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Child restraint use in Shanghai: A multi-round cross-sectional observational study

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Abstract

Objectives: While appropriate child restraint use can reduce the risk of injuries or deaths, few previous studies have assessed child restraint practice in China. We aim to describe the prevalence of child restraint use and to investigate multilevel risk factors affecting child restraint practice in Shanghai.

Design and setting: A cross-sectional observational study was conducted near children's hospitals, kindergartens, entertainment places, and shopping malls between October 2015 and April 2019 in Shanghai.

Participants: Eight rounds of data were collected with a total sample size of 12,061 children.

Primary outcome measures: At each site, trained field workers observed and recorded child restraint use in all passing motorized vehicles with at least one child passenger.

Results: The overall child restraint use rate was 6.42%. Child restraint use rate rose over time, peaking in the last 5 years, from 5.12% in round 1 to 8.55% in round 8 (p value <0.001). Results from the adjusted logistic regression model showed that children occupants with the following risk factors had a higher likelihood of child restraint use: children younger than 5 years compared to those aged 5-12 years (Odds Ratio: 2.12; 95% confidence interval: 1.78-2.53; p<0.001), sitting in rear seat compared to those in front seat (OR: 31.80; 95% CI: 4.45-227.14; p=0.001), children occupants observed near entertainment places (OR: 2.34; 95% CI: 1.67-3.28; p<0.001) or near shopping malls (OR: 1.86; 95% CI: 1.36-2.55; p<0.001) compared to those near children's hospitals, and transportation in the morning compared to afternoon (OR: 1.30; 95% CI: 1.04-1.62; p=0.021).

Conclusions: The overall child restraint use rate was low in Shanghai. Our finding may shed light on monitoring child restraint practice, and have implications for intervention programs for children occupants with the identified risk factors, which may help to promote child restraint use and decrease the road traffic injuries or deaths.

Strengths and limitations of this study

- This study is among the first on child restraint use based on a large city-wide sample in a Chinese city.
- Our multi-round observational study allows for accurate and reliable estimation of trends on child restraint practice over time than previous single-round studies.
- Our study identified multilevel risk factors (child occupant characteristics, geographic location, and vehicle features) associated with child restraint use after adjusting for potential confounders.
- This finding may not be generalizable to the all children passengers in Shanghai or elsewhere in China.
- Most indicators were calculated based on observations, which might suffer from observer bias.

INTRODUCTION

Road traffic injuries (RTIs) rank as the number one killer among children and young adults aged 5-29 years.[1] China documented approximately 13,665 road traffic deaths (RTDs) among children aged 0-14 years in 2017, which accounted for more than 12% of global RTDs in this age group according to the Global Burden of Diseases Study.[2] As reported by the National Bureau of Statistics of China, 244,937 traffic crashes occurred in 2018 which resulted in 63,194 deaths, 258,532 injuries and about $200 million direct economic loss in China.[3] Although road traffic mortality among children in China has decreased steadily since 2009, RTIs among children still pose a large economic and public health burden for individuals and society.[2,4] Additionally, China's rapid motorization over the past decades, leading to the number of motorized vehicles reaching 340 million in July, 2019, will likely lead to an increase in RTIs in the country.[5]

Children are more vulnerable to RTIs and RTDs than adults due to their size and developmental status.[6,7] Furthermore, safety measures, such as seatbelts, that protect adults are less effective for children.[7] Contrastingly, appropriate child restraint use is highly effective in reducing RTIs and RTDs among children.[1] Current studies indicate that appropriate child restraint use reduces the risk of serious injury by 78% to 82%, and reduces the likelihood of death by 28% compared to children of similar age using seatbelts.[8-10] Moreover, children are safer when sitting in back seat than in the front where the risk of death for children younger than 4 years is twice as great as compared to those sitting in the rear.[11,12] However, only 33 countries, covering just 9% of the world's population, have a child restraint law in line with the World Health Organization's (WHO's) best practices, which apply to children from 0 to 10 years of age or 135cm in height.[1] These practices restrict children from sitting in the front seat of a car and require a reference to child restrains that meet certain safety standards.[1] To date, China has not passed a national law that requires the use of child restraints based on age or height and nor has it put in place restrictions on children sitting in the front seat.[1]

The road safety situation in Shanghai, one of the largest and most populous cities in China with about 24.2 million residents, is particularly challenging.[13] Few studies have investigated child passenger safety in China, and Shanghai is not an exception. An observational study indicated that child restraint use rate was as low as 6.1% in Shanghai.[14] Risk factors for non-use of child restraint in previous studies include the child's age, presence of other children or adult passengers, driver's seatbelt use, and vehicle type.[14-16] However, the generalizability of these studies was limited due to small sample sizes, the measurement of child restraint use by self-report, narrow age ranges and time frames, a focus on one or few survey locations, and a lack of controls for potential confounding variables.[14-16]

Prior studies have not conducted observational surveys at varying settings or examined the connection between location and child restraint use. This represents an important question given that child restraint use rates may vary by location types. Moreover, although one study found that child passengers traveling in SUVs had a higher likelihood of being restrained than those traveling in saloon cars,[17] another identified child passengers traveling in SUV/four-wheel drive vehicles (4WD) as having a lower probability of being restrained than those traveling in saloon cars.[15] Considering this discrepancy, the association between different vehicle type and child restraint use is worth further exploration.

Furthermore, a barrier to effective interventions and policy development for RTIs for child passengers is the lack of reliable data on child restraint use. Considering that effective interventions to improve road safety are urgently need, Shanghai participated in the Bloomberg Initiative for Global Road Safety (BIGRS).[18] The BIGRS project is a consortium of international partners supported by Bloomberg Philanthropies and seeks to adopt internationally recognized best practices to reduce road injuries and deaths in 10 selected LMICs (low- and middle-income countries).[18] This multi-round observational study conducted by the Johns Hopkins International Injury Research Unit (JH-IIRU) is one of the first on child restraint use based on a city-wide sample.

The objectives of this paper are to: 1) estimate the prevalence of child restraint use from a city-level representative sample; 2) investigate the child restraint use rate through multi-round cross sectional observations; and 3) evaluate the unadjusted and adjusted association between multilevel risk factors with child restraint use after adjusting for potential confounders.

METHODS

Study design

A multi-round cross-sectional observational study was conducted near children's hospitals, kindergartens, entertainment places, and shopping malls between October 2015 and April 2019 in Shanghai, China. Data collection consisted of eight rounds of observation at Shanghai's four top children's hospitals with the rank of "Grade 3, Class A". This approach increased the accuracy of observations while ensuring a sufficient sample size of child passengers. Eligible observation sites were selected based on the following criteria: the location was safe for observers; the location was likely to have vehicles carrying at least one child passenger; observers were at an elevation that was of equal-height or higher than passing vehicles; the observation site was located in an area where vehicle drivers slowed down or stopped (such as traffic junctions, school gates, and garages); and passing cars were more likely to be occupied by the local population rather than tourists.[19]

Selected observation sites covered central urban areas (within the inner-ring of the expressway), urban areas (between the inner- and outer-ring expressways), and peri-urban areas (outside of the outer-ring expressway) in Shanghai. Observation sites covered eight of the sixteen districts in Shanghai, which was representative of varying traffic flow models of the city. Data were collected twice a year from 2015 to 2019. Observations covered a wide range of hours from 07:00 to 17:30 and were conducted on weekdays and weekends. This allowed for a good representation of varying traffic models during rush and off-peak hours.[19]

A comprehensive training of all field workers was conducted before the first round of data collection, and repeated refresher trainings were conducted before each subsequent round.[19] During trainings, field workers practiced child restraint observation methods, and their results were compared with video footage taken at the scene to identify potential observer bias.[19] At each observation site, trained field workers from the Shanghai Municipal Center for Disease Control and Prevention (CDC) observed and recorded child restraint use in all passing motorized vehicles carrying at least one child passenger. Field workers also collected information on the age, gender and seating position of each child passenger; the number of children in each vehicle; the type of vehicle; and the observation time.[19] Site description information was collected, which included weather, number of traffic lanes, district of the observation location, type of location, traffic volume, road surface conditions, and law enforcement activity before each observation session.[19] Standardized observation methods were employed across all observation locations and rounds, which ensured the comparability of results across observation locations and over time.

