunization clinic for each month of June, July and August 2016. A sample of 32 per month for each clinic was based on sample size calculated to detect an estimated 80% accuracy with a precision of 2.5% with 95% confidence, taking into account clustering within the 19 immunization clinics using an intra-class correlation of 0.01.

Data collection

From the registration books, the following data were abstracted: national ID number, district and subdistrict of vaccine administration and PCV13 vaccination dates. These entries were double-entered into Epidata EntryClient v2.0.10.26 (The Epidata Association, Odense, Denmark) and checked for inconsistencies.

The audit was conducted in August 2016 after the completion of the catch-up campaign. The electronic database was exported twice. The first export was one week after collection of the data from the written records on 23 August 2016 and the second was on 3 October 2016 to ensure any delayed data were captured.

Data analysis

We reviewed the data in the electronic immunization register for internal consistency by describing the proportion of doses that were invalid. We defined vaccination dates as invalid if any dose was dated as given before the date of birth, any dose was dated to have been given after the register was first exported (24 August 2016), the first dose was dated to have been given before

the vaccine became available (6 June 2016), the second dose was dated to have been given less than 28 days after PCV13 first became available (4 July 2016), the first dose was dated to have been given at less than 8 weeks of age or the second dose was dated to have been given at less than 12 weeks of age. We reported proportions of invalid doses and reasons.

Data from the written record database were linked with the electronic immunization register using the national ID number. We considered the records from the written registration books to be the gold standard for the purposes of this audit.

We reported completeness and accuracy using proportions and 95% confidence intervals adjusted for clustering within subdistricts. Accuracy was reported using the first export of the electronic database only. Completeness was assessed for both first and second exports to capture and compare timeliness of data entry. We included both valid and invalid doses in the analyses of completeness and accuracy. We reported accuracy by district, subdistrict and month. We completed the analysis using Stata IC 14 (StataCorp LLC, College Station, Texas, USA).

Ethics

Ethics approval was not sought because this audit was conducted as a part of routine quality assurance in collaboration with the EPI team within the Ministry of Health in Mongolia. No identifying information has been included as part of this report.

RESULTS

Total and invalid vaccination doses in the electronic immunization register

From 6 June to 24 August 2016, there were a total of 19 879 doses of PCV13 recorded in the electronic immunization register, including 15 650 first doses and 4229 second doses. Only 87 (0.004%) doses were invalid. The most common reason for a vaccine date being invalid was that the vaccine was recorded as given before the vaccine became available (**Tables 1a** and **1b**).

Completeness of the electronic immunization register

Of the 1757 records abstracted from written immunization registers, there were 1614 unique IDs (some of the records were different doses for the same patient). The number of records abstracted was slightly less than the intended sample size (n=1824) because some smaller clinics had fewer than 32 doses per month available to abstract. Among the 1614 patients, 1273 were able to be linked using their unique ID to the electronic immunization register abstracted on 24 August 2016, giving the electronic register a completeness of 78.9% (95% CI: 64.7–88.4). For the records that were unable to be linked, we searched the electronic record again on 3 October 2016 and were able to identify 12% additional records, increasing completeness to 90.9% (95% CI: 88.4–93.4).

Accuracy of the electronic immunization register

For the 1273 patients that were able to be linked, there were 1386 records (or doses) that were able to be compared. The PCV13 dates recorded on the electronic record matched the written record for 93.4% (adjusted 95% CI: 84.1–97.4) of records (**Table 2**). The accuracy of the electronic register was similar by district (**Table 3**). For all but five subdistricts, the proportion of PCV13 vaccine dates from electronic record matched the written record by more than 90% (**Table 4**). The accuracy of the electronic register declined over time (P<0.001) (**Table 5**).

DISCUSSION

This audit found that the overall completeness of the Mongolian electronic immunization register was high (90.9%; 95% CI: 88.4–93.4) when compared to written records. The increase in completeness between the first export (one week after collection of written records) and the second export (five weeks later) indicates a significant delay in data entry. Any analyses of vaccination coverage should consider this delay. The accuracy of the vaccination dates recorded on the electronic register was also high (93.3%; 95% CI: 84.1–97.4). However, these results should be considered in the context that administrative

Table 1a. **Validity of pneumococcal conjugate vaccine dates (first dose), recorded in the electronic immunization register, Mongolia, June–August 2016**

		No. vaccine doses (n = 15 650)	%
Valid		15 570	99.5
Invalid	Before 6 Jun	43	0.3
	Before birth	24	0.2
	After export	1	0.0
	< 8 wks of age	12	0.1

Table 1b. **Validity of pneumococcal conjugate vaccine dates (second dose), recorded in the electronic immunization register, Mongolia, June–August 2016**

		No. vaccine doses (n = 4229)	%
Valid		4222	99.8
Invalid	Before 1 Aug	2	0.1
	Before birth	2	0.1
	After export	0	0.0
	< 12 wks of age	3	0.1

Table 2. **Accuracy of pneumococcal conjugate vaccine dates recorded in the electronic immunization register, Mongolia, June–August 2016**

PCV13 dates		No. records (n = 1386)	%
Match	Exact match	1243	89.7
	Within 7 days	51	3.7
No match		92	6.6

Table 3. **Accuracy of pneumococcal conjugate vaccine dates recorded in the electronic immunization register by district, Mongolia, June–August 2016**

	No. linked records available for comparison (n = 1386)	Accuracy (% with matching dates)
District A	557	94.6
District B	829	92.5

vaccination data, which we have used as our gold standard, from low- and middle-income countries may not be reliable.[10]

Results from different audits and evaluations published in the literature have demonstrated vastly different results, reinforcing the need to validate data from registers before use. Many audits, such as those from the national immunization registers in the United Kingdom,[11] Belgium,[7] Australia[8] and some subnational immunization registers in the United States of America (USA),[12,13] have demonstrated a high degree of completeness and accuracy with coverage estimates within 10% of coverage estimated from vaccination surveys.[7,8] However, other audits have demonstrated variability in completeness and accuracy with some noting an improvement in completeness over time from 71.4% to 97.7%;[14] others noted an improvement in accuracy from an error rate of 59% to 18% following specific strategies.[15]

This audit has demonstrated variability in completeness and accuracy by clinic. Details of underperforming clinics have been passed on to the EPI team for follow-up. While this audit was not designed to determine reasons for poor completeness or accuracy, we anticipate that follow-up visits to underperforming clinics will provide insight into potential issues. The decline in accuracy over time suggests that a process of ongoing monitoring and serial auditing of the registry is needed to maintain quality data. As part of the quality assurance programme for the Norwegian immunization registry, annual reports of children who are incompletely vaccinated or have discrepancies in their schedules are sent to the municipality health services for follow-up.[16] Two American registries, in Wisconsin and Philadelphia, noted that completeness and accuracy were greatest among clinics with electronic medical records that linked directly with registry system.[12,13]

While this audit has validated the data recorded in the immunization register, we have not assessed the quality of the denominator (population) data on which the calculation of accurate vaccination coverage depends. To validate vaccine coverage calculated using administrative data, we recommend conducting a vaccination coverage survey using survey methods recommended by the World Health Organization.[1] Our results indicate that

Table 4. **Accuracy of pneumococcal conjugate vaccine dates recorded in the electronic immunization register by subdistrict, Mongolia, June–August 2016**

Subdistrict	No. linked records available for comparison (*n* = 1386)	Accuracy (% with matching dates)
Subdistrict A	75	100.0
Subdistrict B	89	97.6
Subdistrict C	81	97.5
Subdistrict D	78	91.0
Subdistrict E	89	100.0
Subdistrict F	67	71.6
Subdistrict G	78	100.0
Subdistrict H	82	98.8
Subdistrict I	92	100.0
Subdistrict J	79	96.2
Subdistrict K	84	98.8
Subdistrict L	16	87.5
Subdistrict M	87	100.0
Subdistrict N	33	100.0
Subdistrict O	82	54.9
Subdistrict P	55	83.6
Subdistrict Q	36	86.1
Subdistrict R	89	98.9
Subdistrict S	94	96.8

Table 5. **Accuracy of pneumococcal conjugate vaccine dates recorded in the electronic immunization register by month, Mongolia, June–August 2016**

Month	No. linked records available for comparison (*n* = 1386)	Accuracy (% with matching dates)
June	461	97.6
July	370	92.4
August	555	90.1

the electronic registry can be used to reliably estimate vaccination coverage provided that the denominator data are accurate.

