Child pedestrian crossing behaviour and associated risk factors in school zones: a video-based observational study in Kampala, Uganda

Jimmy Osuret [1], Ashley Van Niekerk,[2,3] Olive Kobusingye,[1] Lynn Atuyambe,[4] Victoria Nankabirwa[5]

[1]School of Public Health, Department of Disease Control and Environmental Health, Makerere University College of Health Sciences, Kampala, Uganda
[2]Institute for Social and Health Sciences, University of South Africa, College of Human Sciences, Pretoria, South Africa
[3]South African Medical Research Council and University of South Africa, Masculinity and Health Research Unit, Cape Town, South Africa
[4]School of Public Health, Department of Community Health and Behavioural Sciences, Makerere University College of Health Sciences, Kampala, Uganda
[5]School of Public Health, Department of Epidemiology and Biostatistics, Makerere University College of Health Sciences, Kampala, Uganda

Correspondence to
Jimmy Osuret, School of Public Health, Department of Disease Control and Environmental Health, Makerere University College of Health Sciences, Kampala, Uganda; jimmyosuret@gmail.com

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ABSTRACT

Background Pedestrian crashes, often occurring while road crossing and associated with crossing behaviour, make up 34.8% of road casualties in Uganda. This study determined crossing behaviour and associated factors among child pedestrians around primary schools in Kampala, Uganda.

Methods We conducted a cross-sectional study in 2022 among 2100 primary school children. Data on their crossing behaviour were collected using video recordings from cameras staged at the crossing points of 21 schools. We estimated prevalence ratios (PR) with their corresponding 95% CIs using a modified Poisson regression model for the association between unsafe behaviour and the predictors.

Results The prevalence for each of 5 unsafe child pedestrian behaviour was 206 (25.8%) for crossing outside the crosswalk, 415 (19.8%) for failing to wait at the kerb, 238 (11.3%) for failing to look for vehicles, 361 (17.2%) for running and 235 (13%) for crossing between vehicles. There was a higher likelihood of crossing outside the crosswalk when an obstacle was present (adjusted PR (aPR) 1.8; 95% CI 1.40 to 2.27) and when children crossed alone (aPR 1.5; 95% CI 1.13 to 2.06). Children who crossed without a traffic warden (aPR 2; 95% CI 1.40 to 2.37) had a significantly higher prevalence of failing to wait at a kerb.

Conclusion These findings reveal the interaction between child pedestrians, vehicles and the environment at crossings. Some factors associated with unsafe child pedestrian behaviour were the presence of an obstacle, crossing alone and the absence of a traffic warden. These findings can help researchers and practitioners understand child pedestrian crossing behaviour, highlighting the need to prioritise targeted safety measures.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Pedestrian injuries are the leading cause of injury-related death in children, and the risk factors are known in high-income countries but less so in low-income countries (LICs).
⇒ Child pedestrian crashes often occur while road crossing, yet evidence on the interaction between pedestrians, vehicles and the environment is insufficient in LICs such as Uganda.

WHAT THIS STUDY ADDS

⇒ Most studies in this field assessed behaviour in simulated traffic environments or focused on children's road safety knowledge, but the transfer between knowledge and behaviour is poorly understood.
⇒ This study determined crossing behaviour and associated factors among child pedestrians in Uganda by inconspicuously filming behaviour in realistic traffic situations.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The findings from this study are expected to help road safety planners understand and consider the interaction between pedestrians, vehicles and the environment at road crossings.
⇒ The findings could provide an avenue for future research towards developing guidelines for pedestrian and traffic control around school zones.

BACKGROUND

Pedestrians face unsafe road conditions globally, but more so in low-income and middle-income countries (LMICs), which account for 40% of road deaths.[1 2] Pedestrian road traffic injuries (RTIs) are among the leading causes of death among children and young adults worldwide because their needs are often ignored in road system planning, design and operation.[1] Pedestrian injuries result from an interplay of human (pedestrians and motorists) and environmental factors.[3] The behaviour of motorists and pedestrians is crucial in many LMIC settings, where mobility planning prioritises motor vehicles over pedestrian needs.[1] Violating traffic regulations such as failure to yield, speeding and illegal crossings contribute to pedestrian RTIs and deaths.[2 4 5] Pedestrian crossing behaviour is influenced by various factors related to pedestrian demographics, such as age and gender; driver behaviour; traffic flow; situational factors and the road environment.[6] Pedestrians arriving at a crossing look out for a safe gap between vehicles to cross.[6 7] A pedestrian's waiting time at the kerb is determined by the approaching vehicle distance, speed, traffic volume and the presence of other pedestrians.[6] Children tend to have shorter waiting times at pedestrian crossings because they may accept higher risk depending on their risk appraisal, influenced by individual personality, maturity and experience.[6] Children acquire the logic and experience that enables them to better identify a dangerous situation and be cautious as they grow older to adolescence.[8,9] However, difficulty arises when they begin to deal with complex traffic situations requiring multiple simultaneous processing of more than one event typical of the road environment in many LICs.[8]