Other road safety studies have employed similar observational methods.[14,15,17,20] This method allows us to measure actual child restraint practice across a wide range of people at a reasonable cost, and has stronger validity than self-reporting, which is vulnerable to recall bias and misreporting.[19,21]

Statistical analysis

We employed both descriptive statistics and logistic regression models to analyze the data. For bivariate analysis, we examined the association of child restraint use with each categorical covariate using a χ^2 test and identified statistically significant relationships. For multivariate analysis, we assessed the unadjusted and adjusted (accounting for potential confounders) association between child restraint use and multilevel risk factors by using logistic regression models. The logistic regression model was defined as:

$$logit\ (y_i) = X_i \beta_i + \beta_0$$

Where i represents child passenger; y_i =0/1 is an indicator of occupant i not using (0) or using (1) child restraint; X_i is the vector of covariates for children occupant i; β_i is the vector of regression coefficients; and β_0 is the y-intercept. The covariates included in the model are observation time (morning or afternoon), type of vehicle (sedan/saloon, SUV/4WD, taxi, or other vehicle type like pickup/light truck/bus/minibus/minivan/school bus), location type (entertainment place; shopping mall; kindergarten; children's hospital), child's age (<5 years or 5-12 years), presence of another child (yes or no), and child's seating position (rear seat or front seat). The model coefficients (β_i) assess the effect of a one-unit covariate (X_i) increase on the outcome. We selected covariates based on a review of the literature and backwards and forwards stepwise model selection. Multicollinearity and linearity assumption were checked before fitting the logistic regression model.

All statistical analyses were conducted in STATA 16 SE. Statistical tests were 2-sided and a P-value of less than 0.05 was considered statistically significant. Ethical approval was obtained from Johns Hopkins Bloomberg School of Public Health, Institutional Review Board, USA, and Shanghai CDC, China. **Patient and Public Involvement:** Patients or the public WERE NOT involved in the design, or conduct, or reporting, or dissemination plans of our research

RESULTS

Eight rounds of data were collected from 2015 to 2019, for a total sample size of 12,061 children traveling in 11,587 vehicles (**Table 1**). 774 children (6.4%) with appropriate restraint use were identified and compared with 11,287 children (93.6%) with inappropriate restraint use. About two-thirds of the observed child occupants were younger than 5 years old (7,623, 63.2%), and approximately one-third were 5-12 years old (4,407, 36.5%). More than half of the child occupants were boys (6725, 55.8%) and 37.6% (4,540) were girls. Most of the child occupants sat in rear seat (11,689, 96.9%) and only 3.1% (372) sat in front seat. 92.3% (11,129) of children traveled in a car without other children and 7.7% (932) traveled with other children. Most of the child passengers were observed near hospitals (11,029, 91.4%). 3.7% (446) were observed near shopping malls, 2.4% (295) were observed near kindergartens and 2.4% (291) were observed near entertainment places. The majority of vehicles were sedan or saloon (6,677, 55.4%). The second largest group of vehicles were taxis (3,043, 25.2%) and the third largest group were SUVs/4WDs (1,869, 15.5%). Few other vehicles types (472, 3.9%) were identified. 660 (5.5%) children sat on an adult's lap without using a child restraint.

Table 2 summarizes the vehicles and child occupant characteristics by child restraint use rate. Child restraint use rate rose from 5.12% in round 1 to 8.55% in round 8 (p value <0.001), with some fluctuation over time. Children aged younger than 5 years were more likely to use a child restraint than children aged 5-12 years, except in rounds 3 and round 8 when the confidence intervals overlapped (**Figure 1**). After disaggregating by location (**Figure 2**), child occupants observed near entertainment places (15.5%, 95% confidence-interval [CI]: 11.5%-20.1%) and shopping malls (11.2%, CI: 8.4%-14.5%) had a higher child restraint use rate, compared to observations near kindergartens (6.4%, CI: 3.9%-9.9%) and children's hospitals (6.0%, 5.5%-6.4%).

Results from the unadjusted logistic regression model are similar as those from the adjusted logistic regression model (**Table 3**). After adjusting for all the covariates, children occupants with the following factors had a higher likelihood of using child restraint: children younger than 5 years compared to those aged 5-12 years (Odds Ratio [OR]: 2.12; 95% CI: 1.78-2.53; p<0.001), children sitting in the rear compared to those in the front seat (OR: 31.80; 95% CI: 4.45-227.14; p=0.001), child occupants observed near entertainment places (OR: 2.34; 95% CI: 1.67-3.28; p<0.001) or near shopping malls (OR: 1.86; 95% CI: 1.36-2.55; p<0.001) compared with those near children's hospitals, those traveling in a SUV/4WD compared with those in a sedan/saloon (OR: 1.31; 95% CI: 1.10-1.56; p=0.003), and those observed in the morning compared to the afternoon (OR: 1.30; 95% CI: 1.04-1.62; p=0.021). Children traveling in a taxi were less likely to use child restraints compared with those in a sedan/saloon (OR: 0.03; 95% CI: 0.01-0.06; p<0.001). Children traveling with other child passengers had a high risk of not using child restraints compared to those who were the only child in the car (OR: 0.45; 95% CI: 0.31-0.65; p<0.001).

DISCUSSION

To our knowledge, this study is among one of the first on child restraint use based on a large city-wide sample in a Chinese city. Our multi-round observational study allows for more accurate and reliable estimation of trends on child restraint practice over time than previous single-round studies.[19] Moreover, this study has a large sample size allowing for disaggregation of data by child occupant characteristics, geographic location, and vehicle features.[19] Furthermore, our logistic regression models identified multilevel risk factors associated with child restraint use after adjusting for potential confounders. The results from this study are not only valuable for monitoring road safety performance, but also essential for improving interventions to promote child restraint use and decrease road traffic injuries or deaths among child passengers with the specific risk factors identified in this study.

Although child restraint use rate in Shanghai has increased from 5.12% in 2015 to 8.55% in 2019, the rate over the 4-year period is still as low as 6.4%, a finding that is in line with a previous observational study which found that only 6.1% of children used restraints in Shanghai.[14] The child restraint use rate is higher in high-income countries; for example in the United States (US), the child restraint use rate has reached 94%.[22] The data reported here also indicate that children younger than 5 years are more likely to use restraints than those aged 5-12 years. This finding is in accordance with findings from the US, where the US National Highway Transportation Safety Administration reports that the restraint use rate was 98% among children younger than 1 year, 96% among those aged 1 to 3 years, 85% among those aged 4 to 7 years, and 83% among those aged 8 to 12 years.[23] Due to the WHO's recommendation that all children younger than ten years of age should use appropriate restraint,[1] the importance of appropriately restraint use for children occupants of all ages, particularly for older children, should be emphasized.

We found that child occupants observed near entertainment places and shopping malls had a higher likelihood for using restraints compared with those near Children's hospitals or kindergartens. Previous studies of the relationship between child restraint and location type are limited. Only one previous observational study was conducted in different regions in Ghana, but no difference in child restraint practice between location type was found.[15] We speculate that the low child restraint use rate at kindergartens may be because parents are more comfortable with these locations because the parents frequent them daily. Additionally, child restrain use rate at children's hospitals may be low because parents think when their children are going to the hospital, they are too sick to use child restraints; or when rushing to hospital with sick children, parents forget to restrain their children. Therefore, despite the overall low use rate, lower use at kindergartens and children's hospitals indicates that the initial effort to promote child restraint should start at these locations.

Our finding that compared with children traveling in sedans/saloons, children traveling in taxis have a higher risk of not using child restraints is important from an early risk assessment and prevention perspective. Prior studies have not observed child restraint practice in taxis. However, a qualitative study using self-report data investigating parental knowledge did emphasize the need of providing child restraints in taxis,[24] which somewhat support our findings that the non-use of child restraints is more prevalent in taxis, and may become an important target for future interventions. Our results also indicate that compared to those traveling in sedans/saloons, children traveling in SUVs/4WDs have a higher likelihood of using child restraints, which is in line with previous findings.[17] We speculate this is because that SUVs/4WDs have more space than sedans/saloons, which make them better suited for child restraint use.

Although, based on the WHO's best practice recommendations all children should sit in the rear seat of the vehicle using child restraints,[1] our study findings show that 3.1% of children sit in the front seat of vehicles. However, the prevalence of sitting in the front seat in our study finding is much lower than in other studies. For example, an estimated of 37.9% of children in Australia,[25] an estimated 12.2% in Shanghai in 2009,[14] and an estimated 26% in Ghana were found to sit in the front seat.[15] Our findings also indicate that children sitting in the rear seat had a higher likelihood of using child restraints compared to those sitting in front seat, which is consistent with previous findings from the US.[26] Furthermore, compared with children who were the only child in a car, traveling with other children occupants is associated with a higher risk of not using child restraints, which is in accordance with an observational study conducted in Ghana.[15] We speculate this could be due to the lack of space in the rear seat or limited child restraint seats, making it difficult to use restraints when there are several children in one vehicle.[15]

Based on best practices,[1] the importance of appropriately using child restraints and avoiding suboptimal seating positions, like sitting in the front seat, should be emphasized.

