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Global and Local Road Traffic Injury Epidemiology in Children and Adolescents

Uzma Rahim Khan

Karolinska Institutet

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GLOBAL AND LOCAL ROAD TRAFFIC INJURY EPIDEMIOLOGY IN CHILDREN AND ADOLESCENTS
THESIS FOR DOCTORAL DEGREE (Ph.D.)

By

Uzma Rahim Khan

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Principal Supervisor:
Associate Professor Martin Gerdin Wärnberg
Karolinska Institutet
Department of Global Public Health
Health Systems and Policy Research Group

Co-supervisor(s):
Professor Junaid A.Razzak
Weill Cornell Medicine, New York City, US
Department of Emergency Medicine

Opponent:
Professor Lars Hagander
Lund University
Department of Pediatrics

Examination Board:
Professor Therese Djärv
Karolinska Institutet
Department of Medicine

Professor Muhammad Zafar Iqbal Hydrie
Dow University of Health Sciences
School of Public Health

Matts-Åke Belin
KTH, Royal Institute of Technology
Adjunct Professor on traffic safety

POPULAR SCIENCE SUMMARY OF THE THESIS

The importance of decreasing the burden of road traffic injuries is immense as it is the leading cause of mortality in children and adolescents. Low-and middle-income countries bear 95.% of the burden of childhood unintentional injury mortality. This thesis comprises of four studies aimed at increasing the knowledge of the mortality burden and risk factors of all kind of injuries in children aged 1-4 years and road traffic injuries in adolescents 10-19 years.

The data for studies I and II are from a global data repository, available online for about 204 countries. For study I, we used injury mortality data for children 1-4 years for the year 2010 and for study II, we used mortality data for road traffic injuries for adolescents 10-19 years for years 1990 to 2019. The setting for the other studies III and IV is Karachi, the largest city of lower-middle-income country, Pakistan.

The results showed that there were inequalities in deaths due to injuries in children and adolescents with respect to income level of the country. Some of the high-income countries in Europe had less than 6 deaths per 100, 000 children of age 1-4 years. On the contrary, low-income countries in Sub Saharan Africa had rate as high as 94 per 100,000 children of age 1-4 years. We also found that deaths due to road traffic injuries are declining at a significant rate in high-income countries, but low and lower-middle-income countries are yet to see significant reduction. In Karachi, independent mobility (travel without supervision) of adolescents was associated with a high frequency of road traffic injuries. We also found motorcyclists age13-17 (underage for driving license) and 18-19 years old (early licensure age) were associated with higher odds of severe injuries compared to age 20-24 years (late licensure age).

Low-and middle-income countries can benefit from the progress of high-income countries in injury prevention. Prevention and control of injuries should be part of holistic under-5 child health agenda. For road traffic injury prevention in adolescents, there are many universally implemented policies in high-income countries that do not require further research. Comprehensive legislations for safe built environment with walkways, cross ways, pedestrian and cyclists' traffic signals, and the use of vehicles with built-in safety features along with implementation of use of helmet and seat belt are essential.

ABSTRACT

Background: Every year around the globe, more than 800,000 children and adolescents under the age of 20 die due to injuries from any cause. Globally, low-and middle-income countries bear a disproportionate 95% of the burden of all childhood injury mortality. There is a paucity of data on all injuries in children and road traffic injuries by type of road users among adolescents particularly from low and middle-income countries. The aim of this thesis is to increase the knowledge on the epidemiology of injuries in children 1-4 years and road traffic injuries in adolescents 10-19 years by type of road users in high-income, upper and lower-middle-income and low-income countries with a focus in Pakistan.

Methods: The studies I and II have an ecological study design and used the database by global burden of disease study for the year 2010 and 1990-2019 respectively. The setting for the studies III and IV is Karachi, city of a lower-middle-income country, Pakistan. The study III is a survey of adolescents about their independent mobility and road traffic injuries and the data for study IV are motorcycle injuries from hospitals.

Results: The highest injury rate was 94 per 100,000 in low-income countries of Sub-Saharan Africa and the lowest injury rate was 6 per 100,000 in the high-income countries of Eastern Europe/Central Asia (Study I). The reduction in mortality rates of adolescents' road traffic injuries is more prominent in high-income countries than any other income level from 1990 to 2019. For instance, the mortality reduction in pedestrians 15-19 years in HICs was IRR 0.94 (95% CI 0.90 to 0.98) (Study II). Adolescents who had parental permission to cross main roads alone (adjusted odds ratio 1.39; 95% confidence interval 1.04 to 1.86) and who participated in one or more activities outside the home alone on the previous weekend (adjusted odds ratio 2.61; 95% confidence interval 1.42 to 5.13) had higher odds of road traffic injuries (Study III). Motorcyclists aged 13-17 years (adjusted odds ratio 1.25; 95% confidence interval 1.11, 1.42) and 18-19 years (adjusted odds ratio 1.26; 95% confidence interval 1.10, 1.43) had higher odds of severe injury compared to aged 20-24 years (Study IV).

Conclusions: Child injury mortality is unevenly distributed across income level, to the detriment of low-income countries. There are decreasing trends in mortality for all types of road users in adolescents from 1990 to 2019 at all income levels but high-income countries have a larger decrease in mortality rates for all types of road users as compared with any other income level. Adolescents in Karachi who were allowed to cross main roads alone and who had weekend activities on their own were associated with road traffic injuries. In addition, adolescents aged 13-17 and 18-19 years were associated with higher odds of severe road traffic injuries compared to motorcyclists aged 20-24 years in Karachi, Pakistan.

LIST OF SCIENTIFIC PAPERS

Khan UR, Sengoelge M, Zia N, Razzak JA, Hasselberg M, Laflamme L. Country level economic disparities in child injury mortality. Archives of disease in childhood. 2015;100:S29-S33.

Khan UR, Razzak JA, Wärnberg MG. Global trends in adolescents' road traffic injury mortality, 1990–2019. Archives of disease in childhood. 2021;106:753-7.

Khan UR, Razzak J, Wärnberg MG. Association of adolescents' independent mobility with road traffic injuries in Karachi, Pakistan: a cross-sectional study. BMJ open. 2022;12:e057206.

Khan UR, Razzak JA, Jooma R, Wärnberg MG. Association of age and severe injury in young motorcycle riders: a cross-sectional study from Karachi, Pakistan. Injury. 2022.

