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Using public health scenarios to predict the utility of a national syndromic surveillance programme during the 2012 London Olympic and Paralympic Games

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SUMMARY

During 2012 real-time syndromic surveillance formed a key part of the daily public health surveillance for the London Olympic and Paralympic Games. It was vital that these systems were evaluated prior to the Games; in particular what types and scales of incidents could and could not be detected. Different public health scenarios were created covering a range of potential incidents that the Health Protection Agency would require syndromic surveillance to rapidly detect and monitor. For the scenarios considered it is now possible to determine what is likely to be detectable and how incidents are likely to present using the different syndromic systems. Small localized incidents involving food poisoning are most likely to be detected the next day via emergency department surveillance, while a new strain of influenza is more likely to be detected via GP or telephone helpline surveillance, several weeks after the first seed case is introduced.

Key words: Bioterrorism, *Cryptosporidium*, influenza, public health, surveillance system.

INTRODUCTION

The Health Protection Agency (HPA) provides an integrated surveillance approach to health protection, using a range of tools including syndromic surveillance [1]. Within the HPA national syndromic surveillance is undertaken by the Real-time Syndromic Surveillance Team (ReSST).

Syndromic Surveillance is the real-time (or near real-time) collation, interpretation and dissemination of routine electronic data to allow the early identification of potential public health threats and their impact, enabling effective public health action. The surveillance is based not on the laboratory-confirmed diagnosis of a disease but on the presentation of signs and symptoms or proxy measures available through routine data sources that can constitute a syndrome/provisional diagnosis [2].

Syndromic surveillance was first developed in response to the deliberate release of anthrax in the

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USA following the 9/11 terrorist attacks [3]. The particular strength of this form of surveillance was seen as the ability to detect unusual signals.

In order to rapidly detect potential infectious disease threats during the Olympic and Paralympic Games the HPA set up a suite of robust and multi-source syndromic surveillance systems. These included enhancements of already established systems as well as new systems created for the Games [4].

Prior to the Games, the HPA undertook an assessment of the ability of their syndromic systems to detect various public health incidents, e.g. a *Cryptosporidium* outbreak, pandemic influenza, etc. The aim of the project was to quantify what could and could not be detected, thereby improving understanding of the strengths and weaknesses of syndromic surveillance and so giving policy makers more confidence in conclusions drawn from the surveillance. This paper describes this work to show how scenario planning can be used to evaluate the effectiveness of syndromic surveillance.

METHODS

Overview

A number of scenarios were identified, reflecting potential major incidents that the HPA would be required to provide rapid information about if they occurred during the Games. ReSST used these scenarios to test their syndromic systems and quantify the detection abilities of their statistical surveillance methods.

The ReSST coordinates four main surveillance systems; HPA/NHS Direct (a national telephone health advice line run by NHS Direct), HPA/QSurveillance [in-hours general practitioner (GP) consultations], GP Out-of-hours/unscheduled care (GPOOHSS, out-of-hours GP consultations) [5] and the Emergency Departments Syndromic Surveillance System (EDSSS, emergency department attendances), the latter two having been developed as part of the enhanced Games surveillance programme [6, 7].

Estimating baseline activity – what is normal?

It was initially necessary to describe what is expected under normal circumstances during the Games period. For the established systems this was quite straightforward, the expected activity can be modelled across the relevant syndromic indicators by looking at previous years' summer activity. For the newer systems, where extra providers were continually being recruited, data from previous summers did not reflect the volume of data we expected to see during the Games period. It was necessary to scale up the historical data to take account of the increased coverage as more data providers joined the syndromic systems; for instance during the summer of 2011 information was only being received from two emergency departments, equivalent to 6·5% of London emergency departments by volume, whereas by the Games period coverage was expected to include 51% of London activity.

During the Games there were expected to be population changes (both influx and efflux) that might have an impact on healthcare usage, these included an influx of day visitors and overnight visitors and the possibility of local residents choosing to 'avoid' the Games by taking holidays during this period.