Even though RTI research in LICs including Uganda has evolved, approaches using more sophisticated data collection methods such as video recording to capture road user behaviour and interactions in naturalistic settings to improve the understanding of contextual factors to RTIs are still in their infancy.[10] In particular, pedestrian behaviour, traffic patterns, transport systems, road safety culture and attitudes in HICs differ from the Ugandan context.[11] In Uganda, pedestrians account for 34.8% of road traffic deaths, with the burden more pronounced among children.[10] The reduction of child pedestrian RTIs is associated with implementing interventions encompassing a 'safe system approach' that recognises children's needs in road systems.[12,13] The safe system approach recognises road transport complexity and anticipates human errors, which should be accommodated for in road systems and vehicle designs, rather than blaming and placing such safety burdens on road users.[14] With this approach, road transport planners and designers are accountable for the level of safety within the system.[12] The road system design should mitigate children's vulnerabilities, to minimise the risk to injuries or fatalities.[12] This approach has implications for designing interventions directed towards modifying the pedestrian environments.[14] Children are vulnerable in road environments with limited pedestrian protections, and developing effective pedestrian safety measures requires understanding how they interact with the road, the environment and other road users.[3,7] Considering this, our study explored the relationship between child pedestrian crossing behaviour (ie, crossing outside the crosswalk, failing to wait at the kerb, failing to look out for vehicles, running and crossing between vehicles) with multiple associated risk factors among child pedestrians in primary school zones in Kampala, Uganda. Information on child pedestrian crossing behaviour in urban areas of LICs will contribute to understandings of the roles of the road environment, traffic and pedestrian characteristics on pedestrian crossing decisions, driver and pedestrian compliance with traffic rules and the related safety implications.

METHODS

Study design and setting

This cross-sectional study was conducted in Kampala, central Uganda. Kampala, Uganda's capital, has five divisions with urban and peri-urban communities and an estimated population of 1 766 500.[15] Primary school enrolment in Uganda was 8.8 million children in 2017 from approximately 20 000 schools. Kampala has 89 public primary schools registered with Kampala Capital City Authority (KCCA). Walking is a common mode of transport among school-going children.[16] Pedestrian crossings for most schools include intersections, unmarked crossings, marked crossings and signalised crossings.[17]

Study population

The study was conducted among primary school-going children aged 5–11 years from KCCA schools.[15] Children from the same school wear similar clothes or uniforms that we used to identify them from the video recordings. We excluded children not affiliated with KCCA schools, subjective variables and unobservable crossing behaviour during the extraction and coding of the video recordings. Schools along the Kampala expressway were excluded because pedestrians were prohibited from using this road.

Sample size and sampling

The cluster sampling formula by Bennet *et al* was used to determine the prevalence of unsafe crossing behaviour in children.

$$c = \frac{p\ (1-p)\ D}{S^2 b}$$

Where c was the number of clusters (schools) needed; the estimated proportion (p) of unsafe crossing behaviour, which we estimated at 50% since it was unknown. The SE (s), the measure of the precision of the estimated parameter=5%; the design effect (D), that is, the ratio of the variance of P for cluster sampling design to variance of p due to simple random sampling $D=1+(b-1)$ roh, where b was the average number of children observed from the video recording for each school (100), roh was the rate of homogeneity representing the rate of variation between clusters as compared with the variation within clusters, taken as 0.2 because children from the same school tended to have similar crossing behaviour.

Substituting in the formula, $D=1+(100-1)\times 0.2=20.8$

Thus,

$$c = \frac{0.5\times(1-0.5)\times 20.8}{0.05^2\times 100} = 21$$

Simple random sampling was used to select 21 schools from the 89 public KCCA primary schools.

Data collection

We trained the research assistants on the procedures to mount the mini camera in an elevated position to obtain a view of the crossing location and to extract data from the recordings during the pretest conducted in two schools. We used feedback from the pretest to improve the variables we were to extract and code. A team of 4 trained and experienced research assistants and one field supervisor (JO) mounted cameras in 21 schools to record crossing behaviour over the course of 11 days between January and February 2022. The research assistants underwent a 5-day training to introduce them to all study aspects, such as the objectives, procedures, data extraction and coding protocols using mobile smartphones with KoBo Toolbox, and ethical issues with video recordings. For each school included, the supervisor identified two common crossing points, that is, near (within 300 m of the school) and far (>300 m from the school). At each crossing point, the research assistant mounted a mini GoPro camera to record the behaviour and encounters of various road users. The research assistant fixed the camera in an elevated position to record the view of the crossing point and road user behaviour in the natural setting unobtrusively without any influence. For each crossing point, the research assistant mounted a camera to capture the day's recordings for the three peak periods (ie, 06:30–8:00; 13:00–14:00 and 16:00–19:00 hours) when children arrive at and from school. The same team of research assistants then extracted and coded data on road user behaviour from the video recording into the mobile technology KoBo Toolbox. We applied restrictions in the mobile-based tool's design, including skip patterns and prompts to reduce errors during data coding. The KoBo tool had checks used to address any inconsistencies during the coding. JO continually provided support and oversaw the quality control to spot-check adherence to the extraction and coding protocol. The formula used to calculate the sample size for estimating the 21 school clusters indicated that, on average, 100 children (ie, 50 each at the near and far crossing points) needed to be observed from the video recording for each school. Therefore, at each crossing point where we installed cameras, all children recorded in the video footage were included in a list to create a sampling frame. Following this, a statistician used Microsoft Excel to generate sampling frame numbers, then applied the RAND command to arrange these frame numbers into a randomised sequence and selected 50 from which data were coded and extracted.