CONTENTS

1 LIST OF ABBREVIATIONS

Aor	Adjusted Odds ratio
CI	Confidence interval
ED	Emergency Department
GBD	Global burden of Diseases
GDP	Gross Domestic Product
GNI	Gross National Income
HIC	High-income country
IHME	Institute for Health Metrics and Evaluation
ICD	International Classification of Diseases
IRR	Incidence rate ratio
ISS	Injury Severity Score
LIC	Low-income country
LMIC	Lower-middle-income country
MDG	Millennium Development Goals
NCD	Non-Communicable diseases
n	Number
OECD	Organization of economic cooperation and development
RTI	Road traffic injury
SD	Standard Deviation
SDG	Sustainable Development Goal
SPSS	Statistical Package for the Social Sciences
UMIC	Upper-middle-income country
UN	United Nations
UNICEF	United Nations International Children's Emergency Fund
VRU	Vulnerable road user
WHO	World Health Organization

2 INTRODUCTION

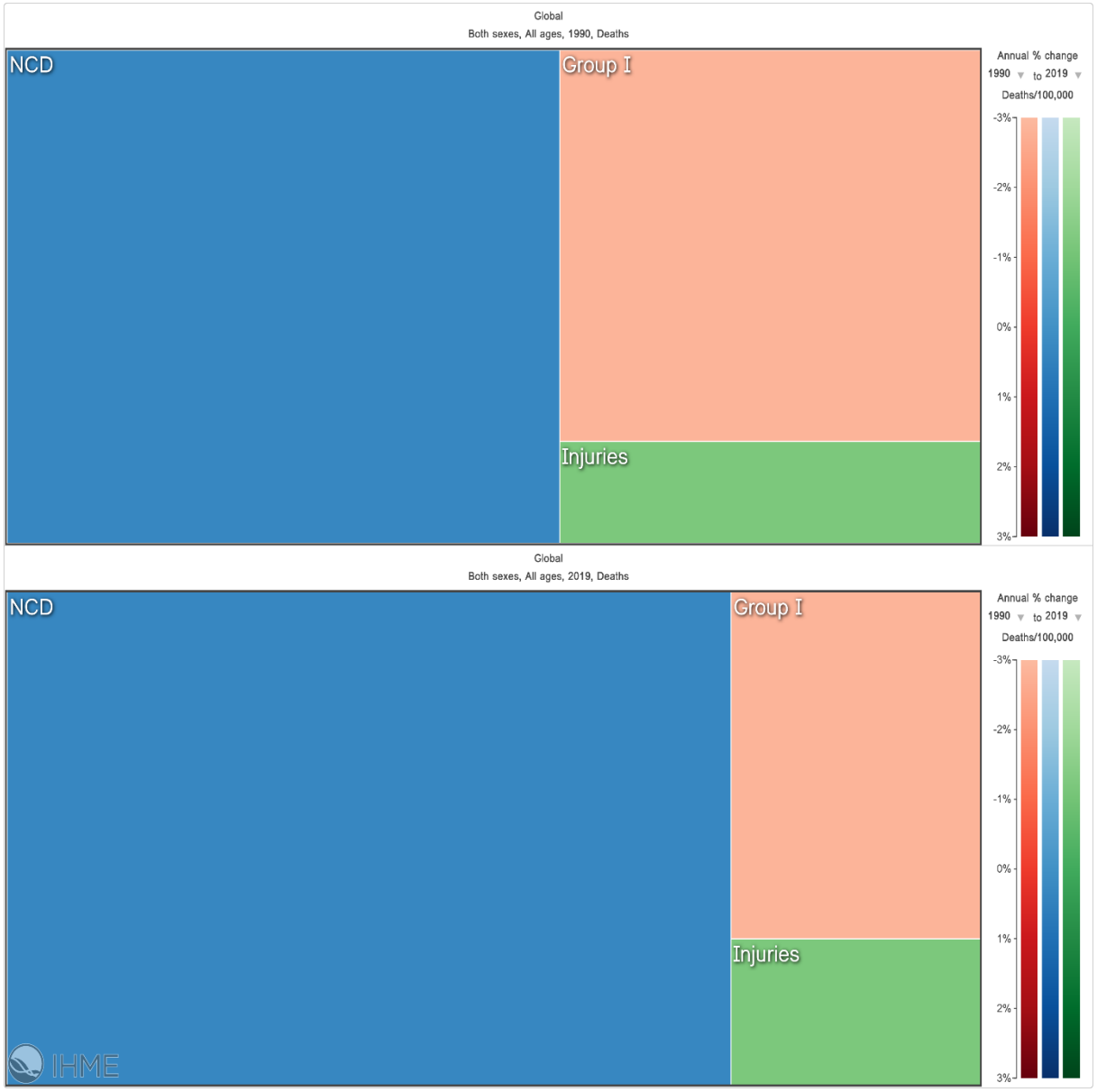
2.1 Health challenges in today's world

2.1.1 Transition in global health

The world has changed rapidly in the last twenty years. The population growth today is 0.9% as compared to two decades ago, which was 1.3% (1). The urban population is booming with half of the world's population living in towns, slums or cities. Poverty has been cut down by half, but with growing economic inequalities 82% of global wealth is at the disposal of 8% world's population (2).

With the evolving lifestyle, environment and development, world has seen an epidemiological transition in the years 1990-2019 with respect to the disease burden (Figure 1). Communicable diseases started decreasing and there is a rise of non-communicable diseases (NCDs) and injuries (3, 4). The transition has not been uniform while high-income countries have observed it earlier while some low- and lower-middle-income are still reaching it (5). The World Health Organization (WHO) set up a high-level commission in October 2017 to tackle the increasing burden of mortality due to both NCDs and injuries(6). Safe road systems and policies conducive for active commuting (walking and cycling) can reduce road traffic crashes and prevent NCDs (7, 8).

Figure 1:Percentage of all age global mortality due to communicable, maternal, neonatal, and nutritional causes (red); non-communicable (blue); and injuries (green) in 1990 versus 2019



Source: Institute for Health Metrics and Evaluation (IHME). Global Burden Of Diseases (GBD)

2.1.2 Child and adolescent health

Under-five child health is historically an important global agenda, and made it place in the convention of child rights (1989), the millennium development goals (MDGs 2000) and now the sustainable development goals (SDGs 2015). Prioritizing child health resulted in the significant decrease in child mortality by more than half from 12.7 million in 1990 to 5 million in 2019-2020 (9-13). This is the largest improvement in survival efforts as compared to any other age group.

