Epidemics 14 (2016) 36–44

Contents lists available at ScienceDirect

Epidemics

journal homepage: www.elsevier.com/locate/epidemics

Comparison of the social contact patterns among school-age children in specific seasons, locations, and times

Dih-Ling Luh[a,b], Zhi-Shin You[a], Szu-Chieh Chen[a,b,*]

[a] Department of Public Health, Chung Shan Medical University, Taichung 40201, Taiwan, ROC
[b] Department of Family and Community Medicine, Chung Shan Medical University Hospital, Taichung 40201, Taiwan, ROC

ARTICLE INFO

Article history:
Received 12 May 2015
Received in revised form 31 July 2015
Accepted 22 September 2015
Available online 3 October 2015

Keywords:
Seasonal influenza
Behavior
Contact patterns
Contact diary
Social mixing
Taiwan

ABSTRACT

Social contact patterns among school-age children play an important role in the epidemiology of infectious disease. This study explored how people interact in specific seasons (flu season and non-flu season), environmental settings (city and county), and times (weekend and weekday). We conducted a survey of junior high school students (grades 7–8) using an established questionnaire during May–June 2013 and December 2013. The sample size with pair-wise comparisons for the times (weekday/weekend) and stratification by location and seasons were 75, 87, 105 and 106, respectively. The sample size with pair-wise comparisons for the seasons (flu/non-flu) and stratification by location were 54 and 83, respectively. Conversation and skin-to-skin contact behaviors were surveyed through diary-based questionnaires, of which 665 valid questionnaires were returned. There was no difference in the number of contacts during the flu and non-flu seasons, with averages of 16.3 (S.D. = 12.9) and 14.6 (S.D. = 9.5) people, respectively. However, statistical analysis showed that the average number of contacts in Taichung City and Yilan County were significantly different ($p < 0.001$). Weekdays were associated with 23–28% more contacts than weekend days during both the non-flu and flu seasons ($p < 0.001$) (Wilcoxon signed-rank test). Our work has important implications for the dynamic modeling of infectious diseases and performance analysis of human contact numbers and contact characteristics for schoolchildren in specific seasons, places, and times.

1. Introduction

Social contact is thought to be a major factor in the transmission process for many important infections, including SARS, influenza, smallpox, measles, pertussis and tuberculosis (Read et al., 2012; Eames et al., 2012; Wallinga et al., 2006). Since many of the greatest threats to human health are spread by direct person-to-person contact, understanding the spread of respiratory pathogens and patterns of human interactions are public health priorities (Read et al., 2012; Eames et al., 2012). The social mixing of schoolchildren is considerable, and favors the spread of infectious diseases in school environments. Such environments are thus an important source of infection into households, from which infections can spread further (McLean et al., 2010; Miller et al., 2010a,b).

Empirical studies of social mixing specifically targeted at understanding the spread of respiratory infections have been performed in the UK (Eames et al., 2011), Switzerland (Smieszek et al., 2012), Italy (Fournet and Barrat, 2014) and other European countries (Mossong et al., 2008), as well as the USA (Destefano et al., 2011) and Vietnam (Horby et al., 2011). Contact studies such as these provide the contact number per day per participant, model the potential transmission risk, and describe the different contact networks and contact characteristics. However, few studies have investigated if seasonal and environmental differences have an impact on contact patterns. In other words, there is a tendency to investigate the role of human contact behavior in the influenza seasons. Consequently, we decided to study how mixing is driven by seasonal variation (specifically, flu season and non-flu season), variation by location (city and county), and variation in time (weekend and weekday).

The seasonality of influenza is governed by numerous factors, and calls for the efforts of researchers from multiple disciplines. The effects of weather on viral survival (Shaman and Kohn, 2009) and host susceptibility (Dowell, 2011) as well as the effects of social contacts on transmission (Cauchemez et al., 2008) favor the spread of influenza during the winter months (Lipsitch and Viound, 2009).

* Corresponding author at: Department of Public Health, Chung Shan Medical University, 110 Sec. 1 Chien-Kuo N. Rd, Taichung 40201, Taiwan, ROC.
Tel.: +886 4 2473 0022x12110; fax: +886 4 2324 8179.
E-mail address: scchen@csmu.edu.tw (S.-C. Chen).

http://dx.doi.org/10.1016/j.epidem.2015.09.002

Furthermore, Willem et al. (2012) provided information on the relationships between weather conditions and those social contact patterns relevant to influenza transmission. They pointed out that while weather conditions are believed to affect the efficiency of transmission and host immunity, seasonality may also be driven by a tendency of people to congregate indoors during periods of bad weather. With regards to this hypothesis, they combined data from a social contact survey in Belgium with local weather data, and found the number of contacts at school increased in conditions of high temperature and low precipitation.

Recently, Read et al. (2014) conducted a study of human contact patterns in Guangzhou, China, which focused on the social mixing patterns in rural and urban areas. They contrasted the contact patterns by age and community urbanization, finding little difference in the number and duration of contacts or the age-mixing patterns between these populations. While animal densities are generally higher in rural areas, urban locations tend to serve as hubs for global spread. The difference between urban and rural populations may be particularly important for the initial spread of zoonotic pathogens (Hufnagel et al., 2004).

Previous studies have suggested that school closures might be effective for controlling the spread of influenza within a school (Eames et al., 2012; Cauchemez et al., 2008; Eames, 2014; Xue et al., 2012; Cowling et al., 2008; Glass et al., 2006). A systematic review of epidemiological studies to assess the effect of school closures on the transmission of influenza has also been reported (Jackson et al., 2013). Miller et al. (2010a,b) agreed that school closure can reduce student–student contacts but may also accelerate spread within a community. Hence, they suggested that the student behavior during a school closure may enhance or detract from the effectiveness of the closure. Eames et al. (2011) presented the results of a prospective survey designed to provide a detailed comparison of social mixing patterns of schoolchildren both during school terms and during school holidays. Eames et al. (2011) also suggested that while infections may spread rapidly within schools during the term, in the holiday period there are increased opportunities for transmission to other schools and other age groups. Hence, a precise quantification of human contacts can help in the identification of possible contagion pathways, and in the design and evaluation of containment strategies such as targeted vaccination, social distancing, and school closures.

This study used social contact diaries to compare the number of contacts per day per participant across different seasons, locations, and times of the week. We also present contact properties such as sex, age, masking, setting, frequency, duration, and contact types among school-age children. This information could provide the basis for investigations into social contact patterns in Taiwan and for the modeling of control measures in the future.