Despite recent progress, especially legislative progress, improving child restraint use still remains a challenge. The new Regulations on Road Traffic Administration of Shanghai Municipality enacted on March 25, 2017 requires the use of child restraint when driving a family passenger car carrying a child under four years of age.[27] Moreover, children under 12 years of age are prohibited to be seated in the front passenger seat.[27] However, enforcement of this regulation is difficult and remains low given that no electronic technology is available for aid enforcement, and stopping vehicles to check for child restrain use will worsen congestion. Therefore, there is an urgent need to enact a national law on mandating child restraint use, which would increase child restraint usage and reduce the RTIs and RTDs.[28] The lack of regulation on the sale and circulation of child restraints remains to be the second challenge. Currently, a wide range of qualities of child restraints are available for purchase on the market, and therefore supporting the production of low-cost and high-quality restraints is critical to the success of child restraint use programs.[29] Given of the low use rate of child restraint in taxis, intervention programs might also include the provision of child restraints for use in taxis, an increase in child restraint installation services, and financial incentives for child restraint use by the government.[24] The third major challenge is the lack of awareness of child restraints, which indicate a need for the launch of education programs on appropriate child restraint use and seating position of child passengers, especially near hospitals and kindergartens.[30-31] Each of these factors may explain the low child restraint use rate and warrant further exploration of initiatives to promote child restraint practice in Shanghai and China.

Our study has several limitations. First, although we intended to randomly select observation sites in our study to provide a good representation of the city's overall situation, we were unable to employ a statistically rigorous random selection method because of the challenges of implementation.[32] Second, though we aimed to cover a wide range of location types and observations times, we still may have missed certain types of locations and times.[32] For example, we did not have observations after 17:30 pm or before 7:00 am, places unsafe for observers, or locations with low prevalence of vehicle carrying child occupants. Therefore, this finding may not be generalizable to the all children passengers in Shanghai or elsewhere in China. Third, causal inference cannot be made using an observational study. Fourth, the majority of indicators were calculated based on observations, which might suffer from observer bias.[32] Some demographic indicators, such as child's age and child's gender, might be misclassified;[33] however, there is no reason to believe that the bias is substantial, systematic or influential of our key findings.[32]

Despite the limitations, our findings are valuable for monitoring child restraint practice, and have important implications for policy-makers and the development of intervention programs for child occupants with the identified risk factors, which may help to promote child restraint use and decrease road traffic injuries and deaths. A comprehensive and effective intervention package might include the enactment a nation-wide child restraint use law, supported by the production of low-cost and high-quality child restraints,[29] the launch of education programs on appropriate child restraint use and appropriate seat position of child occupants,[30-31] child restraint installation services,[24] the provision of child restraints for taxi users,[24] and financial incentives for child restraint use by the government.[24]

Declarations

Authors' contributions

QL and TC designed the study, conducted data analysis, drafted the initial manuscript, and reviewed and revised the manuscript. QL, TC, and AB collected and managed the data, and reviewed the revised the manuscript. All authors approve the submission of this study.

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Patient consent for publication: Not required.

Ethics approval and consent to participate

Ethical approval was obtained from Johns Hopkins Bloomberg School of Public Health, Institutional Review Board, USA, and Shanghai CDC, China.

Data sharing statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Table 1: Descriptive of the sample in 8 rounds of observational study

Characteristics	Round								Total
	1	2	3	4	5	6	7	8	
Total	3,005	890	1,316	1,560	1,472	1,425	1,387	1,006	12,061
Observation time									
Morning	1,151	644	1,316	1,560	1,472	1,425	1,387	1,006	9,961
Afternoon	1,854	246	0	0	0	0	0	0	2,100
Weekday									
No	1,350	653	273	454	475	382	307	297	4,191
Yes	1,655	237	1,043	1,106	997	1,043	1,080	709	7,870
Type of vehicle									
Sedan/Saloon	1,501	601	762	831	810	772	830	570	6,677
SUV/4WD	367	203	201	218	190	225	276	189	1,869
Taxi	1,010	69	299	450	417	347	234	217	3,043
Others #	127	17	54	61	55	81	47	30	472
Area									
Central urban	1,808	18	811	799	959	1,081	996	768	7,240
Urban	1,197	872	421	761	513	344	391	238	4,737
Peri-urban	0	0	84	0	0	0	0	0	84
Location type									
Entertainment places	0	207	84	0	0	0	0	0	291
Shopping malls	0	446	0	0	0	0	0	0	446
Kindergarten	58	237	0	0	0	0	0	0	295
Children's hospital	2,947	0	1,232	1,560	1,472	1,425	1,387	1,006	11,029
Child's Age									
<5 years	1,956	538	739	1,046	921	954	846	623	7,623
5-12 years	1,049	349	575	493	550	467	541	383	4,407
Missing	0	3	2	21	1	4	0	0	31
Child's Gender									
Boy	1,697	491	741	804	820	751	840	581	6,725
Girl	1,147	373	427	587	533	587	498	388	4,540
Missing	161	26	148	169	119	87	49	37	796
Other Child Present									
No	2,793	828	1,164	1,446	1,293	1,337	1,314	954	11,129
Yes	212	62	152	114	179	88	73	52	932
Child's position									
Rear seat passenger	2,850	836	1,261	1,525	1,440	1,410	1,367	1,000	11,689
Front seat passenger	155	54	55	35	32	15	20	6	372
Child restraint use									
No	2,851	782	1,267	1,507	1,367	1,316	1,277	920	11,287
Yes	154	108	49	53	105	109	110	86	774
Child sitting on adult's lap									
No	2,899	868	1,297	1,546	1,465	1,413	1,376	537	11,401
Yes	106	22	19	14	7	12	11	469	660

Notes: 1. # Type of vehicle Other involve: Pickup/Light truck/Bus/Minibus/Minivan/School bus
2. 4WD: four-wheel drive vehicles.

Table 2 Child Restraint use rate by characteristics of vehicles and child occupants (n=12,061).

	Round								Total	χ2
Characteristics	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**		
Total	5.12	12.13	3.72	3.40	7.13	7.65	7.93	8.55	6.42	114.15***
Observation time										
Morning	6.60	13.04	3.72	3.40	7.13	7.65	7.93	8.55	6.75	10.31**
Afternoon	4.21	9.76	-	-	-	-	-	-	4.86	
Weekday										3.82
No	4.96	14.55	5.49	3.52	5.05	6.02	5.86	12.12	7.02	
Yes	5.26	5.49	3.26	3.35	8.12	8.25	8.52	7.05	6.10	
Type of vehicle										275.03***
Sedan/Saloon	7.66	12.81	3.94	4.81	9.26	9.84	9.64	9.12	8.16	
SUV/4WD	9.26	15.27	6.47	5.05	11.58	10.67	10.87	15.34	10.38	
Taxi	0.20	0.00	0.67	0.44	0.24	0.29	0.00	0.00	0.26	
Others #	2.36	0.00	7.41	0.00	12.73	9.88	0.00	16.67	5.72	
Area										6.49*
Central urban	5.53	16.67	5.06	3.50	8.13	6.01	7.33	8.98	6.31	
Urban	4.51	12.04	1.90	3.29	5.26	12.79	9.46	7.14	6.69	
Peri-urban	-	-	0.00	-	-	-	-	-	0.00	
Location type										60.17***
Entertainment places	-	21.74	0.00	-	-	-	-	-	15.46	
Shopping malls	-	11.21	-	-	-	-	-	-	11.21	
Kindergarten	10.34	5.49	-	-	-	-	-	-	6.44	
Children's hospital	5.02	-	3.98	3.40	7.13	7.65	7.93	8.55	5.98	
Child's Age										70.30***
<5 years	6.24	15.80	3.38	4.59	9.45	9.12	10.64	8.67	7.84	
5-12 years	3.05	6.59	4.17	0.81	3.27	4.71	3.70	8.36	3.97	
Missing	-	0.00	0	4.76	0	0	-	-	3.23	
Child's Gender										6.63*
Boy	5.24	13.85	4.05	4.35	7.93	7.46	8.1	9.29	6.91	
Girl	4.88	9.38	3.28	2.56	5.82	7.16	7.43	7.47	5.7	
Missing	5.59	19.23	3.38	1.78	7.56	12.64	10.2	8.11	6.28	
Other Child Present										17.21***
No	5.37	12.32	4.21	3.32	7.73	7.85	7.91	9.01	6.69	
Yes	1.89	9.68	0.00	4.39	2.79	4.55	8.22	0.00	3.22	
Child's position										24.16***
Rear seat passenger	5.40	12.80	3.89	3.48	7.29	7.73	8.05	8.60	6.61	
Front seat passenger	0.00	1.85	0.00	0.00	0.00	0.00	0.00	0.00	0.27	

Notes: 1. *p < 0.05; **p < 0.01; ***p < 0.001;
2. # Type of vehicle Other involve: Pickup/Light truck/Bus/Minibus/Minivan/School bus
3. 4WD: four-wheel drive vehicles.

