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ABSTRACT

Objectives To examine the association between dangerous student car drop-off behaviours and historical child pedestrian-motor vehicle collisions (PMVCs) near elementary schools in Toronto, Canada.

Methods: Police-reported child PMVCs during school travel times from 2000-2011 were mapped within 200m of 118 elementary schools. Observers measured dangerous student morning car drop-off behaviours and number of children walking to school during one day in 2011. A composite score of school social disadvantage was obtained from the Toronto District

School Board. Built environment and traffic features were mapped and included as covariates. A multivariate Poisson regression was used to model the rates of PMVC/number of children walking and dangerous student car drop-off behaviours, adjusting for the built environment and social disadvantage.

Results There were 45 child PMVCs with 29 (64%) sustaining minor injuries resulting in emergency department visits. The mean collision rate was 2.9/10,000 children walking/year (*SD* = 6.7). Dangerous drop-off behaviours were observed in 104 schools (88%). In the multivariate analysis, each additional dangerous drop-off behaviour was associated with a 45% increase in collision rates (IRR = 1.45, 95% CI 1.02, 2.07. Higher speed roads (IRR = 1.27, 95% CI 1.13, 1.44) and social disadvantage (IRR = 2.99, 95% CI 1.03, 8.68) were associated with higher collision rates.

Conclusions Dangerous student car drop-off behaviours were associated with historical non-fatal child PMVC rates during school travel times near schools. Some caution must be taken in interpreting these results due small number of events, and limitations in the data collection, as collision data were collected historically over a 12 year period, whereas driving behaviour was only observed on a single day in 2011. Targeted multifaceted intervention approaches related to the built environment, enforcement and education could address dangerous drop-off behaviours near schools to reduce child PMVCs and promote safe walking to school.

Key words

motor vehicles, walking, injuries, public health, prevention, schools

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INTRODUCTION

Walking to school has become a priority in many urban centres world-wide in order to improve health, foster community relationships and reduce traffic congestion. Reversing the decline in rates of active transportation is also included within the long term transportation plans of government planning agencies in both Canada and the US (Metrolinx 2008). Parental concern regarding traffic safety around schools is an important factor in whether children walk to school.(DiGuiseppi, Roberts et al. 1998; Timperio, Crawford et al. 2004; Kerr, Rosenberg et al. 2006; Rothman, Buliung et al, 2015) Features of the built environment such as the presence of traffic calming, higher speed roadways, and land use mix, are associated with safety perceptions, walking to school and child pedestrian-motor vehicle collisions (PMVCs)(Mueller, Rivara et al. 1990; McMillan 2007; Pont, Ziviani et al. 2009; Rothman, Buliung et al. 2013; Rothman, To et al. 2013). Although concerns regarding poor driving behaviour around schools have been highly publicized in the media,(Mertz Dec, 2014; Carter Sept, 2014) dangerous student car drop-off behaviours have not been well described and there has been no investigation into the relationship between dangerous drop-off behaviours and child PMVCs. Previous research has focused on describing observations regarding speeding, traffic/pedestrian volumes or stop-sign violations within school zones (Thompson, Fraser et al. 1985; Taft, Kane et al. 2000; Anderson, Boarnet et al. 2002; King, Lewis et al. 2011; Cody and M.P. 2013) or has described parent-perceived dangerous driving using surveys.(Collins and Kearns 2001).

Although child PMVCs are relatively rare events, much of children's exposure to traffic as pedestrians is during school travel.(Harten and Olds 2004; Timperio, Crawford et al. 2004; de Vries, Hopman-Rock et al. 2010) In Toronto, Canada there are on average, approximately 150

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PMVCs per year in school age children.(City of Toronto 2013) Warsh et al, found that almost 50% of child pedestrian collisions occurred during school travel times and more than 1/3 of all collisions occurring within 300 meters of a school.(Warsh, Rothman et al. 2009) It is hypothesized that areas surrounding schools where there are more dangerous **s**tudent car drop-off behaviours are associated with historically higher rates of child PMVCs. The objectives of this paper were to 1) describe dangerous student car drop-off behaviours related to parking and dropping children off in the morning at schools in Toronto and 2) to investigate the association between these behaviours and police-reported child PMVC rates near schools controlling for the built environment and school socioeconomic status.