2. Material and methods

2.1. Study population

The study populations were chosen from Taichung City and Yilan County. Taichung City is located in western Taiwan, and has a population of just over 2.7 million people as of April 2014, making it the third largest city in Taiwan. Taichung has a warm, humid subtropical climate with an average annual temperature of 23.3 °C. The highest temperature of the year occurs in July and August, while the lowest temperature occurs in January and February. The average annual rainfall is just above 1700 mm and the average humidity is 75.6%. Yilan is a county in northeastern Taiwan with a population of 458,000. The average annual temperature is 22.5 °C with the highest temperature of the year occurring in July and August and the lowest temperature occurring in January and February. The average annual rainfall is just above 2837 mm and the average humidity is 82%.

Our study was conducted using a questionnaire survey in Chung-Lun and Shun-An junior high schools (grades 7–8, age 13–15 years) in Taichung City and Yilan County, respectively. In Chung-Lun Junior High School, the population was 1052 students in 36 classes, and each grade had 12 classes. In Shun-An Junior High school the population consisted of 313 students in 12 classes, and each grade had 4 classes. Each class had an average of 30 and 27 students in the Chung-Lun and Shun-An junior high schools, respectively. We selected 3 classes in each grade for our analysis. The eligible population was 720 students in Grades 7–8. The study population (selected schools) in Taichung City and Yilan County were chosen with the convenience sampling. However, the grades 7–8 were chosen because the better comprehension to the definition of "contact" in our questionnaire. Besides, those classes were selected with random sampling.

2.2. Study design

Fig. 1 shows the design and framework for this study. We investigated the social contact patterns in specific seasons (flu and non-flu season), locations (Taichung and Yilan), and times (weekday and weekend). During the non-flu season (NS), each participant in the Chung-Lun (T) and Shun-An (Y) junior high schools was asked to fill out two questionnaires during one randomly assigned weekday (denoted NSTa and NSYa) and one randomly assigned weekend (NSTb, NSYb), respectively. Each participant from each school was additionally requested filled out two questionnaires in the same way (FSTa, FSYa and FSTb, FSYb for a random weekday and weekend, respectively) during the flu season (FS).

Time-paired sample sizes were defined by the number of participants who correctly completed the questionnaires during the weekday and weekend, while season-paired sample sizes were defined by the number of participants in the same school who correctly completed questionnaires during flu/non-flu seasons and during the weekday and weekend.

2.3. Questionnaire survey and contact variables

This questionnaire survey was approved by the Institutional Review Board of the Ethical Committee of Chung Shan Medical University (CSMUH No: CS13100). Questionnaires were completed only after the participants and their parents (or legal guardians) signed an informed consent form. Parents signed the consent form but did not participate in this study or assist children when they were completing a questionnaire. The participants were told in advance which days they had been assigned and encouraged to fill out the questionnaire before they went to bed.

A contact was defined as a two-way conversation in which at least 3 words were spoken by each party. Two types of physical contact were defined: (i) two-way conversations during which at least three words were spoken (conversation only), and (ii) contacts that involved any sort of skin-to-skin contact (physical contact) (Horby et al., 2011). A contact diary was used to record all contacts during one day. The diary followed the course of the day, which was broken down by activities, starting with activities in the morning after waking, on the way to school, playing during breaks, and other activities after school until going to bed.

At the beginning of the questionnaire, participants were asked to provide information regarding sex, age, household size, their living situation (at home or in a dormitory), their health status on the day of sampling, their influenza vaccination history of the past six months, and the weather conditions that day. The scores to express the different levels of health status ranged from 0 to 10, e.g., feeling

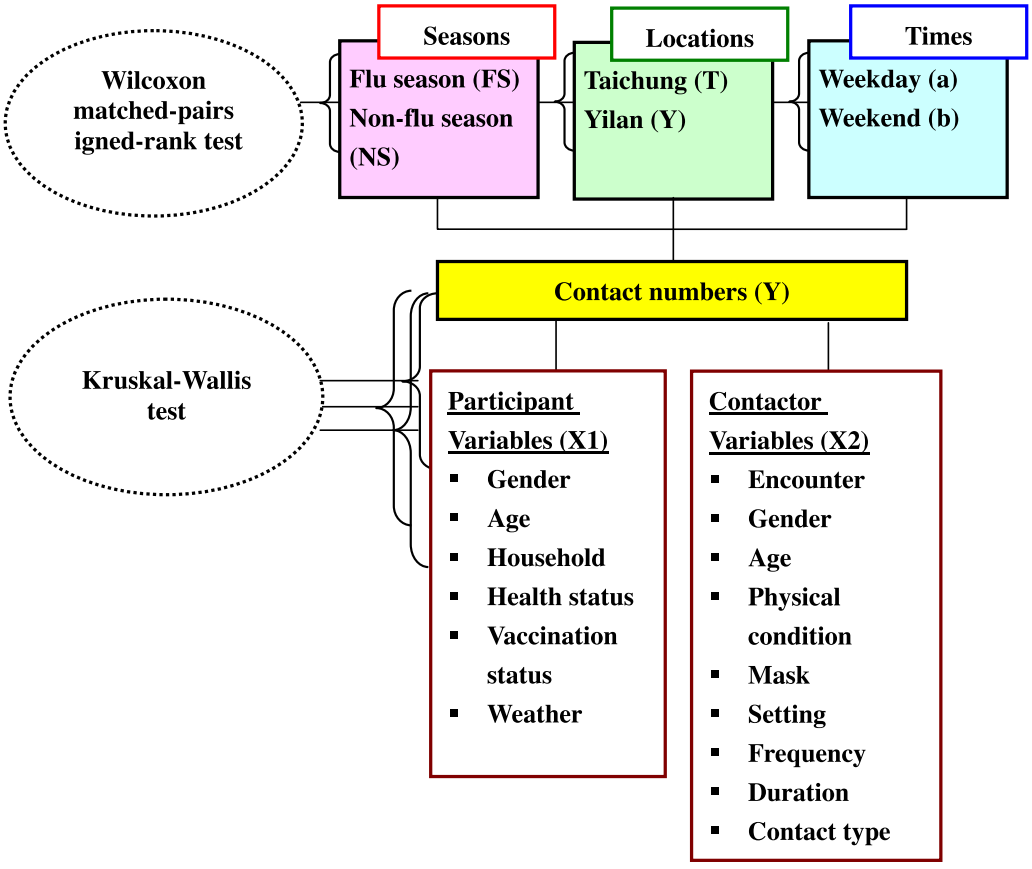

Fig. 1. Study design and framework of the data analysis of this study. We investigated the social contact patterns during specific seasons, locations, and times. Three statistical analyses were used to analyze the differences between the contact numbers (*Y*) and the related variables of participants (*X*1) and contactors (*X*2).

bad (score = 0), normal (score = 5), or good (score = 10). All students were asked to list all contacts they had during the day, as well as the estimated age (0–5, 6–12, 13–19, 20–39, 40–59, or ≥60 yrs), sex, relationship (family, classmate, teacher, and others), and health status (healthy, fever, runny nose, headache, cough, or sore throat) of those contacted. Other recorded items included whether those contacted were wearing a mask (yes or no), the contact setting (school, home, cram school, or others), contact frequency (daily or almost daily, 1–2 times a week, 1–2 times a month, <1 time a month, first time), contact duration (<5 min, 5–15 min, 15 min–1 h, 1–4 h, or >4 h), and contact type (conversation or physical contact or both). In this study, the questionnaire survey was designed to record up to 35 and 52 contacts per day in the non-flu season form and the flu season form, respectively (see Appendix A).