For the influx for example, when assessing the HPA/NHS Direct surveillance system a range of estimates for the number of extra visitors expected in addition to the usual summer London population was used to model the baseline data.

For the efflux, population changes could have an impact on London residents, for example, an upper estimate of a 10% decrease during the Games of the Newham Primary Care Trust resident population was used. [Healthcare in England is commissioned by 152 primary-care trusts (PCTs), typically consisting of 200 000 residents.] If this occurred then there might be a reduction in the consultation rate at doctors' surgeries, where the denominator is the registered population which does not vary due to holidays.

Games scenarios

[*It is important to note that the scenarios were not real events but were constructed purely to test the syndromic systems. They were not the result of any threat analysis undertaken by the HPA or other bodies.*]

A number of different scenarios were considered and identified as the most important:

- Contamination of a local water supply by *Cryptosporidium* oocysts.
- A localized food poisoning incident involving scombrotoxin.
- An outbreak of a new variant of influenza, arriving with Games overseas visitors.

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Table 1. *Parameters used in SEIR influenza model*

Infected population by residency and exposure risk via Games	Average number of new cases for each infectious case								
Residency (abbreviation)	OV	NV	GV	LV	UKV	NnV	GnV	LnV	UKnV
Visiting Games									
Overseas (OV)	0·310	0·011	0·009	0·267	0·551	0·039	0·032	0·962	0·115
Newham (NV)	0·310	0·011	0·009	0·267	0·551	0·735	0·004	0·134	0·046
Greenwich (GV)	0·310	0·011	0·009	0·267	0·551	0·005	0·735	0·133	0·046
Remainder London (LV)	0·310	0·011	0·009	0·267	0·551	0·031	0·026	0·770	0·092
Remainder UK (UKV)	0·310	0·011	0·009	0·267	0·551	0·005	0·004	0·128	0·781
Not visiting Games									
Newham (NnV)	0·039	0·724	0·005	0·031	0·005	0·714	0·001	0·084	0·005
Greenwich (GnV)	0·032	0·004	0·737	0·026	0·004	0·002	0·697	0·096	0·009
Remainder London (LnV)	0·218	0·030	0·030	0·175	0·029	0·002	0·002	1·099	0·022
Remainder UK (UKnV)	0·026	0·010	0·010	0·021	0·174	0·000	0·000	0·010	1·357

Table 2. *Percentage coded to syndromic indicator with upper and lower estimates*

	Main syndromic indicator(s) and percentage of people presenting coded to indicator				
	Cryptosporidium	Scombrotoxin	Influenza	Botulism	Anthrax
NHS Direct calls	Diarrhoea, 75% (75, 100)	Diarrhoea, 50% (25, 75)	Cold/flu, 95% (50, 100)	Diarrhoea 100% (25, 100)	Cold/flu, 80% (80, 100)
General Practitioner consultations	Diarrhoea, 75% (75, 100)	Vomiting, 50% (25, 75) Diarrhoea, 50% (25, 75)	ILI, 100% (75, 100)	Diarrhoea 50% (25, 75)	ILI, 50% (25, 75)
Emergency department attendances	Diarrhoea, 100% (100, 100)	Diarrhoea, 50% (25, 75)	ARI, 100% (100, 100)	Botulism 100% (75, 100)	ILI, 50% (25, 75)

ILI, Influenza-like illness; ARI, Acute respiratory infection.

- An intentional release of botulism into the food chain at a Games venue.
- An intentional release of anthrax via aerosol dispersion.

The *Cryptosporidium* scenario was based on a historical event [8], using the observed epidemic curve to estimate the number of cases each day and translating the location to a London PCT where the impact on the Games would be the greatest. For the other scenarios there were no directly comparable historical examples that could be used although historic information was used to help model some of the scenarios.