Study variables

Outcome variables

Rosenbloom *et al*[6 18] and Zareharofteh *et al*[19] observed unsafe crossing behaviour of children associated with pedestrian collision, like not stopping at the curb, not looking before crossing, crossing outside a crosswalk, running across the road, crossing between cars in traffic jams and attempting to cross when a vehicle is nearing, which informed the primary outcomes. Therefore, for each crossing, we coded whether or not children (1) waited at the kerb for the car to move off before crossing, (2) looked both ways for oncoming vehicles before crossing, determined by the head movements to the right or left, (3) crossed within the boundary of the crosswalk area, (4) walked or ran as they crossed and (5) crossed between vehicles was defined as an illegal behaviour and dangerous action of pedestrians manoeuvring through slow-moving traffic or moving between cars at any point on the roadway in traffic jams.

Predictor variables

Data on the following predictor variables were extracted and coded from video recordings (ie, sex; obstacle present at the time of crossing defined as an object that obstructed and altered pedestrian path, eg, stationary vehicle, deep hole on the street, shallow water puddle; child crossing in a group or alone; traffic warden present; child supervised by an adult; driver yield—whether the first or following drivers from right/left give right of way to pedestrians; nearest vehicle type—two-wheeler and four-wheeler and period of the day—defined as morning, afternoon and evening).

Data management and statistical analysis

Video recordings were saved in hard drives, and data were submitted to a secure cloud aggregate server on completion of extraction and coding. A daily download of all data from the server was done followed by data cleaning. JO enhanced the validity of the submitted data by independently checking for inconsistencies, duplicate records or incomplete data by reviewing the time stamp of the recording. Where there were still areas of disagreement (which were <3% from blurry recordings), we consulted a third person in the research team. Since some behaviour outcome variables had different denominators sample sizes (eg, crossing outside the crosswalk did not apply to school crossings, as some did not have crosswalks), we did not compute a crossing behaviour index. The prevalence for each observed crossing behaviour was estimated as the number of participants with a specific unsafe behaviour (ie, crossed outside the crosswalk, failed to wait at the kerb, failed to look for vehicles, ran and unsafely crossed between vehicles) divided by the total number of participants.

At bivariable analysis, χ^2 tests were used to obtain the association between each outcome crossing behaviour and predictor variables. All factors with a $p<0.2$ and demographics (eg, sex) were included in the multivariable regression model. For the association between the outcome and predictors, prevalence ratios (PRs) with corresponding 95% CIs were estimated using modified Poisson regression models with robust SE variance.[20] A factor was considered statistically significant at a 5% threshold in the multivariable analysis. The models with the lowest Akaike information criterion were selected. PRs were preferred to ORs because of the high prevalence of the outcome (>10%) and it provides a better risk estimate than the OR.[21] All analyses were conducted using STATA statistical software V.14.0.

RESULTS

Data on crossing behaviour from video recordings were extracted and coded for 2100 children from 21 schools (ie, 1075 from the nearby and 1025 from the faraway crossing points). Overall, 1089 (51.9%) were male, while 883 (42.1 %) and 815 (38.8%) of the observations were from the evening and morning sessions, respectively. Most (33/44) crossings were on two-lane roads, and less than half (15/44) had road safety signs. The majority (15/22) of distant crossings were at intersections, of which 16/25 lacked traffic calming humps and 17/27 lacked zebra crossings. There was no significant difference between male and female children in unsafe behaviour (ie, failing to wait at the kerb, failing to look out for oncoming vehicles, crossing outside the crosswalk, running and crossing between vehicles).

Prevalence of each crossing behaviour

Children generally displayed a higher likelihood of unsafe crossing behaviour at the faraway crossing points compared with the nearby crossing point, except for running behaviour (table 1). At marked crosswalks, 206 (25.8%) crossed outside the boundary. At the unmarked crossings, 415 (19.8%) of the child pedestrians failed to wait at the kerb for a passing vehicle prior to crossing, 238 (11.3%) failed to look out for vehicles before crossing, 361 (17.2%) ran while crossing and 235 (13%) crossed between vehicles.

Factors associated with child pedestrians crossing outside the crosswalk

At bivariable analysis, the presence of an obstacle, crossing alone and crossing without a traffic warden were associated with children crossing outside the crosswalk. At multivariable analysis, children who crossed at points with an obstacle (adjusted prevalence ratio (aPR) 1.8, 95% CI 1.40 to 2.27), crossed alone (aPR 1.5, 95% CI 1.13 to 2.06) and crossed without a traffic warden (aPR 1.6, 95% CI 1.21 to 2.18) had a significantly higher prevalence of crossing outside the crosswalk (table 2).