2.4. Surveillance of influenza-like illness

Weekly influenza-like illness (ILI) sentinel physician surveillance data were obtained from the Taiwan CDC for the period from 1999 to 2006. These data represent ILI cases reported in patients under outpatient and hospital care in all medical centers and teaching hospitals in Taiwan. The case definition of ILI included patients with a fever (an ear temperature of over 38 °C), respiratory symptoms, and symptoms such as myalgia, headache, and fatigue (King et al., 2001). We analyzed the 95th percentile and 5th percentile of weekly ILI cases for the period from 1999 to 2006. The definition of the periods of flu season and non-flu season were the times above the 95th percentile and lower than the 5th percentile of weekly ILI cases, respectively. This method was adopted from Wang et al. (2012).

2.5. Statistical analysis

Statistical analyses were carried out with SAS Version 9.3 for Windows (SAS Institute Inc., Cary, North Carolina, USA). Two methods were used for the detection of the difference between the contact numbers (*Y*) with the related variables of participants (*X*1) and contactors (*X*2). Individual-level changes in the number of encounters recorded in specific seasons, locations, and times of the week were tested using the Wilcoxon matched-pairs signed-rank test ($p < 0.05$). The Wilcoxon signed-rank test is a non-parametric statistical hypothesis test used when comparing two related samples, matched samples, or repeated measurements on a single sample to assess whether their population mean ranks differ. We also used the non-parametric Kruskal–Wallis test for comparing more than two samples that were independent (Fig. 1).

3. Results

3.1. Period of investigation and sample size

According to the weekly ILI cases, the flu/non-flu seasons were predominantly in December-January and May-June. The 5th and 95th percentiles were 589 and 2378 cases per week, respectively (Fig. 2). Hence, the questionnaire surveys in the two junior high schools were conducted during May to June 2013 and December 2013, which correspond to the non-flu and flu seasons, respectively.

Table 1 presents the pair-matched sample sizes and response rates. The numbers of time-matched pairs were 75, 87, 105 and 106 participants in NST, FST, NSY, and FSY, respectively. In Taichung, 94 participants (169 minus 75) in the NST group were excluded, including 83 who did not give consent (88%), 10 who did not

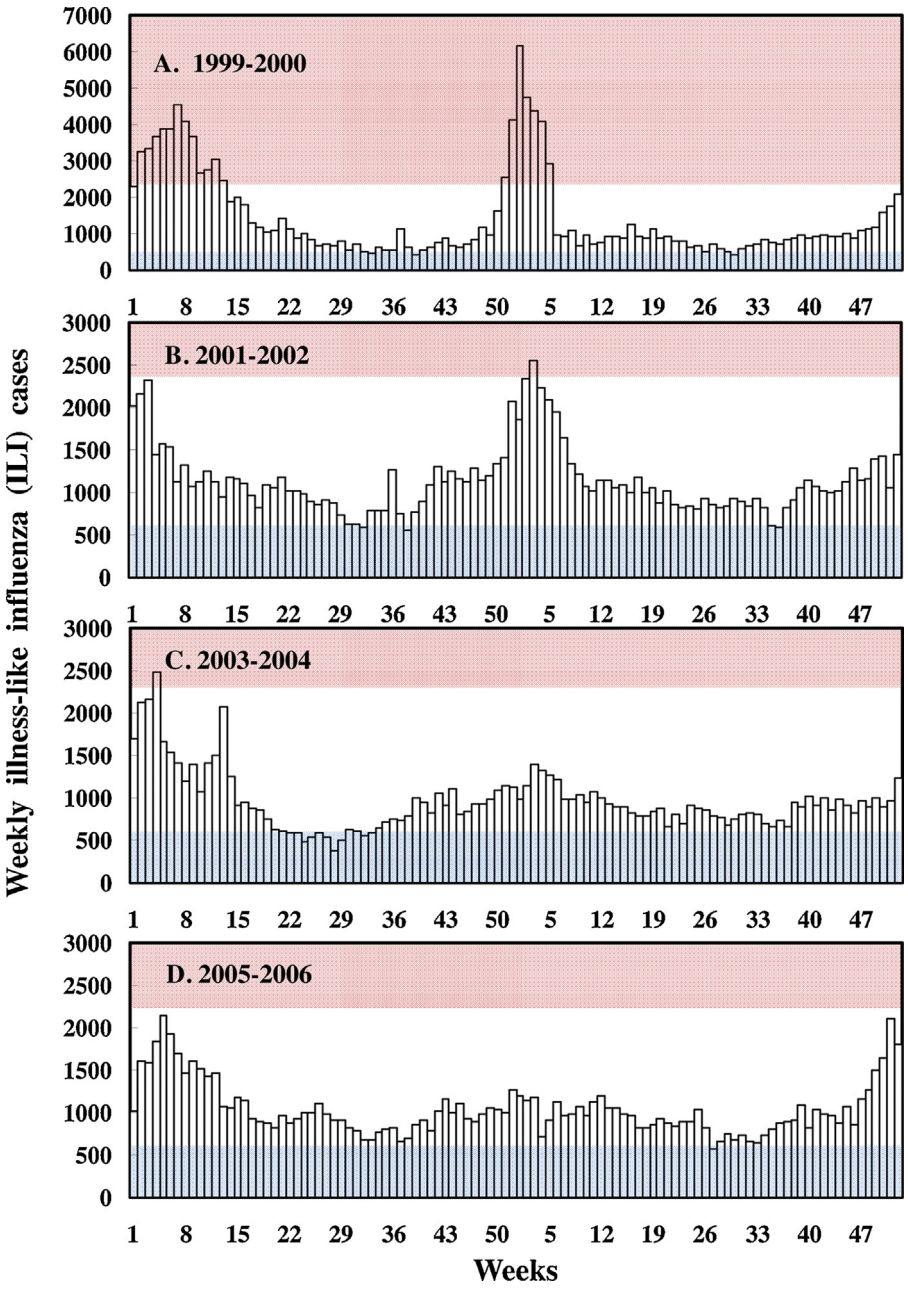

Fig. 2. Weekly illness-like influenza (ILI) cases from 1999 to 2006 in Taiwan. The red and blue bars represent the ILI cases higher than the 95th percentile and lower than 5th percentile of cases, respectively. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 1
The sample sizes and response rates of the questionnaire survey according to location-, season-, and time (day of week)-based analyses.