In the influenza scenario, which involved modelling an infectious disease, a SEIR (susceptible, exposed, infected, resistant) model was used to estimate how the outbreak would develop over time and therefore how many new cases would be expected each day in the early stages. Table 1 shows how transmission was modelled to spread between groups, for instance each infectious overseas visitor is expected to result on average in 0·310 new cases in other overseas visitors and 0·115 in UK residents outside London who are not visiting the Games.

Table 2 shows which of the syndromic indicators we would expect cases to be predominately coded to, including higher and lower estimates.

Modelling healthcare presentation

For each scenario, the proportion of patients choosing to use different methods of healthcare (e.g. telephone advice, local doctors, hospitals) were estimated in order to calculate the number of extra consultations captured in the syndromic systems (Table 3). Research

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Table 3. *Percentage presenting to different healthcare providers with upper and lower estimates*

Denominator population	Percentage of people presenting under each scenario				
	Cryptosporidium	Scombrotoxin	Influenza	Botulism	Anthrax
	Laboratory-confirmed cases	Laboratory-confirmed cases	Symptomatic population	Symptomatic population	Symptomatic population (fulminant symptoms for ED)
NHS Direct calls	184·0% (23·0, 207·0)	76·7% (23·1, 231·0)	2·0% (0·3, 10·0)	11·1% (0·8, 33·3)	4·0% (0·5, 20·0)
General Practitioner consultations	230·0% (100·0, 560·0)	230·0% (100·0, 560·0)	10·0% (5·0, 100·0)	33·3% (10·0, 100·0)	20·0% (10·0, 50·0)
ED attendances	1·0% (0·3, 2·3)	14·0% (5·0, 90·0)	0·5% (0·3, 2·5)	33·3% (10·0, 50·0)	100·0% (70·0, 100·0)

ED, Emergency department.

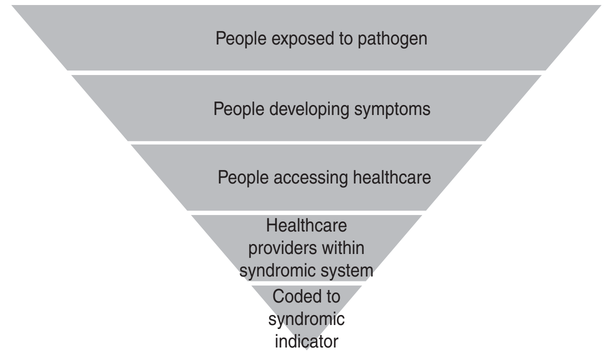

Fig. 1. Presentation pyramid for people exposed to pathogen.

is available to support the healthcare use patterns for some pathogens via the second study of infectious intestinal disease in the community (IID2 study) [9] and self-reporting via influenza surveys (W. Edmunds, personal communication). Where research on specific pathogens was not available estimates were based on similar pathogens or the total volume accessing healthcare by each method. Where estimates were used, an upper and lower estimate was also included to reflect the plausible range of values and a sensitivity analysis performed to identify the impact on the analysis of different estimate values.

The methodology varied slightly between scenarios but the estimates usually took the form of a 'presentation pyramid' (Fig. 1), with the combined effect of estimates for: development of symptoms, healthcare usage, system coverage and coding, giving the number of people expected to be coded to a syndrome within each system.

Overseas visitors, domestic visitors and London residents were considered separately as they would be likely to access care in different locations; domestic visitors may return home before developing symptoms and using local care, international visitors are more likely to use walk-in centres to access general practice services.

With the exception of the HPA/NHS Direct surveillance scheme in England and Wales, population coverage by the syndromic systems is only partial. Coverage varies across the country but is usually well known and it is clear in which parts of the country incidents are more likely to be detected because of better coverage.