The burden of injuries in children under 5 years old is usually overshadowed by the heavy toll of infectious diseases (14). In the last decade, injuries have been identified as an important cause of mortality in under 5 years old (15). The persistence of infectious diseases along with emerging of new viruses, injuries, and non-communicable diseases demands a holistic agenda for child and adolescent health (16). The SDGs are on right track with addition of non-communicable diseases and injuries along with maintaining a continuous focus on infectious diseases driven by MDGs (13, 17, 18).

Adolescents' health was not prioritized until recently. The United Nations define adolescents as persons aged 10-19 years. With 1.2 billion of 10-19 years making up 16% of world's population, adolescent health is crucial to all major agendas of global health (19, 20). Adolescent mortality has declined by nearly 40% since 1990, yet almost a million adolescents died in 2020 (10, 21-23). Recently, the Commission on Adolescent Health and United Nations (UN) Global Strategy for Women's, Children's, and Adolescents' Health was formed (24). The investment on adolescents' health has triple benefits - for the present and future adult life as well as for the next generation of children (25, 26).

2.2 Injuries as a global epidemic

Injuries are a global public health issue with about 5 million deaths reported in 2019 (27). Injury is defined as "a body lesion at the organic level, resulting from an acute exposure to energy (mechanical, thermal, electrical, chemical or radiant) in amounts that exceed the threshold of physiological tolerance (28).

Injuries can be intentional or unintentional (29). Unintentional injuries include road injuries, drowning, falls, thermal injuries, poisonings, mechanical forces, and natural disasters, whereas intentional injuries result from self-harm and interpersonal violence (30). Both unintentional and intentional injuries are preventable. The major causes of injuries are road traffic (29%), self-harm (18%), falls (12%) and interpersonal violence (9%) (31).

2.2.1 Injuries in children 1-4 years

Injuries in children 1-4 years occur mostly in the homes or surroundings (32). Children become mobile and start to explore in this age however they have restricted mobility with supervision The mechanisms of injury in 1-4 years could be due to falls, burns, drowning, road traffic and violence. Injuries in children 1-4 years received little attention in LMICs due to overwhelming burden of other diseases, which are of infection etiology (33). Children under the age of 1, who are not yet mobile are not grouped with children age 1-4 years in injury research due to different patterns of injuries (34). Injuries also lead to disabilities that could have long-term health and socioeconomic consequences in countries where disability is a barrier for many educational, employment and recreational opportunities. A survey from Pakistan reported 3% of injured children under-5 years developed disability (35).

Table 1: Global burden of injury mortality 2010 by type of injury and age group in children and adolescents

	Mortality	All injuries	Road traffic	Drowning	Fall	Burns	Poisoning
Under 5 Years	n	313871	57352	63451	20084	18318	14510
	rate	48	8.8	9.7	3.0	2.8	2.2
5-9 years	n	138883	39464	31876	7405	4075	2916
	rate	22	6.3	5.1	1.1	0.65	0.46
10-14 Years	n	137004	32496	24825	6650	2808	3176
	rate	22	5.3	4.07	1.09	0.46	0.52
15-19 Years	n	278758	86166	19852	8417	4877	3542
	rate	45.3	14	3.2	1.3	0.79	0.57

**Rate per 100,000*

Source: Institute for Health Metrics and Evaluation (IHME). Global Burden Of Diseases (GBD)

The rates and counts of all injuries mortality are higher in children under-5 years of age, while the distribution of injury types show that road traffic injuries accounted for the highest burden in adolescents aged 15-19 years (Table 1).

2.3 Road traffic injuries - most common cause of injury mortality

2.3.1 Mobility revolutionized due to motorization

The means of mobility for primitive humans were their feet needed for constant movement for long distances with high speed, as they were mostly gatherers and hunters of flora and fauna. Over thousands of years, humans switched over to township with domesticated animals for

their travelling and farming needs. The invention of the wheel, a few thousands of years ago permitted movement with much more convenience and efficiency compared to use of animals drawing the carriages. The modern innovation is motorized transportation, which greatly increased the frequency of global mobility. At the start of motorization, pedestrians were on streets without fear of being blamed for road traffic crashes or mortality and the onus for such crashes was more on motorists. Streets that were initially made with the vision of public service were replaced with the economic needs for transportation needs. Eventually, pedestrians were mocked as jaywalkers and less important users of streets (36).

The increased motorization along with economic growth, sprawling urbanization and globalization brings opportunities, given the progressive interconnectedness in technology, trading, communication and transportation (37). These advancements may have opportunities or risks for the health of the population. Free markets are related to the movement of people and goods through motorized transportation causing increased exposure for road traffic injuries (RTIs) (38, 39).

2.3.2 Road traffic injuries- a byproduct of motorization

Road traffic injuries are the ninth leading cause of mortality globally, with 1.2 million road traffic deaths globally in 2019 (40). RTIs cost 3% of gross domestic product (GDP) to most of the countries (41). The UN adopted the "Decade of Action for Road Safety" to reduce the rising trend in road traffic fatalities and save about 5 million lives over the 10-year period (2011–2020) (42-44). The action outlined five key areas, including (i) road safety management; (ii) safer roads and mobility; (iii) safer vehicles; (iv) making road users safer; and (v) improved post-crash response and hospital care (44). The sustainable development goals (SDGs) have target 3.6: to halve RTIs by 2030 (45). RTIs are related to at least four other targets of SDGs: (i) decrease the mortality rate in children under 5 (target 3.2), ii) eradicate extreme poverty (target 1.1), iii) reduce inequalities of outcome (target 10.3) and iv) improving road safety (target 11.2) (45).