Place	Seasons	Times	Survey date	Survey sample (Ns)	Returned sample (Nr)	Time-paired samples[a]	Response rate (%)[b]	Season-paired samples[c]
Taichung	Non-flu season (NS)	Weekday	May 30–Jun 05, 2013	169	160	75	44.37	54
		Weekend		169	160			
	Flu season (FS)	Weekday	December 3–12, 2013	175	145	87	49.71	
		Weekend		175	145			
Yilan	Non-flu season (NS)	Weekday	June 11–19, 2013	161	146	105	65.21	83
		Weekend		161	146			
	Flu season (FS)	Weekday	December 21–27, 2013	160	133	106	66.25	
		Weekend		160	133			

[a] Participants who correctly completed the questionnaires during both the weekday and weekend.
[b] Response rate = (time-paired samples/Ns) × 100%.
[c] Participants in same school who correctly completed the questionnaires during flu/non-flu seasons and during both the weekday and weekend.

Table 2
Average number of contacts, standard deviation (S.D.), median, and 1st–3rd quartiles (Q1–Q3) in specific seasons, locations, and times (days of week).

Locations/Times/Seasons	Weekday	Weekend	Median (Q1–Q3)[a]	Average number of contacts (S.D.)[b]
	Flu season (FS)			
Taichung	22.2 (15.3)	15.8 (14.8)	14.5 (8.5–25)	19.0 (14.0)
Yilan	15.2 (12.9)	12.9 (12.5)	9.5 (6–16.4)	14.0 (11.6)
Average number of contacts[c]	18.4 (14.4)	14.2 (13.6)	12 (7–21.5)	16.3 (12.9)[d]
	Non-flu season (NS)			
Taichung	20.0 (11.7)	12.6 (10.7)	14.5 (7.75–22.5)	16.3 (10.1)
Yilan	14.97 (9.98)	11.81 (9.0)	11.5 (5.5–18.5)	13.4 (8.8)
Average number of contacts[c]	17.04 (11.0)	12.3 (9.8)	12.5 (6.5–21)	14.6 (9.5)[d]

[a] Median and 1st–3rd quartiles (Q1–Q3) of the number of contacts for weekdays and weekends in specific places and seasons.
[b] Average number of contacts for weekdays and weekends in specific places and seasons.
[c] Average number of contacts for both Taichung and Yilan during specific times.
[d] Average number of contacts during the FS and NS.

return the questionnaire (11%), and 1 participant whose responses were invalid (1%). In the FST group, 88 participants (175 minus 87) were excluded, of which 30 did not give consent (34%), 30 did not return the questionnaire (34%), and 28 gave invalid responses (32%). The response rates were thus 44.37% and 49.71% for NST and FST, respectively.

In Yilan, 56 participants (161 minus 105) in the NSY group were excluded: of these, 24 did not give consent (43%), 15 did not return the questionnaire (27%), and 17 gave invalid responses (30%). In the FSY group, 54 participants (160 minus 106) were excluded, of whom 11 did not give consent (20%), 27 did not return the questionnaire (50%), and 16 gave invalid responses (30%). The response rates were thus 65.22% and 66.25% for NSY and FSY, respectively.

3.2. Number of contacts

Table 2 lists the statistical summary for the comparison of the average number of contacts per participant per day. The results indicate that there was no difference in the number of contacts during the flu and non-flu seasons, with an average respondent contact number of 16.3 (S.D. = 12.9) and 14.6 people, (S.D. = 9.5), respectively. However, statistical analysis showed that the average number of contacts in Taichung City and Yilan County were significantly different ($p < 0.001$). Weekdays were associated with 23% and 28% more contacts than weekend days during the non-flu and flu seasons, respectively ($p < 0.001$) (Wilcoxon signed-rank test).

3.3. Chronological differences in contact properties

The average numbers of recorded contacts per day and 1st–3rd quartiles of reported contacts at specific times (weekday or weekend) across all variables are summarized in Table 3. The contacts were recorded from 373 participants, of whom 57% were female. The number of contacts was significantly different between weekdays and weekends ($p < 0.05$), regardless of the participant's sex or household size. During the weekdays, 48%, 23%, and 30% of

Table 3
Average number of contacts with the standard deviation (S.D.), median and 1st–3rd quartiles (Q1–Q3) for different times (weekday and weekend), according to different variables.

Variables	Covariate	Weekday			Weekend		
		Number of participants (%)	Average number of contacts (S.D.)	Median (Q1–Q3)	Number of participants (%)	Average number of contacts (S.D.)	Median (Q1–Q3)
Sex	Male	160 (42.9)	16.6 (13.1)	13 (6–26)	160 (42.9)	12.0 (11.8)	7.0 (4–15)
	Female	213 (57.1)	18.6 (12.7)	14 (8–28)	213 (57.1)	14.0 (12.0)	10 (6–17)
Grade	7	135 (36.2)	17.3 (13.2)	13 (7–25)	135 (36.2)	14.5 (13.0)	9 (5–19)
	8	238 (63.8)	18.0 (12.7)	13 (7–28)	238 (63.8)	12.4 (11.2)	8.5 (5–15)
Household	2	5 (1.3)	4.2 (3.3)	3	5 (1.3)	4 (2.8)	3
	3	47 (12.6)	17.1 (13.2)	13 (7–25)	47 (12.6)	12.7 (13.2)	8 (3–16)
	4	115 (30.8)	19.1 (14.1)	14 (7–29)	115 (30.8)	12.6 (12.0)	8 (5–15)
	5	107 (28.7)	18.0 (11.9)	14 (8–28)	107 (28.7)	14.0 (11.2)	10 (5–19)
	>5	99 (26.5)	16.7 (12.2)	13 (7–26)	99 (26.5)	13.6 (12.3)	9 (6–15)
School day	Monday	85 (22.8)	19.6 (13.4)	16 (9–29)			
	Tuesday	71 (19.0)	16.6 (12.4)	13 (6–25)			
	Wednesday	71 (19.0)	16.5 (12.5)	13 (7–25)			
	Thursday	75 (20.1)	15.4 (11.7)	13 (7–23)			
	Friday	71 (19.0)	20.2 (13.8)	19 (7–30)			
Holiday	Saturday				199 (53.4)	13.7 (11.7)	10 (5–17)
	Sunday				174 (46.6)	12.6 (12.2)	8 (4–15)
Health status	0–4	33 (8.8)	21.6 (12.1)	24 (13–30)	37 (9.9)	12.6 (10.3)	8 (6–15)
	5–7	179 (48.0)	17.8 (12.8)	13 (8–27)	169 (45.3)	12.8 (11.9)	8 (5–15)
	8–10	161 (43.2)	16.9 (13.0)	13 (6–25)	167 (44.8)	13.7 (12.4)	9 (5–17)
Vaccine	Yes	50 (13.4)	18.8 (12.3)	15 (8–27)	49 (13.1)	14.1 (12.9)	8 (5–18)
	No	323 (86.6)	17.6 (13.0)	13 (7–28)	324 (86.9)	13.1 (11.8)	9 (5–16)
Weather	Sunny	177 (47.5)	19.4 (13.2)	15 (8–29)	189 (50.7)	14.0 (12.3)	8 (5–18)
	Rainy	86 (23.1)	16.5 (13.1)	13 (7–23)	88 (23.6)	12.8 (10.9)	9.5 (6–15)
	Cloudy	110 (29.5)	16.0 (12.0)	13 (7–25)	96 (25.7)	12.8 (12.2)	9 (5–16.5)