Factors associated with child pedestrians failing to wait at the kerb before crossing

At bivariable analysis, factors associated with child pedestrians failing to wait at the kerb included: the absence of a traffic warden, crossing alone, a four-wheeler vehicle present at the time of crossing, a child being unsupervised, a driver failing to yield and the period of the day. At multivariable analysis, children who crossed without a traffic warden (aPR 2; 95% CI 1.40 to 2.37) and those who crossed alone (aPR 1.9; 95% CI 1.52 to 2.37) had a significantly higher prevalence of failing to wait at a kerb before crossing. The presence of a four-wheeler vehicle at the time of crossing (aPR 0.5; 95% CI 0.40 to 0.61) and a driver failing to yield (aPR 0.5; 95% CI 0.43 to 0.70) were associated with a 50% lower likelihood of children failing to wait at the kerb (table 3).

Factors associated with child pedestrians failing to look out for vehicles before crossing

At bivariable analysis, being unsupervised by an adult, crossing in the evening, the morning and a four-wheeler vehicle at the

Table 1 Prevalence of crossing behaviour

Crossing behaviour	Prevalence (95% CI)						
	Overall	Morning		Afternoon		Evening	
		Far	Near	Far	Near	Far	Near
Crossed outside the crosswalk (n=797)	25.8 (22.9 to 29)	38.5 (29 to 48.9)	17.3 (12.5 to 23.4)	37.3 (27.1 to 48.9)	26.4 (19.3 to 35.1)	29.7 (22.6 to 37.9)	20.4 (15.2 to 27)
Failed to wait at kerb (n=2100)	19.8 (18.1 to 21.5)	22.5 (18.6 to 26.6)	21.9 (18.1 to 26.4)	11.6 (7.2 to 18.1)	15.2 (11.3 to 20)	25.7 (21.9 to 29.9)	14.3 (11.2 to 17.9)
Failed to look out for vehicles (n=2100)	11.3 (10 to 12.8)	14.1 (11.1 to 17.7)	7.8 (5.5 to 11)	25.4 (18.8 to 33.3)	12.9 (9.3 to 17.5)	11.7 (9 to 14.9)	5.8 (4 to 8.5)
Ran (n=2100)	17.2 (15.6 to 18.9)	9.7 (7.2 to 12.9)	17.8 (14.2 to 21.9)	28.3 (21.3 to 36.4)	29.5 (24.3 to 35.4)	11.6 (9 to 14.9)	18.9 (15.5 to 22.9)
Crossed between vehicles (n=1808)	13 (11.5 to 14.6)	15.5 (12.1 to 19.6)	8.7 (6.1 to 12.3)	13.2 (8.2 to 20.6)	3.7 (1.8 to 7.2)	19.8 (16.2 to 23.9)	12.4 (9.4 to 16.2)

time of crossing were associated with child pedestrians failing to look out for vehicles. At multivariable analysis, a child being unsupervised by an adult (aPR 0.3; 95% CI 0.19 to 0.33) and those who crossed in the evening (aPR 0.7; 95% CI 0.47 to 0.96) had a 70% and 30% lower prevalence, respectively of failing to look out for a vehicle before crossing (table 4).

Factors associated with child pedestrians running while crossing

At bivariable analysis, children crossing alone, a driver failing to yield to pedestrians, the evening period, morning period, four-wheeler vehicle at the time of crossing and the absence of a traffic warden were associated with running while crossing. At multivariable analysis, the prevalence of running was two times higher among children who crossed alone than those who crossed in a group (aPR 2; 95% CI 1.62 to 2.58). A driver failing to yield to pedestrians, the evening period, the morning period and a four-wheeler vehicle present at the time of crossing were significantly associated with a lower prevalence of child pedestrians running (aPR 0.6, 95% CI 0.52 to 0.81; aPR 0.6, 95% CI 0.47 to 0.77; aPR 0.5, 95% CI 0.36 to 0.61; aPR 0.7 95% CI 0.53 to 0.80, respectively) (table 5).

Factors associated with child pedestrians crossing between vehicles

At bivariable analysis, the absence of a traffic warden, a driver failing to yield to child pedestrians, the presence of an obstacle at the time of crossing, crossing in the evening period, the morning period and a four-wheeler vehicle present at the time of crossing were associated with child pedestrians crossing between vehicles. At multivariable analysis, children who crossed without a traffic warden (aPR 3.4, 95% CI 1.90 to 5.98), crossed in situations where a driver failed to yield (aPR 1.5, 95% CI 1.07 to 2.09), crossed at points with an obstacle present (aPR 3; 95% CI 2.37 to 3.62), crossed in the evening (aPR 2.4; 95% CI 1.65 to 3.60), the morning period (aPR 1.8, 95% CI 1.20 to 2.72) and crossed in the presence of a four-wheeler vehicle (aPR 9.3, 95% CI 5.12 to 16.90) had a significantly higher likelihood of crossing between vehicles (table 6).

