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The impact of school holidays on the social mixing patterns of school children

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ABSTRACT

School holidays are recognised to be of great epidemiological importance for a wide range of infectious diseases; this is postulated to be because the social mixing patterns of school children – a key population group – change significantly during the holiday period. However, there is little direct quantitative evidence to confirm this belief. Here, we present the results of a prospective survey designed to provide a detailed comparison of social mixing patterns of school children during school terms and during the school holidays. Paired data were collected, with participants recording their social contacts once during term time and once during the holiday period. We found that the daily number of recorded encounters approximately halved during the holidays, and that the number of close contact encounters fell by approximately one third. The holiday period also saw a change in the age structure of children's social contacts, with far fewer contacts of their own age, but an increase in the number of encounters with adults, particularly older adults. A greater amount of mixing between children at different schools was recorded during the holiday. We suggest, therefore, that whilst infections may spread rapidly within schools during term time, in the holiday period there are increased opportunities for transmission to other schools and other age groups.

Introduction

School-aged children are a key epidemiological group. School pupils mix together in large numbers and generally have low levels of prior immunity, making them vulnerable to infection and presenting ample opportunity for onward transmission. Incidence of the 2009 influenza H1N1v pandemic was highest in children, and many other common infections are concentrated in school pupils (Anderson and May, 1992; Baguelin et al., 2010; Donaldson et al., 2009; Keeling and Rohani, 2008).

Patterns of mixing determine how infection spreads within a population, both within and between subgroups. If, as is often the case, a population is categorised into groups based on age, it is necessary to know how individuals of different ages interact (Anderson and May, 1992; Keeling and Rohani, 2008). Until recently, models had to rely on fairly crude approximations for these mixing patterns, but thanks to large scale survey data (Glass and Glass, 2008; Mossong et al., 2008) mathematical epidemic models can now use detailed information about patterns of social contacts between different age groups (Baguelin et al., 2010; Mossong et al., 2008).

Although recent datasets represent a huge advance in our understanding of social contact behaviour, they are not complete. This is because most available information relates to normal contact behaviour, and there are circumstances in which normal behaviour will not apply. For example, mixing patterns may change when people are ill, or during a pandemic (Eames et al., 2010). Here, we consider another possibility: changes in mixing patterns during school holidays.

The behaviour of school children during school holidays is expected to differ from that during term time; we would anticipate that children make fewer contacts and, in particular, fewer contacts with people their own age. Epidemiological evidence supports this expectation, with school holiday periods being associated with large reductions in incidence (Baguelin et al., 2010; Cauchemez et al., 2008; Conlan et al., 2010a, 2010b; Fine and Clarkson, 1982; Heymann et al., 2004; Heymann et al., 2009). It is anticipated that, whenever children are strongly involved in transmission, term-time patterns of epidemic spread would not be sustained during holidays periods, and this assumption is intrinsic to the consideration of school closure as an outbreak control strategy (Bootsma and Ferguson, 2007; Cauchemez et al., 2009; Ferguson et al., 2006; Hatchett et al., 2007; Lee et al., 2010; Markel et al., 2007).

A small number of studies have taken place to explore mixing behaviour of school pupils during school term (Conlan et al., 2010a, 2010b; Glass and Glass, 2008; Salathé et al., 2010), but few studies exist that shed light on the impact of holiday periods. Hens et al. (2009) used existing data (Mossong et al., 2008), some of which had been collected during school holidays, to assess the changes in mixing patterns that occur during school holiday periods, concluding that there were significant changes in population mixing patterns; however, their focus was on changes within the population, not specifically in school pupils. Miller et al. (2010) carried out a survey

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studying the social behaviour of pupils during an influenza-related school closure, but did not measure behaviour when the schools were open. Despite the clear importance of holiday periods, no prospective study has previously been carried out to measure, at an individual level, changes in mixing patterns during school holidays.

Here, we describe the results from a survey designed to provide a direct comparison between term and holiday periods. We collected detailed social mixing behaviour from the same set of school pupils on two separate occasions: once during term time and once during a school holiday. This survey thus quantifies the impact of school holidays on the social mixing patterns of school children.

Methods

In September 2009 we began a study in the UK aiming to quantify changes in mixing patterns due to influenza-like-illness and due to H1N1v-related school closure. Although during the autumn of 2009 there were many cases of influenza, few schools closed, so the school-closure part of the study could not be carried out as had been intended; instead, in February 2010 we carried out a convenience contact survey to measure the changes in school children's contact patterns that occur during school holidays. The results of the illness-related contact pattern changes and a very brief outline of the school holiday study can be found elsewhere (Eames et al., 2010); here, we present a more detailed analysis of the methods and results of the school holiday study.