There are several limitations to this study. First, this audit relies on accurate clinic health records for comparison. While we have not reviewed the quality of the clinic data, it is the current source for vaccination coverage estimates and, to our knowledge, the best available source of vaccination information. However, we have also examined completeness using another source – parent-held immunization records. Between November 2016 and February 2017, 569 children recruited as part of enhanced IB-VPD surveillance were noted as having received at least one dose of PCV13 according to their parent-held immunization records. Of these, 86.5% (95%CI: 83.4–89.0) were recorded in the electronic immunization register, indicating similar levels of completeness to our results using clinic data, albeit for a different time period (unpublished data). This process is ongoing. Another potential method to assess vaccination coverage in this population is serosurveys; however, this may not be applicable to pneumococcal conjugate vaccines since there is debate surrounding the reliability of serology as immune correlates of protection.[17,18]

A second limitation is that we used systematic sampling by month. We chose this method for simplicity to ensure data collection was consistent over the 19 subdistricts. A sample was taken from the beginning of each of the three months, accounting for changes in accuracy from one month compared to another. Therefore, estimates of accuracy are designed to be interpreted over the entire three-month period, and estimates from each month are not reflective of the entire month since the sample was drawn only from the beginning of that month. Third, the study was conducted in an urban setting where the electronic register is being piloted and may not be applicable to other more rural settings. When the electronic register is rolled out country-wide it will be important to re-examine completeness and accuracy of the register. Lastly, our study was not designed to determine reasons for decreases in data accuracy over time; an additional qualitative component may be a useful adjunct.

Immunization registries are increasingly being recognized as important public health tools with both the European Centre for Disease Prevention and Control and United States Centers for Disease Control and Prevention outlining goals to encourage adoption of these systems provided the data entry is timely and accurate.[19,20] This audit has demonstrated that electronic registers are technically viable in an urban middle-income country setting. This paper describes an effective method for auditing the electronic registers in comparison to health provider records. Comparisons with alternative sources

of vaccination data, such as parent-held immunization records, should be considered to triangulate these results given the issues with reliability of administrative data in low- and middle-income countries.[10] Based on our experience, we would recommend the adoption of electronic registers, accompanied by routine quality assurance procedures, for the monitoring of vaccination programmes.

Conflicts of interest

None to declare.

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Emergency Department demand associated with seasonal influenza, 2010 through 2014, New South Wales, Australia

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Introduction: Influenza's impact on health and health care is underestimated by influenza diagnoses recorded in health-care databases. We aimed to estimate total and non-admitted influenza-attributable hospital Emergency Department (ED) demand in New South Wales (NSW), Australia.

Methods: We used generalized additive time series models to estimate the association between weekly counts of laboratory-confirmed influenza infections and weekly rates of total and non-admitted respiratory, infection, cardiovascular and all-cause ED visits in NSW, Australia for the period 2010 through 2014. Visit categories were based on the coded ED diagnosis or the free-text presenting problem if no diagnosis was recorded.

Results: The estimated all-age, annual influenza-attributable respiratory, infection, cardiovascular and all-cause visit rates/100 000 population/year were, respectively, 120.6 (99.9% confidence interval [CI] 102.3 to 138.8), 79.7 (99.9% CI: 70.6 to 88.9), 14.0 (99.9% CI: 6.8 to 21.3) and 309.0 (99.9% CI: 208.0 to 410.1). Among respiratory visits, influenza-attributable rates were highest among < 5-year-olds and ≥ 85-year-olds. For infection and all-cause visits, rates were highest among children; cardiovascular rates did not vary significantly by age. Annual rates varied substantially by year and age group, and statistically significant associations were absent in several years or age groups. Of the respiratory visits, 73.4% did not require admission. The non-admitted proportion was higher for the other clinical categories. Around 1 in 100 total visits and more than 1 in 10 respiratory or infection visits were associated with influenza.

Discussion: Influenza is associated with a substantial and annually varying burden of hospital-attended illness in NSW.

Influenza remains a public health challenge.[1] It is associated with annual, varying, excess deaths in populations internationally.[2,3] Influenza is a vaccine-preventable disease,[1] and the extent of its contribution to morbidity and mortality is poorly recognized. Estimating the burden of influenza in various settings is thus a priority for the World Health Organization (WHO).[4] There are few studies estimating the impact of influenza on lower severity health outcomes including hospital Emergency Department (ED) visits.[5–8] There is increasing recognition that the impact of influenza extends beyond respiratory illness to circulatory and other diseases.[2,9]

Influenza-related illness is poorly recorded in hospital and death databases, and counting only laboratory-confirmed influenza infections will markedly underestimate influenza's population impact. Diagnoses commonly assigned to patients with an influenza infection in hospital EDs in Australia include fever, an unspecified infection or a non-respiratory illness.[10] During influenza season, febrile convulsions in infants increase.[11] Thus, statistical time-series analysis is used to estimate population levels of illness and death attributable to influenza.[2,10,12]

We used time-series analysis to estimate the rate, number and proportion of ED visits attributable to influenza in the state of New South Wales (NSW), Australia by age and year for the period 2010 to 2014. Since a proportion of visits lead to admission and can be included in hospitalization estimates, we also prepared estimates for non-admitted visits.

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METHODS

Study design and setting

This was a retrospective, ecological time-series analysis of ED visits recorded in a state-wide administrative information system database for NSW over the five calendar years of 2010 to 2014. NSW is the most populous state in Australia with a diverse urban and rural population of 7.5 million over 800 000 km^2.[13,14]

Data sources

The available study data included all visits recorded in the NSW Emergency Department Data Collection database during the study period.[15] The database contains routinely collected administrative and clinical data for patient-level visits across most public hospitals in NSW. Exclusion criteria were: hospitals not submitting data for the entire study period, prearranged (planned) visits that are usually for follow-up from a previous attendance, patients dead on arrival and transfers from other facilities.[15] Population denominators were obtained from the Australian Bureau of Statistics.[14]

Prior to analysis, we assigned a single, mutually exclusive clinical category to each visit in the ED database. The category was assigned using the recorded primary ED diagnosis code, and if necessary, the presenting problem, as defined in a previous publication, which also includes examples of diagnoses in each category.[15] For each ED visit, a physician selects a diagnosis name from a list used by the hospital's electronic patient medical record information system. The information system then assigns a diagnosis code depending on the diagnostic classification standard used by the hospital. Classification standards vary among the information systems and can be: the International Classification of Diseases versions 9 or 10 (ICD-9, ICD-10) or the Systematized Nomenclature of Medicine Clinical Terminology (SNOMED-CT).

To estimate the contribution of influenza to population-level health outcomes, a time series representing the relative weekly change in incidence of influenza infections in the population is needed as an independent variable in the regression analysis. Since all influenza infections diagnosed in microbiology laboratories in Australia are notifiable to regional and state health authorities, we used influenza notifications from NSW to prepare the time series. Non-identified, state-level notification data are available from the national health authority.[16]

Outcomes

We modelled outcome time series as population rates for each of respiratory, infection, cardiovascular and all-cause (total) visits. The association between influenza infection and adverse cardiovascular outcomes is becoming well known and is often included in influenza-attributable mortality studies.[9] All-cause visits cast the widest net to estimate total influenza-attributable outcomes in time-series approaches to influenza burden estimation.[2]

Time series of the total and non-admitted ED outcome rates were prepared for persons of all ages as well as age groups broadly consistent with WHO guidelines for influenza burden estimation: 0–4, 5–14, 15–49, 50–64, 65–84 and ≥ 85 years.[4]

Analysis

We used semi-parametric generalized additive modelling to regress the ED outcome against the influenza time series. For each clinical category, age and admission status group, the weekly rates of ED visits provided the dependent (outcome) variable for a time-series model. Each time series included 260 observations covering whole weeks occurring during the study period.

Weekly influenza notification counts were split into separate variables for each year as there is an evident increase in influenza testing and thus notifications over time.[2,17] Each annual influenza time series was set to zero in all years except the year to which it referred.

Much of the variation in the observed time series of ED visits is not due to influenza and much of that variation may be due to seasonal and other nonlinear factors. Therefore, a natural cubic smoothing spline of time (represented by consecutive week number) was included in the model as a non-parametric independent variable.[12]

For a given clinical category, age group and admission status group, the model equation was:

$$Expected(visit\ rate) = \beta_0 + \beta_1(ChristmasNewYear) + \beta_2(SchoolHoliday) + \beta_3(Easter) + \beta_4(JanuaryWeek2) + \left[\sum_{year=2010}^{2014} \beta_{5,year}\left(influenza_{year}\right)\right] + \beta_6 t + spline(t)$$

in which "Christmas", "New Year", "School Holiday", "Easter" and "January Week 2" were holiday indicator variables (value 0 or 1) for periods of low ED demand, identified using a box whisker plot of the distribution of week of the year counts of all-cause visits. The $influenza_{year}$ variable was the respective annual weekly time series of seasonal influenza notifications. The β values were the model parameter estimates for the respective parametric independent variables, with β_0 the model intercept. We specified 31 degrees of freedom for the flexibility of the smoothing spline based on previous research.[12]

The estimated weekly component of visits associated with the influenza variable was obtained by multiplying the influenza parameter estimate ($\beta_{5,year}$) by the observed rate of the influenza variable ($influenza_{year}$) in each week. Annual total counts were converted to rates using mid-year population estimates.

