

BMJ Open Association of adolescents' independent mobility with road traffic injuries in Karachi, Pakistan: a cross-sectional study

Uzma Rahim Khan ^{1,2}, Junaid Razzak,^{3,4} Martin Gerdin Wärnberg ^{1,5}

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¹Department of Global Public Health, Karolinska Institutet, Stockholm, Sweden

²Department of Emergency Medicine, Aga Khan University, Karachi, Pakistan

³Department of Emergency Medicine, New York Presbyterian Weill Cornell Medicine, New York City, New York, USA

⁴Centre of Excellence for Trauma and Emergencies, Aga Khan University, Karachi, Pakistan

⁵Function Perioperative Medicine and Intensive Care, Karolinska University Hospital, Solna, Sweden

Correspondence to

Dr Uzma Rahim Khan;
uzma.khan@ki.se

ABSTRACT

Objective Participation in walking, cycling and taking public transportation without adult supervision is defined as independent mobility of children and adolescents. The association between adolescents' independent mobility and road traffic injury (RTI) is unclear. The purpose of this study is to determine measures of adolescents' independent mobility associated with RTIs in an urban lower middle-income setting.

Study design Cross-sectional survey.

Setting Schools in Karachi, Pakistan.

Participants Adolescents aged 10–19 years in grades 6–10 were enrolled from private and public schools.

Outcome Any self-reported lifetime RTI sustained as a pedestrian, as a cyclist or while in a car or another vehicle that resulted in any first aid at home/school or consultation in a healthcare setting.

Exposure Self-reported independent mobility was assessed by four variables. (1) Any travel companion from school to home on the survey day, (2) parental permission to cross main roads alone, (3) parental permission to travel by public bus alone and (4) activity/activities outside the home on the previous weekend alone.

Results Data from 1264 adolescents, 10–19 years old, were included. Most were females (60%). Adolescents who had parental permission to cross main roads alone (adjusted OR (aOR) 1.39; 95% CI 1.04 to 1.86) and who participated in one or more activities outside the home alone on the previous weekend (aOR 2.61; 95% CI 1.42 to 5.13) or participated in a mixture of activities with and without adult accompaniment (aOR 2.50; 95% CI 1.38 to 4.89) had higher odds of RTIs.

Conclusions Parental permission to cross main roads alone and participation in activity/activities outside the home on the previous weekend alone were two measures of independent mobility associated with higher odds of RTIs among adolescents. The study provides an understanding of the risk posed by adolescents' independent mobility in road traffic environments.

INTRODUCTION

Independent mobility refers to the freedom of children and adolescents to move around in public spaces without being accompanied by an adult. Independent mobility positively impacts psychological, social, cognitive, motor, spatial

Strengths and limitations of this study

- This is one of the largest face-to-face surveys of adolescents' independent mobility covering 73 schools which is the highest number of schools compared with previous studies.
- Multistage stratified random cluster sampling of schools with at least one classroom of adolescents per school with an approximate equal number of classrooms of grades 6–10 was conducted.
- The ability to assess a temporal relationship between independent mobility (exposure) and road traffic injury (outcome) is lacking.

and analytical development.^{1 2} Independent mobility facilitates physical activity and decreases the risk of obesity, hypertension, diabetes and many other non-communicable diseases.^{3 4} Children's and adolescents' independent mobility is influenced by many psychosocial factors, such as the parent's concerns about weak ties at the neighbourhood level, encounters with strangers and fears of road traffic, which are also attributed to adolescents' limited independent mobility.^{5–8}

Adolescents are vulnerable to road traffic injuries (RTIs), which are the leading cause of death in adolescents aged 10–19 years. In 2019, 95 586 deaths from RTIs in adolescents aged 10–19 years occurred worldwide,⁹ and 90% of these deaths occurred in low-income and middle-income countries.¹⁰ A survey from Turkey reported that 12.5% of high school adolescents aged 14–18 years had RTIs.¹¹ In Nigeria, RTIs accounted for 10% of all injuries in adolescents aged 11–17 years.¹² While in Qatar, RTIs accounted for 6% of injuries in trauma patients aged 10–18 years presenting to a trauma centre.¹³

Male sex and low socioeconomic status are risk factors associated with RTIs in adolescents.¹⁴ Deaths and injuries from RTIs are most common among pedestrians, cyclists and motorcyclists in low-income and middle-income countries, where the constructed environment

is least likely to be adapted to the needs of vulnerable road users.^{15–17} The number of severe injuries per distance travelled was higher in young adolescents than in any other age group, as reported by a study in the Netherlands.¹⁸ RTIs are also a leading contributor to disability adjusted life years in children and adolescents.¹⁹ The rate of permanent disability due to RTIs among children and adolescents aged 1–17 years is 20 per 100 000 children.²⁰