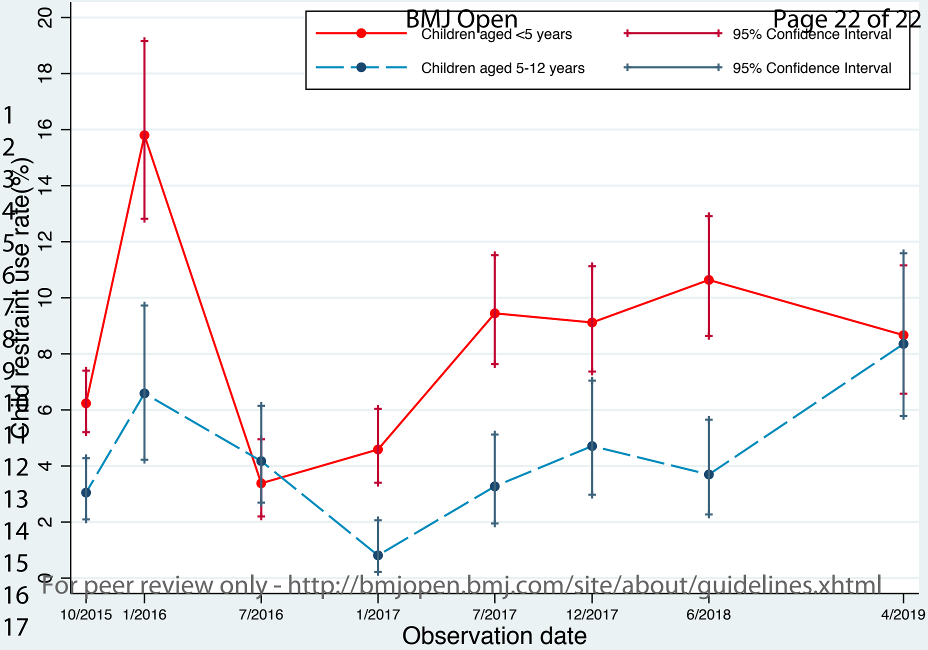
Table 3: Unadjusted and adjusted logistic regression model of risk factors associated with child restraint use in Shanghai (n=12,061).

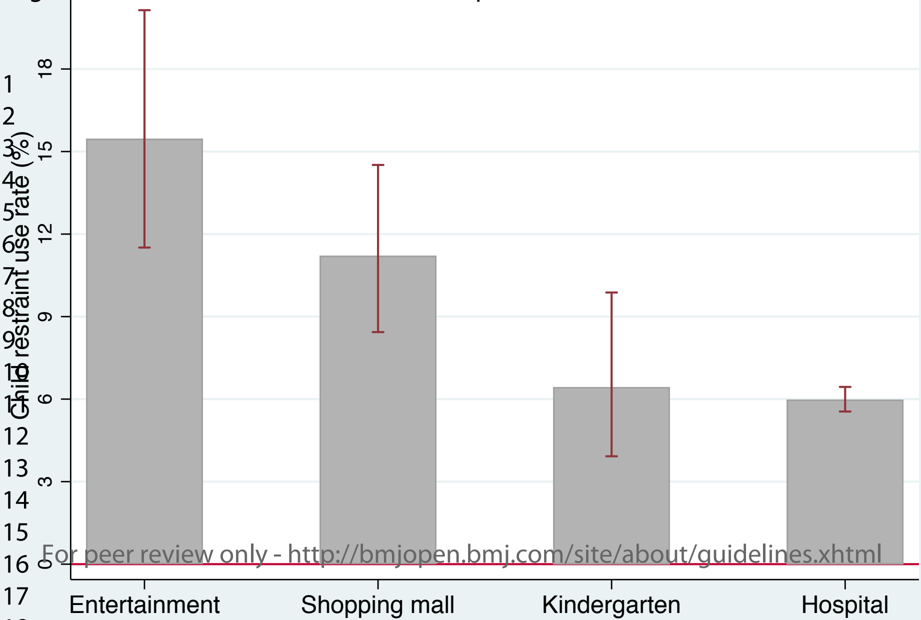
	Unadjusted Model			Adjusted Model		
Covariate	**OR**	**95% CI**		**OR**	**95% CI**	
Observation time (ref: Afternoon)						
Morning	1.42**	1.14	1.75	1.30*	1.04	1.62
Type of vehicle (ref: Sedan/Saloon)						
SUV/4WD	1.30**	1.10	1.55	1.31**	1.10	1.56
Taxi	0.03***	0.01	0.06	0.03***	0.01	0.06
Others	0.68	0.46	1.02	0.82	0.55	1.23
Location type (ref: Children's hospital)						
Kindergarten	1.08	0.67	1.73	0.92	0.57	1.48
Entertainment places	2.87***	2.07	3.99	2.34***	1.67	3.28
Shopping malls	1.98***	1.46	2.69	1.86***	1.36	2.55
Child's Age (ref: age 5-12 years)						
<5 years	2.06***	1.73	2.45	2.12***	1.78	2.53
Missing	0.81	0.11	5.94	0.77	0.10	5.73
Other Child present (ref: No)	0.46***	0.32	0.67	0.45***	0.31	0.65
Child's position (ref: front passenger)	26.27**	3.69	187.25	31.80**	4.45	227.14

Notes: 1. *p < 0.05; **p < 0.01; ***p < 0.001;
2. [#] Type of vehicle Other involve: Pickup/Light truck/Bus/Minibus/Minivan/School bus
3. 95% CI: 95% confidence interval; OR: Odds Ratio.

Figure 1: Trend of restraint use rate for children by age group in Shanghai.

Figure 2: Restraint use rate for children by type of location in Shanghai.


Children aged <5 years
95% Confidence Interval
Children aged 5-12 years
95% Confidence Interval
Child restraint use rate(%)
0
2
4
6
8
10
12
14
16
18
20
10/2015
1/2016
7/2016
1/2017
7/2017
12/2017
6/2018
4/2019
Observation date


Child restraint use rate (%)
0
3
6
9
12
15
18
Entertainment
Shopping mall
Kindergarten
Hospital

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Child restraint use in motor vehicles in Shanghai, China: A multi-round cross-sectional observational study

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Abstract

Objectives: While appropriate child restraint use in motor vehicles can reduce the risk of injuries or deaths, few previous studies have assessed child restraint practice in China. We aim to describe the prevalence of child restraint use and investigate risk factors affecting child restraint practice in Shanghai, China.

Design and setting: A cross-sectional observational study was conducted near children's hospitals, kindergartens, entertainment places, and shopping malls in Shanghai, China.

Participants: Eight rounds of data were collected between October 2015 and April 2019 with a total sample size of 12,061 children.

Primary outcome measures: At each site, trained field workers observed and recorded child restraint use in all passing motor vehicles with at least one child passenger.

Results: The overall child safety restraint use rate was 6.42%. Child restraint use rate rose over time, from 5.12% in round 1 to 8.55% in round 8 (p-value <0.001). Results from the adjusted logistic regression model showed that children occupants with the following risk factors had a higher likelihood of child restraint use: children younger than five years compared to those aged 5-12 years (Odds Ratio: 2.12; 95% confidence interval: 1.78-2.53; p<0.001), sitting in rear seat compared to those in front seat (OR: 31.80; 95% CI: 4.45-227.14; p=0.001), children occupants observed near entertainment places (OR:

2.34; 95% CI: 1.67-3.28; p<0.001) or near shopping malls (OR: 1.86; 95% CI: 1.36-2.55; p<0.001) compared to those near children's hospitals, and transportation in the morning compared to afternoon (OR: 1.30; 95% CI: 1.04-1.62; p=0.021).

Conclusions: The overall child safety restraint use rate was low in Shanghai. Our findings may shed light on monitoring child restraint practice and have implications for intervention programs for children occupants with the identified risk factors, which may help to promote child restraint use in motor vehicles and prevent road traffic injuries or deaths.

Strengths and limitations of this study

- This study is among the first on child restraint use based on a large city-wide sample in a Chinese city.
- Our multi-round observational study allows for accurate and reliable estimation of trends on child restraint practice over time than previous single-round studies.
- Our study examined multilevel risk factors associated with child restraint use in motor vehicles
- This finding may not be generalizable to all children passengers in Shanghai or elsewhere in China.
- Indicators were calculated based on observations, which might suffer from observer bias.