DISCUSSION

This paper analyses five unsafe child pedestrian crossing behaviours and the associated factors in Kampala, Uganda. We found a prevalence of 25.9% for crossing outside the crosswalk, 19.8% for failing to wait at the kerb, 11.3% for failing to look for vehicles, 17.2% for running and 13% for unsafely crossing between vehicles. Notably, these unsafe behaviours are associated with pedestrian collisions in similar settings.[19] For instance, running increases the risk of falling, failing to yield can lead to pedestrian motor vehicle conflict and children who cross between vehicles may not be visible, increasing collision risk.[19] This high prevalence of unsafe crossing behaviour among children is of concern in Uganda, where pedestrian safety is a low priority and safe pedestrian infrastructure is limited.[11] These findings are consistent with other studies examining child pedestrian behaviour.[22–24] In contrast, lower estimates of unsafe crossing behaviour were reported in Qatar, a setting with developed pedestrian infrastructure and lower and generally safer vehicle speeds.[25]

This study indicated no difference in pedestrian behaviour between males and females. These findings contradict other studies that report a relatively higher proportion of pedestrian crash risk and unsafe behaviour among male children.[22 26]

Table 2 Factors associated with crossing outside the crosswalk

Factors	N=2100	N (% crossed outside crosswalk)	Crude		Adjusted	
			Prevalence ratio	95% CI	Prevalence ratio	95% CI
Obstacle present						
No	1807	144 (22.1%)	Ref		Ref	
Yes	293	62 (42.5%)	1.9	(1.51 to 2.43)	1.8	(1.40 to 2.27)
Group crossing						
Group	1726	173 (24.2%)	Ref		Ref	
Alone	374	33 (40.2%)	1.7	(1.24 to 2.23)	1.5	(1.13 to 2.06)
Traffic warden present						
Yes	445	48 (16.7%)	Ref		Ref	
No	1655	158 (31%)	1.9	(1.39 to 2.47)	1.6	(1.21 to 2.18)
Sex						
Female	1011	113 (28.7%)	Ref			
Male	1089	93 (23.1%)	0.8	(0.63 to 1.02)	0.8	(0.66 to 1.05)

Ref, reference.

Such conflicting results may be attributed to the young age of primary school children in our study. Young children, irrespective of their gender, have greater exposure to traffic threats in complex road environments than adults, because their cognitive, behavioural, physical and sensory abilities are still developing, which may make it difficult for them to make appropriate crossing decisions.[4 27] We found a higher prevalence of unsafe crossing behaviour at the faraway crossing points compared with the nearby ones, consistent with other studies.[28 29] The observed difference in behaviour patterns could be due to school traffic wardens who help young children safely cross by regulating traffic on the roads near the school.[18] A child's compliance with traffic rules may also be influenced by the presence of the school, with proximity to the school prompting safer behaviour.[30] Most of the distant crossings were at intersections which lacked traffic calming measures and young children could not appraise potential sources of danger or negotiate these complex road situation at intersections.[31] Intersections have higher traffic risks due to the characteristics of the roadway and traffic volume, increasing pedestrian exposure.[32] Factors related to the roadway design, vehicle volumes and speed are all associated with higher rates of pedestrian motor vehicle collisions,[32] which may therefore influence where permanent pedestrian interventions are necessary, at both distant and nearby school crossings.

The factors significantly associated with unsafe child pedestrian crossing behaviour were: the presence of an obstacle, time

Table 3 Factors associated with failing to wait at the kerb before crossing

Factors	N=2100	N (% failed to wait at the kerb)	Crude		Adjusted	
			Prevalence ratio	95% CI	Prevalence ratio	95% CI
Traffic warden present						
Yes	445	51 (11.5%)	Ref		Ref	
No	1655	364 (22%)	1.9	(1.46 to 2.52)	2	(1.40 to 2.37)
Group crossing						
Group	1726	298 (17.3%)	Ref		Ref	
Alone	374	117 (31.3%)	1.8	(1.51 to 2.17)	1.9	(1.52 to 2.37)
Nearest vehicle type						
Two wheels	655	151 (23.1%)	Ref		Ref	
Four wheels	1153	135 (11.7%)	0.5	(0.41 to 0.63)	0.5	(0.40 to 0.61)
Child supervised						
Yes	346	53 (15.3%)	Ref		Ref	
No	1754	362 (20.6%)	1.3	(1.03 to 1.75)	1.0	(0.77 to 1.37)
Driver yield						
Yes	359	77 (21.5%)	Ref		Ref	
No	1449	209 (14.4%)	0.7	(0.53 to 0.85)	0.5	(0.43 to 0.70)
Period						
Afternoon	402	56 (13.9%)	Ref		Ref	
Evening	883	178 (20.2%)	1.4	(1.10 to 1.91)	1.1	(0.77 to 1.44)
Morning	815	181 (22.2%)	1.6	(1.21 to 2.10)	1.2	(0.87 to 1.63)
Obstacle present						
No	1807	368 (20.4%)	Ref		Ref	
Yes	293	47 (16%)	0.8	(0.60 to 1.04)	0.9	(0.67 to 1.30)

Ref, reference.