Studies on independent mobility are mostly descriptive studies of school travel, and in some analytical studies, its association with physical activity and distance was determined.²¹ Research on the independent mobility of adolescents and RTIs is scarce, and an association between independent mobility and RTIs has been assessed previously in very few studies. A study from New Zealand that determined the effect of adult accompaniment in RTI showed that adult accompaniment of children and adolescents aged 5–12 years old was associated with reduced risk of pedestrian injury, but this result was not statistically significant.⁴ A study from India considered independent mobility as a confounding variable in association of distance and mode of travel with RTIs in adolescents aged 11–14 years.²² In a study from Singapore, pedestrian injuries in adolescents aged 16 years and younger involved walking alone.²³

Sustainable development goals (SDGs) advocate for safe transportation and an improvement in road safety by targeting the special needs of children and adolescents.²⁴ It is important to determine whether adolescents' independent mobility is associated with an increased risk of RTIs to decide how to advocate for independent mobility. The aim of this study is to determine measures of adolescents' independent mobility associated with RTIs in an urban lower middle-income setting in Karachi.

METHODS

Study design

We conducted a cross-sectional study between September and December 2014.

Setting and participants

Adolescents (aged 10–19 years) in grades 6–10 were enrolled from the participating schools in Karachi, Pakistan. The city has an estimated population of 20 million. In 2019, Pakistan reported approximately 2393 deaths due to RTIs in 10–19 year-olds.⁹ In Karachi, the annual incidence of RTIs was 54.7 per 100 000 population, and the mortality rate was 1.5 per 100 000 population aged less than 15 years, of which 89% were men.²⁵ A previous travel survey from Pakistan reported that 10–14 years old adolescents who were men made 36% more trips than women. At 15 years and older, this sex gap increases to more than 50%.²⁶ The public transportation system is inadequate in the city. There is a lack of paved areas for pedestrians, and vendors occupy space for their roadside businesses.²⁷ Roads have potholes and are in poor condition.²⁸

Overall, there were 4098 private schools and 2828 public schools in Karachi at the time of data collection, as per

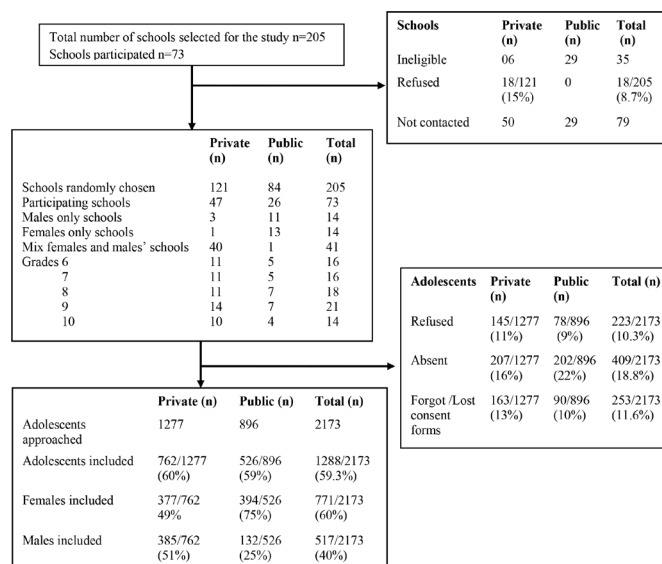


Figure 1 Flow chart of adolescents' recruitment from schools.

official lists from the education department. A total of 73 schools participated in our study, of which 26 (36%) were public schools and 47 (64%) were private schools (figure 1). The ratio of public to private schools in the sample was determined based on the distribution of schools in urban Pakistan.²⁹ We used multistage stratified random cluster sampling to select the schools. In the first stage, schools were stratified by private and public secondary schools (grades 6–10) status. The random sample of schools was chosen with quotas of 60% private schools and 40% public schools, proportional to school enrolment in Karachi. In the next stage, at least one classroom in each school was selected as a convenience cluster sample. Approximately equal numbers of grades 6, 7, 8, 9 and 10 were selected within each stratum of public and private school. Research assistants informed school management beforehand about grade selection from that school, while the school management guided the section selection of the selected grades.

Outcome

An RTI is any self-reported lifetime RTI sustained as a pedestrian, as a cyclist or while in a car or another vehicle that resulted in any first aid at home/school or consultation in a healthcare setting.

Exposures

Adolescents' self-reported independent mobility was assessed by four variables. (1) Any travel companion from school to home on the survey day ('with a parent or adult', 'alone or with an adolescent of the same age' or 'mixed travel pattern either with parents or alone'). (2) Parental permission to cross main roads alone ('yes' or 'no'). (3) Parental permission to travel by public bus alone ('yes' or 'no'). (4) Participation in at least one activity outside the home on the previous weekend alone ('no activities', 'with a parent or adult', 'alone or with an adolescent of the same age' or 'mixed activity pattern either with parents or alone').