With each scenario specialist epidemiological colleagues were consulted as to the most likely symptoms that people will present with, and estimates made as to the proportion of these that will get coded to the

Table 4. *Central estimates used to calculate numbers presenting*

Percentage of Games visitors from London	25%
Percentage of Games visitors from overseas	27%
Percentage of GP surgeries in London covered by in-hours system	56%
Percentage of out-of-hours consultations given a Read code	21%
Percentage of London ED attendances covered by system	51%

		Scenario				
		Cryptosporidium	Scombrotoxin	Influenza	Botulism	Anthrax
Syndromic indicator and percentage coded to indicator	NHS Direct	Diarrhoea, 100%	Diarrhoea, 50%	Cold/flu, 95%	Diarrhoea 100%	Cold/flu, 100%
	Other systems	Diarrhoea, 100%	Diarrhoea, 50%	ILI, 100%	Diarrhoea, 50% (GP), botulism, 100% (ED)	ILI, 50%

ILI, Influenza-like illness; GP, general practitioner; ED, emergency department.

syndromic indicators. There is considerable uncertainty in some of these estimates, particularly where there are no historical precedents. The symptoms with which patients present can have a considerable effect on what can be detected because some indicators have a much lower level of background activity than others.

The central estimates used for coverage and proportion coded are presented in Table 4.

Simulating outbreaks

The baseline expected activity for the Games period (July–September) was combined with the extra activity predicted for each scenario to test whether or not the syndromic systems could detect the changes and how quickly extra activity would be identified.

The simulated number of diarrhoea calls under the *Cryptosporidium* scenario, combining the modelled baseline, extra cases due to expected population changes during the Olympics and outbreak calls, are presented as an example in Figure 2. Here the upper confidence interval forms the 'alarm threshold' and it can be seen that the outbreak would only be detected in this example at its peak.

For the HPA/NHS Direct scheme, a simulation approach was used; the background data were combined with the scenario data plus random background noise, to reflect the historical variation outside epidemics, and the proportion of true alarms was counted, along with failed detections and false alarms. This approach was applicable to HPA/NHS Direct because the data had been well modelled using 8 years of historical data and the statistical methodology had been validated over many years of use; hence it was possible to accurately estimate the random variation in terms of a series of over-dispersed Poisson distributions for each indicator and Strategic Health Authority (SHA) area. For the newer systems there was no tried and tested parametric model for the random variation so simulations were not appropriate.

For the other systems the general approach was to add the extra activity predicted by the scenarios to the base data 'once for each date in the Games period' and then calculate the proportion of dates which resulted in the extra activity being detected. These combined datasets enable an estimate to be given for the minimum size of incident that can be detected with a probability of at least 50% (Table 5) and the time until probability of detection reaches 50%

Table 5. *Minimum size of incidents detectable by syndromic surveillance during the Olympics*

	Scenario size			
	Number of people ill in one London primary-care trust community due to *Cryptosporidium* oocysts in water supply.	Number of people developing symptoms in one London primary-care trust due to scombrotoxin poisoning.	Number of people developing symptoms due to ingesting botulism at a Games venue.	Number of people developing symptoms due to anthrax exposure in London.
Syndromic surveillance system	Minimum size of incident detectable at least 50% of the time			
HPA/NHS Direct	2200	510	1400	2500
HPA/QSurveillance	3300	133	26 000	34 000
GPOOHSS	1100	1300	2200	23 000
EDSSS	7000	43	65	510

HPA/NHS Direct, A national telephone health advice line run by NHS Direct; HPA/QSurveillance, in-hours general practitioner (GP) consultations; GPOOHSS, GP out-of-hours/unscheduled care; EDSSS, Emergency Departments Syndromic Surveillance System.