Estimated influenza-attributable counts and total counts, respectively, were used as the numerator and denominator for influenza-attributable proportions in each outcome category and age group.

Since estimates were made for numerous year, age group and visit category combinations, 99.9% confidence intervals ($\alpha = 0.001$) were calculated to reduce chance statistical significance. We used the formula: parameter estimate ± 3.290 x standard error of the parameter estimate where 3.290 is the 99.9% critical value (z-value) from a standard normal distribution. Standard errors for confidence intervals of five-year averages were the square root of the sum of the squared standard errors of the annual values divided by five (the number of years averaged). Non-statistically significant annual values were included in averages as zero with zero standard error.

SAS version 9.4 (SAS, Cary, NC, USA) was used for analysis using procedures and options described elsewhere.[12] Normally distributed model residuals was assumed and this was checked using quantile-quantile (QQ) plots of the residuals. Lack of serial independence (autocorrelation) over time in the model residuals was checked using autocorrelation plots.

Sensitivity analysis

As a sensitivity analysis to assess whether influenza incidence was associated with visit categories that would implausibly be caused by influenza, injury visit rates were also regressed on the influenza notification time series.

Ethics

The study was approved by the NSW Population and Health Services Research Ethics Committee. Information that could identify patients was not included in the study data.

RESULTS

Characteristics of the study data used

There were 11.8 million ED visits recorded between January 2010 and December 2014 of which 10.8 million visits to 115 hospitals met the inclusion criteria. Of these, 7.82 million (72.8%) were not admitted.

Among the clinical categories included in the study, injury comprised the largest group (mean = 117 visits/100 000 population/week) followed by respiratory (49.0 visits/100 000 population/week), cardiovascular (44.2 visits/100 000 population/week) and infection (22.9 visits/100 000 population/week). Among non-admitted visits, a similar pattern was observed. Increased influenza testing over time was evident; of the 44 308 influenza notifications during the study period, almost one half (20 744, 46.8%) occurred in 2014.

Model fitting

Except for cardiovascular disease visits in the older population, at least one statistically significant holiday effect was identified in each clinical category and age group. Apart from some departures from normality for extreme observations and some residual autocorrelation, the QQ plots showed the modelling provided a good fit to the observed data.

Main results

Exceedances in visit rates associated with circulating influenza are evident in each clinical category, particularly respiratory and infection. The exceedances are most distinct in years 2012, 2013 and 2014 (**Fig. 1**).

For respiratory visits, exceedances were greatest in 2012 in < 5-year-olds (939.0 visits [99.9% confidence interval (CI) 559.4 to 1318.7]/100 000 population/year) and ≥ 85-year-olds (987.7 [99.9% CI: 793.4 to 1181.9]/100 000 population/year) (**Fig. S1**, **Table S1**, **Supplementary File 1**). For infection visits, exceedances were most prominent in < 5-year-olds in 2012 (821.6 visits [99.9% CI: 657.8 to 985.4]/100 000 population/year) (**Fig. S2**, **Table S1**). Exceedances among cardiovascular visits were more difficult to distinguish and were most evident in ≥ 85-year-olds in 2011 (433.0 [99.9% CI: 179.8 to 686.3]/100 000 population/year) (**Fig. S3**, **Table S1**). Among all-cause visits, 2012 again stood out in < 5-year-olds (2368.0 [99.9% CI: 1544.1 to 3191.8]/100 000 population/year) and ≥ 85-year-olds (1778.4 [99.9% CI: 1060.0 to 2496.9]/100 000 population/year) (**Fig. S1**, **Table S1**).

When averaged from 2010 through 2014, there was a U-shaped relationship between age and estimated respiratory visit rates with < 5-year-olds and ≥ 65-year-olds higher than 15–64-year-olds based on confidence intervals. Compared with other age groups, estimated infection visit rates were highest in < 5-year-olds, followed by 5–14-year-olds, and these differences were statistically significant. The estimated infection visit rate in < 5-year-olds was significantly higher than the estimated respiratory rate in the same age group. For cardiovascular visits, significant rates were present only in the 5–14, 15–49 and 65–84 age groups, and these were not significantly different across those age groups. Estimated all-cause rates were highest in < 5-year-olds and declined with age until the 50–64 year age group and then increased again with the rate in ≥ 85-year-olds about half that of < 5-year-olds (**Table 1**).

Among persons of all ages, the average annual estimated influenza-attributable rate for respiratory visits was 120.6 [99.9% CI: 102.3 to 138.8]/100 000 population/year (8887 [99.9% CI: 7548 to 10 227] visits/year). For infection visits, the rate was 79.7 [99.9% CI: 70.6 to 88.9]/100 000 population/year (5856 [99.9% CI: 5192 to 6519] visits/year). For cardiovascular visits, the average was 14.0 [99.9% CI: 6.8 to 2.3]/100 000 population/year (1033 [99.9% CI: 499 to 1567] visits/year). For all-cause visits, the all-age average annual estimated rate was 309.0 [99.9% CI: 208.0 to 410.1]/100 000 population/year (22 619 [99.9% CI: 15 268 to 29 969] visits/year) (**Table 1**).

In < 50-year-olds, differences between the estimated rates in total and non-admitted visits are not significantly different. In older age groups, the rates of estimated non-admitted visits were substantially and significantly lower than those of total visits, particularly for the respiratory and infection categories. For persons of all ages, estimates for non-admitted visits were broadly similar to those of total visits. Averaged across all years, these patterns were also broadly reflected. These results indicate that older persons with influenza-related illness are more likely to be admitted (**Tables S2** and **S4**, **Supplementary File 1**).

Compared with total visits (**Table 1**), a similar pattern of statistically significant associations was evident among non-admitted visits. The average annual estimated all-age rate of influenza-attributable, non-admitted respiratory visits was 88.5 (99.9% CI: 74.7 to 102.3)/100 000 population/year or 73.4% of total influenza-attributable respiratory visits/year). For non-admitted infection visits, the rate was 69.8 (99.9% CI: 61.9 to 77.7)/100 000 population/year (87.4%). For non-admitted cardiovascular visits, the rate was 12.2 (99.9% CI: 7.9 to 16.5)/100 000 population/year (87.1%). The rate of excess average annual all-cause non-admitted visits was 287.1 (99.9% CI: 196.2 to 378.0)/100 000 population/year; 92.8%) (**Table 2**).

An annual average of 4.7% of total respiratory visits and 5.6% of non-admitted respiratory visits was estimated to be attributable to influenza. Among infection visits, the average annual proportion was 6.7% (non-admitted: 8.4%). Among cardiovascular and all-cause visits, the average annual proportions were 0.6% (non-admitted: 1.1%) and 1.1% (non-admitted: 1.3%), respectively. The highest proportion by age was 12.4% (non-admitted: 13.6%) of infection visits in 5–14-year-olds (**Table S5**, **Supplementary File 1**).

Fig. 1. **Observed weekly counts of influenza notifications, estimated influenza-attributable and non-influenza-attributable (background) ED visit rates/100 000 population/week for all-cause, cardiovascular, infection and respiratory clinical categories and observed visit rates/100 000 population/week in each clinical category, for persons of all ages, NSW, 2010 through 2014 (n = 260 weeks)**