Other covariates

Age, grade, sex, type of school (public or private), travel time to school by any mode of transportation and mode of transportation home from school were included as covariates based on their association with RTIs in previous literature.³⁰ The type of school was included as a proxy variable for the children's socioeconomic status, as public schools cater to low-income families; furthermore, the type of school indicates the style of parental licencing.²² Travel time to school was included as a proxy variable for distance, which is associated with RTI in previous literature.²²

Data sources/measurements

The study questionnaire was adapted from London Policy Studies Institute. It had multiple-choice questions, was available in English and was also translated into Urdu. The adapted questionnaire has been used in many countries, including Sri Lanka and India, which are in the same region as Pakistan and have similar population dynamics.^{31 32} In India, the questionnaire was found to be reliable.³² Questions on RTI outcomes were not in original questions. They were added in Indian study and also used in the current study with some modifications. The Cronbach alpha for the variables that are used in this analysis is found to be 0.70.

The questionnaire was piloted to assess its effectiveness, acceptability and clarity, and modifications were made accordingly before launching the main data collection process. The pilot study was completed in two private schools and one public school, and 196 children and adolescents participated. Aspects of the questionnaire were changed to clarify some questions. For example, some modifications were made to adapt the questions to the local context, such as replacing 'local buses' with 'public buses'. Definitions of a few variables were added; for example, adults were defined as a person aged 18 years and older. Traffic crashes were clarified by adding the word 'road' to 'traffic crash'.

Research assistants supervised the survey and read and explained each question to adolescents in each class to ensure that the adolescents understood the questionnaire clearly. The questionnaire took approximately 25 min to be completed by a class of adolescents. In each class, a parental permission letter that provided details of the study (in either Urdu or English language, as advised by the school administration) was distributed to each adolescent. Adolescents were instructed to obtain letters signed by their parents or guardians within 1 week. It was confirmed that a weekend fell between the distribution of permission letters and the research assistants' second school visit to allow parents adequate time to read the permission letters. Written informed consent was obtained from the parents/guardians of the adolescents, and informed verbal assent was obtained from the adolescents.

Study size

The sample size calculated for the original survey was 1270 school adolescents. The original question was designed to assess the prevalence of travel modes to school based on the assumption that at least 50% of adolescents were active commuters (since no past information on adolescents'

school mobility patterns in Pakistan was available). We used a 95% CI, an error bound of $\pm 5\%$, and a design effect of 3, and we inflated the sample size by 10% to account for non-responders.

Statistical analysis

The analysis was performed by using R.³³ Categorical variables are described using frequencies and percentages. Logistic regression was used to estimate unadjusted and adjusted associations, as well as 95% CIs, between the measures of independent mobility and RTIs. Four models were developed by using each of the four exposures with RTI as the outcome. The models were adjusted for age, sex, type of school, travel time to school by any mode of transportation and mode of transportation home from school. However, the model with the exposure 'activities on the weekend alone' was adjusted only for age, sex and type of school, because the travel time to school and mode of transportation to school were not related to activities on weekends. The sample size requirements for this type of analysis have been described as between 10 and 25 events (participants with the outcome) and at least as many non-events per parameter in the model.³⁴ With 265 events, less than 10 parameters were accommodated in the models.

Involvement of patients and the public

Patients and/or the public were not involved in this study.

RESULTS

There were 1288 children and adolescents included in the survey. The complete case analysis was performed on a sample of 1264 adolescents after removing cases with missing values and the three cases who were either younger or older than the age criteria for adolescents 10–19 years old.

The majority of the adolescents were females (60%) and in the 10–14 years age group (59%). Most of them walked to school (76%). Almost half of the adolescents arrived at the school within 5–15 min. Overall, 21% reported RTIs (table 1). Approximately 55% of RTIs occurred in the 10–14 years age group, and 45% occurred in the 15–19 years age group. More than half of RTIs were among men (56%). The majority of RTIs (71%) happened to adolescents whose mode of transportation home from school was walking (table 1).

In the unadjusted analyses, male sex (OR 2.21, 95% CI 1.68 to 2.91), use of four-wheeled transportation home from school (OR 1.44, 95% CI 1.01 to 2.04), travel time of 31–45 min to school (OR 2.95, 95% CI 1.56 to 5.48) and travel time of 46 or more minutes to school (OR 2.89, 95% CI 1.17 to 6.82), parental permission to cross main roads alone (OR 1.62; 95% CI 1.24 to 2.13), parental permission to use public buses alone (OR 1.9; 95% CI 1.38 to 2.6), engagement in weekend activities alone (OR 3.51; 95% CI 1.98 to 6.74) and a mixed pattern of weekend activities (OR 2.92; 95% CI 1.63 to 5.62) were associated with an increased OR of RTIs (table 2).