In order to measure patterns of social contacts, school pupils were recruited to take part in the survey. Participants were asked to complete a contact diary, similar to those used in other social contact studies, in which they were asked to give details about all the people they met over the course of a day. Similarly to previous studies (Eames et al., 2010; Mossong et al., 2008; Read et al., 2008), a meeting was defined as "talking face-to-face or skin-to-skin contact (e.g. a handshake, a kiss, contact sports, etc.)". Participants were asked to include each person they met, even if the meeting was short and even if they did not know that person's name. Phone contacts were specifically excluded. Since the aim of the study was to quantify changes in social mixing behaviour that took place during the school holiday, participants were asked to complete a contact diary on two separate occasions: once during school term, and once during the holidays.

In the contact diary, participants were asked to list each person whom they met during a day, and to give some details about each of these contacts: age (or age range — replaced by the mid-point of this range for the purposes of analysis), gender, whether there was skin-to-skin contact, the duration and setting of the encounter, and frequency with which they met. Participants were also asked whether each person they met was in the same school year as them, and whether they went to the same school as them. Participants were asked to record some background details about themselves, including their age, gender, household size, and use of public transport on the days of the surveys. The survey was designed to be fully anonymous: the names of participants were not recorded at any point. The study received ethical approval from the London School of Hygiene and Tropical Medicine.

The two-part questionnaire was handed out to pupils in eight schools in London and the South East of England during February 2010; the questionnaire can be found in the supplementary material. Surveys were marked for the attention of parents/guardians for their approval, and for reasons of practicality it was left to their discretion whether the surveys were completed by the school pupil or by their parent/guardian on their behalf. Participants were requested to complete one part of the survey during school term and the other part on a weekday during their half term holiday. Once both parts had been completed, participants returned their surveys in a pre-paid envelope.

Here, we compare the number of encounters and the age distribution of contacts that were reported during the term time and the school holiday. The impact of age, gender, school type (primary versus secondary), and household size was explored. To account for the paired data obtained, a population averaged Poisson model with robust standard errors was used (a negative binomial model was also considered, but the differences were slight) to analyse the number of encounters reported. Analyses were carried out in Stata 11. Individual-level changes in numbers of encounters recorded during term time and during the half term holiday were tested using the Wilcoxon matched-pairs signed-rank test; this non-parametric test was used because of a lack of previous studies indicating the likely distribution of holiday-related changes in individual-level contact behaviour.

Results

1100 questionnaires were given to schools for distribution, of which 135 were returned. A small number had not been completed correctly (e.g. only one part was returned, or both parts were filled in during school term time), and these were excluded; 122 paired contact diaries were included in the sample used for analysis.

Ages of respondents ranged from 5 to 19, with 16 primary school and 106 secondary school respondents. 40 (33%) respondents were male, 81 (66%) female and 1 (1%) of unrecorded gender.

There is a marked difference in the number of encounters recorded during term time (mean number of encounters 19.0) and the half term holiday (mean 9.4), Fig. 1A and Table 1. The change in the number of encounters reported in a day – defined as the number