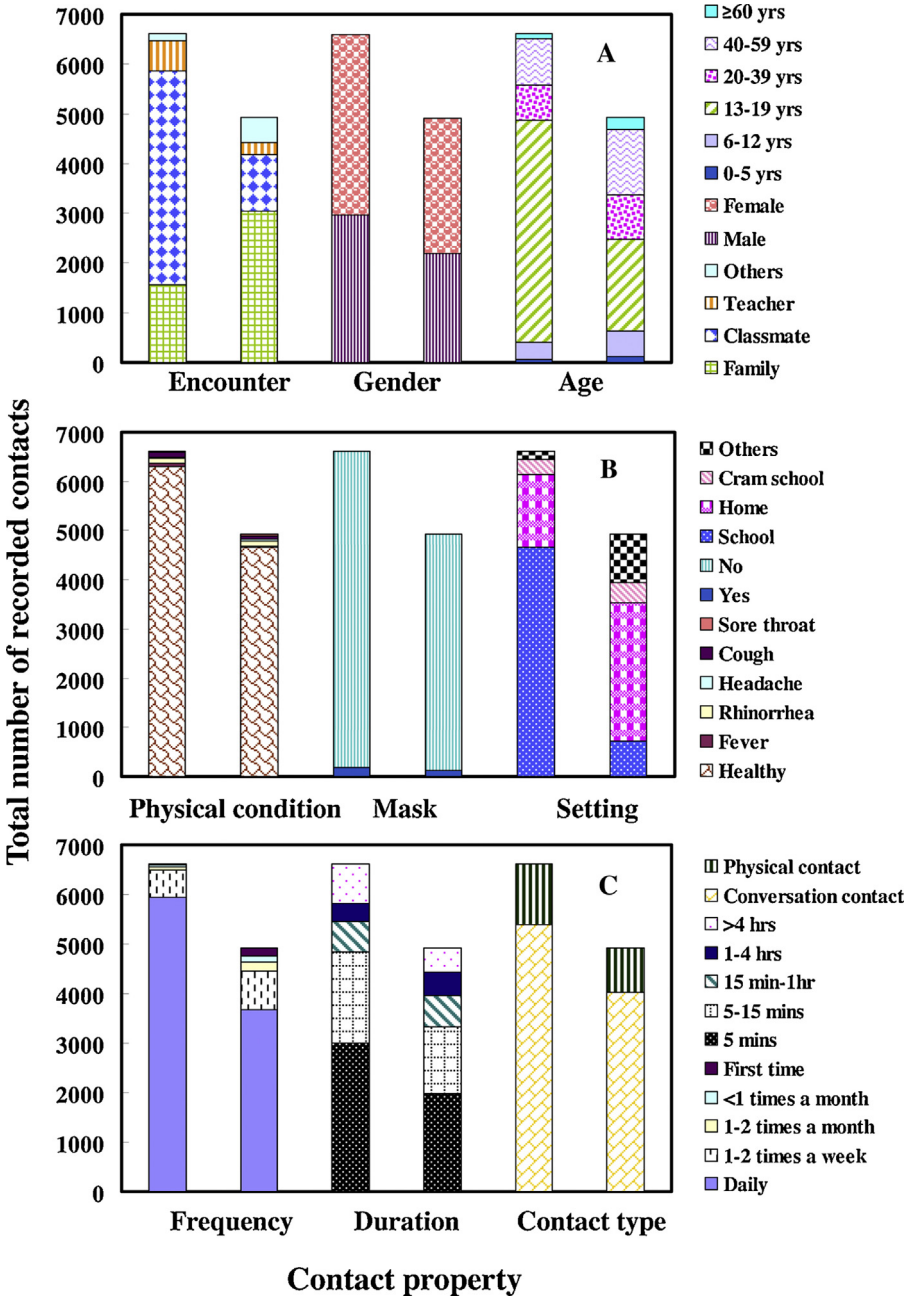

Fig. 3. Properties of encounters during weekdays (left bar) and weekends (right bar). (A) Comparison of encounter (family, classmate, teacher, or others), sex (male, female), and age groups (0–5, 6–12, 13–19, 20–39, 40–59, and ≥60 years). (B) Comparison of physical condition (healthy, fever, rhinorrhea, headache, cough, or sore throat), mask (used or not) and setting (school, home, cram school, or others). (C) Comparison of contact frequency (daily or almost daily, 1–2 a week, 1–2 a month, <1 a month, never met before), contact duration (<5 min, 5–10 min, 10 min–1 h, 1–4 h, or >4 h), and contact type (conversation or physical contact).

participants responded that the weather conditions were sunny, rainy, or cloudy, respectively. In contrast, 51%, 24%, and 26% of participants reported these conditions, respectively during the weekend.

Fig. 3 shows the contact characteristics during weekdays and weekend days. There were 6610 contacts during weekdays, which was markedly higher than during weekends (4922 contacts). Most contacts during weekdays were with females (57.94%), and of the conversation type (86%). The most highly encountered groups were classmates (4305 contacts) and families (1567 contacts). The dominant contact frequency was everyday contact (90.8%) and the dominant contact duration was <5 min (41.8%). 69.4% of contacts took place at school on weekdays and 57.7% of contact numbers were at home during weekends.

Furthermore, the age distribution of weekday and weekend contacts is shown by contact type in Table 4. The average number of all contacts during weekdays (17.7 contacts per day) and weekends (13.2 contacts per day) were significantly different ($p < 0.05$) (Wilcoxon signed-rank test). A significant difference (6.4 per day) took place in the 0–19 age group, showing that it was most common for junior high school students to decrease the contacts with their classmates during weekends.

3.4. Location-based differences in contact characteristics

Statistical analysis showed that the average number of contacts (Table 2) in Taichung City and Yilan County were significantly different ($p < 0.05$) (Wilcoxon signed-rank test). In Table 5, the

Table 4
Average number and standard deviation (S.D.) of reported encounters by all contact types (sum of physical and conversation contacts) and physical contact. The numbers of encounters reported during specific times (weekday and weekend) are compared.