In the adjusted analysis, travel home from school (adjusted OR (aOR) 1.14; 95% CI 0.71 to 1.89) was compatible with reduced odds, increased odds and no association with RTIs. Adolescents who had parental permission to cross main roads

**Table 1** Characteristics of adolescents surveyed from schools in Karachi, Pakistan

Variables	10–19, n=1264 n (%)	No RTIs, n=999 n (%)	RTIs, n=265 n (%)
Age group (years)			
10–14	746 (59.0)	601 (60.2)	145 (54.7)
15–19	518 (41.0)	398 (39.8)	120 (45.3)
Sex			
Female	757 (59.9)	639 (64.0)	118 (44.5)
Male	507 (40.1)	360 (36.0)	147 (55.5)
Grade			
6	262 (20.7)	197 (19.7)	65 (24.5)
7	255 (20.2)	216 (21.6)	39 (14.7)
8	200 (15.8)	147 (14.7)	53 (20.0)
9	342 (27.1)	285 (28.5)	57 (21.5)
10	205 (16.2)	154 (15.4)	51 (19.2)
Type of school			
Private	753 (59.6)	588 (58.9)	165 (62.3)
Public	511 (40.4)	411 (41.1)	100 (37.7)
Mode of transportation home from school on the day of the survey			
Walking	954 (75.5)	766 (76.7)	188 (70.9)
Two-wheeled or three-wheeled vehicle	107 (8.5)	83 (8.3)	24 (9.1)
Four-wheeled vehicle	203 (16.0)	150 (15.0)	53 (20.0)
Travel time to school by any mode of transportation (minutes)			
<5	462 (36.6)	511 (51.2)	131 (49.4)
5–15	642 (50.8)	29 (2.9)	19 (7.2)
16–30	48 (3.8)	67 (6.7)	22 (8.3)
31–45	89 (7.0)	14 (1.4)	9 (3.4)
>46	23 (1.8)	511 (51.2)	131 (49.4)
Companion for travel home from school on the day of the survey			
With either a parent or any other adult	139 (11.0)	111 (11.1)	28 (10.6)
Alone or with someone of the same age	1039 (82.2)	817 (81.8)	222 (83.8)
Mixed travel pattern, that is, alone or with parents	86 (6.8)	71 (7.1)	15 (5.7)
Parental permission to cross main roads alone			
No	716 (56.6)	591 (59.2)	125 (47.2)
Yes	548 (43.4)	408 (40.8)	140 (52.8)
Parental permission to travel on public buses alone			
No	1028 (81.3)	835 (83.6)	193 (72.8)
Yes	236 (18.7)	164 (16.4)	72 (27.2)
Activity/activities outside the home on the previous weekend			
With a parent or another adult	229 (18.1)	200 (20.0)	29 (10.9)
No activities on the weekend	139 (11.0)	126 (12.6)	13 (4.9)
Alone or with another young person	455 (36.0)	334 (33.4)	121 (45.7)
Mixed activities, that is, either with parents or alone	441 (34.9)	339 (33.9)	102 (38.5)

RTI, road traffic injury.

(aOR 1.39; 95% CI 1.04 to 1.86) had significantly higher odds of RTIs. Adolescents who had parental permission to use public buses had statistically insignificant odds compatible with reduced odds of, increased odds of and no association with RTIs (aOR 1.34; 95% CI 0.93 to 1.91). Unaccompanied

adolescents who performed any activity outside the home on the previous weekend (aOR 2.61; 95% CI 1.42 to 5.13) or had a mixed pattern of weekend activities, either accompanied or alone (aOR 2.50; 95% CI 1.38 to 4.89), had significantly higher odds of RTIs (table 3).

Table 2 Unadjusted associations of road traffic injuries with the variables of independent mobility and other covariates in adolescents in Karachi, Pakistan, n=1264