Table 4 Factors associated with failing to look out for vehicles before crossing

Factors	N=2100	N (% never looked out for vehicles)	Crude		Adjusted	
			Prevalence ratio	95% CI	Prevalence ratio	95% CI
Child supervised						
Yes	346	107 (30.9%)	Ref		Ref	
No	1754	131 (7.5%)	0.2	(0.19 to 0.30)	0.3	(0.19 to 0.33)
Period						
Afternoon	402	69 (17.2%)	Ref			
Evening	883	78 (8.8%)	0.5	(0.38 to 0.70)	0.7	(0.47 to 0.96)
Morning	815	91 (11.2%)	0.7	(0.49 to 0.87)	0.9	(0.67 to 1.25)
Nearest vehicle type						
Two wheels	655	54 (8.2%)	Ref		Ref	
Four wheels	1153	139 (12.1%)	1.5	(1.08 to 1.97)	1.3	(0.99 to 1.76)

Ref, reference.

period of the day, drivers failing to yield, crossing alone and the absence of traffic controls such as a school traffic warden. Visibility limitations due to obstacles on the road, such as parked vehicles, is a risk factor for pedestrian motor vehicle collisions.[33] From this study, such obstacles near pedestrian crossings altered the navigation path, prompting the children to cross outside demarcated boundaries or between vehicles putting them at risk. The high proportion of crashes reporting obstruction from stationary vehicles or other obstacles suggests a specific problem of detectability and conspicuity of child pedestrians.[33] Child pedestrian conspicuity-related crashes are often characterised by a high level of severity.[34] We also found that the morning and evening periods were associated with unsafe road use behaviour of crossing between vehicles, which concurs with several other studies.[19 35] Pedestrians during the morning and evening rush hours tend to cross where it is convenient for them and with as minimal delay as possible, judging from the frequency of illegal crossings.[35] From the 2022 Uganda traffic police report, the highest number of crashes were recorded in the evening as road users returned home from the day's activities. This finding may be partly attributed to the reduced visibility at this time.[36]

Our findings indicate that a driver failing to yield was associated with child pedestrians crossing illegally between vehicles. Similar findings have been highlighted previously in Bangladesh.[26] Drivers prefer travelling with minimum delays and stops in the absence of effective pedestrian traffic control measures.[37] Pedestrians, too, are reluctant to be delayed at the kerb and so resort to finding a gap between vehicles to cross, especially when the flow of vehicles is continuous.[6] Not knowing who will yield to another creates confusion, resulting in pedestrian motor vehicle collisions. These findings have implications for road safety measures to eliminate driver-pedestrian uncertainty and conflict at school crossings.

In this study, child pedestrians who crossed alone displayed a higher likelihood of crossing outside the boundary of marked crossings, failing to wait at the kerb and running while crossing compared with those who crossed in a group. Similar findings of unsafe road user behaviour in children who walked alone compared with those in groups were in South Africa.[22] This result demonstrates a psychology of shared protection and vigilance among groups, that is, groups exert social control over individual pedestrians.[38] Conversely, some studies among

Table 5 Factors associated with child pedestrians running while crossing

Factors	N=2100	N (% run)	Crude		Adjusted	
			Prevalence ratio	95% CI	Prevalence ratio	95% CI
Group crossing						
Group	1726	261 (15.1%)	Ref		Ref	
Alone	374	100 (26.7%)	1.8	(1.45 to 2.16)	2	(1.62 to 2.58)
Driver yield						
Yes	359	79 (22%)	Ref		Ref	
No	1449	216 (14.9%)	0.7	(0.54 to 0.85)	0.6	(0.52 to 0.81)
Period						
Afternoon	402	117 (29.1%)	Ref		Ref	
Evening	883	134 (15.2%)	0.5	(0.42 to 0.65)	0.6	(0.47 to 0.77)
Morning	815	110 (13.5%)	0.5	(0.37 to 0.58)	0.5	(0.36 to 0.61)
Nearest vehicle type						
Two wheels	655	139 (21.2%)	Ref		Ref	
Four wheels	1153	156 (13.5%)	0.6	(0.52 to 0.78)	0.7	(0.53 to 0.80)
Traffic warden present						
Yes	445	98 (22%)	Ref		Ref	
No	1655	263 (15.9%)	0.7	(0.59 to 0.89)	0.8	(0.66 to 1.09)

Ref, reference.