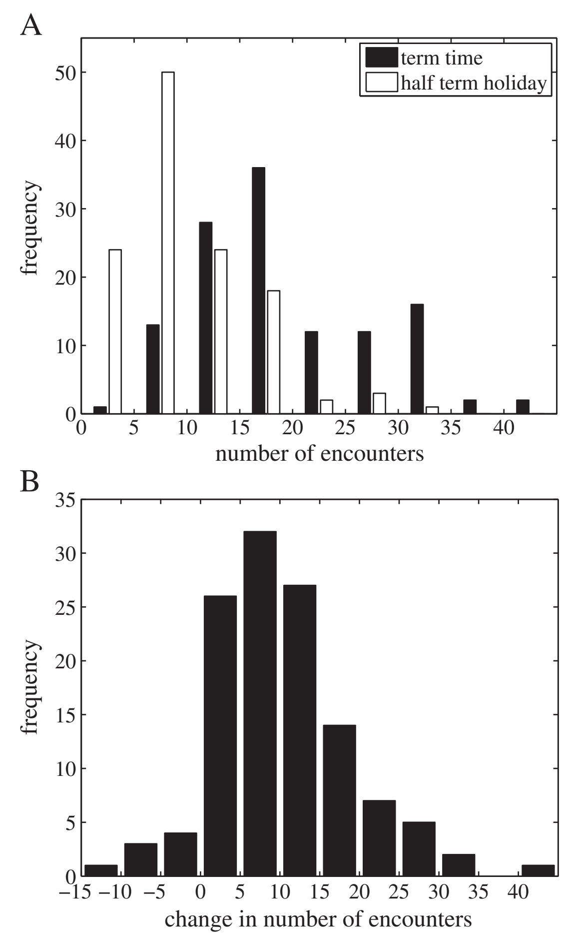

Fig. 1. A.) Distribution of number of encounters. Number of encounters recorded during term time (black) and during half term (white) is shown. B.) Distribution of change in number of encounters recorded by each participant. The change in number of encounters is defined as the number in term minus the number in holiday.

Table 1
Mean number (standard deviation) of reported encounters of different types. Number of encounters reported during term time and the holiday period are compared. p-values for the significance of the change (measured at the level of the individual participant) are taken from Wilcoxon matched-pairs signed-rank test.

		Term time	Holiday	Difference	p-value
All contacts	Total	19.0 (8.9)	9.4 (6.0)	9.5 (8.7)	<0.0001
	School aged children at other schools	1.2 (1.8)	2.4 (3.0)	−1.1 (2.6)	<0.0001
	Adults aged 20–50	3.7 (2.4)	3.9 (3.0)	−0.1 (2.9)	0.78
	Adults aged over 50	0.7 (1.2)	1.0 (1.7)	−0.3 (1.7)	0.042
Close contacts	Total	8.9 (7.3)	5.7 (4.4)	3.2 (6.7)	<0.0001
	School aged children at other schools	0.7 (1.3)	1.4 (2.1)	−0.8 (1.8)	<0.0001
	Adults aged 20–50	1.6 (1.3)	2.2 (1.9)	−0.6 (1.6)	<0.0001
	Adults aged over 50	0.3 (0.6)	0.5 (0.9)	−0.3 (0.9)	0.0012

during term time minus the number during the holiday – was highly significant ($p<0.0001$), with the number of encounters approximately halving during the holiday period (Table 1, Fig. 1B).

Factors including gender, age, school type (primary or secondary), household size, public transport use, and time period (holiday or term time) were considered for inclusion in the statistical model; school type was omitted owing to colinearity with age. Ages were grouped into classes, chosen to be of approximately fixed width whilst maintaining the divide between primary school and secondary school participants. There was a small but significant influence of gender, household size, and public transport usage, and a large, highly significant, holiday effect (Table 2); the analysis confirms a halving in the daily number of encounters made during the school holiday compared to term time.

Not only does the number of encounters change during the holiday period; the properties of contacts change also (Fig. 2). Encounters made during school term are less likely to involve physical contact, and more likely to be with people met frequently (once or twice weekly or more often). As expected, encounters during the holiday period are more likely to take place at home.

During term-time pupils recorded the majority of their encounters with individuals of similar age to themselves (Fig. 3). During holidays, encounters are more likely to be with older individuals. When looking at the distribution of the difference in age between participants and their contacts (Fig. 4), we see a spike at zero, a second, smaller, spike around 30 years, and a third, even smaller, spike at 65 years. These secondary spikes are notably higher during the half term holiday.

The number of encounters school children report with adults aged 20–50 did not change significantly (mean term time 3.7; holiday 3.9; $p>0.7$). However, there was a marginally statistically significant change in the number of encounters with adults aged over 50 (mean term time 0.7; holiday 1.0; $p\approx0.04$).

Table 2
The impact of potentially significant factors on the number of reported encounters. Sample sizes represent number of reports; note that each participant reported twice (once during term time and once during the holiday).