METHODS

Study Design, Setting and Population

A cross-sectional observational study of driving behaviour was conducted in the spring, 2011 at 118 junior kindergarten (JK) to grade six schools in Toronto, Canada in the context of a larger study entitled "Child pedestrian-motor vehicle collisions and walking to school in the City of Toronto: The role of the built environment."(Rothman, To et al. 2013; Rothman, Macarthur et al. 2014) Exclusion criteria included schools with other grade combinations and participation in other studies related to school travel. Schools with designated special programs were also excluded (e.g. schools with specialized French language programs) as these schools are not typical neighbourhood schools, as children come from further distances resulting in more car travel than the neighbourhood schools.

Two trained observers counted the numbers of children walking to school on a single day in 2011. Counts were repeated one week apart at 10% of the schools to assess test-retest

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reliability.(Rothman, To et al. 2013) One observer stood at the main car drop off area and the other at the optimum location for counting pedestrians as identified by the school administration or crossing guard whenever possible. Observers also conducted school site audits during and after the morning drop off period to assess the traffic situation around schools and indicated whether any dangerous student car drop-off behaviours were observed. The site survey was a checklist adapted from the Delaware Department of Transportation's School Site Audits,(Delaware Department of Transportation) developed for the U.S. Safe Routes to School (SRTS) programs. A pilot study of the site survey was conducted in the spring, 2010 in 22 schools. Items that had a high agreement between raters (>80%) were retained. Feedback from observers contributed to new/adapted items included in the final checklist. Dangerous drop-off behaviours included in the checklist were; whether cars appeared to be driving too fast creating a dangerous pedestrian environment on roadways near the school, double parking when dropping children off, drop-offs of children on the opposite side of the road from the school, cars waiting blocking the vision of other motorists and pedestrians, cars parked blocking crossing controls, and cars not adequately following traffic controls. Ethics approval was obtained from the Hospital for Sick Children and the Toronto District School Board (TSDB) Research Ethics Boards.

Outcome

Police-reported PMVC data were obtained from City of Toronto, Transportation Services from 2000-2011 for children ages 4-12 years. Longitudinal and latitudinal coordinates, date, time, age and police-assigned injury severity were provided for each collision. Child PMVC rates were calculated using the number of collisions during school travel times within 200m of

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the schools per year. School travel times were defined as 08:00 -- 09:00, 11:30 -- 13:00 and 15:00 -- 16:15 on weekdays only, and excluded the summer holiday months, July and August and any school staff professional activity days when the children weren't attending school. The numbers of children counted walking to each of the schools in the morning of a single day was used as the rate denominator.

Exposure

Binary variables indicated on the site survey whether each of the dangerous student car drop-off behaviours was observed at the school. The number of observed behaviors were totalled together and included as a continuous exposure variable in the model.

Covariates

Binary variables were created from the site survey, which assessed presence of: school crossing guards (yes/no), a subjective measure of traffic congestion (i.e. traffic not moving or moving very slowly around the school during drop off period, yes/no), and posted speed limit of roadway in front of the school (30/40 km versus 50/60 km). A binary variable was also created indicating central city status. Central city status was indicated if >50% of the school boundary overlapped with the older neighbourhoods of the City of Toronto located within the pre-amalgamated city boundary (the city's older neighbourhoods were politically joined to its inner ring suburban neighbourhoods in 1993), versus the newer surrounding inner ring suburbs which include more car-oriented post-World War II neighbourhoods.(2001) City of Toronto Centreline data were used to calculate the number of intersections and the presence of an off-road walkway/trail unrelated to the roadway within 200 m of the school. Centreline data was also used to calculate length (in meters) of high speed/traffic volume minor and major arterial roads within the 200m. Major/minor arterial roads have >8,000 vehicles daily with speed limits ≤ 60 km/hr, collector roads have 2500-8000 vehicles daily, and local roadways have <2,500 vehicles daily, with collector and local roads having speed limits at ≤50 km/hr. Arterial roads were therefore, considered a proxy in this analysis, for higher speed and higher volume traffic. Centreline data were also used to calculate the length (in meters) of walkways or trails within the 200m boundary. Finally, the 2011 Learning Opportunities Index (LOI) was provided by the Toronto District School Board, which is a composite measure of external factors for each school that affect educational achievement including parental income, housing, education and immigration. The index ranges from 0 (lowest level of external challenge) to 1 (greatest level of external challenge).