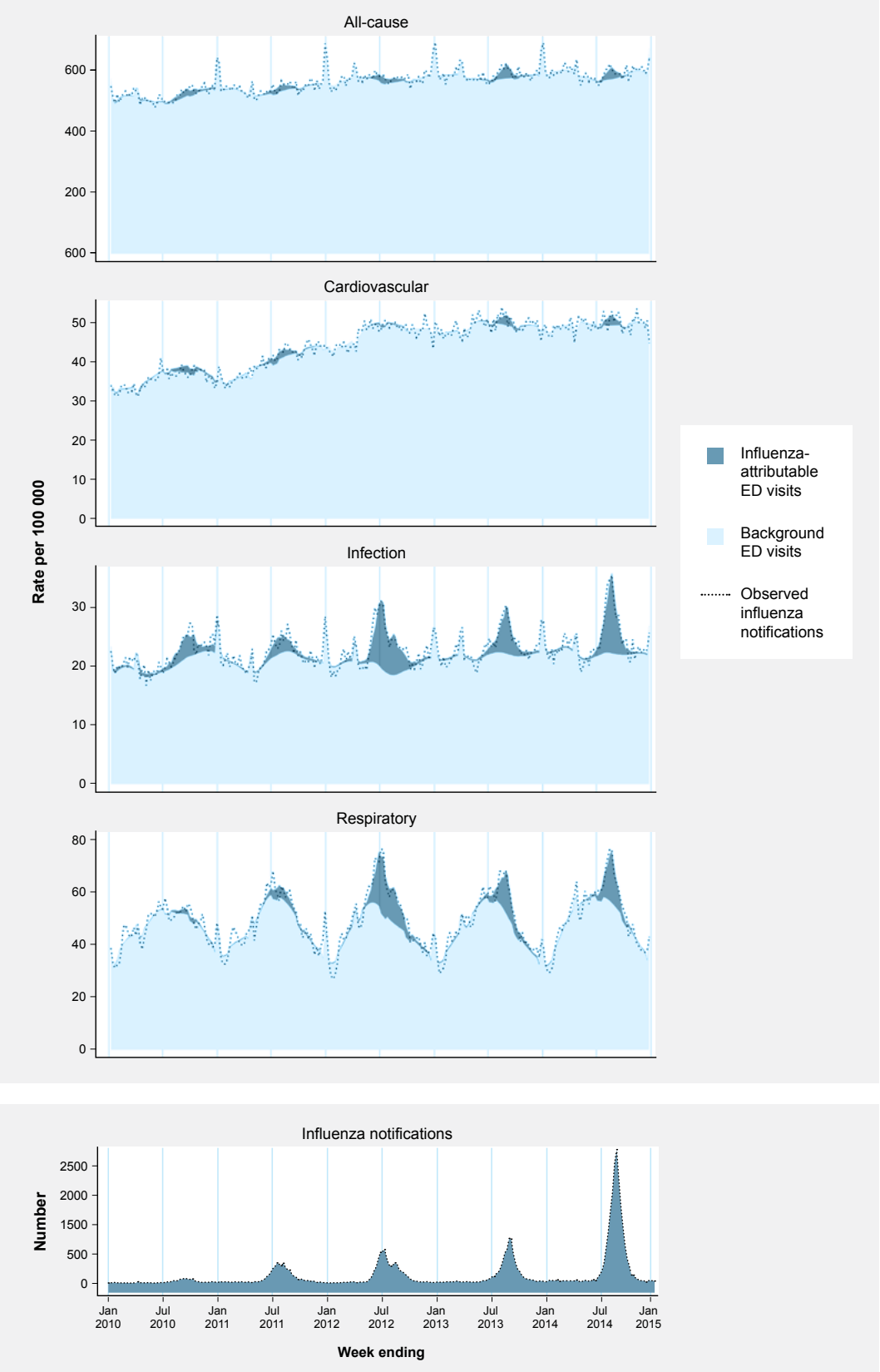

Table 1. **Average annual estimated rate/100 000 population and number of influenza-attributable ED visits, by clinical category and age, NSW, 2010 through 2014**

Clinical category	Age group (years)	Rate	(99.9% CI)	Number	(99.9% CI)
Respiratory	0–4	**187.8**	**(111.9 to 263.7)**	**902**	**(537 to 1266)**
	5–14	**106.9**	**(71.2 to 142.6)**	**976**	**(651 to 1301)**
	15–49	**80.7**	**(72.6 to 88.9)**	**2845**	**(2558 to 3132)**
	50–64	**95.0**	**(80.7 to 109.3)**	**1275**	**(1085 to 1465)**
	65–84	**178.6**	**(160.1 to 197.1)**	**1724**	**(1544 to 1903)**
	≥ 85	**208.6**	**(115.1 to 302.0)**	**335**	**(200 to 470)**
	All ages	**120.6**	**(102.3 to 138.8)**	**8887**	**(7 548 to 10 227)**
Infection	0–4	**361.0**	**(291.2 to 430.8)**	**1740**	**(1405 to 2076)**
	5–14	**144.1**	**(123.3 to 165.0)**	**1304**	**(1117 to 1492)**
	15–49	**57.9**	**(51.2 to 64.6)**	**2035**	**(1800 to 2269)**
	50–64	**24.8**	**(20.1 to 29.6)**	**336**	**(272 to 401)**
	65–84	**25.6**	**(19.7 to 31.6)**	**248**	**(191 to 305)**
	≥ 85	**45.5**	**(25.2 to 65.8)**	**68**	**(38 to 99)**
	All ages	**79.7**	**(70.6 to 88.9)**	**5856**	**(5192 to 6519)**
Cardiovascular	0–4	*-3.4*	*(−5.8 to −0.9)*	*-16*	*(−28 to −4)*
	5–14	**6.3**	**(2.8 to 9.7)**	**57**	**(26 to 89)**
	15–49	**5.7**	**(1.9 to 9.6)**	**203**	**(67 to 339)**
	50–64	0.0	(0.0 to 0.0)	0	(0 to 0)
	65–84	**16.7**	**(0.2 to 33.2)**	**152**	**(2 to 301)**
	≥ 85	17.0	(−63.3 to 97.3)	28	(−82 to 138)
	All ages	**14.0**	**(6.8 to 21.3)**	**1033**	**(499 to 1567)**
All-cause	0–4	**1013.9**	**(692.1 to 1 335.8)**	**4856**	**(3315 to 6397)**
	5–14	**455.5**	**(311.7 to 599.3)**	**4115**	**(2820 to 5410)**
	15–49	**175.3**	**(102.8 to 247.7)**	**6174**	**(3625 to 8724)**
	50–64	**49.3**	**(15.7 to 82.9)**	**668**	**(213 to 1123)**
	65–84	**194.3**	**(125.0 to 263.6)**	**1870**	**(1199 to 2540)**
	≥ 85	**506.9**	**(318.4 to 695.5)**	**761**	**(475 to 1047)**
	All ages	**309.0**	**(208.0 to 410.1)**	**22 619**	**(15 268 to 29 969)**

Notes: Non-statistically significant annual values were included in averages as zero, with zero standard error. CI=confidence interval. Statistically significant positive results are shown in **bold**. Statistically significant negative results are *italicized*.

Table 2. **Average annual estimated rate/100 000 population and number of influenza-attributable *non-admitted* ED visits, by clinical category and age, NSW, 2010 through 2014**

Clinical category	Age group (years)	Rate	(99.9% CI)	Number	(99.9% CI)
Respiratory	0-4	**276.8**	**(185.9 to 367.8)**	**1337**	**(896 to 1778)**
	5-14	**142.7**	**(106.5 to 179.0)**	**1295**	**(968 to 1621)**
	15-49	**69.0**	**(61.9 to 76.2)**	**2432**	**(2182 to 2682)**
	50-64	**54.2**	**(44.9 to 63.4)**	**727**	**(605 to 850)**
	65-84	**70.6**	**(59.9 to 81.4)**	**682**	**(578 to 787)**
	≥85	**30.6**	**(2.4 to 58.8)**	**49**	**(8 to 91)**
	All ages	**88.5**	**(74.7 to 102.3)**	**6525**	**(5511 to 7538)**
Infection	0-4	**319.5**	**(258.2 to 380.7)**	**1539**	**(1245 to 1833)**
	5-14	**131.6**	**(112.8 to 150.5)**	**1191**	**(1021 to 1361)**
	15-49	**53.3**	**(47.7 to 59.0)**	**1875**	**(1677 to 2073)**
	50-64	**18.5**	**(14.9 to 22.2)**	**251**	**(202 to 300)**
	65-84	**11.9**	**(7.1 to 16.6)**	**113**	**(69 to 158)**
	≥85	*-15.3*	*(-22.8 to -7.7)*	*-22*	*(-32 to -11)*
	All ages	**69.8**	**(61.9 to 77.7)**	**5121**	**(4547 to 5694)**
Cardiovascular	0-4	*-2.2*	*(-4.2 to -0.2)*	*-11*	*(-21 to -1)*
	5-14	**5.8**	**(2.7 to 8.9)**	**53**	**(25 to 82)**
	15-49	**9.3**	**(5.4 to 13.2)**	**329**	**(191 to 467)**
	50-64	**5.6**	**(1.3 to 9.9)**	**77**	**(17 to 136)**
	65-84	**12.8**	**(4.2 to 21.4)**	**116**	**(38 to 194)**
	≥85	22.0	(-6.2 to 50.3)	30	(-11 to 70)
	All ages	**12.2**	**(7.9 to 16.5)**	**900**	**(586 to 1214)**
All-cause	0-4	**1090.0**	**(787.1 to 1392.8)**	**5235**	**(3780 to 6690)**
	5-14	**432.0**	**(301.3 to 562.7)**	**3903**	**(2726 to 5080)**
	15-49	**174.2**	**(109.7 to 238.8)**	**6141**	**(3869 to 8413)**
	50-64	**89.4**	**(37.5 to 141.3)**	**1177**	**(497 to 1857)**
	65-84	**122.3**	**(52.1 to 192.4)**	**1106**	**(473 to 1739)**
	≥85	*-93.9*	*(-178.7 to -9.1)*	*-132*	*(-252 to -13)*
	All ages	**287.1**	**(196.2 to 378.0)**	**20997**	**(14 383 to 27 611)**

Notes: Non-statistically significant annual values were included in averages as zero, with zero standard error. CI=confidence interval. Statistically significant positive results are shown in **bold**. Statistically significant negative results are *italicised*.