Category	Covariate (reports)	Relative number of reported contacts (95% CI)	p value
Gender	Male (n = 80)	1.00	
	Female (n = 162)	1.25 (1.06, 1.46)	0.025
Age	5–10 (n = 28)	1.00	
	11–15 (n = 172)	0.99 (0.81, 1.23)	0.600
	16–19 (n = 44)	1.07 (0.70, 1.45)	0.522
Period	Holiday (n = 122)	1.00	
	Term time (n = 122)	2.00 (1.79, 2.24)	<0.001
Household size (including participant)	≤3 (n = 56)	1.00	
	>3 (n = 186)	1.23 (1.01, 1.46)	0.035
Public transport use	No (n = 169)	1.00	
	Yes (n = 72)	1.22 (1.06, 1.39)	0.004

Of the school-aged contacts recorded by participants, during term time the great majority (89%) are recorded as attending the same school as the participant, falling to 39% during the holiday period. Despite the reduction in the total number of encounters made during the half term holiday, the increase in the fraction of contacts that do not attend the same school as the participant translates into an increase from 1.2 to 2.4 encounters per day made with school age children who do not attend the same school as the participant ($p<0.0001$), Table 1.

There was a significant change in the number of encounters at home (mean term time 3.1; holiday 4.3; $p<0.0001$); the number of home encounters was, unsurprisingly, strongly dependent on household size, each additional household member resulting in approximately 0.7 additional home contacts (95% confidence interval [0.23, 1.19], $p\approx0.004$).

Close contact encounters

The questionnaire used in this study gives us many different ways of defining an encounter. In the above analysis we have considered all interactions equally, but whether this is the correct unit of investigation for epidemiological purposes will depend on the pathogen and transmission route of interest. For many infections,

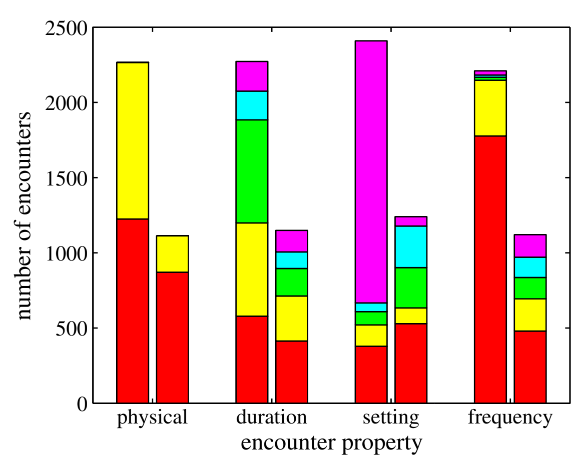

Fig. 2. Properties of encounters. Encounters recorded during term time (left bar of pair) and half term holiday (right bar of pair) are compared. Encounter property was described in several ways: physical — yes (red), no (yellow); duration — >4 h (red), 1–4 h (yellow), 10 min–1 h (green), 5–10 min (cyan), <5 min (maroon); setting — home (red), travel (yellow), leisure (green), other (cyan), and school/college/work (maroon); frequency — daily or almost daily (red), once or twice weekly (yellow), once or twice monthly (green), less than monthly (cyan), and never met before (maroon). In each case, the height of the portion of the bar represents the number of reported encounters that matched that property. The slight difference in heights between categories arises because of a small number of missing data and a small number of encounters that took place in more than one setting.

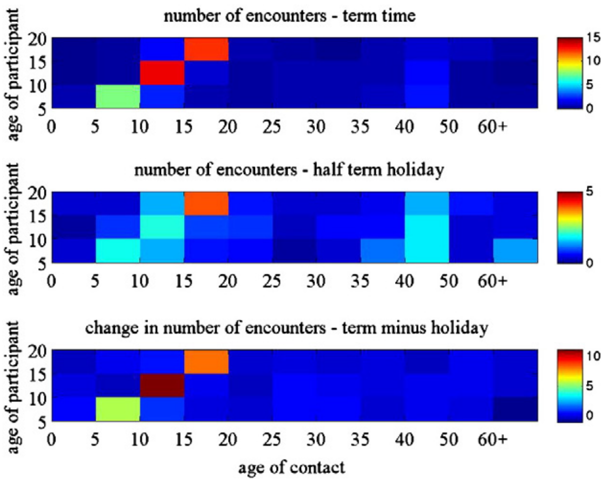

Fig. 3. Age distribution of reported encounters. Colour represents the mean number of encounters named by each participant within the relevant age group, during term time (top) and the half term holiday (middle). The change in the number of reported encounters is also shown (bottom). Note different scales on different panels.

we would expect that encounters that are in closer proximity and longer lasting would be more important; we might expect such encounters to be more likely to involve family members and less likely to change during holiday periods. Thus, we repeat the above analysis, restricting our attention to "close contact" encounters. Following established precedents (Hens et al., 2009; Mossong et al., 2008; Read et al., 2008), we define a close contact encounter to be one that includes physical (skin-to-skin) contact.