INTRODUCTION

The global burden of road traffic deaths (RTDs) remains high, and the number of RTDs reached 1.35 million per 100,000 population in 2016, with an average rate of 18.2 deaths per 100,000 population.[1] Young people are especially at high risk for traffic injuries.[1] Road traffic injuries (RTIs) rank as the number one killer among children and young adults aged 5-29 years.[1] Approximately 93,729 global RTDs occurred among children aged 0-14 years in 2019 according to the Global Burden of Diseases Study.[2] In 2016, high-income countries accounted for 7% of RTDs worldwide, while 93% of RTDs occurred in low and middle-income countries which comprise only 85% of the world population and 60% registered motor vehicles.[1] China documented approximately 9,640 RTDs among children aged 0-14 years in 2019, which accounted for more than 10% of global RTDs in this age group according to the Global Burden of Diseases Study.[2] As reported by the National Bureau of Statistics of China, 244,937 traffic crashes occurred in 2018, which resulted in 63,194 deaths, 258,532 injuries and about $200 million direct economic loss in China.[3] Although road traffic mortality among children in China has decreased steadily since 2009, RTIs among children still pose a large economic and public health burden for individuals and society.[2,4] Additionally, China's rapid motorization over the past decades, leading to the number of motorized vehicles reaching 340 million in July, 2019, will likely lead to an increase in RTIs in the country.[5]

Children are more vulnerable to RTIs and RTDs than adults due to their size and developmental status.[6,7] Compared to adults, children are less tolerable of trauma due to their proportionately large head, higher center of gravity, different growth rate, lack of skull protection, mobility of limb bones, and less-protected organs.[7] Substantial safety measures and methods have been developed and implemented to reduce the RTDs and RTIs among child passengers, such as age and size-appropriate safety restraints for children, seatbelt usage, education programs, mass media advertising programs for promoting child restraint usage, and policies for regulating children's traveling in motor vehicles.[8-9] While, some safety measures, such as seatbelts, that protect adults are less effective for children.[7] Child-specific restraints with appropriate size have been proved to be highly effective in reducing RTIs and RTDs among child passengers.[1,8-9] Current studies indicate that appropriate child restraint use reduces the risk of serious injury by 78% to 82%, and reduces the likelihood of death by 28% compared to children of similar age using seatbelts.[8,10-11] Moreover, children are safer when sitting in back seats than in the front where the risk of death for children younger than four years is twice as great as compared to those sitting in the rear seats.[12-13] However, only 33 countries, covering just 9% of the world's population, have a child restraint law in line with the World Health Organization's (WHO) best practices, which apply to children from 0 to 10 years of age or 135cm in height.[1] These practices restrict children from sitting in the front seat of a car and require a reference to child restrains that meet certain safety standards.[1] To date, China has not passed a national law that requires the use of child restraints based on age or height, and nor has it put in place restrictions on children sitting in the front seat.[1]

The road safety situation in Shanghai, one of the largest and most populous cities in China with about 24 million residents in 2019, is particularly challenging due to the large population size and a large number of registered motor vehicles.[14] However, few studies have investigated child passenger safety in China, and Shanghai is not an exception. An observational study indicated that child restraint use rate was as low as 6.1% in Shanghai.[15] Risk factors for non-use of child restraint in previous studies include the child's age, presence of other children or adult passengers, driver's seatbelt use, and vehicle type.[9,15-16] However, the generalizability of these studies was limited due to small sample sizes, the measurement of child restraint use by self-report, narrow age ranges and time frames, a focus on one or few survey locations, and a lack of controls for potential confounding variables. [9,15-16]

Prior studies have not conducted observational surveys at varying settings or examined the connection between location and child restraint use. This represents an important question given that child restraint use rates may vary by location type. Moreover, although one study found that child passengers traveling in SUVs had a higher likelihood of being restrained than those traveling in sedans or saloon cars,[17] another identified child passengers traveling in SUV/four-wheel drive vehicles (4WD) as having a lower probability of being restrained than those traveling in sedans or saloon cars.[9] Considering this discrepancy, the association between different vehicle types and child restraint use is worth further exploration.

Furthermore, a barrier to effective interventions and policy development for RTIs for child passengers is the lack of reliable data on child restraint use. Considering that effective interventions to improve road safety are urgently need, Shanghai participated in the Bloomberg Initiative for Global Road Safety (BIGRS).[18] The BIGRS project is a consortium of international partners supported by Bloomberg Philanthropies and seeks to adopt internationally recognized best practices to reduce road injuries and deaths in 10 selected LMICs (low- and middle-income countries).[18] This multi-round observational study conducted by the Johns Hopkins International Injury Research Unit (JH-IIRU) is one of the first on child restraint use based on a city-wide sample.

The objectives of this paper are to: 1) estimate the prevalence of child restraint use in motor vehicles through multi-round cross-sectional observations from a city-level representative sample; and 2) evaluate the unadjusted and adjusted association between multilevel risk factors with child restraint use after adjusting for potential confounders.

METHODS

Study design

A multi-round cross-sectional observational study was conducted near children's hospitals, kindergartens, entertainment places, and shopping malls between October 2015 and April 2019 in Shanghai, the largest city as well as finance and cultural center in China, with a resident population of more than 24 million in 2019.[14] Data collection consisted of eight rounds of observation including all four of Shanghai's top children's hospitals, which are tertiary referral hospitals with Grade A in China. Hospitals are classified as "primary, secondary, and tertiary" and graded as either "A, B, C" in China. "Grade A" indicates the best health care quality. This approach increased the accuracy of observations while ensuring a sufficient sample size of child passengers. Eligible observation sites were selected based on the following criteria: the location was safe for observers; the location was likely to have vehicles carrying at least one child passenger; observers were at an elevation that was equal to or higher than passing vehicles; the observation site was located in an area where vehicle drivers slowed down or stopped (such as traffic junctions, school gates, and garages); and passing cars were more likely to be occupied by the local population rather than tourists.[19]

Selected observation sites covered central urban areas (within the inner-ring of the expressway), urban areas (between the inner- and outer-ring expressways), and peri-urban areas (outside of the outer-ring expressway) in Shanghai. Observation sites covered eight of the sixteen districts in Shanghai, which was representative of varying traffic flow models of the city. Data were collected twice a year from 2015 to 2019. Observations covered a wide range of hours from 07:00 to 17:30 and were conducted on weekdays and weekends. This allowed for a good representation of varying traffic models during rush and off-peak hours.[19]

All the field workers recruited were researchers and experts with professional training and experience from Shanghai Municipal Center for Disease Control and Prevention (CDC). The team of our field workers was relatively stable throughout the eight rounds of observations. Furthermore, comprehensive training of all field workers was conducted before the first round of data collection, and repeated refresher training was conducted before each subsequent round.[19] The comprehensive training covered the child road safety knowledge and theory, types of child safety restraint devices, observation techniques, observation procedures, data recording procedures, data entry, and management procedures. During the training, field workers practiced estimation of children's age and gender at various kindergartens, where children of different age groups and gender were observed. Field workers also conducted on-site practice about child restraint observation, and their results were compared with video footage taken at the scene to identify potential observer bias.[19] Feedback from field workers was collected after each round of observations, which helped the improvement of observations of the following rounds.

At each observation site, trained field workers from the Shanghai Municipal Center for Disease Control and Prevention (CDC) observed and recorded child restraint use in all passing motorized vehicles carrying at least one child passenger. Exclusion criteria are those passing motorized vehicles without carrying any child passenger. If there were more than one child in a passing motorized vehicle, we took each child as a separate observation.

Field workers collected information on the following study variables: observer's name, city, location, day, month, year, vehicles per hour (total number of vehicles (total number observed within 1 hour before the observation time, vehicles passing in the same direction), the start time of observation, end time of observation, vehicle type (0: motorcycles; 1: car; 2: small truck; 3: big truck; 4: public bus; 5: small van; 6: SUV; 7: taxi; 8: other (please specify)), the number of occupants in each vehicle (including the driver), each child passenger's gender (male; female), each child passenger's age (1:0-4 years; 2:5-12 years), each child passenger's restraint use (yes; no), each child passenger's location and seating position (0: rear; 1: front row, not holding by adults; 2: front row, holding by an adult).[19] If there were more than one child in a passing motorized vehicle, we took each child as a separate observation and collected information for each child passenger. Site description information was also collected, which included weather, number of traffic lanes, district of the observation location, type of location, traffic volume, road surface conditions, and law enforcement activity before each observation session.[19] Standardized observation methods were employed across all observation locations and rounds, which ensured the comparability of results across observation locations and over time.

Other road safety studies have employed similar observational methods.[9,15,17,20] This method allows us to measure actual child restraint practice across a wide range of people at a reasonable cost, and has stronger validity than self-reporting, which is vulnerable to recall bias and misreporting.[19,21]

Statistical analysis

We employed both descriptive statistics and logistic regression models to analyze the data. For descriptive analysis, total sample size and sample size among each categorical covariate were presented.

For bivariate analysis, we examined the difference of child restraint use rate (the prevalence of child restraint use) in each categorical covariate using a χ^2 test and identified statistically significant relationships. For multivariate analysis, we assessed the unadjusted and adjusted (accounting for potential confounders) association between child restraint use and multilevel risk factors by using logistic regression models. The logistic regression model was defined as:

$$logit\ (y_i) = X_i \beta_i + \beta_0$$

Where i represents child passenger; $y_i = p/(1-p)$ is an indicator of the probability of occupant i using child restraint (p) divided by the probability of occupant i not using child restraint ($1-p$); β_i is the vector of regression coefficients; and β_0 is the y-intercept. The covariates included in the model are observation time (morning or afternoon), type of vehicle (sedan/saloon, SUV/4WD, taxi, or other vehicle type like pickup/light truck/bus/minibus/minivan/school bus), location type (entertainment place; shopping mall; kindergarten; children's hospital), child's age (<5 years or 5-12 years), presence of another child (yes or no), and child's seating position (rear seat or front seat). The model coefficients (β_i) assess the effect of a one-unit covariate (X_i) increase on the outcome. We selected covariates based on a review of the literature and stepwise model selection. Potential multicollinearity was checked before fitting the logistic regression model.