Sensitivity analysis

When injury visit rates were regressed on influenza incidence, a positive statistically significant association was identified for one age group in one year (5–14 year-olds in 2013; 208.5 (99.9% CI: 44.9 to 372.2)/100 000 population/year). Statistically significant negative results were identified for six of seven age groups in 2012 and three of seven age groups in 2014 (**Table S6**, **Supplementary File 1**). The overall proportion of estimated influenza-attributable injury visits was −0.6%.

DISCUSSION

We estimated that influenza was associated with approximately 1 in every 100 ED visits and more than 1 in 10 respiratory or infection visits, on average, concentrated across mid-winter to early spring. Over 300 all-cause visits/100 000 population/year were associated with influenza. Of these, 121 and 80/100 000 population/year were respiratory and infection visits, respectively. Influenza possibly explained 14 cardiovascular visits/100 000 population/year, although age groups and years with significant associations did not appear comparable with those for respiratory and infection visits. Depending on the type of visit, the burden appears to be borne to the greatest degree by the youngest and oldest age groups. Over 1000 all-cause visits/100 000 population/year in children aged under 5 years were associated with influenza and over 400/100 000 population/year in ≥ 85 year-olds. Approximately three quarters of influenza-attributable respiratory visits did not require admission, compared with 87% for infection visits and 93% of all-cause visits. Young children were less likely than older adults to be admitted to hospital.

Our post-pandemic, influenza-attributable, annual respiratory visit rate estimate of 121/100 000 population/year for the period 2010–2014 in NSW was substantially lower than estimates from Ontario, Canada and New York, NY, USA at different time periods.[5,8] Varying influenza activity and virulence over time, immunization coverage and effectiveness, availability and cost of health services or different modelling approaches could explain the difference. The post-pandemic year in our study, namely 2010, did have unusually low influenza activity, and our modelling approach may provide more conservative estimates than the modelling method used in the other studies.[12]

Interpreting variation in influenza-attributable burden from year to year requires an understanding of the influenza strains that circulated and the effectiveness of influenza vaccines. In Australia, influenza vaccination is free to certain risk groups, the largest group being the older population, with coverage around 70% in ≥ 65-year-olds during the study period.[18] Coverage in younger persons is substantially lower: around 33% in 50–64-year-olds and below 20% in younger age groups.[19]

The 2009 influenza A(H1N1)pdm09 pandemic strain dominated in Australia in 2010, although levels of circulation were low (**Table S7**, **Supplementary File 1**). This is consistent with the low levels of influenza-attributable ED demand, although there was substantial demand in the younger age groups, particularly in the infection clinical category.

Influenza A(H3N2) reappeared in 2011 and co-circulated with the pandemic strain, but overall levels remained relatively low (**Table S7**). The vaccine in those years showed good effectiveness of at least 70% against the pandemic strain.[20,21] The older age group experienced relatively low susceptibility to the pandemic strain due to pre-existing immunity.[2,12,19,22,23] These combined factors would explain the relatively low overall levels of influenza-attributable visits in 2010–2011.

The 2012 season showed the highest relative influenza circulation of the study period with A(H3N2) dominating and influenza B accounting for the remainder (**Table S7**). This season had the highest estimated incidence of respiratory or infection ED visits of all years studied in persons of all ages and in < 5-year-olds. The rates in ≥ 65-year-olds were also highest in 2012 for respiratory, infection and all-cause visits. Vaccine effectiveness in Australia against the circulating H3N2 strain in that season was low at 30% in 2012, which may be due to antigenic drift in the H3N2 virus. Effectiveness against influenza B was moderate (56%).[24]

There was relatively low overall influenza circulation in 2013. Influenza A(H3N2) continued to dominate (**Table S7**). Substantial estimated influenza-attributable visits were evident in younger age groups broadly comparable to surrounding years. Vaccine effectiveness against A(H3N2) in 2013 was good at 67%,[24] which may explain the relatively lower levels of influenza-attributable visit rates in older age groups compared with the surrounding years.

In 2014, the pandemic strain dominated but A(H3N2) co-circulated. This year had the second highest total apparent influenza circulation of the years studied (**Table S7**). In that year, the vaccine effectiveness was moderate (55%) against pandemic A(H1N1) but low (26%) against A(H3N2),[24] possibly explaining substantial influenza-attributable rates in the older population.

The study had limitations. In NSW, the ED diagnosis is recorded as part of the routine workflow of physicians and not by health information managers trained in health care classification. Changes in information systems over time may have led to inconsistencies in the recording of diagnoses and other information. Diagnosis classifications varied across hospitals.[15] We did not have information on other viruses, such as respiratory syncytial virus, which may have caused some residual confounding. Biases can arise in the influenza notifications we used because the decision to test for influenza is at the discretion of the health-care provider and notifications arise from any type of medical service. On the other hand, notifications provide a combination of wide geographic coverage and are very specific to influenza.

Of the 186 EDs in NSW, 19% did not report to the Emergency Department Data Collection database during the study period and another 3% were excluded. Therefore, our results will be an underestimate of state-wide figures. Non-participating and excluded hospitals were smaller regional hospitals in more remote areas.[15] Nevertheless, the data set we analysed included approximately 87% of public hospital visits in the state.[25] ED services in NSW are almost wholly public.[26,27]

The statistically significant associations with injury are challenging to explain. The positive association may have been a chance finding even though we set a restrictive level of statistical significance. Unmeasured confounding could have occurred due, for example, to weather or other factors that vary on a similar time scale to influenza seasons. Confinement at home due to influenza may lead to fewer opportunities for injury, although this needs further study.

Using all-age rather than age-specific influenza notifications in the model might explain negative influenza-attributable estimates, which are, in reality, impossible. Using age-specific notifications in the model may improve estimates, but this requires further research.

In summary, seasonal influenza is associated with a substantial but annually varying burden of hospital-attended illness on EDs in NSW and thus on the overall population. The greatest demand occurs among young children and in the oldest population in some years. Varying vaccine effectiveness may have explained varying impact in the relatively well immunised older population. Improved vaccines and vaccination strategies that protect young children as well as older adults are needed to reduce morbidity in the population. Influenza surveillance information may be useful in forecasting and managing peaks in ED demand and to facilitate improved workload, staff and bed management. Improved control of influenza may substantially reduce surges in ED demand caused by influenza.

Conflict of interest

All authors report no conflicts of interest relevant to this article.

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Lessons learnt from a three-year pilot field epidemiology training programme

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Problem: The Pacific region has widely dispersed populations, limited financial and human resources and a high burden of disease. There is an urgent need to improve the availability, reliability and timeliness of useable health data.

Context: The purpose of this paper is to share lessons learnt from a three-year pilot field epidemiology training programme that was designed to respond to these Pacific health challenges. The pilot programme built on and further developed an existing field epidemiology training programme for Pacific health staff.

Action: The programme was delivered in country by epidemiologists working for Pacific Public Health Surveillance Network partners. The programme consisted of five courses: four one-week classroom-based courses and one field epidemiology project. Sessions were structured so that theoretical understanding was achieved through interaction and reinforced through practical hands-on group activities, case studies and other interactive practical learning methods.

Outcome: As of September 2016, 258 students had commenced the programme. Twenty-six course workshops were delivered and one cohort of students had completed the full five-course programme. The programme proved popular and gained a high level of student engagement.

Discussion: Face-to-face delivery, a low student-to-facilitator ratio, substantial group work and practical exercises were identified as key factors that contributed to the students developing skills and confidence. Close engagement of leaders and the need to quickly evaluate and adapt the curriculum were important lessons, and the collaboration between external partners was considered important for promoting a harmonized approach to health needs in the Pacific.

The Pacific island countries and areas in the WHO Western Pacific Region (the Pacific) are American Samoa, Cook Islands, Fiji, French Polynesia, Guam, Kiribati, Marshall Islands, Federated States of Micronesia, Nauru, New Caledonia, Niue, Commonwealth of the Northern Mariana Islands, Palau, Papua New Guinea, Pitcairn Islands, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, and Wallis and Futuna. The Pacific has widely dispersed populations as well as limited financial and human resources. Health systems are highly reliant on donor funding and are influenced by the development partners' regional and global health priorities. Despite efforts by different programmes, average life expectancy is generally low[1] and has not significantly improved over the past two decades.[2] The Global Burden of Disease 2015 Study estimated that lower respiratory infections, ischaemic heart disease, and diabetes cause the greatest disease burden in the Pacific;[3] however, due to a scarcity of good-quality useable data, global burden of disease estimates for the Pacific are largely derived from models.[4]

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There is an urgent need to improve the availability, reliability and timeliness of useable data to better inform, monitor and evaluate actions for halting this triple burden of disease in the Pacific. Substantial amounts of data are often collected in the Pacific, but very little of these are analysed and made available for policy and planning in a timely manner.[4] The data that are available show that the Pacific is facing recurrent epidemics of communicable diseases, extremely high rates of noncommunicable diseases (NCDs)[2,5] and accelerating effects of climate change on health.[2]

The purpose of this paper is to share lessons learnt from a pilot field epidemiology training programme, officially known as the Pacific Data for Decision Making (DDM) Programme, or simply, Programme, which was designed to foster informed and appropriate responses to these Pacific health challenges.