Variables	OR (95% CI)
Age group (years)	
10–14	1
15–19	1.25 (0.95 to 1.64)
Sex	
Female	1
Male	2.21 (1.68 to 2.91)
Type of school	
Private	1
Public	0.87 (0.65 to 1.14)
Mode of transportation home from school on the day of the survey	
Walking	1
Two-wheeled or three-wheeled vehicle	1.18 (0.71 to 1.88)
Four-wheeled vehicle	1.44 (1.01 to 2.04)
Travel time to school by any mode of transportation (minutes)	
<5	1
5–15	1.15 (0.85 to 1.57)
16–30	1.48 (0.85 to 2.5)
31–45	2.95 (1.56 to 5.48)
>46	2.89 (1.17 to 6.82)
Companion for travel home from school on the day of the survey	
With either a parent or any other adult	1
Alone or with someone of the same age	1.08 (0.7 to 1.7)
Mixed travel pattern, that is, alone or with parents	0.84 (0.41 to 1.66)
Parental permission to cross main roads alone	
No	1
Yes	1.62 (1.24 to 2.13)
Parental permission to travel on public buses alone	
No	1
Yes	1.9 (1.38 to 2.6)
Activity/activities outside the home on the previous weekend alone	
No activities on the weekend	1
With a parent or another adult	1.41 (0.72 to 2.89)
Alone or with another young person	3.51 (1.98 to 6.74)
Mixed activities, that is, either with parents or alone	2.92 (1.63 to 5.62)

Bold text indicates statistically significant results.

DISCUSSION

This study shows that the odds of RTIs for adolescents with parental permission to cross main roads alone was 1.39 times higher than that for adolescents without parental permission to cross main roads and that the odds of RTIs for adolescents who participated in activities outside the home on the previous weekend alone was 2.6 times higher than that for adolescents who participated in no activities on the previous weekend. Other measures of independent mobility, such as parental permission to use public buses and travel

home from school alone, had point estimates that indicated increased odds but had 95% CIs compatible with reduced odds, increased odds and no association with RTIs.

The finding that adolescents who had parental permission to cross main roads alone had greater odds of RTIs is consistent with previous studies that conclude that the number of streets crossed by adolescents is associated with injury.³⁵ In addition, a qualitative study from India—a neighbouring country of Pakistan with a similar road environment—reported that adolescents displayed various distracted behaviours as pedestrians, such as using earphones and mobile phones as well as talking and playing with friends.³⁶ Both the distracted behaviours and the unsafe road environment for pedestrians in Pakistan could be linked to an increased risk for RTIs. The roads are dilapidated with potholes, pedestrian signals to assist in road crossing are lacking and vehicles are generally considered to have the right of way; therefore, poor yield compliance for pedestrians at crosswalks is substantially higher by vehicle drivers.^{27 37 38}

Adolescents' activities outside the home on the previous weekend alone were associated with RTIs. The odds were higher when adolescents were alone or with their peers during weekend activities or when they had mixed patterns of weekend activities than when they engaged in activities accompanied by adults. It is understandable that leisure activities with peers provoke several comparatively risky behaviours, for example, smoking, substance abuse, risky driving and risky pedestrian behaviours.³⁹ Previous studies have shown that children and adolescents with unsafe road safety behaviours have peers with similar behaviours.⁴⁰ Multiple risk behaviours are associated with injuries in youth.⁴¹ The means of mobility in weekend activities was not captured in our study, but in our context, we assume it could be walking, motorcycles, public buses or private cars. Underage driving is also witnessed in young adolescents in the study setting.⁴²

The other two exposures—travelling from school to home alone and parental permission to travel on public buses alone—were associated with slightly higher odds of RTIs, but the 95% CIs were compatible with reduced odds of, increased odds of and no association with RTIs. This uncertainty indicates that within the groups of adolescents, some had reduced odds of RTIs, while others had increased odds. A previous study in Auckland showed that adult accompaniment on the school–home journey may be associated with reduced pedestrian injuries, but the effect was not statistically significant, similar to the findings of our study.⁴ Future research should focus on identifying those traits that distinguish these groups of adolescents with increased and reduced odds for RTIs.

The independent mobility of adolescents has many inherent benefits and needs to be valued by society. Children need to move in public spaces for different activities, such as to travel to school, their work and other leisure activities, which are important for the development of social skills. However, parents are the licencing bodies that control their children's independent mobility, and their willingness to allow their adolescents to move independently is influenced by many factors, such as traffic and public safety. Safe public spaces lead to an increased number of children who move

**Table 3** Adjusted ORs (aOR) of the independent mobility exposures and the outcome road traffic injury (RTI) in adolescents n=1264