All statistical analyses were conducted in STATA 16 SE. Statistical tests were 2-sided, and a P-value less than 0.05 was considered statistically significant. Ethical approval was obtained from Johns Hopkins Bloomberg School of Public Health, Institutional Review Board, USA, and Shanghai CDC, China.

Patient and Public Involvement:

Patients or the public WERE NOT involved in the design, or conduct, or reporting, or dissemination plans of our research

RESULTS

Table 1 summarizes the vehicles and child occupant characteristics by child restraint use rate. Child restraint use rate rose from 5.12% in round 1 to 8.55% in round 8 (p value <0.001), with some fluctuation over time. Eight rounds of data were collected from 2015 to 2019, for a total sample size of 12,061 children traveling in 11,587 vehicles (**Table 2**). 774 children (6.4%) with restraint use in motor vehicles were identified and compared with 11,287 children (93.6%) without restraint use. About two-thirds of the observed child occupants were younger than five years old (7,623, 63.2%), and approximately one-third were 5-12 years old (4,407, 36.5%). More than half of the child occupants were boys (6725, 55.8%) and 37.6% (4,540) were girls. Children aged younger than five years were more likely to use a child restraint than children aged 5-12 years, except in rounds 3 and round 8 when the confidence intervals overlapped (**Figure 1**).

Most of the child passengers were observed near hospitals (11,029, 91.4%). 3.7% (446) were observed near shopping malls, 2.4% (295) were observed near kindergartens and 2.4% (291) were observed near entertainment places (**Table 2**). After disaggregating by location (**Figure 2**), child occupants observed near entertainment places (15.5%, 95% confidence-interval [CI]: 11.5%-20.1%) and shopping malls (11.2%, CI: 8.4%-14.5%) had a higher child restraint use rate, compared to observations near kindergartens (6.4%, CI: 3.9%-9.9%) and children's hospitals (6.0%, 5.5%-6.4%).

Most of the child occupants sat in rear seats (11,689, 96.9%) and only 3.1% (372) sat in front seats (**Table 2**). 92.3% (11,129) of children traveled in a car without other children and 7.7% (932) traveled with other children. The majority of vehicles were sedan or saloon (6,677, 55.4%). The second largest group of vehicles were taxis (3,043, 25.2%) and the third largest group were SUVs/4WDs (1,869, 15.5%). Few other vehicles types (472, 3.9%) were identified. 660 (5.5%) children sat on an adult's laps without using a child restraint.

Results from χ^2 test identified that children in the following categories of covariates were more likely to use child restraint: observation time in the morning, type of vehicle of sedan/saloon and SUV/4WD, in central urban, urban area, location at entertainment places and shopping malls, children's age < 5 years, boy, no other child present, and rear seat child passenger ($p < 0.05$) (**Table 1**). There were no statistically significant differences in child restraint use rate between weekdays and weekends ($p \geq 0.05$).Results from the unadjusted logistic regression model are similar to those from the adjusted logistic regression model (**Table 3**). After adjusting for all the covariates, children occupants with the following factors had a higher likelihood of using child restraint: children younger than five years compared to those aged 5-12 years (Odds Ratio [OR]: 2.12; 95% CI: 1.78-2.53; p<0.001), children sitting in the rear compared to those in the front seat (OR: 31.80; 95% CI: 4.45-227.14; p=0.001), child occupants observed near entertainment places (OR: 2.34; 95% CI: 1.67-3.28; p<0.001) or near shopping malls (OR: 1.86; 95% CI: 1.36-2.55; p<0.001) compared with those near children's hospitals, those traveling in an SUV/4WD compared with those in a sedan/saloon (OR: 1.31; 95% CI: 1.10-1.56; p=0.003), and those observed in the morning compared to the afternoon (OR: 1.30; 95% CI: 1.04-1.62; p=0.021). Children traveling in a taxi were less likely to use child restraints compared with those in a sedan/saloon (OR: 0.03; 95% CI: 0.01-0.06; p<0.001). Children traveling with other child passengers had a high risk of not using child restraints compared to those who were the only child in the car (OR: 0.45; 95% CI: 0.31-0.65; p<0.001).

DISCUSSION

To our knowledge, this study is among one of the first on child restraint use in motor vehicles based on a large city-wide sample in a Chinese city. Our multi-round observational study allows for a more accurate and reliable estimation of trends on child restraint practice over time than previous single-round studies.[19]

Moreover, this study has a large sample size allowing for disaggregation of data by child occupant characteristics, geographic location, and vehicle features.[19] Furthermore, our logistic regression models identified multilevel risk factors associated with child restraint use after adjusting for potential confounders. The results from this study are not only valuable for monitoring road safety performance, but also essential for improving interventions per WHO's best practices to promote child restraint use and decrease road traffic injuries or deaths among child passengers with the specific risk factors identified in this study.

Although child restraint use rate in Shanghai has increased from 5.12% in 2015 to 8.55% in 2019, the rate over the 4-year period is still as low as 6.4%, a finding that is in line with a previous observational study which found that only 6.1% of children used restraints in Shanghai.[15] The child restraint use rate is higher in high-income countries; for example in the United States (US), the child restraint use rate has reached 94%.[22] The data reported here also indicate that children younger than five years are more likely (OR:2.12) to use restraints than those aged 5-12 years. This finding is in accordance with findings from the US, where the US National Highway Transportation Safety Administration reports that the restraint use rate was 98% among children younger than one year, 96% among those aged 1 to 3 years, 85% among those aged 4 to 7 years, and 83% among those aged 8 to 12 years.[23] Due to the WHO's recommendation that all children younger than ten years of age should use appropriate restraint,[1] the importance of appropriately restraint use for children occupants of all ages, particularly for older children, should be emphasized.

We found that child occupants observed near entertainment places (OR:2.34) and shopping malls (OR:1.86) had a higher likelihood for using restraints compared with those near Children's hospitals or kindergartens. Previous studies of the relationship between child restraint and location type are limited. Only one previous observational study was conducted in different regions in Ghana, but no difference in child restraint practice between location types was found.[9] We speculate that the low child restraint use rate at kindergartens (6.4%) may be because parents are more comfortable with these locations because the parents frequent them daily. Additionally, child restrain use rate at children's hospitals (6.0%) may be low because parents think when their children are going to the hospital, they are too sick to use child restraints; or when rushing to hospital with sick children, parents forget to restrain their children. Therefore, despite the overall low use rate, lower use at kindergartens and children's hospitals indicates that the initial effort to promote child restraint should start at these locations.

Our finding that compared with children traveling in sedans/saloons, children traveling in taxis have a higher risk (OR:0.03) of not using child restraints is important from an early risk assessment and prevention perspective. Prior studies have not observed child restraint practice in taxis. However, a qualitative study using self-report data investigating parental knowledge did emphasize the need of providing child restraints in taxis,[24] which somewhat support our findings that the non-use of child restraints is more prevalent in taxis, and may become an important target for future interventions. Our results also indicate that compared to those traveling in sedans/saloons, children traveling in SUVs/4WDs have a higher likelihood (OR:1.31) of using child restraints, which is in line with previous findings.[17] We speculate this is because that SUVs/4WDs have more space than sedans/saloons, which make them better suited for child restraint use.

Although based on the WHO's best practice recommendations all children should sit in the rear seat of the vehicle using child restraints,[1] our study findings show that 3.1% of children sit in the front seat of vehicles. However, the prevalence of sitting in the front seat in our study finding is much lower than in other studies. For example, an estimated of 37.9% of children in Australia,[25] an estimated 12.2% in Shanghai in 2009,[14] and an estimated 26% in Ghana were found to sit in the front seat.[9] Our findings also indicate that children sitting in the rear seat had a higher likelihood of using child restraints compared to those sitting in the front seats, which is consistent with a city-wide survey in Michigan and a previous finding from the US.[26-27] Furthermore, compared with children who were the only child in a car, traveling with other children occupants is associated with a higher risk (OR:0.45) of not using child restraints, which is in accordance with an observational study conducted in Ghana.[9] We speculate this could be due to the lack of space in the rear seat or limited child restraint seats, making it difficult to use restraints when there are several children in one vehicle.[9] Based on the WHO's best practices,[1] the importance of appropriately using child restraints and avoiding suboptimal seating positions for children passengers, such as restricting children passengers from sitting in the front seat of a car, should be emphasized to potentially avoid serious consequences of traffic accidents.