Statistical Analysis

A straight line (Euclidean) distance buffer of 200m (approximately within a block) surrounding the schools was created and was the unit of analysis. All features were mapped using ArcMap v.10.(ESRI 2011) Collision rates were reported as an annualized rate per 10,000 children walking. Child PMVC rates were modeled using Poisson regression, as no over-dispersion of the outcome was evident, as indicated by the goodness of fit deviance statistic, which was close to 1. A p value ≤ 0.2 in the unadjusted analysis was used to screen for inclusion in the multivariate models, as using lower p values may miss important correlates once other variables are taken into account.(Hosmer and Lemeshow 2004) Incident rate ratios (IRR) and 95% confidence intervals were calculated. Statistical analysis was conducted using SAS, v.9.3.(SAS Institute Inc. 2012)

RESULTS

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There were 245 JK-grade 6 schools of which 126 met inclusion criteria. A total of 118 schools participated in the study with 8 refusals to participate. There were a total of 1850 child PMVCS throughout the 12 year time period, representing an average of 154 collisions reported to police per year. Of these collisions, there were 1767 with a reported injury, 983 of which involved a visit or an admission to a hospital, and 5 fatalities. There were 411 child PMVCs within 200m of the schools, with 45 occurring during school travel times. The mean and median age of children involved in collisions during school travel times were both 8 years (standard deviation (SD) 2.27). Sixteen children (36%) had minimal injuries, and 29 (64%) had minor injuries resulting in a visit to an emergency department (ED). There were no major injuries with hospital admissions or fatalities. The greatest proportion of collisions occurred on collector roads (18, 40%) and local roads (16, 36%), with 10 collisions on higher speed major or minor arterials (22%). One collision occurred on private property. The average collision rate was 2.9/10,000 children walking per year (SD = 6.7, range 0 -- 44.1/10,000/year). Eighty-nine schools had no collisions. Table 1 portrays the pedestrian action during the time of the collision, with crossing with right of way being the most common (12, 26%) followed by running onto roadway (9, 20%) and being on sidewalk/shoulder (8, 17%)

The three most frequent dangerous student car drop-off behaviours observed during the drop off period were identified as cars observed to drop off children on the opposite side of the road resulting in uncontrolled midblock crossings, cars stopped and blocking the vision of other motorists and pedestrians and double parking. Figure 1 portrays the proportion dangerous drop-off behaviours by type, around sampled schools. Drop-offs occurring on the opposite side of the roads from school (70%) and cars waiting and blocking the view of pedestrians and other cars

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(62%) were observed in most of the schools. Double parking was observed at almost half of schools. Two or more dangerous drop-off behaviours were observed in 88 schools (75%). Only 10 schools (9%) had no observed dangerous drop-off behaviours.

Table 2 provides the descriptive statistics for all variables and the unadjusted and adjusted incident rate ratios for child PMVCs occurring during school travel times. The mean number of the dangerous drop-off behaviours was 1.78 per school. Of particular note, was that both the mean and median LOI score was .50 (SD ± .28) which indicates no skewedness towards either high or low income schools in this sample.

In the unadjusted analysis, higher numbers of total dangerous student car drop-off behavio**urs** and intersections, higher minor/major arterial road lengths and a higher LOI score (i.e. greater external challenges) were associated with increased collision rates (Table 1). In the adjusted analysis, each additional dangerous drop-off behaviour was associated with a 45% increase in collision rates and each additional 100 meters of arterial roads were associated with a 30% increase in collision rates. Higher LOI scores were associated with higher collision rates with an IRR of 2.99 (95% CI 1.03, 8.68) which is equivalent to an 11.6% increase in collision rates per 10% increase in score.