Variables	Model with exposure companion for travel home from school on the day of the survey aOR for RTI (95% CI)	Model with exposure parental permission to cross main roads alone aOR for RTI (95% CI)	Model with exposure parental permission to travel on public buses alone aOR for RTI (95% CI)	Model with exposure activity/activities outside the home on the previous weekend alone aOR for RTI (95% CI)
Companion for travel home from school on the day of the survey				
With either a parent or any other adult	1	–	–	–
Alone or with someone of the same age	1.14 (0.71 to 1.89)	–	–	–
Mixed travel pattern, that is, alone or with parents	0.84 (0.40 to 1.71)	–	–	–
Parental permission to cross main roads alone				
No	–	1	–	–
Yes	–	1.39 (1.04 to 1.86)	–	–
Parental permission to travel on public buses alone				
No	–	–	1	–
Yes	–	–	1.34 (0.93 to 1.91)	–
Activity/activities outside the home on previous weekend				
No activities on the weekend	–	–	–	1
With a parent or another adult	–	–	–	1.48 (0.75 to 3.06)
Alone or with another young person	–	–	–	2.61 (1.42 to 5.13)
Mixed; both with parents and alone	–	–	–	2.50 (1.38 to 4.89)
Age group (years)				
10–14 years	1	1	1	1
15–19 years	1.28 (0.95 to 1.71)	1.23 (0.91 to 1.65)	1.22 (0.91 to 1.65)	1.28 (0.96 to 1.71)
Sex				
Female	1	1	1	1
Male	2.18 (1.63 to 2.92)	2.06 (1.53 to 2.77)	2.03 (1.49 to 2.76)	1.73 (1.26 to 2.38)
Type of school				
Private	1	1	1	1
Public	1.05 (0.76 to 1.44)	1.00 (0.73 to 1.39)	1.04 (0.75 to 1.43)	1.01 (0.74 to 1.36)
Mode of transport home from school on the day of the survey				
Walking	1	1	1	–
Two-wheeled or three-wheeled vehicle	1.13 (0.66 to 1.89)	1.10 (0.65 to 1.78)	1.07 (0.64 to 1.73)	–
Four-wheeled vehicle	1.30 (0.84 to 1.99)	1.25 (0.82 to 1.88)	1.22 (0.80 to 1.84)	–
Travel time to school by any mode of transportation (minutes)				
<5	1	1	1	–
5–15	1.12 (0.82 to 1.55)	1.10 (0.80 to 1.52)	1.11 (0.81 to 1.54)	–
16–30	1.30 (0.72 to 2.29)	1.24 (0.69 to 2.20)	1.28 (0.71 to 2.26)	–
31–45	2.61 (1.32 to 5.11)	2.61 (1.32 to 5.11)	2.60 (1.31 to 5.08)	–
>46	2.50 (0.97 to 6.18)	2.34 (0.90 to 5.79)	2.40 (0.93 to 5.95)	–

Bold text indicates statistically significant results.

independently, a factor that has important public health implications.⁴³

SDGs promote physical activity as well as safe transportation. The study findings call for improvement in road systems as chalked out in Global Plan for the Decade of Action; improving the safety of vehicles; and enhancing the behaviour of road users.⁴⁴ The majority of adolescents in our study attend schools through independent mobility; therefore, it is highly important for urban planners, environmentalists and public health practitioners to emphasise a safe road environment to prevent adolescents' road crashes.⁴⁵ Pedestrian sidewalks, pedestrian signals, use of pedestrian bridges, provision of safe routes to school and deployment of volunteers to accompany adolescents who walk or travel by bus to school or provision of subsidised school transportation are some important aspects to be improved. The addition of road safety curricula in schools could be a helpful strategy to create awareness on safe conduct in road traffic environments.

Limitations

This study has limitations. First, the study design is cross-sectional and is not meant to assess the temporal associations of independent mobility and RTI. It is unclear when an injury occurred, as lifetime injuries were reported, and there is a possibility that any previous RTI might lead to a decrease in independent mobility. Second, we did not collect details on the modes of RTIs. Determining the details of whether an injury occurred to an adolescent as a pedestrian or as a vehicle occupant could further help to assess the cause of an RTI. Third, our current analysis included more females, as the sample was not stratified based on sex. There were fewer males in public schools, and it was found that the number of males enrolled per class was lower than that of females in public schools in Karachi. There might be additional reasons for the lower numbers of males in public schools, such as lower attendance. It was also observed in our study that more males than females forgot their consent forms. Any future study should also consider the enrolment rates of males and females separately in private and public schools in sampling. Furthermore, including a lower number of males in the study would have meant that fewer injuries were reported in the study, as injuries are more common in males, which would have impacted the strength of the association. Finally, we did not consider independent cycle use by adolescents in our analysis, as only 23% of adolescents 10–19 years old reported having a cycle. The unadjusted analysis (not reported) showed a statistically insignificant association between being allowed to ride a cycle on their own and RTIs. The addition of this variable in the multivariable analysis was not appropriate, as the total data count for this variable was much lower ($n=277$) than those for the other variables, which would have decreased the sample size for the complete model. Similarly, underage use of motorcycles and cars by adolescents was not evaluated in this study. These transportation modes need to be explored to determine their relationship with RTIs.