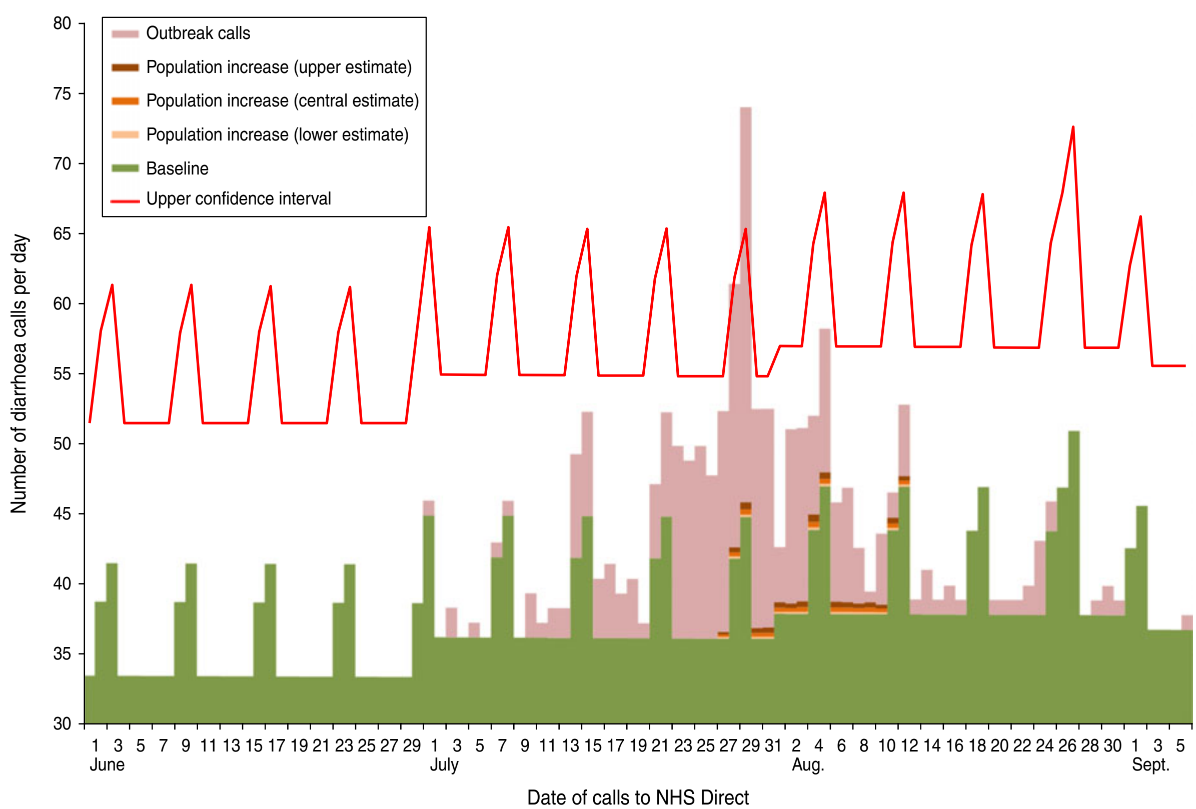

Fig. 2 [*colour online*]. Modelled diarrhoea calls to NHS Direct (London).

(Table 6). This approach has the advantages of using the actual random variation in the baseline data which came from previous years and identifying how changes due to day of week effects and bank holidays might affect detection.

Using simulated and modelled datasets it was also possible to vary the scale of the incidents in order to ascertain how big an incident needed to be before it was detectable and how soon incidents of different sizes would be observed.

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Table 6. *Expected number of days between incident and detection*

Syndromic surveillance system	Scenario onset: Onset date of first laboratory-confirmed case of *Cryptosporidium*, based on historical outbreak with 300 confirmed cases	Scombrotoxin food poisoning within one London primary-care trust	Fifty overseas visitors to the Games arrive already infected by a new strain of influenza	Botulism ingestion at a Games venue	Aerosol release of anthrax in London, leading to 5000 people being infected
	Days until probable detection more than 50%				
HPA/NHS Direct	23	Next day when incident is large enough to be detected	34	Next day when incident is large enough to be detected	9
HPA/QSurveillance	Never		54		Never
EDSSS	Never		40		5
GPOOHSS	27		15		Never

HPA/NHS Direct, A national telephone health advice line run by NHS Direct; HPA/QSurveillance, in-hours general practitioner (GP) consultations; EDSSS, Emergency Departments Syndromic Surveillance System; GPOOHSS, GP out-of-hours/unscheduled care.