Contact types	Age	Weekday	Weekend	Difference[a]	*p*-Value[b]
All contact	Total	17.7 (12.9)	13.2 (11.9)	4.5 (9.8)	<0.0001*
	0–19 yrs	13.0 (11.0)	6.6 (8.3)	6.4 (9.3)	<0.0001*
	20–59 yrs	4.4 (5.1)	5.9 (6.4)	−1.53 (5.1)	0.0004*
	≥60 yrs	0.3 (0.8)	0.67 (1.6)	−0.34 (1.5)	0.0069*
Physical contact	Total	3.3 (4.7)	2.4 (3.8)	0.9 (4.6)	0.0032*
	0–19 yrs	2.8 (4.2)	1.5 (3.1)	1.3 (4.2)	<0.0001*
	20–59 yrs	0.5 (1.08)	0.9 (1.5)	−0.36 (1.6)	0.0002*
	≥60 yrs	0.02 (0.2)	0.06 (0.3)	−0.03 (0.3)	0.0489*

[a] The difference is defined as the number of contacts during weekdays minus the number of contacts during weekends.
[b] Wilcoxon signed-rank test.
* *p*-Value <0.05.

contact levels are shown by age and setting. The average numbers of all contacts were 17.7 (S.D. = 12.3) and 13.7 (S.D. = 10.3) contacts per day in Taichung City and Yilan County, respectively. For all contact patterns (conversation and physical contact), a significant difference appeared in the 0–19 age group ($p < 0.05$) in a school setting ($p < 0.05$) (Wilcoxon signed-rank test). Furthermore, Fig. 4 reveals the properties of contacts in the two locations. There were 2872 and 2895 contacts in Taichung City and in Yilan County, respectively. On average, the most highly encountered groups were classmates (approximately 47%) and families (approximately 40%). The dominant contact frequency was everyday contact (83%) and the dominant contact duration was <5 min (43%).

4. Discussion

This study compared the social contact patterns among school-age children in specific seasons, locations, and times (of the week) using a contact questionnaire survey. Though we did not find statistically significant differences in the daily contact numbers between non-flu and flu seasons, there were significant differences in social contact patterns in different locations and times. The following paragraphs cover discussion points based on the results.

First, in this study, the daily contact numbers were not significantly different between the non-flu and flu seasons. One of the reasons for this may be the short period of the investigations, i.e., one week in each season. There was insufficient evidence to describe the differences in social contact patterns between the two seasons. However, this study did not quantify the effect of the psychological pressures to attend school. If a student developed mild symptoms, they might nonetheless choose to attend school; thus, the influence of contact frequency or seasonal forces may be less than the pressure of learning. However, the seasonal fluctuations of influenza cases were not correlated with social contact patterns. In this study, the analysis of the weather conditions of the sampling day indicated that, during the flu season, the highest number of contacts were during sunny days (on average 18.8 contacts, compared to 14.5 and 15.6 contacts on rainy and cloudy days, respectively). The differences between the weather conditions were not significant.

Table 5
Average number and standard deviation (S.D.) of reported encounters by all contact types (sum of physical and conversation contacts) and physical contact. The numbers of encounters reported in Taichung and Yilan are compared.

Contact types	Age	Taichung	Yilan	*p*-Value[a]
All contact	Total	17.7 (12.3)	13.7 (10.3)	0.0003*
	0–19 yrs	11.7 (9.2)	8.4 (7.7)	<0.0001*
	20–59 yrs	5.6 (6.4)	4.8 (4.0)	0.1663
	≥60 yrs	0.5 (0.9)	0.5 (1.1)	0.4328
Physical contact	Total	3.14 (3.8)	2.7 (3.4)	0.2007
	0–19 yrs	2.5 (3.2)	1.9 (2.8)	0.1021
	20–59 yrs	0.6 (1.1)	0.7 (1.0)	0.1438
	≥60 yrs	0.04 (0.2)	0.05 (0.2)	0.4885
	Setting	Taichung	Yilan	*p*-Value[a]
All contact	Total	17.7 (12.3)	13.7 (10.3)	0.0003*
	School	8.9 (7.3)	5.9 (5.7)	<0.0001*
	Home	6.1 (7.3)	5.5 (5.1)	0.1856
	Cram school	1.1 (2.5)	0.9 (2.2)	0.4701
	Others	1.5 (2.5)	1.5 (3.0)	0.4798
Physical contact	Total	3.14 (3.8)	2.7 (3.4)	0.2007
	School	1.6 (2.6)	1.4 (2.5)	0.4355
	Home	1.03 (1.8)	0.6 (1.1)	0.0159*
	Cram school	0.13 (0.5)	0.3 (0.9)	0.1013
	Others	0.33 (1.2)	0.3 (0.8)	0.3968

[a] Wilcoxon signed-rank test.
* *p*-Value <0.05.

One study of social contact patterns during the flu season was reported by Destefano et al. (2011). They reviewed population-based telephone surveys in four North Carolina counties to determine the number of social interactions between individuals during the 2007–2008 influenza seasons. Among 3845 adults, there were an average number of 10 contacts per day. In our study, there were 16.3 contacts per day with a standard deviation of 12.9. The number of social contacts in our study is evidently higher, which might be the result of different investigation methods.

Second, the number of contacts in Taichung City (average 17.1 contacts) was statistically higher than that in Yilan County (average 13.7 contacts). This may be due to differences in class size and population density related to urbanization in the city. There were 30 and 27 students, on average, in each class in the Chung-Lun (Taichung City) and Shun-An (Yilan County) junior high schools, respectively. Fig. 4 indicates that 2872 and 2876 contacts were investigated in Chung-Lun and Shun-An junior high schools, respectively, and that 1438 (50%) and 1255 (53%) of those contacts were at school. Statistical analysis shows that there were significant differences in the contact setting (school) and age group (0–19 years) between the two locations. This contrasts with other findings from Taiwan by Fu et al. (2012), which indicated that most regional differences were not significant within Taiwan. In their study, the average number of contacts was 12.4 in the north and 12.3 in the south, albeit with the exception of those living in the more remote eastern area (where the average number of contacts was 9.5) (Fu et al., 2012).

Third, the results indicated that the difference between the number of encounters reported for all contact types during weekdays and the number during weekends was highly significant. As well as this change in the number of contacts (a 26% decrease), the age distribution and setting of those contacts were also different.