DISCUSSION

The first objective of this paper was to describe dangerous student car drop-off behaviours related to parking and dropping children off in the morning at schools. The most frequently observed dangerous drop-off behaviours were identified dropping children off on the opposite side of the road resulting in uncontrolled midblock crossings, cars stopped and blocking the vision of other motorists and pedestrians, and double parking. The second objective was to

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investigate the association between dangerous student car drop-off behaviours driving behaviours and police-reported elementary school age child PMVC rates near schools controlling for the built environment and school socioeconomic status. Dangerous drop-off behaviours were associated with historically higher child PMVC rates during school travel times after controlling for the presence of higher speed roadways and social disadvantage. Higher speed roadways and higher LOI scores were associated with higher collision rates. Dangerous drop-off behaviours were observed at the majority of schools, with children being dropped off on the opposite side of the road from the school being the most common. Most schools had more than one type of observed dangerous drop-off behaviours.

Few studies have quantified dangerous student car drop-off behaviours surrounding schools despite the recent focus on school travel safety, and none have correlated these behaviours with child PMVCs during school travel times. In a study by National Safe Kids, 2/3 of drivers exceeded the posted speed limit in school zones before and after-school, despite 85% of the schools having more than 11 safety measures (crosswalk, flashing lights, stoplight, or crossing guard).(Taft, Kane et al. 2000) In another study by National Safe Kids, 45% of vehicles violated stop signs and another 25% stopped in or past crosswalks.(Cody and M.P. 2013) Anderson et al also described excessive speeding and high vehicle/pedestrian volumes around schools.(Anderson, Boarnet et al. 2002) All reported collisions in this study produced a minor or minimal injury leading to an ED visit with no major injuries or fatalities. As speed has been identified as the major determining factor of severe and fatal collisions,(World Health Organization 2004; Organisation for Economic Co-operation and Development (OECD) 2006) it might be assumed that these were lower speed collisions. Although collision speed was not available for the reported collisions in this study, 76% did occur on roadways with lower road classifications (local and collector roads versus higher speed arterials), which would have lower traffic speeds. In addition, observed traffic congestion during drop off time could lower traffic speeds around schools. However, it must be noted that 64% of collisions produced a hospital visit, which may indicate injuries affecting short-term function. It is also likely that there were other less severe unreported collisions; evidence suggests that less severe collisions and collisions involving children are under-reported to the police.(Maas and Harris 1984; Barancik and Fife 1985)

The relationship between higher collisions rates and higher speed roads is well documented.(Insurance Institute for Highway Safety (IIHS) 1987; World Health Organization 2004; Organisation for Economic Co-operation and Development (OECD) 2006) The World Health Organization cites speed as the core of the road injury problem with speed influencing crash risk and consequence.(World Health Organization 2004) The correlation between social disadvantage and higher child PMVC rates has also been extensively documented with many attributing this correlation to differential exposure of children to various hazards in deprived socioeconomic areas.(Rivara and Barber 1985; Dougherty, Pless et al. 1990; Braddock, Lapidus et al. 1991; Laflamme and Diderichsen 2000; Cloutier and Apparicio 2008; Rothman, Macarthur et al. 2014) Society has an obligation to ensure that children in disadvantaged areas, who may be more likely to walk to school, have a safe school walking environment. However, the increased access to and use of cars for school transportation is not a solution. It creates two health problems for children; first the traffic danger related to increased driving in the school zone, and second, the missed opportunity for the health benefits of active transportation.

The major strength of the study was that it used multivariate analysis to quantify the association between directly observed dangerous drop-off behaviours and police reported child PMVCs directly around schools during school travel times, controlling for roadway type. Objective measurements of driving behaviours were collected by trained observers which have not been done previously in Toronto. Finally, observations were conducted at 94% regular program JK-grade 6 schools in the City of Toronto, and it is likely that the results are generalizable to all elementary schools in Toronto.