2.3.3 Exposure of adolescents as road users and their vulnerability to road traffic injuries

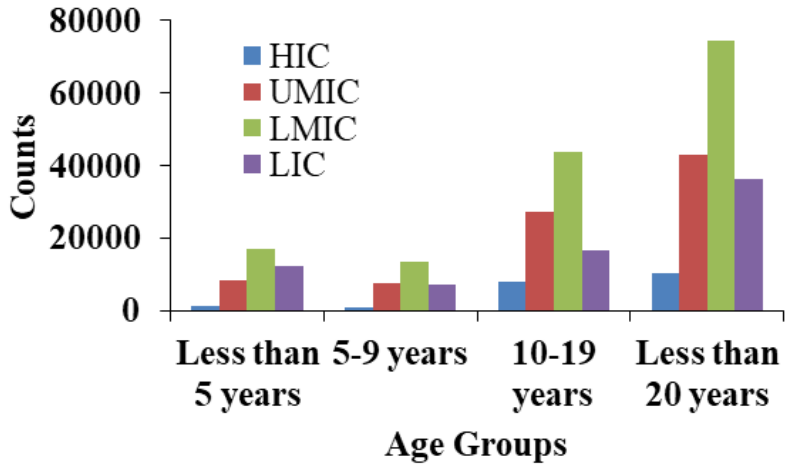
Children start mobility as pedestrians and as they grow older start to cycle, use motorcycles and then as adolescents and young adults starts driving (46). The school travel is the most regular of all children's trip. Children 10-19 years are specifically known as adolescents. Over the last 20 years, adolescents' independent mobility as a pedestrian or cyclist has decreased (16, 47). Parents have fears about their children's safety due to both strangers and motor vehicle

collisions (17, 18, 21). (48). Globally, 81% of school-going adolescents are not adequately physically active (49). A goal of WHO is to reduce 10% of physical inactivity by 2025 (50, 51).

Adolescents 10-19 years as road users are distinct groups in terms of physical and psychological skills as well as choice of transport mode compared to children under 10 years. Their limited skills to perceive movement and velocity, source of a sound, and distance compromise traffic safety (52, 53). While, adolescents are also prone to indulge in risk taking behaviors as pedestrians, bicyclists, motorcyclists and motor vehicle occupants (54).

The leading cause of mortality in adolescents 10-19 years old worldwide is road traffic injuries due to their growing independence in mobility (55) (Figure 2). In 2019, nearly 100 000 adolescents (10–19 years) died as a result of road traffic injuries (56). About 58% of RTIs mortality under 20 years are in age range of 10-19 years (57). RTIs are also the number two cause of disability among adolescents (3, 58).

Figure 2: Burden of road traffic injuries in children and adolescents by age Categories in income groups



Abbreviations: HICs High-income countries, UMICs Upper-middle-income countries, LMICs Lower-middle-income countries and LICs Lowincome-countries

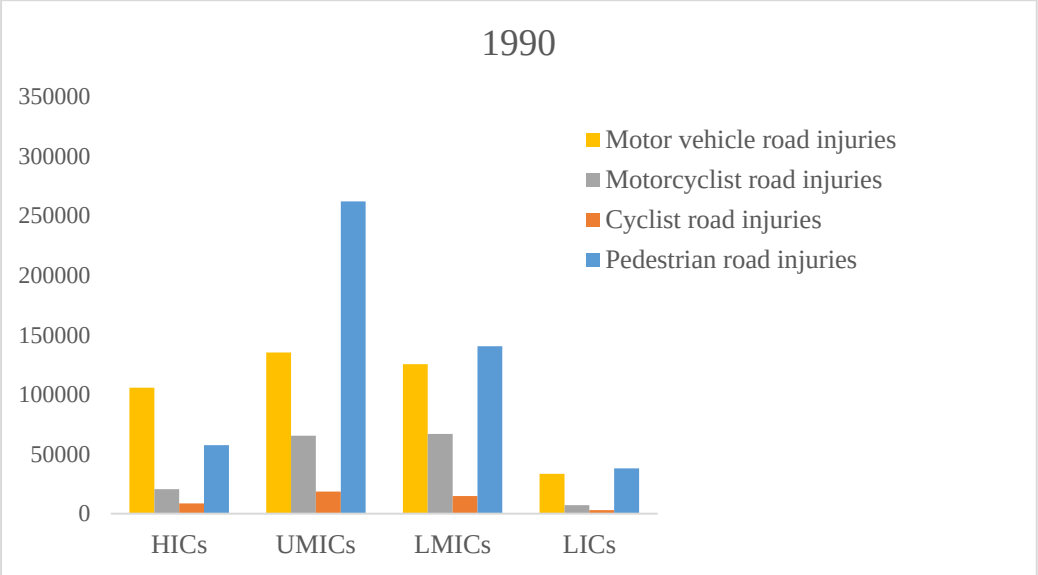
Source: Institute for Health Metrics and Evaluation (IHME). Global Burden Of Diseases (GBD)

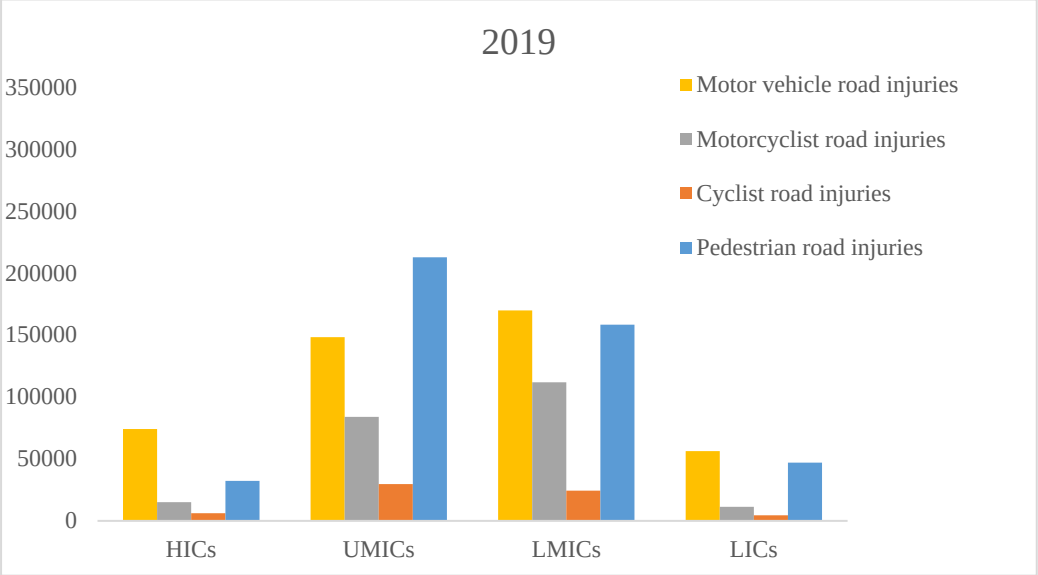
Road traffic mortality in males exceed that of females younger than 20 years (59). Gender differences in road traffic exposure are reported with boys having more road trips than girls (60). In 2008, the WHO and United Nations International Children's Emergency Fund (UNICEF) made seven concrete recommendations to improve child injury prevention in the World report on child injury prevention (54). In 2011, the World Health Assembly adopted a resolution to prioritize child and adolescent injury prevention in national policy for the member states (61).