CONTEXT

The need for a coordinated and sustainable public health surveillance training programme and the identification of opportunities for field training has been advocated in the Pacific over the past two decades.[6,7] The Pacific Public Health Surveillance Network (PPHSN) partners, including (in alphabetical order) the Centers for Disease Control and Prevention (CDC), Fiji National University (FNU), Pacific Community (SPC), Pacific Island Health Officers Association (PIHOA) and World Health Organization (WHO), have been building capacity in surveillance and response across the Pacific for many years.[8,9] Several efforts have been previously initiated to address the gap in Pacific epidemiological capacity, including sending Pacific health staff to Field Epidemiology Training Programmes (FETPs) overseas; however, it was not until 2004 that a harmonized approach to epidemiology training was established in the Pacific itself, as we describe below. Since 2012, one Pacific country, Papua New Guinea, has also established its own successful FETP (Bieb S, et al., unpublished, 2017).

In 2004, the curriculum of the DDM Programme[10] of the Fiji School of Medicine and CDC was adapted to the Pacific and delivered in several areas and countries by PPHSN partners between 2004 and 2011. The goal of the DDM Programme was to build capacity in field epidemiology for Pacific health staff whose jobs require them to have a basic understanding of the area but whose skill level needed to be enhanced to perform their responsibilities effectively. The curriculum was focused on surveillance and response to outbreak-prone diseases. Academic accreditation was achieved in 2010 with the establishment of the Post-Graduate Certificate in Field Epidemiology by the Fiji School of Medicine, which is now the College of Medicine, Nursing and Health Sciences of FNU. More recently, meetings of the Pacific Island Health Ministers in 2011 and 2013 reinforced the need to further build epidemiology capacity of staff in the Pacific. Regional development partners were called on once again to assist with training programmes "to address the lack of trained and experienced epidemiologists in the region … [and] development of comprehensive training programmes to develop core competencies in 'data techs', 'epi techs' and epidemiologists".[11] Further, sound epidemiological capacity was deemed necessary for meeting the obligations of the International Health Regulations (2005) and the WHO Asia Pacific Strategy for Emerging Diseases and Public Health Emergencies.[12,13]

In response, PPHSN partners revamped the existing DDM Programme to ensure greater student engagement, improve relevance to current Pacific island priorities and needs and adopt a health-system-wide approach applicable to both communicable diseases and NCDs. The modified Pacific DDM Programme, as outlined below, was pilot-tested from 2013 to 2016.

ACTION

Overview of pilot programme

The goal of the Pacific DDM Programme remained unchanged. The main target groups were epi-techs and health workers who must be able to: 1) work with and understand data sets to perform their roles; 2) identify health threats and assure the quality of source data; 3) operate well-designed data and surveillance systems; 4) generate, understand, present and explain high-quality information products from these systems; and 5) perform descriptive and basic data analysis. The Pacific DDM Programme consisted of five sequential courses: four delivered as one-week classroom-based courses and one field epidemiology project (**Table 1**). The courses are described in **Appendix I**.

Table 1. **Courses and number of students completing each course, Pacific DDM Programme, August 2013 to September 2016**

Course	Number of times delivered	Number of students undertaking course	Number of students successfully completing course	Percentage of students successfully completing course*
Introduction to Epidemiology and Field Epidemiology	5	112	105	94%
Public Health Surveillance	5	103	94	91%
Outbreak Investigations	12	244	178	73%
Computing for Public Health Practice	2	43	33	77%
Field Epidemiology Project	2	47	26	55%

* Students who did not successfully complete a course either opted out of being assessed or undertook the assessment and did not pass

Programme entry requirements

Prior to enrolling in the Pacific DDM Programme, students were required to have either a bachelor's degree or a minimum of five years' experience in the health sector (demonstrated on their curriculum vitae) with a written and positive reference from a supervisor.

Teaching methods

The Pacific DDM Programme was delivered in country by epidemiologists working for PPHSN partners, including (in alphabetical order) CDC, FNU, PIHOA, SPC, University of Guam, University of Newcastle (Australia), and WHO. The original DDM Programme was modified to increase the use of participatory learning methods based on adult learning principles. Sessions were structured so that theoretical concepts were presented in an interactive way and reinforced through practical hands-on group activities, case studies and other interactive practical learning methods. On average, each course had six facilitators and 25 students.

Curriculum

The curriculum accredited previously by FNU was modified substantially. Some objectives were reallocated across the continuum of courses to improve programme flow. Most of the existing presentations, exercises and resources were re-developed to ensure the newly acquired knowledge and skills could be applied immediately by students within their health systems. The Pacific DDM Programme covered both communicable diseases and NCDs. Students assessed the efficiency and effectiveness of their own surveillance systems and developed a plan for strengthening them. Students reviewed and analysed data sets collected at their workplace.

In addition, the curriculum was aligned with the Health Metrics Network framework (**Fig. 1**).[14] Students were required to develop an information product in each course (e.g. own data analysis product, standard operating procedures for their surveillance systems, outbreak situation reports). The changes to the existing FNU-accredited programme were accredited through an FNU programme amendment.

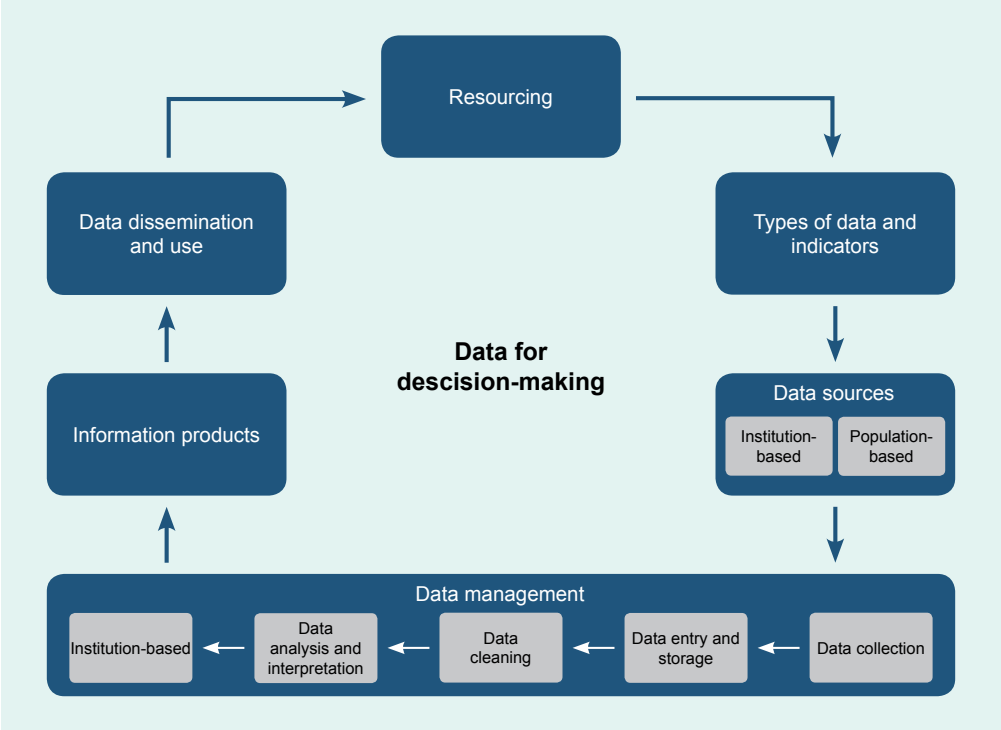
Student assessment

Students in each of the first four courses were assessed through both formative and summative assessments. Formative assessments consisted of a variety of assessment methods that did not contribute to the final grade and were intended to provide feedback to students. Summative assessments comprised both continuous (50%) and final endpoint assessment (50%). Continuous assessments consisted of presentation of student products during each classroom-based course. The endpoint assessment was most commonly an exam consisting of multiple choice and short answer questions.

Monitoring and evaluation

After every classroom-based course, facilitators met to review the course and make necessary refinements. For example, if it was felt that students were not understanding a particular topic, greater time was allocated to it the following day as well as in subsequent delivery of the

Fig. 1. **Curriculum framework for Pacific DDM Programme aligned with the Health Metrics Network framework, 2013–2016**



course. At each course, an evaluation was undertaken to assess students' self-reported level of understanding and skill pre- and post-course and to capture students' feedback on the most/least valuable elements and areas for improvement (see **Appendix II**).