The limitations of the study included the small number of events due to the rare nature of the collision outcome. In addition, the assumption was also made that driving behaviour around a particular school had been consistent over the 12 year period. Collision data were from 2000-2011, and driving behaviour was only observed on a single day in 2011. Causality cannot be assumed due to the cross-sectional nature of the data; however, the study demonstrated an association between a dangerous school driving environment and historical child PMVCs. Walking to school counts used for the PMVC rate denominator were only collected before school started on a single day and are assumed to be representative of all walking to/from the school, including after school and over lunchtime. Dangerous drop-off behaviours may have been underestimated, as observers generally only stood at locations to optimize car and pedestrian counts immediately adjacent to the schools, and weren't able to rate all dangerous behaviours surrounding the schools within 200 meters. Observers were unable to count the number of occurrences of dangerous drop-off behaviours but just whether or not they observed at least one occurrence of the specific behaviours (yes/no) at the school. Other important dangerous driving behaviours including those related to driver distraction and failure to stop at stop signs

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should be considered within school zones. Finally, injury severity was coded by police, and police-reported collision data has been found to underreport child pedestrian-motor vehicle collisions.(Maas and Harris 1984; Barancik and Fife 1985; Agran, Castillo et al. 1990) It is not likely however, that more severe collisions were missed, as police tend to underreport milder injuries.

Implications

There have been very few attempts to measure driving behaviours around schools and no prior studies have attempted to define the association between dangerous student car drop-off behaviours and child pedestrian collisions. This study points to some important findings and outlines some of the methodological issues regarding the measurement of dangerous drop-off behaviours. There is a need for further studies that count and determine the rate of dangerous drop-off behaviours. Exploration also needs to be done into incorporating more frequent outcomes which place children at risk of collisions, such as observed child-vehicle interactions, to deal with the limitations related to using historical collision data due to their rarity; however, it is unclear how these surrogate variables relate to actual injury.

The results of this study found that dangerous drop-off behaviours were most commonly related to unsafe parking and drop-offs, which are specifically related to driving children to school. Dangerous drop-of behaviours and may be reflective of caregivers who were rushed or unwilling to make the effort to park safely, or who were unable to park safely because there was no spot available. Potential interventions directed at these drivers should include the promotion of a transportation modal shift by schools and health care professionals from driving to walking to school. It has been demonstrated that walking to school is safe in terms of pedestrian collisions, providing the built environment around schools is safe.(Rothman, Macarthur et al. 2014) More children walking to school would result in increased pedestrian safety by reducing the vehicular traffic. Active school transportation also has many benefits beyond safety, including being a source of physical activity to encourage healthy active lifestyles and the reduction of the prevalence of obesity and its associated chronic conditions.(Faulkner, Buliung et al. 2009; Faulkner, Stone et al. 2013; Liu and Mendoza 2014)

Policies at the school level and at all levels of the government must reflect the commitment to active school transportation. For example, in Toronto, Canada, the TDSB recently adopted the "Charter for Active Safe and Sustainable Transportation" which committed the support and investment in active transportation for students.(Toronto District School Board 2013) In 2008, the Ontario government's Metrolinx Agency initiated a Regional Transportation Plan entitled "The Big Move" with plans to spend $200 million over 20 years towards active transportation infrastructure and research in the Greater Toronto and Hamilton area, which includes school travel planning programming.(Metrolinx 2008),(Metrolinx 2012),(Buliung, Faulkner et al. 2011; Mammen, Stone et al. 2014) In the US, the Department of Transportation policy released their Policy Statement on Bicycle and Pedestrian Accommodation Regulations and Recommendations in March 2010, which emphasized the needs and requirements to integrate walking and bicycling into transportation systems.(United States Department of Transportation 2010) Public commitment to active school transportation will ultimately affect parents' decision on school travel mode choice.

For those drivers who either are unwilling to walk, feel they live too far from the school, have time constraints, have children unable to walk due to disability or who are passing through the school area and are not involved in school pickup/drop-offs, a multifaceted approach could be effective The behaviours of the drivers passing through may be the most difficult to affect, as it would not be possible to approach them through the school community. The World Health Organization recommends a systems approach to tackle road safety, which includes legislation, enforcement, education and the road environment.(World Health Organization 2004) Dangerous driver behaviour can be reduced around by developing campaigns targeted at school locations which combine education at both the school and the public level with both active and passive enforcement and the adaptation of the roadway environment.

Schools are intended to be a safe place for children. Each school has a unique traffic situation, and parents, schools and the surrounding community should t work together to initiate the political process to lobby for change. Creative solutions should be developed to discourage dangerous student car drop-off behaviour to ultimately reduce child PMVCs near schools and promote safe walking to school.