2.3.4 Vulnerable road users

Globally, almost half of all mortality on the roads are among motorcyclists, cyclists and pedestrians, also known as vulnerable road users (VRUs) i.e. with the least protection (62). They suffer severe consequences as they are unprotected by an outside shield that would absorb energy in a collision against the speed and mass of the other party (63). Motorization in LMICs without planning for safety and mobility creates a traffic environment that is particularly unsafe for children(64). There is an increase in the two and three wheeled vehicles in middle-income countries. In addition, the built environment is not according to the needs of the vulnerable road users which has resulted in increase in injuries to VRUs (65) (Figure 3). The built environment in low and middle-income countries lacks in traffic calming measures, speed bumps, sidewalks, cross overs and separating pedestrians and cyclists from motorized traffic (66, 67).

Figure 3: Distribution of road traffic injuries related mortality in all ages by road user type in World Bank Income groups in 1990 versus 2019





Abbreviations: HICs High-income countries, UMICs Upper-middle-income countries, LMICs Lower-middle-income countries and LICs Low-income-countries

Source: Institute for Health Metrics and Evaluation (IHME). Global Burden Of Diseases (GBD)

2.4 The economic divide of road traffic injuries

2.4.1 Disparities in burden of road traffic injuries

Low-and middle-income countries have a disproportionate burden of mortality due to road traffic crashes (90%) relative to their contribution to the world's motorization (54%) (41, 68, 69). RTIs cause losses of up to 3% of Gross Domestic Product (GDP) in LMICs (70, 71). Even the progress in reducing injuries show steep inequality between HICs and LMICs (72-74). Road mortality rates are declining in most high-income countries, whereas from 2010 to 2013, 84% of the countries considered low or middle-income have seen a rise in the number of road traffic mortality (40). The inequalities in road traffic mortality between LMICs and HICs of the WHO European region have widened by 2.3 times in 2015 as compared to 2000 among children <15 years old (61, 75).

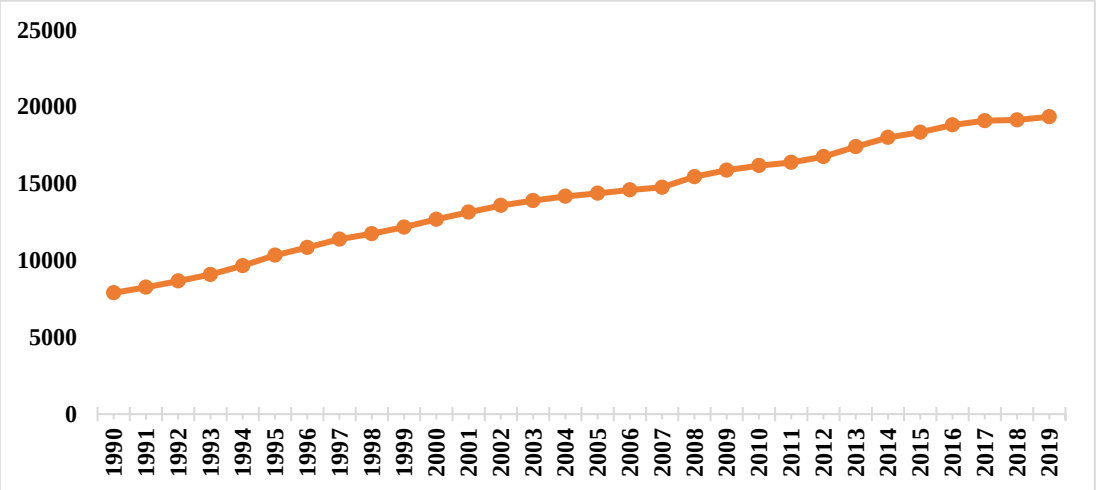
2.4.2 Case study of lower-middle-income country with heavy toll of road traffic mortality, Pakistan

Pakistan is the sixth most populous country in the world with over 207 million people (8) and 29 percent of Pakistani population is between 15 and 29 years old (21, 22). Adolescents aged 10-19 years comprise about 22 percent (%) of Pakistan's population, approximately 42 million (76).Pakistan is a lower middle-income country with Gross National Income per capita of 1500 United States dollar (USD) in 2021. The health expenditure per capita is 39 USD. Pakistan ranks 26th in the world for under-5 child mortality with the rate of 65 per 1,000 live births (77).

The injury data gaps are huge in Pakistan and prior injury work was primarily from secondary data sources such as ambulance data, hospital records and demographic health surveys (78-91). The current estimates are lacking particularly there is no epidemiological evidence on road traffic injuries among adolescents in Pakistan. Injuries were the sixth leading cause of mortality in children under 5 years old in Pakistan according to Pakistan Demographic Health Survey in 1996-97 (92). The overall annual incidence rate of unintentional injuries under 5 years of age was 47 per 1000 per year; according to the 1990-94 National Health Survey of Pakistan (35). The road traffic injuries incidence per 1000 is 9 for children under 15 years of age in national injury survey administered in 1997 (93, 94). WHO estimates Pakistan's rates to be 14 per 100,000 (42). A population survey in 2013-2014 in two of the provinces in Pakistan included 18 years old and above showed that the burden might have doubled. Road traffic injury surveillance in major hospitals of Karachi

enumerated an annual incidence rate of 142 per 100,000 and a mortality rate of 4.9 per 100,000 (95). Common road users affected were motorcyclists and bicyclists (43.6%), followed by pedestrians 16% (95). The GBD estimates also showed increase of many folds in road traffic mortality over last three decades (Figure 4) (96).