A two-day facilitators' retreat was held at the two-year mark of the pilot phase; focus group discussions were held to review and discuss the pilot phase. The student assessments and standardized course evaluations revealed students' perceptions of how well the course learning objectives were being met in the short term. For areas that students found particularly challenging, teaching methods were modified by using more interactive exercises and greater time was allocated to these topics for subsequent course deliveries. Long-term effects on both student competency and their performance in applying the new knowledge and skills in their work setting will require further evaluation.

Further logistical aspects of the Pacific DDM Programme are discussed in **Appendix III**.

OUTCOME

From August 2013 to September 2016, 258 students entered into the Programme. Twenty-six course workshops were delivered and one cohort of students completed the full five-course Programme. As of September 2016, 17 students had completed all courses, 32 had completed three courses, 28 had completed two courses and 181 had completed one course. Plans are currently being made to move those students interested through to completion of all courses. The frequency of course delivery was somewhat constrained by the time spent in re-developing the curriculum and funding limitations. Please see **Appendix II** for qualitative findings.

DISCUSSION

The pilot phase was considered to be highly successful. Student engagement and stakeholder collaboration were considered the two greatest outcomes. Several opportunities for further improvement were also identified.

One of the most significant findings from the pilot phase was the importance of closely engaging Pacific

health leaders. At times, leaders had not fully appreciated that the Pacific DDM Programme was a series of sequential courses; consequently, some students were sent to subsequent courses regardless of readiness. Some participants did not have the study and mathematical skills needed to succeed in the courses, which detracted from the learning experience of other students. In the future, before commencing delivery, standardized consultations will be held with health department and other leaders (outlined in **Appendix IV**). Further, the development of self-study "pre-courses" that can be delivered online will be explored.

The facilitators determined that students should begin the Field Epidemiology Project immediately after the first course and be followed up at each of the subsequent courses. This would ensure that the students had more time to complete their project and ensure classroom-based courses were relevant to their projects. Facilitators also considered that there needed to be greater clarity of the specific products for each of the courses. The proposed products of each course are:

1. Introduction to Epidemiology and Field Epidemiology: a clean data set, data dictionary (to be used at the Computing for Public Health Practice course) and data communication brief or infographic;
2. Public Health Surveillance: a planning template for either: (a) CD standard operating procedures (including template for weekly CD surveillance report); (b) an NCD monitoring and surveillance plan (including template for annual NCD reports/dashboard); or (c) standard operating procedures (including report templates) for other routine health information products;
3. Outbreak Investigations: a report on an outbreak investigation (i.e. a situation report);
4. Computing for Public Health Practice: a poster from the data set analysis; and
5. Field Epidemiology Project: (a) CD surveillance standard operating procedures (including weekly CD surveillance reports); (b) NCD disease monitoring and surveillance plan (including annual NCD reports/dashboard); or (c) other routine health information product.

Delivering each DDM course required substantial logistical work (see **Appendix III** for more information). Sustainability will require a dedicated administrative unit to support DDM delivery. One of the greatest challenges of programme implementation was not having a funding stream dedicated specifically to the Pacific DDM Programme. This hampered the ability to plan strategically for the Programme, forecast how many students could be trained and ensure broad coverage across the Pacific. Additionally, some facilitator staff were on short-term contracts and had to pursue other employment at the end of their term. This problem needs to be addressed through longer-term facilitator contracts to minimize staff turn-over and loss of institutional knowledge. This will also help to ensure a high level of course coordination, including consolidated storage and real-time analysis and action from course evaluations. Further, greater contribution of funding and facilitation from countries will help to ensure sustainability.

In recent years, Pacific health ministers urged regional development partners to contribute further to training programmes in epidemiology. The three-year pilot Pacific DDM Programme built on an existing programme and was a direct response to that ministerial request. The Pacific DDM Programme proved popular and achieved high levels of student engagement. The collaboration between external partners was considered important for promoting a harmonized approach to surveillance in the Pacific as was the need for high levels of engagement from Pacific health leaders. The Programme will continue to evolve and adapt to Pacific health needs.

Conflicts of interests

The authors declare that they have no competing interests.

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Disclaimer

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the CDC, WHO or any of the other organizations involved.

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External quality assessment for arbovirus diagnostics in the World Health Organization Western Pacific Region, 2013–2016: improving laboratory quality over the years

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Arboviruses continue to pose serious public health threats in the World Health Organization (WHO) Western Pacific Region. As such, laboratories need to be equipped for their accurate detection. In 2011, to ensure test proficiency, the WHO Regional Office for the Western Pacific piloted an external quality assessment (EQA) programme for arbovirus diagnostics. By 2016, it had grown into a global programme with participation of 96 laboratories worldwide, including 25 laboratories from 19 countries, territories and areas in the Region. The test performance of the 25 laboratories in the Region in 2016 was high with 23 (92%) reporting correct results in all specimens for dengue and chikungunya viruses. For Zika virus, 18 (72%) of the 25 laboratories reported correct results in all specimens, while seven (28%) demonstrated at least one error. When comparing iterations of this EQA programme in the Region between 2013 and 2016, the number of participating laboratories increased from 18 to 25. The first round only included dengue virus, while the latest round additionally included chikungunya, Zika and yellow fever viruses. Proficiency for molecular detection of dengue virus remained high (83–94%) over the four-year period. The observed proficiency for arbovirus diagnostics between 2013 and 2016 is an indicator of laboratory quality improvement in the Region.

Arboviruses continue to pose a serious threat to human health worldwide as evidenced by the emergence and re-emergence of arboviral infections in the form of outbreaks globally in the last five years. During this time, the world witnessed the re-emergence of chikungunya virus (CHIKV) and Zika virus (ZIKV) while dengue virus (DENV) and yellow fever virus (YFV) continued to circulate widely. In February 2016, the Director-General of the World Health Organization (WHO) declared a Public Health Emergency of International Concern (PHEIC) in response to ZIKV, microcephaly and other neurological disorders reported in Brazil, following a similar cluster in French Polynesia in 2014.[1] This declaration ended in November 2016 in favour of a longer-term programmatic approach.[2]

The WHO Western Pacific Region bears a large arboviral disease burden. For dengue alone, there were more than 860 000 cases and 1500 deaths reported between 2013 and 2016 (WHO Regional Office for the Western Pacific, unpublished data, 2017). CHIKV is endemic in the Region and considered a threat to the Pacific island countries and areas with recent outbreaks in New Caledonia and Papua New Guinea.[3] The first recorded outbreak of ZIKV disease in the Region was in the Federated States of Micronesia in 2007.[4] The virus has since been detected in the majority of the countries and occasionally causes outbreaks such as in Singapore in 2016.[5]

Preparedness in the face of such potential disease occurrences is paramount. Therefore, public health laboratories and their equivalent in the research sector throughout the Region have developed or adopted molecular methods for arbovirus detection. These new assays complement serological assays already in use and allow for diagnosis in the early stages of illness. To assess the competency of laboratories in the Region, an external quality assessment (EQA) programme for arbovirus diagnostics was developed in 2011 with the goal of enabling the laboratories to gauge their proficiency and to identify areas for improvement. While test capacity is an indication of whether laboratories have the necessary elements, including required equipment,

[a] Health Emergencies Programme, World Health Organization Regional Office for the Western Pacific, Manila, Philippines.
[b] Health Emergencies Programme, World Health Organization, Lyon, France.
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reagents and protocols in place to perform a test and to gauge the throughput, proficiency relates to how reliably and accurately a test is performed. The establishment of an EQA programme for dengue diagnostics was part of the *Asia Pacific Strategy for Emerging Diseases (2010)*, an action framework for building International Health Regulations core capacities.[6] Participation in EQA programmes is a requirement for achieving the International Organization for Standardization 15189 accreditation, which specifies the quality management system requirements particular to medical laboratories.[7]

The development of the EQA programme involved the main reference laboratories and collaborating centres in the Region (**Fig. 1**). A pilot to assess the feasibility, including panel preparation and logistics, of EQA for dengue diagnostics was first conducted by the National Institute of Infectious Diseases, Japan in 2011. This informed the development of the first round of EQA for dengue, which was introduced in 2013.[8] Eighteen laboratories participated in the programme, which was coordinated by the Environmental Health Institute (EHI), Singapore, a WHO Collaborating Centre for Reference and Research of Arbovirus and their Associated Vectors. There was no round of EQA in 2014 due to logistic and technical review of the first round for improvement of subsequent iterations. In 2015, a second round of EQA, not only for dengue but also chikungunya diagnostics, was prepared by EHI[9] and involved 24 laboratories, including 19 in the Region and five in the WHO South-East Asia Region. In 2016, in succession to the two regional programmes, WHO organized the first global EQA programme for arbovirus diagnostics. The programme was developed and managed by the Royal College of Pathologists of Australasia Quality Assurance Programs. As of July 2017, global participation stands at 96 laboratories throughout all WHO regions.