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Table 1: Pedestrian collision action (n = 45)

Crossing with right of way	11 (24%) 4 (36%) traffic signal, 4 (36%) stop sign 3 (27%) unknown
Running onto roadway	9 (20%)
On sidewalk/shoulder	8 (18%)
Crossing without right of way	4 (9%)
Crossing at pedestrian crossover	3 (7%)
Crossing with no traffic control	3 (7%)
Coming from behind parked car	3 (7%)
Getting in/out of vehicle	2 (4%)
Unknown	2 (4%)

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Table 2: Descriptive statistics, unadjusted and adjusted incident rate ratios (IRR) and 95% confidence intervals (CI) for child pedestrian-motor vehicle collisions occurring during school travel times (n = 45)

		Child school travel time collisions within 200 m of school N = 45	
	N (%) Mean (SD)	**Unadjusted IRR (95% CI)**	**Adjusted IRR (95% CI)**
Exposure Total dangerous driving behaviours	1.78 (SD±0.97)	**1.36 (1.04, 1.80)**	**1.45 (1.02, 2.07)**
Explanatory Variables Traffic congestion	76 (64.4%)	0.78 (0.42, 1.42)	-
Number of intersections	9.3 (SD± 6.7)	1.03 (0.99, 1.07)	-
School crossing guard observed	45 (38.1%)	1.20 (0.67,2.15)	-
Front of school speed limit > 40 km/h	9 (7.6%)	1.60 (0.57, 4.47)	-
Central City Status	39 (33.1)	0.98 (0.52, 1.84)	
Walkway/trail	21 (17.8)	0.72 (0.30, 1.70)	-
Major and minor arterial road length (100 meters)	160 (SD± 205)	**1.29 (1.14, 1.46)**	**1.27 (1.13, 1.44)**
Learning Opportunities Index	0.50 (SD ± .28)	**4.19 (1.36, 12.92)**	**2.99 (1.03, 8.68)**

ACCEPTED MANUSCRIPT

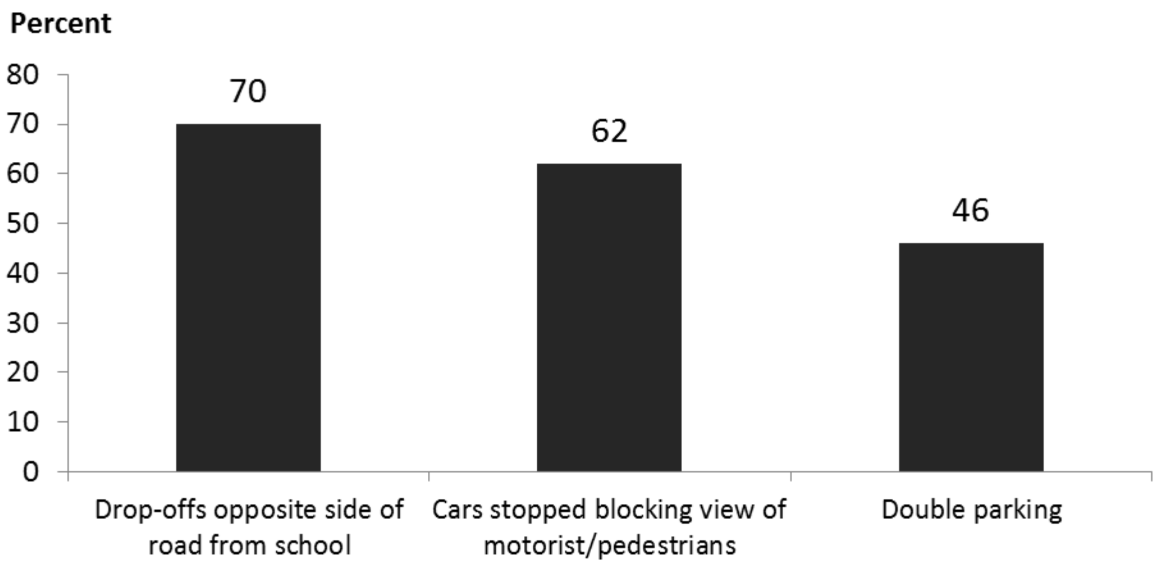

Figure 1: Dangerous driving behaviors near schools (n = 118)