Figure 4: Burden of road traffic mortality in Pakistan from 1990 to 2019



Source: Institute for Health Metrics and Evaluation (IHME). Global Burden Of Diseases (GBD

2.4.3 The megacity Karachi and its transport woes

There is lack of any centralized transport system in the city of Karachi (82, 97, 98). A circular railway was established in 1964 but it was closed in 1998 (99). The public transport such as

buses and motor rickshaws meets the need of more than half of trips generated every day in Karachi (100). Many new app-based transportation services such as Careem and Uber are also operational and in high demand. However, there is a shortfall of buses which is cost effective travelling option (101).

In order to overcome the shortage of public transport, qingqi (motorcycles with six- seat carriages) were introduced in the city, which are also unsafe (102, 103). The number of motorcycles has increased tremendously from 500,000 in 2004 to 1.65 million in 2013 (104). Motorcycles are an efficient commuting mode for men but women in general do not drive motorcycles due to traditional cultural norms in Pakistan however recently women motorcycle drivers are also seen in the streets (105).

There are also infrastructural problems in the city (98, 106). The roads are in poor conditions with very limited unsafe pavements for pedestrians and most of the time vendors occupy pavements for their roadside business (107). Pedestrian bridges are not used due to safety issues (108). Motorized vehicles do not slow down to accommodate for the pedestrians crossovers (109). Separate lanes for bicycles are non-existent (107). There is also a lack of stops for buses and rickshaws (107). Getting on and off buses is commonly associated with injuries as drivers are in a rush. The enforcement of road traffic laws are very weak (59).

3 RESEARCH AIMS

3.1 Study rationale

There is limited evidence on injury research for specific age groups in children and adolescents particularly from low and middle-income country context (13). Previous studies of injury in children have used broad age ranges such as under 14, under 15 or under 18. The broad age masks the understanding of injury patterns unique for different ages which is critical for action research (110). The age groups adopted widely are >1, 1–4, 5–9, 10–14, and 15–19 years (110).

Injuries in children aged 1-4 years received little attention in LMICs due to overwhelming burden of other diseases, which are of infectious etiology. The literature on injuries in children exclusively covers unintentional injuries and the comprehensive injury data including both unintentional and intentional injuries is not available. This underestimates the accurate magnitude of injuries in children 1-4 years and eventually miss the public health significance it deserves to create political will to include injuries in holistic under-5 health agenda. (111, 112).

Another area of concern is road traffic injuries, which are the leading cause of mortality in adolescents aged 10-19 years. Despite the disproportionate burden in LMICs, the current evidence of road traffic injuries in adolescents is mostly from few high-income countries using wide age range of under 19 or under 20 years (13, 113-117).

The thesis is an attempt to generate new knowledge on injuries in children and adolescents by considering two specific age groups; injuries including both unintentional and intentional types in children 1-4 years and road traffic injuries in adolescents 10-19 years at all income levels but with the focus on LMIC context.

3.2 Study aim

The aim of this thesis is to increase the knowledge on the epidemiology of injuries in children 1-4 years and road traffic injuries in adolescents 10-19 years by type of road users in high-income, upper and lower-middle-income and low-income countries with a focus in Pakistan.

3.3 Specific objectives

I. To assess the proportion and distribution of injury mortality in children 1–4 years within regions and across country income levels. To measure the correlation between country gross domestic product (GDP) and injury mortality within regions.

II. To determine the trends of road traffic injury (RTI) mortality among adolescents aged 10–14 years and 15–19 years across the country's different income levels with respect to the type of road users from 1990 to 2019.

III. To determine measures of adolescents' independent mobility associated with road traffic injuries in an urban lower-middle-income setting.

IV. To assess the association between age and severe injury in young motorcycle riders.

4 METHODS

Table 2: Overview of studies included in the thesis

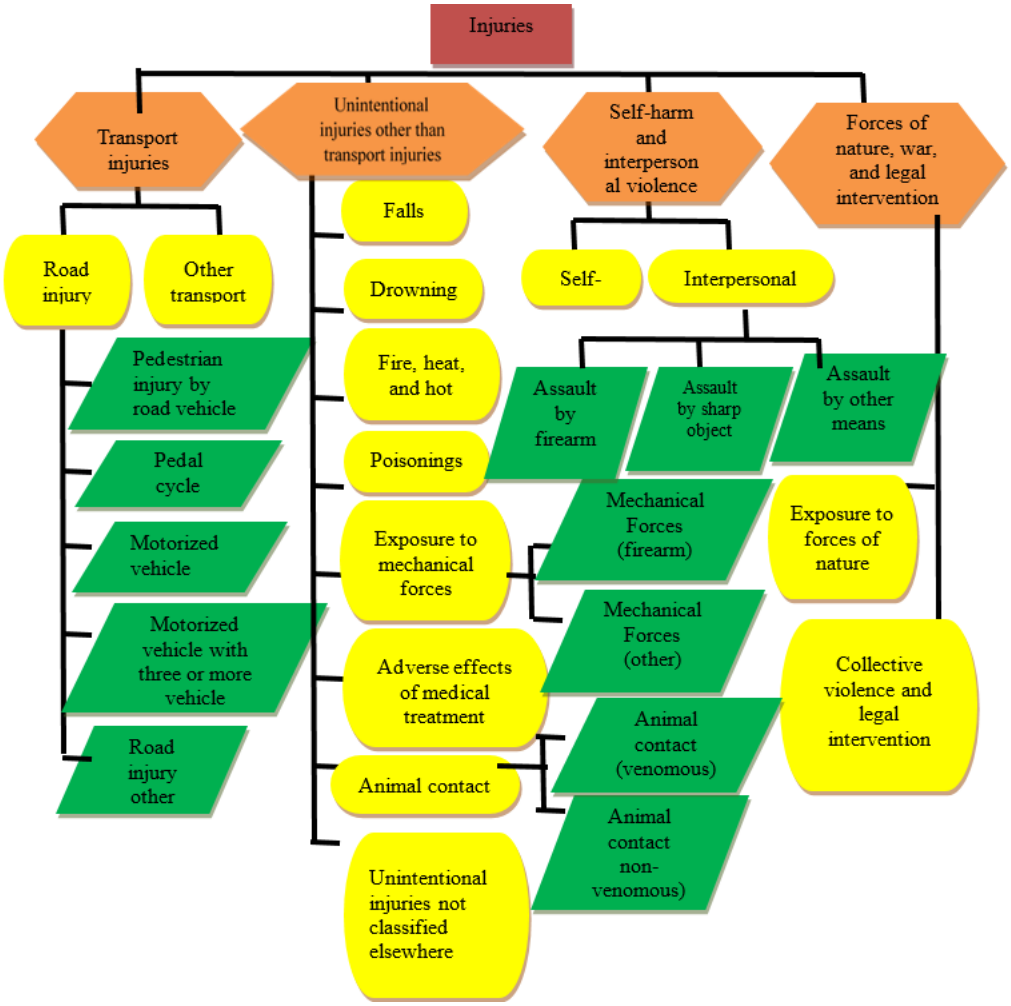
Component of study	Study 1	Study 2	Study 3	Study 4
Title	Country level economic disparities in child injury mortality	Global trends in adolescents' road traffic injury mortality, 1990–2019	Association of adolescents' independent mobility with road traffic injuries in Karachi, Pakistan- A Cross-sectional study	Association of age and severe injury in young motorcycle riders: A cross-sectional study from Karachi, Pakistan
Design	Ecological	Ecological	Cross sectional	Cross sectional
Setting	Global	Global	Karachi, Pakistan	Karachi, Pakistan
Data Source	Global burden of diseases data	Global burden of diseases data	Schools	Hospitals
Duration	2010	1990-2019	2014	2007-2015
Population	Children under 5 years	Adolescents 10-19 years	Adolescents 10-19 years	Young people 13-24 years
Outcome	Injury mortality rate per 100,00	RTI Mortality rates per 100,000	Number of RTIs	Injury severity scores
Main Variables	GDP	Age	Independent mobility	Age
Sample Size	60	1500	1264	45,366
Unit of Analysis	Geographic regions Economic level of countries Global	Economic level of countries Global	Individual level	Individual level
Method of analysis	Descriptive	Poisson regression	Logistic regression	Logistic regression