School holidays appeared to have a similar impact on close contact encounters to that on all encounters (Table 1). The number of close contact encounters reported fell by over a third during the school holidays, from a mean of 9.0 to 5.9 ($p<0.0001$). Again, significant effects of household size and gender are found, as well as term time/holiday period (Table 3). Public transport use does not have a statistically significant impact.

Close contact encounters show similar patterns in their age distribution to those seen for all encounters, with a large amount of like-with-like mixing during term time and a greater proportion of interactions with adults during the holidays (Fig. 5).

We find statistically significant changes in the numbers of close contact encounters with adults aged between 20 and 50 (mean term time 1.6; holiday 2.2; $p<0.0001$), with adults aged over 50 (mean term time 0.3; holiday 0.5; $p\approx0.001$), and with school-aged children at different schools (mean term time 0.7; holiday 1.4; $p<0.0001$), Table 1.

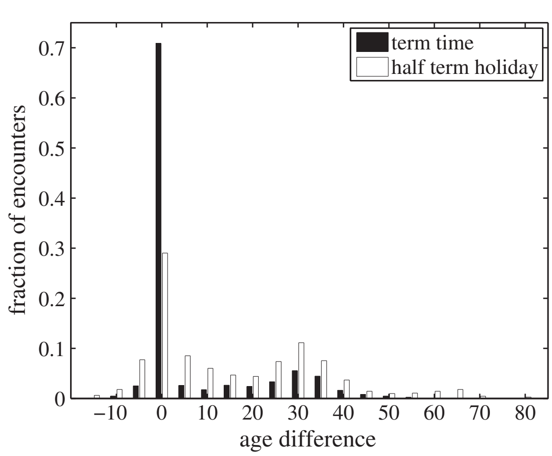

Fig. 4. Age difference between participant and contact. Age difference during term time (black) and the half term holiday (white) is shown. Age difference (contact age minus participant age) is grouped into bins of width 5 years, centred at the points shown.

Table 3
The impact of potentially significant factors on the number of reported close contact (skin-to-skin) encounters. Sample sizes represent number of reports; note that each participant reported twice (once during term time and once during the holiday).

Category	Covariate (reports)	Relative number of reported contacts (95% CI)	p value
Gender	Male (n = 80)	1.00	
	Female (n = 162)	1.32 (1.04 1.69)	0.025
Age	5–10 (n = 28)	1.00	
	11–15 (n = 172)	1.13 (0.78 1.63)	0.522
	16–19 (n = 44)	1.27 (0.83 1.95)	0.279
Period	Holiday (n = 122)	1.00	
	Term time (n = 122)	1.52 (1.29 1.79)	<0.001
Household size (including participant)	≤3 (n = 56)	1.00	
	>3 (n = 186)	1.55 (1.17 2.05)	0.002
Public transport use	No (n = 169)	1.00	
	Yes (n = 72)	1.20 (0.97 1.48)	0.095

Discussion

School holidays are associated with dramatic and important changes in the contact patterns of school children. In common with other studies, we find a decrease in the number of encounters on days when children are not at school (Cauchemez et al., 2008; Glass and Glass, 2008; Hens et al., 2009; Mikolajczyk et al., 2008); to our knowledge, this is the first prospective study to demonstrate this change on an individual level.

Not only did the number of reported encounters change, but so did the age-distribution of these encounters. Most term time encounters were made with individuals of very similar ages, but during the half term holiday a greater fraction of contacts were with adults, and the number of close contact encounters with adults increased significantly during the holiday. During term time, most reported encounters were with individuals who were not only of very similar age to but who attend the same school as the participant. Despite a fall in absolute

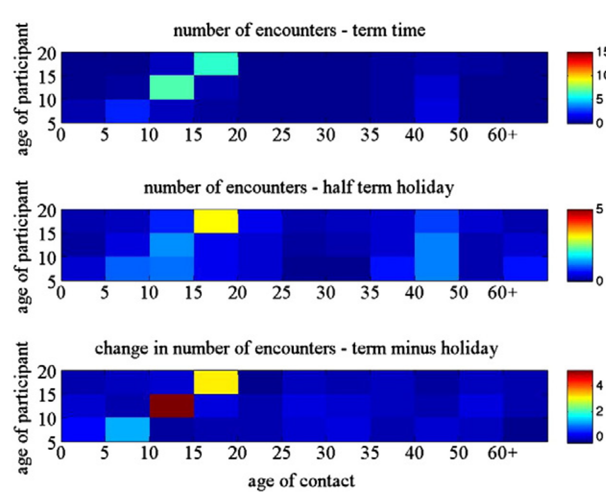

Fig. 5. Age distribution of reported close contact encounters. Colour represents the mean number of encounters named by each participant within the relevant age group, during term time (top) and the half term holiday (middle). The change in the number of reported encounters is also shown (bottom). Note different scales on different panels.