RESULTS

Sensitivity analysis

The sensitivity analysis identified which assumptions and estimates had the most impact on detection rates given the different levels of uncertainty involved in the estimates. Estimates needed for the analysis can be divided into the following broad categories:

(1) Estimates of the number of people falling ill and becoming symptomatic and modelling assumptions about reproduction rates for infectious diseases.
(2) Estimates of the proportion of symptomatic people who access care via telephone helplines, GPs, or emergency departments and assumptions about differences between weekend and work-day proportions.
(3) Estimates of population changes during the Games period, travel and spectator demographics and assumptions about visitor healthcare use.
(4) Estimates of local coverage by syndromic systems.
(5) Estimates of proportion coded to syndromic indicators.

In most scenarios the biggest impact, reflecting the greatest uncertainty, was linked to estimates of the proportion accessing various types of healthcare. This was true even in the *Cryptosporidium* scenario where more robust information was available of estimates for the proportion of people likely to call HPA/NHS Direct or visit their GP. Where healthcare use was not the main factor affecting detection rates, the main issue was local coverage and this was reflected in sub-scenarios used to quantify these differences. For instance the GP system, HPA/QSurveillance, provides data regularly from all the GP surgeries within one London PCT, while for a neighbouring PCT the scheme only covers around 13% of surgeries.

Probability of detection

The probability of detecting scombrotoxin poisoning via HPA/NHS Direct is presented in Figure 3; under this scenario patients may present with either diarrhoea or vomiting, this graph shows that incidents are more likely to be detected using the diarrhoea indicator.

The minimum size of incident expected to be detected with at least 50% probability is shown in Table 5. (The influenza scenario is not included in this table because in all cases considered the numbers

Table 7. *Sensitivity analysis example – hypothetical* Cryptosporidium *outbreak on 1 July 2012*

Assumption	Range of values considered	Probability of a diarrhoea control chart exceedance before day 25	Date when probability of exceedance first reaches 50%
Patients ringing NHS Direct and recorded under diarrhoea indicator	75% recorded as diarrhoea, rest spread over other indicators	51%	24 July
	100% recorded as diarrhoea	**67%**	**23 July**
Total calls and diarrhoea calls rise due to increase in Greater London overnight population during Olympics	Between 0·3% and 1·3% increase	Results unaffected across entire range considered	
'Reporting ratio' – ratio of calls to laboratory-confirmed cases. Central estimate based on GP to laboratory ratio estimate and a 3:1 GP to NHS Direct call ratio	0·1	24%	9 August
	0·4	38%	28 July
	0·8	**67%**	**23 July**
	0·9	76%	22 July
Cryptosporidium more common in some age ranges and HPA/NHS Direct reporting ratio varies by age range	No differences between ages	51%	24 July
	Age-specific reporting ratios	**67%**	**23 July**

Bold text shows assumptions and results used as central estimates.

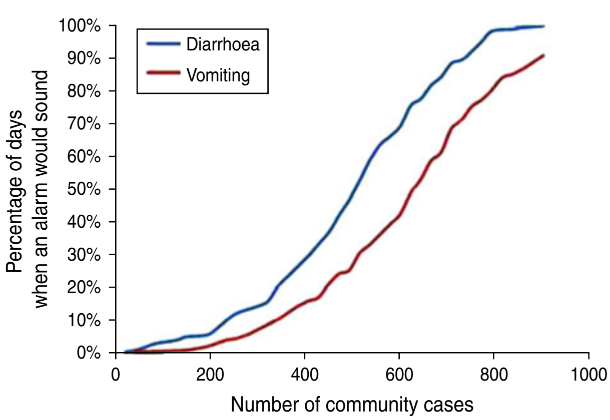

Fig. 3 [*colour online*]. Probability of detecting diarrhoea/vomiting cases, NHS Direct, 2010–2011.

would grow exponentially and be detected at some point.)