4.1 Settings and designs

The studies I and II were ecological analyses of all injuries aggregated and road traffic injuries, respectively, at the global scale and comparing income levels - low, middle (upper and lower) and high-income countries by using the Global Burden of Disease (GBD) data (118). GBD data repositories are available online for 187-204 countries (119, 120). GBD use many data sources and evaluates the quality of the data before applying modeling (121, 122). A detailed explanation of modeling GBD mortality causes has been previously published (121). Mortality were extracted from www.healthdata.org. The yearly estimates are available from 1990 to 2019

(123). Injury mechanisms were coded according to the International Classification of Disease, Version 10 (ICD 10) codes (124) (Figure 5).

Figure 5: Global Burden of Diseases classification of Injuries



The other two studies III and IV are cross sectional surveys and the setting for these two studies was Karachi, Pakistan (Table 2). The city of Karachi has an estimated population of 17 million (125).

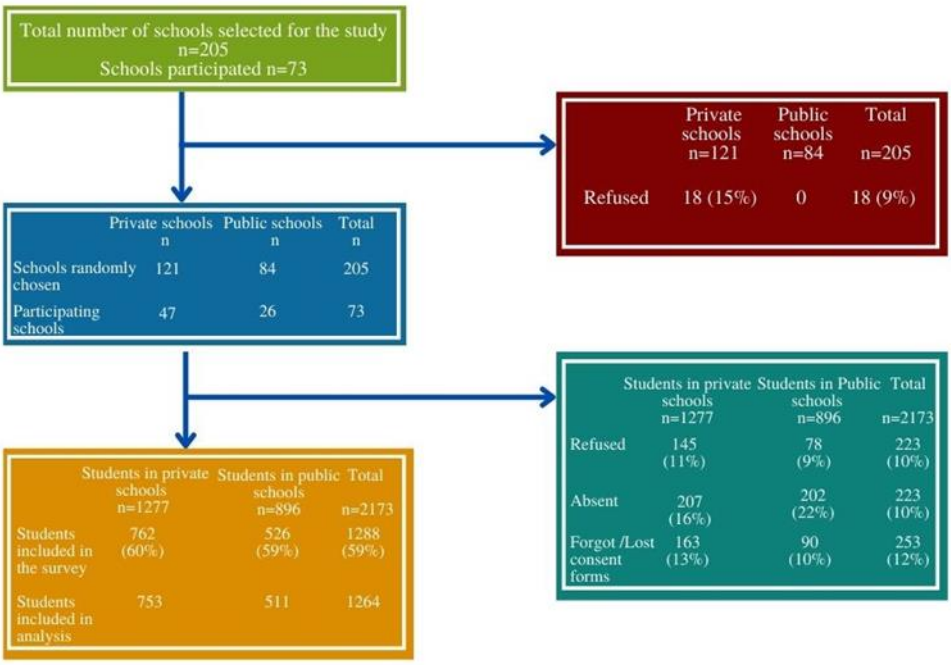
4.2 Data sources

For study I, the data were from the Institute for Health Metrics and Evaluation (IHME) Global Burden of Disease (GBD) study 2010 (126). Data on GDP per capita and gross national income (GNI) per capita for the year 2010 were extracted from the World Bank data base (62). In addition, the study I had analysis at the geographical level of seven super regions as grouped by Institute for Health Metrics and Evaluation (IHME) Global Burden of Diseases (GBD) data (127). These regions are i) Sub-Saharan Africa, ii) South Asia iii) Latin America and Caribbean, iv) Eastern Europe and Central Asia, v) Asia East, South East and Pacific, vi) North African and Middle East, and vii) Organization of economic cooperation and development (OECD) (Appendix Table 1).

In study II, the RTI global data and the World Bank income groups for the years 1990 to 2019 was also extracted from IHME GBD data (57).

Study III was conducted on adolescents from grades 6 to 10 (aged 10 to 19 years) in both public and private sector schools of Karachi, Pakistan (Figure 6). This age group was chosen because children generally begin to travel independently (walking, cycling, etc.) around the age of 10 years. Data was collected using a questionnaire adapted from the London Policy Studies Institute (128). The questionnaire was also translated to Urdu from English. The questions were pertaining to their modes of transport to and from school, the people who accompanied them, whether they had suffered or witnessed any road traffic injury (RTI) in the past, and their weekend activities. The questionnaires had a combination of pictorial multiple-choice questions, as well as open-ended questions. The study questionnaires were first pilot tested and modifications were made accordingly. Multistage stratified random cluster sampling was used.