Despite recent progress, especially legislative progress, improving child restraint use still remains a challenge. The new Regulations on Road Traffic Administration of Shanghai Municipality enacted on March 25, 2017 requires the use of child restraint when driving a family passenger car carrying a child under four years of age.[28] Moreover, children under 12 years of age are prohibited from being seated in the front passenger seat.[28] However, enforcement of this regulation is difficult and remains low given that no electronic technology is available for aid enforcement, and stopping vehicles to check child restrain use will worsen congestion. Therefore, there is an urgent need to enact a national law on mandating child restraint use, which would increase child restraint usage and reduce the RTIs and RTDs.[29] The lack of regulation on the sale and circulation of child restraints remains to be the second challenge. Currently, a wide range of qualities of child restraints are available for purchase on the market, and therefore supporting the production of low-cost and high-quality restraints is critical to the success of child restraint use programs.[30] Given the low use rate of child restraint in taxis, intervention programs might also include the provision of child restraints for use in taxis, an increase in child restraint installation services, and financial incentives for child restraint use by the government.[24] The third major challenge is the lack of awareness of child restraints, which indicates a need for the launch of education programs on appropriate child restraint use and seating position of child passengers, especially near hospitals and kindergartens.[31-32] Each of these factors may explain the low child restraint use rate and warrant further exploration of initiatives to promote child restraint practice in Shanghai and China.

Our study has several limitations. First, although we intended to randomly select observation sites in our study to provide a good representation of the city's overall situation, we were unable to employ a statistically rigorous random selection method because of the challenges of implementation.[33] Second, though we aimed to cover a wide range of location types and observations times, we still may have missed certain types of locations and times.[33] For example, we did not have observations after 17:30 pm or before 7:00 am, places unsafe for observers, or locations with a low prevalence of vehicle carrying child occupants. Therefore, this finding may not be generalizable to all children passengers in Shanghai or elsewhere in China. Third, causal inference cannot be made using an observational study. Fourth, although our study investigated on the trends on child restraint practice over time and covered multilevel risk factors, our study didn't measure whether child passengers were appropriately using the child restraint devices per children's age, size, and weight. The major reason is that within a limited observational time frame for motor vehicles, it is hard for our field workers to quickly make a complex decision about appropriate child restraint use. However, our observational study is still valid since similar observational methods have been widely employed in other studies on child restraint use.[9,15,17,20] In addition, this method allows us to measure actual child restraint practice across a wide range of people at a reasonable cost, and has stronger validity than self-reporting, which is vulnerable to recall bias and misreporting.[19,21] Fifth, the majority of indicators were calculated based on observations, which might suffer from observer bias.[33] Some demographic indicators, such as a child's age and gender, might be misclassified;[34] however, since training and on-site practice of all field workers were conducted before each round of data collection, and the child's age was categorized into two broad groups, there is no reason to believe that the bias is substantial, systematic, or influential of our key findings.[33]

Despite the limitations, our findings are valuable for monitoring child restraint practice and emphasized that the prevalence of child safety restraint use rate was low in Shanghai, China. Our study also found that children occupants with the following risk factors had a higher likelihood of using child restraints in motor vehicles: children younger than 5 years, sitting in the rear seat, children occupants observed near entertainment places or near shopping malls, and transportation in the morning. Our findings might have important implications for policy-makers and the development of intervention programs for child occupants with the identified risk factors, which may help to promote child restraint use and decrease road traffic injuries and deaths. A comprehensive and effective intervention package might include the enactment of a nation-wide child restraint use law, supported by the production of low-cost and high-quality child restraints, the launch of education programs on appropriate child restraint use and appropriate seat position of child occupants, child restraint installation services, the provision of child restraints for taxi users, and financial incentives for child restraint use by the government.

Declarations

Authors' contributions

QL and TC designed the study, conducted data analysis, drafted the initial manuscript, and revised the manuscript. QL, TC, and AB collected and managed the data. QL, TC, and AB reviewed the revised manuscript. All authors approve the submission of this study.

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Competing interests statement: None declared.

Patient consent for publication: Not required.

Ethics approval and consent to participate

Ethical approval was obtained from Johns Hopkins Bloomberg School of Public Health, Institutional Review Board, USA, and Shanghai CDC, China.

Data sharing statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Word count: 4333

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Table 1 Prevalence of child restraint use by characteristics of vehicles and child occupants (n=12,061).

Characteristics	**Round**								**Total**	**χ2**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**		
Total	5.1%	12.1%	3.7%	3.4%	7.1%	7.7%	7.9%	8.6%	6.4%	114.2*
Observation time										10.3*
Morning	6.6%	13.0%	3.7%	3.4%	7.1%	7.7%	7.9%	8.6%	6.8%	
Afternoon	4.2%	9.8%	-	-	-	-	-	-	4.9%	
Weekday										3.8
No	5.0%	14.6%	5.5%	3.5%	5.1%	6.0%	5.9%	12.1%	7.0%	
Yes	5.3%	5.5%	3.3%	3.4%	8.1%	8.3%	8.5%	7.1%	6.1%	
Type of vehicle										275.0*
Sedan/Saloon	7.7%	12.8%	3.9%	4.8%	9.3%	9.8%	9.6%	9.1%	8.2%	
SUV/4WD	9.3%	15.3%	6.5%	5.1%	11.6%	10.7%	10.9%	15.3%	10.4%	
Taxi	0.2%	0%	0.7%	0.4%	0.2%	0.3%	0%	0%	0.3%	
Others [#]	2.4%	0%	7.4%	0%	12.7%	9.9%	0%	16.7%	5.7%	
Area										6.5*
Central urban	5.5%	16.7%	5.1%	3.5%	8.1%	6.0%	7.3%	9.0%	6.3%	
Urban	4.5%	12.0%	1.9%	3.3%	5.3%	12.8%	9.5%	7.1%	6.7%	
Peri-urban	-	-	0%	-	-	-	-	-	0%	
Location type										60.2*
Entertainment places	-	21.7%	0%	-	-	-	-	-	15.5%	
Shopping malls	-	11.2%	-	-	-	-	-	-	11.2%	
Kindergarten	10.3%	5.5%	-	-	-	-	-	-	6.4%	
Children's hospital	5.0%	-	4.0%	3.4%	7.1%	7.7%	7.9%	8.6%	6.0%	
Child's Age										70.3*
<5 years	6.2%	15.8%	3.4%	4.6%	9.5%	9.1%	10.6%	8.7%	7.8%	
5-12 years	3.1%	6.6%	4.2%	0.8%	3.3%	4.7%	3.7%	8.4%	4.0%	
Missing	-	0%	0%	4.8%	0%	0%	-	-	3.2%	
Child's Gender										6.6*
Boy	5.2%	13.9%	4.1%	4.4%	7.9%	7.5%	8.1%	9.3%	6.9%	
Girl	4.9%	9.4%	3.3%	2.6%	5.8%	7.2%	7.4%	7.5%	5.7%	
Missing	5.6%	19.2%	3.4%	1.8%	7.6%	12.6%	10.2%	8.1%	6.3%	

Other Child Present										17.2*
No	5.4%	12.3%	4.2%	3.3%	7.7%	7.9%	7.9%	9.0%	6.7%	
Yes	1.9%	9.7%	0%	4.4%	2.8%	4.6%	8.2%	0%	3.2%	
Child's position										24.2*
Rear seat passenger	5.4%	12.8%	3.9%	3.5%	7.3%	7.7%	8.1%	8.6%	6.6%	
Front seat passenger	0%	1.9%	0%	0%	0%	0%	0%	0%	0.3%	

Notes: 1. * indicates p-value < 0.05;
2. [#] Type of vehicle Other involve: Pickup/Light truck/Bus/Minibus/Minivan/School bus;
3. 4WD: four-wheel drive vehicles;
4. The prevalence of child restraint use was calculated by the number of observed child passengers using child restraint divided by the total observed sample in this specific category;
5. χ2 test was used to examine the association of child restraint use with each categorical covariate.

Table 2: Descriptive of the sample in 8 rounds of observational study

	Round								Total
Characteristics	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
Total	3,005	890	1,316	1,560	1,472	1,425	1,387	1,006	12,061
Observation time									
Morning	1,151	644	1,316	1,560	1,472	1,425	1,387	1,006	9,961
Afternoon	1,854	246	0	0	0	0	0	0	2,100
Weekday									
No	1,350	653	273	454	475	382	307	297	4,191
Yes	1,655	237	1,043	1,106	997	1,043	1,080	709	7,870
Type of vehicle									
Sedan/Saloon	1,501	601	762	831	810	772	830	570	6,677
SUV/4WD	367	203	201	218	190	225	276	189	1,869
Taxi	1,010	69	299	450	417	347	234	217	3,043
Others [#]	127	17	54	61	55	81	47	30	472
Area									
Central urban	1,808	18	811	799	959	1,081	996	768	7,240
Urban	1,197	872	421	761	513	344	391	238	4,737
Peri-urban	0	0	84	0	0	0	0	0	84
Location type									
Entertainment places	0	207	84	0	0	0	0	0	291
Shopping malls	0	446	0	0	0	0	0	0	446
Kindergarten	58	237	0	0	0	0	0	0	295
Children's hospital	2,947	0	1,232	1,560	1,472	1,425	1,387	1,006	11,029
Child's Age									
<5 years	1,956	538	739	1,046	921	954	846	623	7,623
5-12 years	1,049	349	575	493	550	467	541	383	4,407
Missing	0	3	2	21	1	4	0	0	31
Child's Gender									
Boy	1,697	491	741	804	820	751	840	581	6,725
Girl	1,147	373	427	587	533	587	498	388	4,540
Missing	161	26	148	169	119	87	49	37	796
Other Child Present									
No	2,793	828	1,164	1,446	1,293	1,337	1,314	954	11,129
Yes	212	62	152	114	179	88	73	52	932
Child's position									

Rear seat passenger	2,850	836	1,261	1,525	1,440	1,410	1,367	1,000	11,689
Front seat passenger	155	54	55	35	32	15	20	6	372
Child restraint use									
No	2,851	782	1,267	1,507	1,367	1,316	1,277	920	11,287
Yes	154	108	49	53	105	109	110	86	774
Child sitting on adult's lap									
No	2,899	868	1,297	1,546	1,465	1,413	1,376	537	11,401
Yes	106	22	19	14	7	12	11	469	660

Notes: 1. [#] Type of vehicle Other involve: Pickup/Light truck/Bus/Minibus/Minivan/School bus
2. 4WD: four-wheel drive vehicles.