Under the influenza scenario, which assumed a similar reproduction rate to the H1N1 outbreak in 2009, the number of cases would grow exponentially and always be detected by the syndromic systems at some point, even if it was introduced by just a handful of seed cases.

The different strengths of different systems can be seen in Table 5:

- Fewer cases are needed to trigger an alarm in the emergency departments for incidents involving the most severe symptoms.
- The size of incidents that can be detected vary widely across systems and between scenarios. Differences between scenarios depend on which indicators patients' consultations are coded to, how geographically contained the incident is and over how many days patients are likely to present with symptoms.
- Some systems, for instance HPA/QSurveillance, are better able to detect local events because larger numbers enable local as well as regional surveillance, but coverage varies across the UK.

An example of a sensitivity analysis, in this case for the HPA/NHS Direct surveillance system using the *Cryptosporidium* scenario, with a hypothetical onset date of 1 July 2012 is presented in Table 7. The greatest range of detection probabilities occurs under the assumption about the 'reporting ratio', which is based on evidence for the proportion accessing healthcare in the IID2 study [9].

Timeliness of detection

Timeliness is measured by how many days would elapse after an incident occurs before there is a better than 50% chance of detecting the incident (Table 6).

The speed of detection depends mainly on the organism involved; with cases of food poisoning at one event, people are likely to all become ill within 1 day, while with infectious diseases like influenza

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there will be a gradual increase in cases over time and symptoms will take a few days to develop. A scenario involving people being ill over several weeks will be harder to detect than a similar sized incident occurring on just one day.

DISCUSSION

This study showed that the syndromic surveillance systems could detect the key incidents of public health concern identified in the scenarios, and provided estimates for the scale of incident that could be detected and the speed of detection. The probability of detection by syndromic surveillance alone remains low when the total number of people symptomatic is small. With scenarios involving patients with very severe symptoms the new emergency department system is the most sensitive detection system, provided the incident occurs near a sentinel site. Which system provides the timeliest detection varies depending on the scenario (Table 6).

Demographic changes due to the 2012 Olympic and Paralympic Games were found to have a negligible impact on detection rates, although the increased travel would make detection harder; incidents are easier to spot when concentrated spatially and temporally. An incident at a Games venue would be harder to detect if those affected came from many different places and returned home before developing symptoms.

There were, fortunately, no major health issues affecting the games and the demographic changes did not impact on the ability of syndromic systems to monitor public health.

An intrinsic limitation of syndromic surveillance is that although an incident may lead to a noticeable rise in a syndromic indicator, it is very unlikely that the cause or pathogen would be identified by syndromic systems alone, but rather that the rise will lead to further investigation.

The accuracy of simulations depends on having good historical baseline data. Where systems are introduced prior to a mass gathering it is preferable to have good coverage for at least a year prior to the event.

The ability of syndromic surveillance to identify the scale of public health issues in the UK would be greatly enhanced by better understanding of healthcare use for common infections/conditions. With better estimates for the proportion of symptomatic patients who access the different types of healthcare it would be possible to extrapolate from increased activity to incidence in the community. Ideally data collected for syndromic surveillance at mass gatherings should include information on whether patients have attended the event(s).

By better quantifying the detection abilities of syndromic surveillance in the UK, public health practitioners will have better information when planning for emergencies and have more confidence in interpreting syndromic data alongside other intelligence. During the Olympics, the Health Protection Agency was able to provide reassurance that no major health incidents had occurred and that none of the local incidents recorded had become major incidents, and was able to quantify what was meant by a major incident. This is an approach that can be used in any country for their syndromic surveillance and should be a prerequisite when providing reports that seek to reassure that no major incident has occurred both during mass gatherings and in routine surveillance.

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DECLARATION OF INTEREST

None.

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