Table 6 Factors associated with crossing between vehicles

Factors	N=2100	N (% crossed between vehicles)	Crude		Adjusted	
			Prevalence ratio	95% CI	Prevalence ratio	95% CI
Traffic warden present						
Yes	445	12 (3.2%)	Ref		Ref	
No	1655	223 (15.6%)	4.9	(2.75 to 8.60)	3.4	(1.90 to 5.98)
Driver yield						
Yes	359	32 (8.9%)	Ref		Ref	
No	1449	203 (14%)	1.6	(1.10 to 2.24)	1.5	(1.07 to 2.09)
Obstacle present						
No	1807	147 (9.5%)	Ref		Ref	
Yes	293	88 (33.3%)	3.5	(2.78 to 4.41)	3	(2.37 to 3.62)
Period						
Afternoon	402	24 (7.1%)	Ref		Ref	
Evening	883	126 (16.2%)	2.3	(1.51 to 3.47)	2.4	(1.65 to 3.60)
Morning	815	85 (12.3%)	1.7	(1.12 to 2.66)	1.8	(1.20 to 2.72)
Nearest vehicle type						
Two wheels	655	11 (1.7%)	Ref		Ref	
Four wheels	1153	224 (19.4%)	11.6	(6.36 to 21.03)	9.3	(5.12 to 16.90)
Child supervised						
Yes	346	51 (16.1%)	Ref		Ref	
No	1754	184 (12.3%)	0.8	(0.58 to 1.02)	0.8	(0.62 to 1.01)

Ref, reference.

teenagers have found that walking in groups could negatively impact crossing behaviour due to peer conformity, which is a strong predictor of adolescents' risky behaviour.[39] Some pedestrians may behave similarly to others in a group, for example, if someone illegally crosses, others are likely to follow.[40] Despite this, drivers are more likely to give way to child pedestrians crossing in groups than those crossing alone, reducing the chances of conflict.[25] Additionally, the absence of a traffic warden was associated with crossing outside crosswalks, failing to wait at the kerb and crossing between vehicles. This corroborates with findings from China where the presence of traffic wardens significantly reduced traffic violations and unsafe behaviour at crosswalks.[40]

Limitations

We recognise the range of developmental variation in this age range included in the study. We could not objectively estimate the children's specific age or a more restricted age range from the video recordings. We, therefore, excluded variables such as age and vehicle speed because they were subjective, and their interpretation would vary. We used a random method for selecting intersections, which was challenging due to their heterogeneous and widely dispersed nature. Additionally, we opted for a random selection of children from each crossing location rather than including all children recorded. While we improved the validity by conducting independent checks for inconsistencies, we acknowledge that the strategies employed were not optimal. Moreover, the study was conducted over a period of 11 days and could not explore the effects of for example, seasonality which is reported to influence road safety. Future research should prolong observation to account for factors such as seasonality. Notwithstanding these limitations, this study contributes to an emerging body of knowledge on child pedestrian road use behaviour in Uganda and, more broadly, in the African context.

Conclusion

We found a higher prevalence of unsafe crossings at the faraway crossing points from schools. The main factors associated with unsafe crossing behaviour in this study were the presence of an obstacle at crosswalks, the morning and evening periods, drivers failing to yield and crossing alone. These findings offer insights to road safety planners regarding the interaction between vehicles and pedestrians at crossings, emphasising the need to prioritise child pedestrian safety measures. The findings suggest an urgent need to create safer child pedestrian environments at school crossings. Ultimately, comprehensive interventions that include better infrastructure are necessary to address the high prevalence of unsafe behaviour at distant school crossings and school routes. Further research should explore the role of other important built environment characteristics that affect, for example, vehicle speed, traffic and pedestrian volume on pedestrian risks.

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Patient consent for publication Not applicable.

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ORCID iD
Jimmy Osuret http://orcid.org/0000-0002-3382-620X