number of encounters with school-aged children, during the holiday there was an increase in the number of encounters with school-aged children who did not attend the same school as the participant. It appears that holidays facilitate mixing between schools. We postulate, therefore, that infections spread predominantly within school during term time but that holiday periods offer increased opportunities for transmission to other schools and to other age groups.

The study reported here comes with a number of caveats. It is based on a small sample of individuals within a small number of state schools in London and the South East of England. Although these schools covered a range of settings from inner-city to rural, with this small sample it was not possible to represent the full range of different school types in the UK. Whilst there is no evidence that individuals who participated in the study have different social contact patterns from those who did not, it is a possibility, and larger studies with a greater geographical range are necessary to test the generalisability of our results. Our study was not large enough to justify drawing any conclusions about differences between schools, but we would expect larger studies to find that there are differences in contact patterns at different schools, arising for example from differences in school size, classroom structure, or setting. Whilst our study suggested that there may be differences between schools, pupils from all schools surveyed reported a reduction in social contacts during the school holiday.

The response rate was low, with only 11% of distributed surveys being correctly completed and returned. This was disappointing, although not very different from responses to other unsolicited surveys carried out during the same period; Rubin et al. (2009) report a 7% response rate for a UK general population telephone survey; a similar survey to that used in this paper received an 8% response from people receiving antiviral medication during the 2009 epidemic (Eames et al., 2010). In contrast to these examples, it seems that when it is possible to spend considerable amounts of time working with schools involved in studies – engaging potential participants and explaining survey aims and background, for example – the response is far better, as reported by several school studies (Conlan et al., 2010a, 2010b; Mikolajczyk et al., 2008; Salathé et al., 2010), albeit with less onerous survey tools than that used in this study. Our belief is that the low response received for this study is a result of the lack of prolonged pre-study contact with the schools involved and the requirement that the survey be completed on two separate occasions. Further, to ensure anonymity, the survey team did not have names and addresses of participants, thus preventing the possibility of sending reminder messages. In the future, the ability to complete a similar survey electronically might improve response rates.

This study shows good agreement with the largest available study of contact patterns (Mossong et al., 2008), in which school-aged participants reported on average around 14–20 encounters per day (some survey days being during school holiday periods). However, as with most other surveys, there is no guarantee that questionnaires were completed correctly. It might be the case, for example, that on days when they made many encounters participants were less likely to record all of the people they met; if, as seems likely, more encounters are made during school term, such underreporting would mean that true differences between term time and holidays were larger than reported here. Alternatively, large, unreported, holiday gatherings would contribute biases in the other direction. For the youngest children, it was expected that parents/guardians would complete the surveys on their child's behalf; whilst unavoidable, this has the potential to include other inaccuracies, although the observation that the effect of school holidays did not change significantly with age suggests that such effects were small.

This study only examines the effect of planned school closure (i.e. a school holiday); further studies are necessary to determine whether the changes in contact patterns of school children would be any different in the case of an unplanned closure, for instance as a result of high levels of infection within a school. Such unplanned closures might result in parents making different child care arrangements. We note that whilst unplanned school closure is unusual, school holidays occur regularly and have an established impact on epidemic patterns (Baguelin et al., 2010; Cauchemez et al., 2008).

Despite the low response rate, participants provided detailed data that permitted the first detailed direct analysis of the changes in social mixing patterns that take place during school holidays. Until now, a lack of data has meant that modelling work that attempts to evaluate the impact of school closure on disease spread has been obliged to make assumptions about how mixing patterns change when schools close. The study reported here is the first prospective study designed to provide detailed quantitative data describing the changes in mixing patterns that arise when schools are closed. This information will be invaluable in assisting modellers and public health planners to understand the impact of school holidays on the spread of a wide range of infectious diseases and in assessing the effectiveness of school closure as an infection control measure.

Supplementary materials related to this article can be found online at 10.1016/j.epidem.2011.03.003.

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