One limitation of our study is the relatively low response rates, which were 44.37% and 49.71% in Taichung City and 65.22% and 66.25% in Yilan County for the non-flu and flu seasons, respectively. This low response rate may have been related to the disagreement

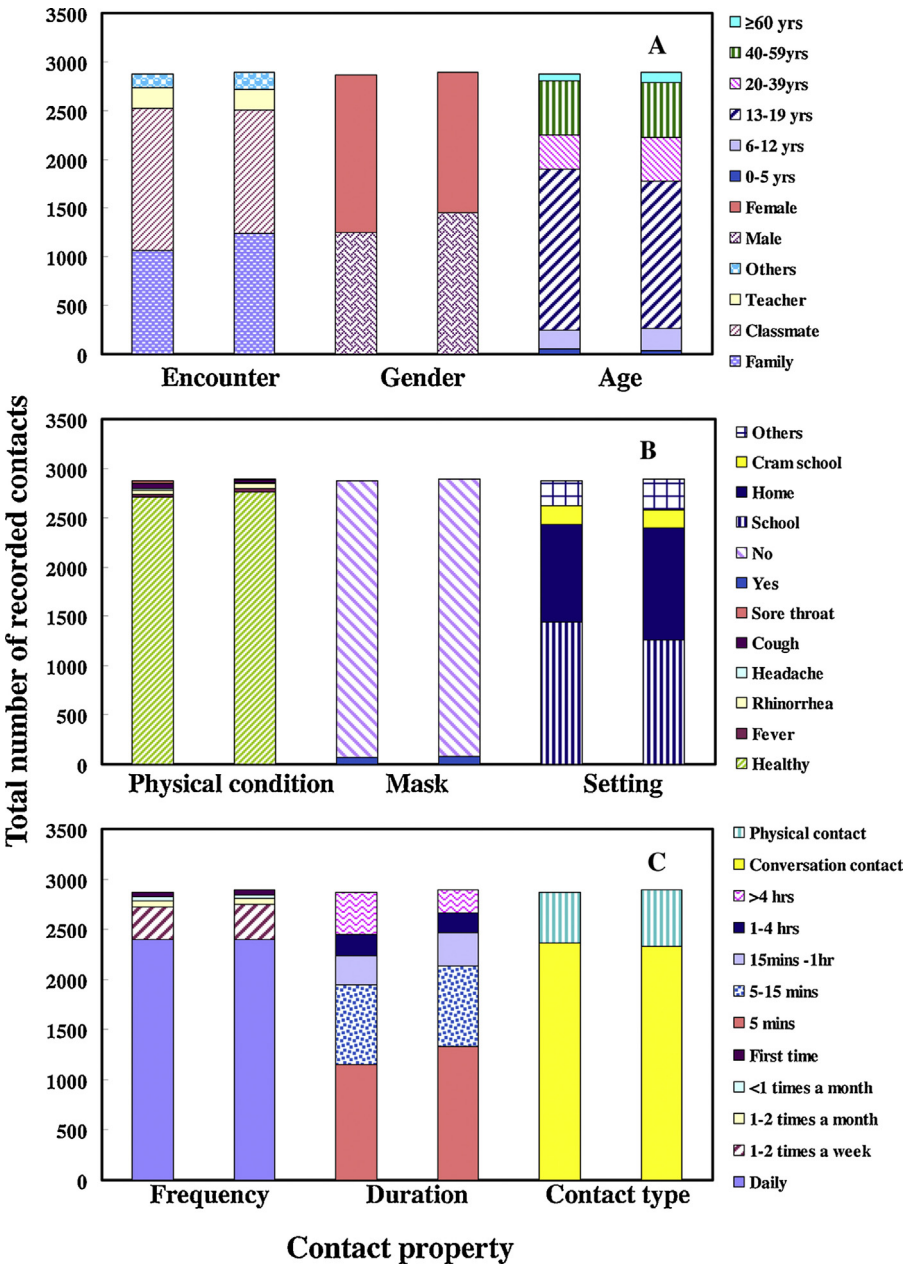

Fig. 4. Properties of encounters in Taichung (left bar) and Yilan (right bar). (A) Comparison of encounter (family, classmate, teacher, or others), gender (male, female), and age groups (0–5, 6–12, 13–19, 20–39, 40–59, and ≥60 years). (B) Comparison of physical condition (healthy, fever, rhinorrhea, headache, cough, or sore throat), mask (used or not) and setting (school, home, cram school, or others). (C) Comparison of contact frequency (daily or almost daily, 1–2 a week, 1–2 a month, <1 a month, never met before), contact duration (<5 min, 5–10 min, 10 min–1 h, 1–4 h, or >4 h), and contact type (conversation or physical contact).

of parents or legal guardians, which averaged at 61% and 32% among returned samples in Taichung City and Yilan County. That being said, these response rates could actually be high compared with other studies, Eames et al. (2010) reported an 8% response rate, and Rubin et al. (2009) reported a 7% response rate, each for general population telephone surveys in the UK. Eames et al. (2011) reported that 11% of distributed surveys were correctly completed and returned.

5. Conclusions

In conclusion, from an infectious disease epidemiology viewpoint, it is important to understand how people interact in different times and locations. This investigation provides basic information on contact patterns, and we believe that it can augment our understanding of differences in contact characteristics in specific locations and times. Our work has important implications for the dynamics of modeling infectious diseases and for performance analysis using human contact numbers and contact characteristics for schoolchildren in specific seasons, locations, and times in Taiwan.

Conflict of interest statement

The authors declare no conflict of interests.

Acknowledgements

We are indebted to the school classmates who participated in the study. This work was supported by Ministry of Science and Technology under grant no. MOST 104-2314-B-040-005.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.epidem.2015.09.002.

References

Cauchemez, S., Valleron, A.J., Boelle, P.Y., Flahault, A., Ferguson, N.M., 2008. Estimating the impact of school closure on influenza transmission from Sentinel data. Nature 452, 750–754, http://dx.doi.org/10.1038/nature06732.

Cowling, B.J., Lau, E.H.Y., Lam, C.L.H., Cheng, C.K.Y., Kovar, J., Chan, K.H., et al., 2008. Effects of school closures, 2008 winter influenza season, Hong Kong. Emerg. Infect. Dis. 14, 1660–1662, http://dx.doi.org/10.3201/eid1410.080646.

Destefano, F., Haber, M., Currivan, D., Farris, T., Burrus, B., Stone-Wiggins, B., et al., 2011. Factors associated with social contacts in four communities during the 2007–2008 influenza season. Epidemiol. Infect. 139, 1181–1190, http://dx.doi.org/10.1017/S095026881000230X.

Dowell, S.F., 2011. Seasonal variation in host susceptibility and cycles of certain infectious diseases. Emerg. Infect. Dis. 7, 369–374, http://dx.doi.org/10.3201/eid0703.010301.

Eames, K.T.D., 2014. The influence of school holiday timing on epidemic impact. Epidemiol. Infect. 142, 1963–1971, http://dx.doi.org/10.1017/S0950268813002884.