REFERENCES

1 World Health Organisation. Global status report on road safety. 2018.
2 Zafri NM, Rony AI, Rahman MdH, *et al*. Comparative risk assessment of pedestrian groups and their road-crossing Behaviours at intersections in Dhaka, Bangladesh. *Int J Crashworth* 2022;27:581–90.
3 Cinnamon J, Schuurman N, Hameed SM. Pedestrian injury and human behaviour: observing road-rule violations at high-incident intersections. *PLoS One* 2011;6:e21063.
4 Fu L, Zou N. Analysis of child pedestrians' unsafe road crossing behavior at intersections in school zones, in green. *Smart and Connected Transportation Systems* 2020:397–406.
5 Muni KM, Ningwa A, Osuret J, *et al*. Estimating the burden of road traffic crashes in Uganda using police and health sector data sources. *Inj Prev* 2021;27:208–14.
6 Jain A, Gupta A, Rastogi R. Pedestrian crossing behaviour analysis at intersections. *IJTTE* 2014;4:103–16.
7 Papadimitriou E, Lassarre S, Yannis G. Introducing human factors in pedestrian crossing behaviour models. *Transportation Research Part F: Traffic Psychology and Behaviour* 2016;36:69–82.
8 Schieber RA, Thompson NJ. Developmental risk factors for childhood pedestrian injuries. *Inj Prev* 1996;2:228–36.
9 Ellis J. Child pedestrian safety education: applying learning and developmental theories to develop safe street-crossing behaviors. 2009.
10 Uganda Police. The 2022 annual crime report. 2023.
11 United Nations. Road safety performance review Uganda. 2018.
12 Cloutier M-S, Beaulieu E, Fridman L, *et al*. State-of-the-art review: preventing child and youth pedestrian motor vehicle collisions: critical issues and future directions. *Inj Prev* 2021;27:77–84.
13 Arason N. Canada and the safe systems approach to road safety. Institute of transportation engineers. *ITE Journal* 2019;89:26–30.
14 World Health Organisation. Global plan for the decade of action for road safety 2021-2030. 2021.
15 Uganda Bureau of Statistics. Population and censuses. 2023.
16 Ministry of Lands, H.a.U.D. National physical planning standards and guidelines; Uganda. 2011.
17 Osuret J, Namatovu S, Biribawa C, *et al*. State of pedestrian road safety in Uganda: a qualitative study of existing interventions. *Afr Health Sci* 2021;21:1498–506.
18 Rosenbloom T, Haviv M, Peleg A, *et al*. The effectiveness of road-safety crossing guards: knowledge and behavioral intentions. *Safety Science* 2008;46:1450–8.
19 Zareharofteh F, Hidarnia A, Morowatisharifabad MA, *et al*. Unsafe Behaviours in Iranian adult pedestrians. *Journal of Transport & Health* 2021;21:101058.
20 Zou G. A modified Poisson regression approach to prospective studies with binary data. *Am J Epidemiol* 2004;159:702–6.
21 Martinez BAF, Leotti VB, Silva G de SE, *et al*. Odds ratio or prevalence ratio? an overview of reported statistical methods and appropriateness of interpretations in cross-sectional studies with Dichotomous outcomes in veterinary medicine. *Front Vet Sci* 2017;4:193.
22 Koekemoer K, Van Gesselleen M, Van Niekerk A, *et al*. Child pedestrian safety knowledge, behaviour and road injury in Cape town, South Africa. *Accident Analysis & Prevention* 2017;99:202–9.
23 Schwebel DC, Wu Y, Swanson M, *et al*. Child pedestrian street-crossing behaviors outside a primary school: developing observational Methodologies and data from a case study in Changsha, China. *J Transp Health* 2018;8:283–8.
24 Tiwari RR, Patel S, Soju A, *et al*. Road use pattern and street crossing habits of schoolchildren in India. *Front Public Health* 2021;9:628147.
25 Shaaban K, Muley D, Mohammed A. Analysis of illegal pedestrian crossing behavior on a major divided arterial road. *Transportation Research Part F: Traffic Psychology and Behaviour* 2018;54:124–37.
26 Zafri NM, Tabassum T, Himal MRH, *et al*. Effect of pedestrian characteristics and their road crossing behaviors on driver yielding behavior at controlled intersections. *J Safety Res* 2022;81:1–8.
27 Amanda B, Paula B, Suzie D. *Lazarus and Folkman's Psychological Stress and Coping Theory*. John Wiley & Sons, Ltd, 2017.
28 Sisiopiku VP, Akin D. Pedestrian behaviors at and perceptions towards various pedestrian facilities: an examination based on observation and survey data. *Transportation Research Part F: Traffic Psychology and Behaviour* 2003;6:249–74.
29 Rasouli A, Tsotsos JK. Autonomous vehicles that interact with pedestrians: A survey of theory and practice. *IEEE Trans Intell Transport Syst* 2019;21:900–18.
30 Granié M-A. Gender differences in preschool children's declared and behavioral compliance with pedestrian rules. *Transportation Research Part F: Traffic Psychology and Behaviour* 2007;10:371–82.
31 Pretorius K, Van Niekerk A. Childhood Psychosocial development and fatal injuries in Gauteng, South Africa. *Child Care Health Dev* 2015;41:35–44.
32 Rothman L, Perry D, Buliung R, *et al*. Do school crossing guards make crossing roads safer? a quasi-experimental study of pedestrian-motor vehicle collisions in toronto, canada. *BMC Public Health* 2015;15:732.
33 Miao M, Yang Y, Liang Y. Pedestrian crash risk assessment and intervention. *Advances in Mechanical Engineering* 2016;8:168781401665329.
34 Martin O. Powered two Wheelers: visibility, Conspicuity, sight obstruction and small size, European road safety decision support system, developed by the H2020 project Safetycube. 2017.
35 King MJ, Soole D, Ghafourian A. Illegal pedestrian crossing at signalised intersections: incidence and relative risk. *Accident Analysis & Prevention* 2009;41:485–90.
36 Uganda Police. Annual crime report. 2021.
37 Kong X, Das S, Zhang Y, *et al*. Lessons learned from pedestrian-driver communication and yielding patterns. *Transportation Research Part F: Traffic Psychology and Behaviour* 2021;79:35–48.
5 Rosenbloom T. Crossing at a red light: behaviour of individuals and groups. *Transportation Research Part F: Traffic Psychology and Behaviour* 2009;12:389–94.
39 Zhou R, Horrey WJ, Yu R. The effect of conformity tendency on pedestrians' road-crossing intentions in China: an application of the theory of planned behavior. *Accid Anal Prev* 2009;41:491–7.
40 Ren G, Zhou Z, Wang W, *et al*. Crossing behaviors of pedestrians at Signalized intersections: observational study and survey in China. *Transportation Research Record* 2011;2264:65–73.