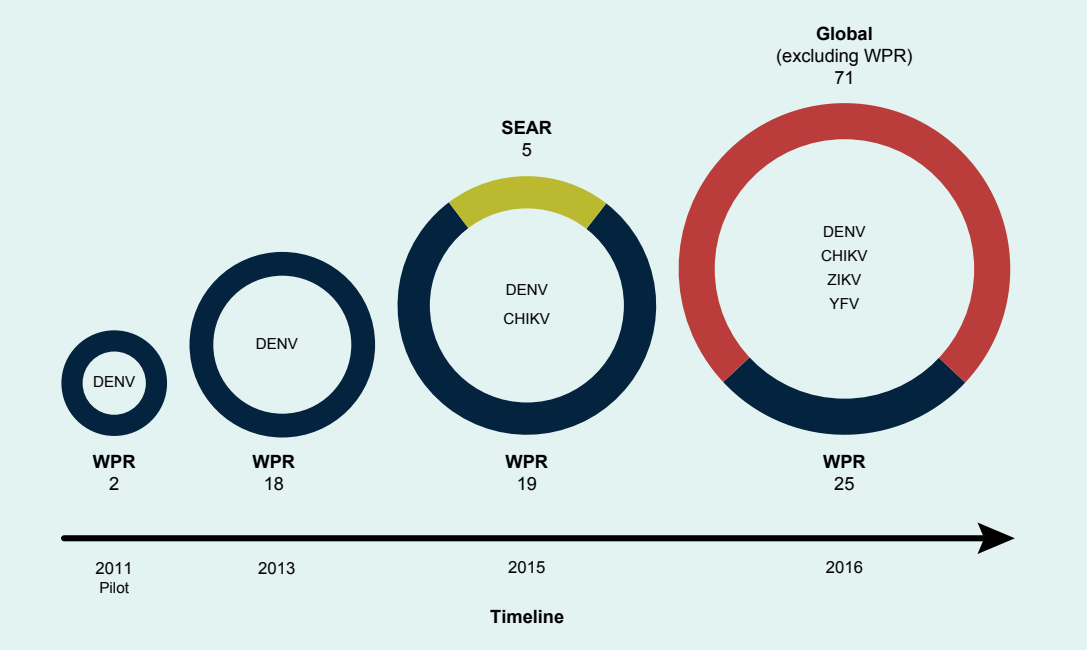
In 2016, 26 laboratories in the Region were invited to participate in the EQA programme. This iteration of the EQA assessed participating laboratories' capacity and proficiency for DENV, CHIKV, ZIKV and YFV (optional) diagnosis by polymerase chain reaction (PCR). Panels containing blinded samples of various dilutions of the four arboviruses to be identified by participating laboratories were shipped between November and December 2016. Of the 26 laboratories invited, 25 laboratories from 19 countries, territories and areas in the Region returned results; one laboratory was unable to participate due to logistical issues preventing delivery of the panel. All 25 laboratories participated in PCR diagnosis of the three required viruses; additionally, 22 performed DENV serotyping and 13 participated in the optional YFV component of the EQA. Results from the 2016 EQA are presented in **Fig. 2**.

In 2016, test performance was high with 23 of 25 (92%) laboratories reporting correct results in all specimens in the panel for DENV and CHIKV. For ZIKV, 18 (72%) laboratories reported correct results in all specimens, while seven (28%) demonstrated at least one error. Twenty-one of 22 (95%) laboratories were able to correctly identify DENV serotypes. All four laboratories that performed ZIKV lineage testing correctly determined whether the strain was of Asian or African lineage. Overall, errors appeared to be randomly distributed, and no patterns of inaccuracy could be observed for particular specimens or laboratories (data not shown). Of the 13 laboratories that took part in the optional module for detection of YFV, nine (69%) successfully identified YFV in test specimens. While not endemic or reported in Asia, demonstrating regional preparedness to detect and confirm YFV is vital in the event an outbreak were to occur. The importance of having diagnostic capacity for YFV was highlighted by the recent importations of laboratory-confirmed YFV cases from Angola into China.[10]

A laboratory preparedness survey to determine test capacity for arboviruses in the Region was conducted in February 2016, immediately after the declaration of a PHEIC related to ZIKV.[11] It revealed that of the 19 national-level public health laboratories surveyed, 16 (84%) reported molecular testing capacity for ZIKV. The results of the 2016 EQA for arboviruses indicate that, in addition to test capacity, laboratories have a high level of test proficiency for ZIKV. Additionally, three countries that indicated not having test capacity at the time of the survey had this capacity in place at the time of the 2016 EQA (data not shown).

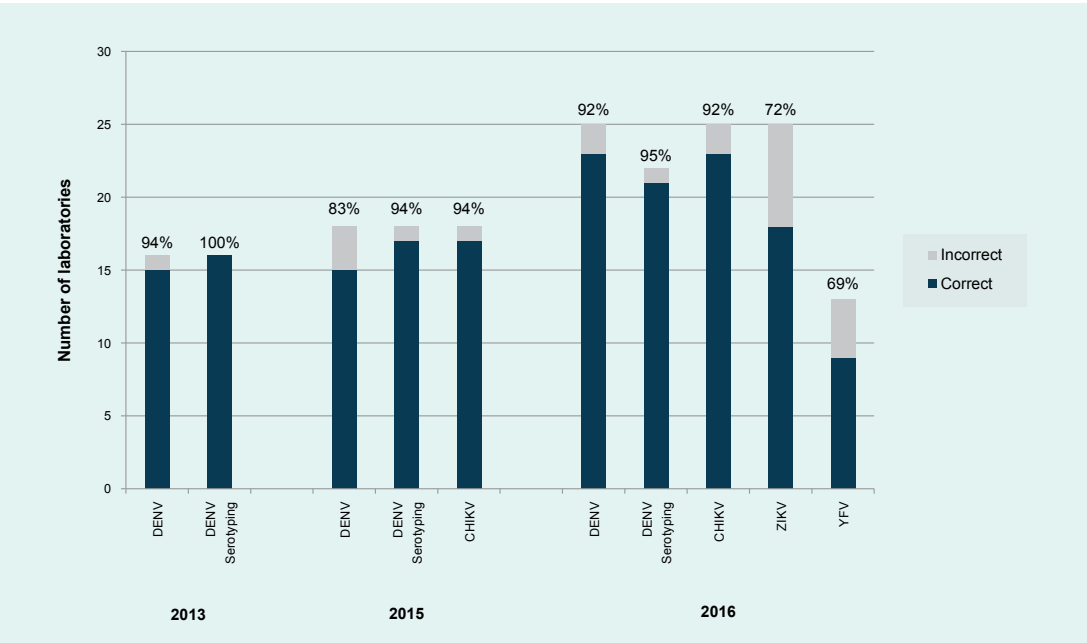
When comparing the results of the EQA programmes in the Region between 2013 and 2016, EQA participation has consistently increased since 2013 (**Fig. 2**). Laboratories in the Region demonstrated good proficiency at detecting DENV in 2013 and both DENV and CHIKV in 2015 with more than 83% of laboratories reporting correct results for all specimens in the panels. The Region can now claim at least 23 national-level public health laboratories with

Fig. 1. **Increase in the number of participating laboratories, geographic coverage and variety of pathogens of the WHO EQA programme for arbovirus diagnostics from pilot to global programme, 2011–2016**



Legend: Evolution of the EQA programme for arbovirus diagnostics from 2011 to 2016 showing an increase in number of participating laboratories, geographic coverage and variety of pathogens included. No round of EQA was conducted in 2014. Circles and their relative size provide an illustration of this growth over time and by WHO region. Numbers under respective region or global indicate number of participating laboratories. Pathogens included in each panel are listed inside each circle. CHIKV = chikungunya virus; DENV = dengue virus; Global (red); SEAR = South-East Asia Region (green); WPR = Western Pacific Region (dark blue); YFV = yellow fever virus; and ZIKV = Zika virus.

Fig. 2. **Proficiency* of laboratories in the WHO Western Pacific Region participating in the EQA programme for arbovirus diagnostics, 2013–2016**



Legend: CHIKV = chikungunya virus; DENV = dengue virus; YFV = yellow fever virus; and ZIKV = Zika virus.

*Proficiency is defined as the percentage of laboratories reporting all correct results for a component of the EQA panel. No round of EQA was conducted in 2014.

consistently high accurate molecular detection capacity for DENV and CHIKV compared to previous years. The observed increase in participation and improvements in EQA results suggest that laboratory managers are continuously improving their laboratory operations. Their commitment is important in making sure that the Region is prepared for health emergencies, supporting routine surveillance and providing accurate diagnoses.

The EQA programme is an evolving tool that will continue to be reviewed and changed to monitor and inform improvement of laboratory diagnostic testing for arboviral diseases. It shows that small initiatives can grow into larger accomplishments in a stepwise manner when sufficient investments are made and when the impact on public health by better surveillance and response is recognized. The observation of an increasing number of participants and high proficiency between 2013 and 2016 is an indicator of improvement in laboratory capacity and performance in the Region.

Conflicts of interest

None declared.

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