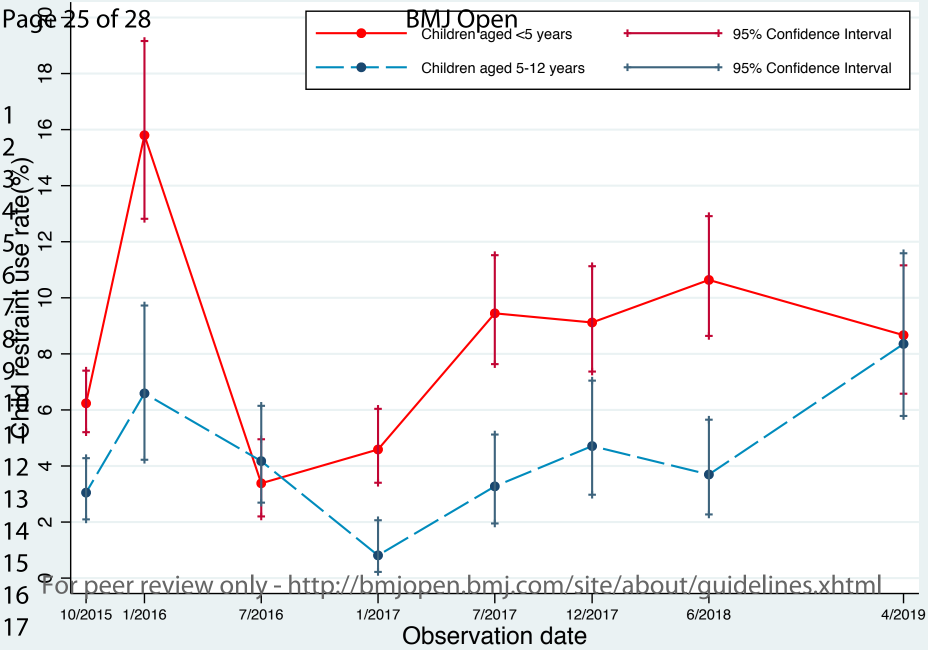
Table 3: Unadjusted and adjusted logistic regression model of risk factors associated with child restraint use in Shanghai (n=12,061).

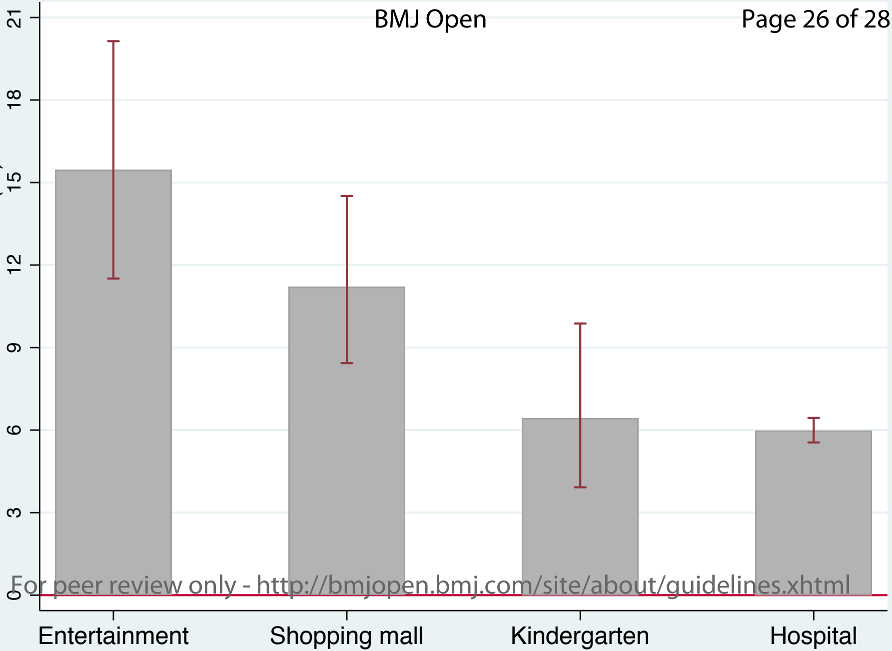
	Unadjusted Model			Adjusted Model		
Covariate	**OR**	**95% CI**		**OR**	**95% CI**	
Observation time (ref: Afternoon)						
Morning	1.42*	1.14	1.75	1.30*	1.04	1.62
Type of vehicle (ref: Sedan/Saloon)						
SUV/4WD	1.30*	1.10	1.55	1.31*	1.10	1.56
Taxi	0.03*	0.01	0.06	0.03*	0.01	0.06
Others	0.68	0.46	1.02	0.82	0.55	1.23
Location type (ref: Children's hospital)						
Kindergarten	1.08	0.67	1.73	0.92	0.57	1.48
Entertainment places	2.87*	2.07	3.99	2.34*	1.67	3.28
Shopping malls	1.98*	1.46	2.69	1.86*	1.36	2.55
Child's Age (ref: age 5-12 years)						
<5 years	2.06*	1.73	2.45	2.12*	1.78	2.53
Missing	0.81	0.11	5.94	0.77	0.10	5.73
Other Child present (ref: No)	0.46*	0.32	0.67	0.45*	0.31	0.65
Child's position (ref: front passenger)	26.27*	3.69	187.25	31.80*	4.45	227.14

Notes: 1. * indicates p-value < 0.05;
2. [#] Type of vehicle Other involve: Pickup/Light truck/Bus/Minibus/Minivan/School bus
3. 95% CI: 95% confidence interval; OR: Odds Ratio.

Figure 1: Trend of restraint use rate for children by age group in Shanghai.

Figure 2: Restraint use rate for children by type of location in Shanghai.


Children aged <5 years
95% Confidence Interval
Children aged 5-12 years
95% Confidence Interval
Child restraint use rate (%)
0
2
4
6
8
10
12
14
16
18
20
10/2015
1/2016
7/2016
1/2017
7/2017
12/2017
6/2018
4/2019
Observation date


Child restraint use rate (%)
0
3
6
9
12
15
18
21
Entertainment
Shopping mall
Kindergarten
Hospital

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No.	Relevant text from manuscript
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1	A multi-round cross-sectional observational study
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1	Abstract
Introduction				
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-5	Introduction: background
Objectives	3	State specific objectives, including any prespecified hypotheses	5	Introduction: Objectives
Methods				
Study design	4	Present key elements of study design early in the paper	5	Methods: Study design
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6	Methods: Study design
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	6-7	Methods: Study design
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case		
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7	Methods: Study design
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*7*	Methods: Study design
Bias	9	Describe any efforts to address potential sources of bias	7	Methods: Study design

Study size	10	Explain how the study size was arrived at	5	Methods: Study design
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-8	Methods: Statistical analysis
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-8	Methods: Statistical analysis
		(*b*) Describe any methods used to examine subgroups and interactions	7-8	Methods: Statistical analysis
		(*c*) Explain how missing data were addressed		
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy		
		(*e*) Describe any sensitivity analyses		
Results				
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8	Results
		(b) Give reasons for non-participation at each stage		
		(c) Consider use of a flow diagram		
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8	Results/Table 2
		(b) Indicate number of participants with missing data for each variable of interest	8	Results/Table 2
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)		
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time		
		Case-control study—Report numbers in each exposure category, or summary measures of exposure		
		Cross-sectional study—Report numbers of outcome events or summary measures	8-9	Results/Table 1 & 2
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9-10	Results/Table 3
		(*b*) Report category boundaries when continuous variables were categorized	9	Results/Table 3
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period		
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9	Results/Table 3,

				Figure 1 & 2
Discussion				
Key results	18	Summarise key results with reference to study objectives	10	Discussion
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13	Discussion
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10-14	Discussion
Generalisability	21	Discuss the generalisability (external validity) of the study results	10-14	Discussion
Other information				
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15	Declarations

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.