Eames, K.T.D., Tilston, N.L., Brooks-Pollock, E., Edmunds, W.J., 2012. Measured dynamic social contact patterns explain the spread of H1N1v influenza. PLoS Comput. Biol. 8, e1002425, http://dx.doi.org/10.1371/journal.pcbi.1002425.

Eames, K.T.D., Tilston, N.L., Edmunds, W.J., 2011. The impact of school holidays on the social mixing patterns of school children. Epidemics 3, 103–108, http://dx.doi.org/10.1016/j.epidem.2011.03.003.

Eames, K.T.D., Tilston, N.L., White, P.J., Adams, E., Edmunds, W.J., 2010. The impact of illness and the impact of school closure on social contact patterns. Health Technol. Assess. 1434, 267–312, http://dx.doi.org/10.3310/hta14340-04.

Fournet, J., Barrat, A., 2014. Contact patterns among high school students. PLoS ONE 9, e107878, http://dx.doi.org/10.1371/journal.pone.0107878.

Fu, Y.C., Wang, D.W., Cheng, J.H., 2012. Representative contact diaries for modeling the spread of infectious diseases in Taiwan. PLoS ONE 7, e45113, http://dx.doi.org/10.1371/journal.pone.0045113.

Glass, R.J., Glass, L.M., Beyeler, W.E., Min, H.J., 2006. Targeted social distancing design for pandemic influenza. Emerg. Infect. Dis. 12, 1671–1681, http://dx.doi.org/10.3201/eid1211.060255.

Horby, P., Thai, P.Q., Hens, N., Yen, N.T.T., Mai, L.Q., Thoang, D.D., et al., 2011. Social contact patterns in Vietnam and implications for the control of infectious diseases. PLoS ONE 6, e16965, http://dx.doi.org/10.1371/journal.pone.0016965.

Hufnagel, L., Brockmann, D., Geisel, T., 2004. Forecast and control of epidemics in a globalized world. Proc. Natl. Acad. Sci. U.S.A. 101, 15124–15129, http://dx.doi.org/10.1073/pnas.0308344101.

Jackson, C., Vynnycky, E., Hawker, J., Olowokure, B., Mangtani, P., 2013. School closures and influenza: systematic review of epidemiological studies. BMJ Open 3, e002149, http://dx.doi.org/10.1136/bmjopen-2012-002149.

King, C.C., Kao, C.L., Liu, D.P., Cheng, M.C., Yen, H.L., Lee, M.S., et al., 2001. Seven integrated influenza surveillance systems in Taiwan. Int. Congr. Ser. 1219, 107–118, http://dx.doi.org/10.1016/S0531-5131(01)00331-4.

Lipsitch, M., Viound, C., 2009. Influenza seasonality: lifting the fog. Proc. Natl. Acad. Sci. U.S.A. 106, 3645–3646, http://dx.doi.org/10.1073/pnas.0900933106.

McLean, E., Pebody, R.G., Campbell, C., Chamberland, M., Hawkins, C., Nguyen-Van-Tam, J.S., Oliver, I., Smith, G.E., Ihekweazu, C., Bracebridge, S., et al., 2010. Pandemic (H1N1) 2009 influenza in the UK: clinical and epidemiological findings from the first hundred (FF100) cases. Epidemiol. Infect. 138, 1531–1541, http://dx.doi.org/10.1017/S0950268810001366.

Miller, E., Hoschler, K., Hardelid, P., Stanford, E., Andrews, N., Zambon, M., 2010a. Incidence of 2009 pandemic influenza A H1N1 infection in England: a cross-sectional serological study. Lancet 375, 1100–1108, http://dx.doi.org/10.1016/S0140673609621267.

Miller, J.C., Danon, L., Goldstein, E., Lajous, M., O'Hagan, J.J., Lipsitch, M., 2010b. Student behavior during a school closure caused by pandemic influenza A/H1N1. PLoS ONE 5, e10425, http://dx.doi.org/10.1371/journal.pone.0010425.

Mossong, J., Hens, N., Jit, M., Beutels, P., Auranen, K., Mikolajczyk, R., et al., 2008. Social contacts and mixing patterns relevant to the spread of infectious diseases. PLoS Med. 5, e74, http://dx.doi.org/10.1371/journal.pmed.0050074.

Read, J.M., Edmunds, W.J., Riely, S., Lessler, J., Cummings, D.A.T., 2012. Close encounters of the infectious kind: methods to measure social mixing behaviour. Epidemiol. Infect. 140, 2117–2130, http://dx.doi.org/10.1017/S0950268812000842.

Read, J.M., Lessler, J., Riley, S., Wang, S., Tan, L.J., Kwok, K.O., et al., 2014. Social mixing patterns in rural and urban areas of southern China. Proc. Biol. Sci. 281, 20140268, http://dx.doi.org/10.1098/rspb.2014.0268.

Rubin, G.J., Amlot, R., Page, L., Wessely, S., 2009. Public perceptions, anxiety, and behaviour change in relation to the swine flu outbreak: cross sectional telephonesurvey. Br. Med. J. 339, b2651, http://dx.doi.org/10.1136/bmj.b2651.

Shaman, J., Kohn, M., 2009. Absolute humidity modulates influenza survival, transmission, and seasonality. Proc. Natl. Acad. Sci. U.S.A. 106, 3243–3248, http://dx.doi.org/10.1073/pnas.0806852106.

Smieszek, T., Burri, E.U., Scherzinger, R., Scholz, R.W., 2012. Collecting close-contact social mixing data with contact diaries: reporting errors and biases. Epidemiol. Infect. 140, 744–752, http://dx.doi.org/10.1017/S0950268811001130.

Wallinga, J., Teunis, P., Kretzschmar, M., 2006. Using data on social contacts to estimate age-specific transmission parameters for respiratory-spread infectious agents. Am. J. Epidemiol. 164, 936–944, http://dx.doi.org/10.1093/aje/kwj317.

Wang, Y.C., Lin, Y.K., Chuang, C.Y., Li, M.H., Chou, C.H., Liao, C.H., 2012. Associating emergency room visits with first and prolonged extreme temperature event in Taiwan: a population-based cohort study. Sci. Total Environ. 416, 97–104, http://dx.doi.org/10.1016/j.scitotenv.2011.11.073.

Willem, L., Kerckhove, K.V., Chao, D.L., Hens, N., Beutels, P., 2012. A nice day for an infection? Weather conditions and social contact patterns relevant to influenza transmission. PLoS ONE 7, e48695, http://dx.doi.org/10.1371/journal.pone.0048695.

Xue, Y., Kristiansen, I.S., de Blasio, B.F., 2012. Dynamic modelling of costs and health consequences of school closure during an influenza pandemic. BMC Public Health 12, 962, http://dx.doi.org/10.1186/1471-2458-12-962.