CONCLUSIONS

The study is one of the first studies in the context of the independent mobility of adolescents in low-middle income settings where opportunities for physical activities, both structured and unstructured, are less likely because of a lack of safe public spaces. Independent mobility is an easy strategy for physical activity and has many health and social benefits for children and adolescents. This study highlights the risk of RTIs associated with measures of independent mobility. Measures of independent mobility in adolescents—parental permission to cross main roads and independent mobility in weekend activities—are associated with an increased risk of RTIs. Effect size of association of measures of independent mobility with RTIs may be biased towards null because of under-representation of boys in the sample compared with the actual adolescent population.

Learning road safety is an important need for children and adolescents to enhance their safe mobility. These findings may help policymakers to consider the concept of independent mobility and apply relevant findings to policies for urban planning, road traffic, transportation, school and supervision. It is critical for public health officials, urban and transportation planners and policymakers to recognise growing transportation problems in school catchment areas around school start and end times and respond to the transportation needs of children and adolescents. Investment in making road infrastructure and policies friendly for commuting pedestrians and cyclists as well as providing safe public transportation is warranted to facilitate independent commuting of adolescents.

Twitter Uzma Rahim Khan @uzmark

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Contributors URK: Developed study objective, data management and analysis; wrote the first draft. URK supervised the project, had full access to the data, controlled the decision to publish and accepts full responsibility for the conduct of this study, as the guarantor. JR: Reviewed the manuscript for critical input. MGW: Supervised all data analysis, manuscript writing and provided critical input to the manuscript.

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ORCID iDs

Uzma Rahim Khan <http://orcid.org/0000-0002-7706-6572>

Martin Gerdin Wärnberg <http://orcid.org/0000-0001-6069-4794>

REFERENCES

- Marzi I, Reimers A. Children's independent mobility: Current knowledge, future directions, and public health implications. *Int J Environ Res Public Health* 2018;15:2441.
- Schoeppe S, Duncan MJ, Badland HM, et al. Associations between children's independent mobility and physical activity. *BMC Public Health* 2014;14:91.
- Lubans DR, Boreham CA, Kelly P, et al. The relationship between active travel to school and health-related fitness in children and adolescents: a systematic review. *Int J Behav Nutr Phys Act* 2011;8:1–12.
- Roberts I. Adult accompaniment and the risk of pedestrian injury on the school-home journey. *Inj Prev* 1995;1:242–4.
- Alparone FR, Pacilli MG. On children's independent mobility: the interplay of demographic, environmental, and psychosocial factors. *Child Geogr* 2012;10:109–22.
- Prezza M, Piloni S, Morabito C, et al. The influence of psychosocial and environmental factors on children's independent mobility and relationship to peer frequentation. *J Community Appl Soc Psychol* 2001;11:435–50.
- Foster S, Villanueva K, Wood L, et al. The impact of parents' fear of strangers and perceptions of informal social control on children's independent mobility. *Health Place* 2014;26:60–8.
- Fyhri A, Hjorthol R, Mackett RL, et al. Children's active travel and independent mobility in four countries: Development, social contributing trends and measures. *Transp Policy* 2011;18:703–10.
- Institute for Health Metrics and Evaluation. 'GBD Results Tool'. *Global Health Data Exchange*. University of Washington, editor: In: Seattle WA, 2019.
- Global Burden of Disease Pediatrics Collaboration, Kyu HH, Pinho C, et al. Global and national burden of diseases and injuries among children and adolescents between 1990 and 2013: findings from the global burden of disease 2013 study. *JAMA Pediatr* 2016;170:267–87.
- Kilinc E, Gür K. Behaviours of adolescents towards safety measures at school and in traffic and their health beliefs for injuries. *Int J Nurs Pract* 2020;26:e12861.
- Tiruneh BT, Biftu BB, Dachew BA. Prevalence and factors associated with road traffic incident among adolescents and children in the hospitals of Amhara national regional state, Ethiopia. *BMC Emerg Med* 2019;19:1–6.
- Consunji R, Malik S, El-Menyar A, et al. Pediatric road traffic injuries in Qatar: evidence for a developmental stage approach to road safety. *Qatar Med J* 2020;20:3.
- Mannocci A, Saulle R, Villari P, et al. Male gender, age and low income are risk factors for road traffic injuries among adolescents: an umbrella review of systematic reviews and meta-analyses. *J Public Health* 2019;27:263–72.
- World Health Organization. *Global status report on road safety 2013: supporting a decade of action: summary*. World Health Organization, 2013.
- Schwebel DC. Children crossing streets: the cognitive task of pedestrians across nations. *Ann Glob Health* 2017;83:328–32.
- Khan UR, Razzak JA, Wärnberg MG. Global trends in adolescents' road traffic injury mortality, 1990–2019. *Arch Dis Child* 2021;106:753–7.
- Twisk DAM, Bos NM, Weijermars WAM. Road injuries, health burden, but not fatalities make 12- to 17-year olds a high risk group in the Netherlands. *Eur J Public Health* 2017;27:981–4.
- GBD 2017 Child and Adolescent Health Collaborators, Reiner RC, Olsen HE, et al. Diseases, injuries, and risk factors in child and adolescent health, 1990 to 2017: findings from the global burden of diseases, injuries, and risk factors 2017 study. *JAMA Pediatr* 2019;173:e190337–e.
- Peden M, Oyegbite K, Ozanne-Smith J. *World report on child injury prevention*. Geneva: World Health Organization, 2009.
- Ikeda E, Hinckson E, Witten K, et al. Assessment of direct and indirect associations between children active school travel and environmental, household and child factors using structural equation modelling. *Int J Behav Nutr Phys Act* 2019;16:1–17.
- Tetali S, Edwards P, Murthy GVS, et al. Road traffic injuries to children during the school commute in Hyderabad, India: cross-sectional survey. *Inj Prev* 2016;22:171–5.
- Feng XYJ, Nah SA, Lee YT, et al. Pedestrian injuries in children: who is most at risk? *Singapore Med J* 2015;56:618.
- Murray CJL. Shifting to Sustainable Development Goals--Implications for Global Health. *N Engl J Med* 2015;373:1390–3.
- Shamim S, Razzak JA, Jooma R, et al. Initial results of Pakistan's first road traffic injury surveillance project. *Int J Inj Contr Saf Promot* 2011;18:213–7.
- Adeel M, Yeh AGO, Zhang F. Gender inequality in mobility and mode choice in Pakistan. *Transportation* 2017;44:1519–34.
- Minhas KS, Batool Z, Malik BZ, et al. Pedestrian environment and behavior in Lahore, Pakistan. *J Transp Health* 2017;7:181–9.
- Hasan A, Raza M. Responding to the transport crisis in Karachi. *IIED and Urban Resource Center*, 2015. Available: <http://pubs.iied.org/10733IIED.html>
- School education in Pakistan a sector assessment Asian development bank 2019.
- Dandona R, Kumar GA, Raj TS, et al. Patterns of road traffic injuries in a vulnerable population in Hyderabad, India. *Inj Prev* 2006;12:183–8.
- Rudner J, Wickramaarachchi N. *Sri Lankan children's independent mobility*, 2013.
- Tetali S, Edwards P, Murthy GVS, et al. Development and validation of a self-administered questionnaire to estimate the distance and mode of children's travel to school in urban India. *BMC Med Res Methodol* 2015;15:92.
- Team R Core. *R: a language and environment for statistical computing [Internet]*. Vienna, Austria: R Foundation for Statistical Computing, 20202017.
- Pajouheshnia R, Pestman WR, Teerenstra S, et al. A computational approach to compare regression modelling strategies in prediction research. *BMC Med Res Methodol* 2016;16:107.
- Macpherson A, Roberts I, Pless IB. Children's exposure to traffic and pedestrian injuries. *Am J Public Health* 1998;88:1840–3.
- Jagnoor J, Sharma P, Parveen S, et al. Knowledge is not enough: barriers and facilitators for reducing road traffic injuries amongst Indian adolescents, a qualitative study. *Int J Adolesc Youth* 2020;25:787–99.
- Khan FM, Jawaid M, Chotani H, et al. Pedestrian environment and behavior in Karachi, Pakistan. *Accid Anal Prev* 1999;31:335–9.
- Raza M. *Exploring Karachi's transport system problems*, 2016.
- Wegner L, Flisher AJ. Leisure boredom and adolescent risk behaviour: a systematic literature review. *J Child Adolesc Ment Health* 2009;21:1–28.
- Kwon MS, Vorobyev V, Moe D, et al. Brain structural correlates of risk-taking behavior and effects of peer influence in adolescents. *PLoS One* 2014;9:e112780.
- Pickett W, Schmid H, Boyce WF, et al. Multiple risk behavior and injury: an international analysis of young people. *Arch Pediatr Adolesc Med* 2002;156:786–93.
- Tahir MN, Haworth N, King M. Observations of road safety behaviours and practices of motorcycle rickshaw drivers in Lahore, Pakistan. *Proceedings of the 2015 Australasian Road Safety Conference (ARSC2015)*, Australasian College of Road Safety (ACRS), 2015.
- Chaudhury M, Oliver M, Badland HM. Public open spaces, children's independent mobility. In: *Play, recreation, health and well being, geographies of children and young people*. , 2015: 9, 315–35.
- World Health Organization. *Global launch: decade of action for road safety 2011–2020*. World Health Organization, 2011.
- 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.