Figure 6: Flow chart of adolescents' recruitment from schools for study II



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The sample size was 1267 with the assumption that 50% students walk to schools keeping 95% confidence level, bound on error of ± 5%, design effect of 3 and 10% inflation for non-responders.

Picture shows data collection in school (study III)

The data for study IV was from the emergency departments (EDs) of the major tertiary care hospitals in Karachi (Table 3). Three hospitals were government and two were private tertiary care hospitals. All these hospitals are teaching hospitals for undergraduate and postgraduate medical training for the affiliated medical schools. The data was collected prospectively 24/7 by data collectors who worked in three eight-hour shifts. The demographics and details of the crash were obtained by asking victims, their relatives, ambulance drivers, or any eyewitnesses. The data collection was piloted in late 2006 after which launched in 2007, ran for nine years and ended in the year 2016 (87).

Table 3: Details of tertiary care hospitals included in study IV

	Aga Khan Hospital	**Liaquat National Hospital**	**Civil Hospital**	**Jinnah Postgraduate Medical Center**	**Abbasi Shaheed Hospital**
Sector	Private teaching	Private teaching	Public teaching	Public teaching	Public teaching
Triage in place	Yes	No	No	No	No
Cost to patient	Out of pocket	Out of pocket	Free	Free	Free
Approximate number of patients per day	120-160	100-150	800-1100	800-1100	800-1100

4.3 Variables

In study I, the outcome was injury mortality rate per 100,000 for 1-4 years. Injury in the GBD includes transport and unintentional causes of injuries, intentional causes such as self-harm and interpersonal violence, and injuries due to forces of nature, war, and legal interventions (Figure 5) (129). Year, income level, and geographical regions were the covariates.

In study II, the mortality rates per 100,000 were extracted for road injuries and four sub-categories of road injuries (Figure 5). The four subcategories of road injuries, pedestrian road injuries, cyclist road injuries, motorcyclist road injuries and motor vehicle road injuries were included for the age groups 10-14 years and 15-19 years. Years 1990 to 2019 were the main exposure variable. Income level, and age were covariates.

In study III, RTI was included that was sustained as a pedestrian, cyclist, or while in a car or another vehicle in life time that resulted in any first aid at home/school or consultation in a healthcare setting (128). Adolescents' 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”] (128).

In study IV, the outcome was severe injury defined as an injury severity score (ISS) ≥ 16. The exposure was age; 13-17 years were categorized as underage, age of 18-19 years as early licensing age, and 20-24 years as late licensing age. The covariates were sex, profession of injured riders (students versus professionals those who were earning), time of the crash (night time versus day time), day of the crash (weekday versus weekend), month of the crash (summer versus winter), road structure (intersection versus midblock), crash location (within the city versus outside the city including highways), helmet use (helmet versus no helmet), patient transfer vehicle, hospital, injured body regions, and outcome of patients in the emergency department (mortality versus alive).

4.4 Data analysis

The statistical software Microsoft Excel, Statistical Package for the Social Sciences (SPSS), and R were used for all statistical analyses in this thesis (104, 130, 131).

In study I, rates of injury mortality in children 1-4 years were reported by GBD regions and country's income level groups for the year 2010. Scatterplots between Gross Domestic Product (GDP) and injury mortality for the countries in each GBD region were created with Spearmen coefficient correlations (r) (129). The GDP was log transformed to account for skewness (129).

In study II, mean rates with standard deviation (SD) were reported. Poisson regression with a log link was conducted to quantify the percentage change in the rate per year. The incidence rate ratios (IRRs) were reported (129).

In study III, logistic regression was applied to check for associations between the measures of independent mobility and RTIs. Four models were developed by using each of the four exposures of independent mobility. The models were adjusted for age, sex, type of school, travel time to school by any mode of transportation, and mode of transportation to home from school. However, the model with the exposure activities on the weekend alone was not

adjusted for travel time to school and mode of transportation to school which were not related to activities on weekends (128).

In study IV, logistic regression was used to assess the associations of age groups (13-17 years and 18-19 years compared with 20-24 years) and severe injury (ISS ≥ 16) (130).

4.5 Ethical considerations

The data for study I and II were extracted from public data repository the global burden of disease (GBD). We did not file for ethics waiver or approval. The setting for the studies III and IV was Karachi, Pakistan. Both the studies were granted ethical approval from ethics review committees of the involved institutions. For the study IV, we did the secondary analysis.

Study III (Approval from Aga Khan University 2883-EM-ERC-13) was based on a survey of adolescents in schools about their exposure to road traffic. Research involving adolescents (under 18 years) needs special ethical attention. Adolescents constitute a vulnerable population because of their limited ability to take autonomous decisions for taking part in research. Involvement of adolescents in the research process to include their opinion in the overall perspective is important. The participation in research also builds the capacity of adolescents. We developed all the field processes in the protocol phase to ensure that research meets ethical standards and quality data are collected in a consistent manner across all the schools surveyed.

4.5.1 Principle Of Autonomy

Adolescents are minors and therefore the process of informed consent from guardian/custodian is mandatory. We took their parents written consent on the participation of adolescents in the survey. We also took oral assents from adolescents because the study does not include any sensitive information. The most important part of consent is to provide information at their level of understanding and to inform them about their right to withdraw. The consent should be with their free will and without any form of coercion. Hard copies of data collection materials had identifiers and therefore were locked in a secure cabinet or room with limited access for the research team. The study involved minimal risks and the data collected was not sensitive. No personal identifiers were included in the electronic database for analysis.

4.5.2 Principle Of Beneficence And Non–Maleficence

The objective of any research study should be a beneficial outcome for research participants and minimizing harm. Harm in terms of psychological impact such as embarrassment and exploitation because of adolescents' vulnerabilities should be avoided. In our study, we were respectful and paid full attention by valuing their opinion during the conduct of study. We were compassionate while conducting research to maintain their dignity and protection.

4.5.3 Principle Of Justice

In any research project, the research participants are more important than any research protocol. Adolescents are entitled to same degree of confidentiality and privacy as adult research subjects. The participation of adolescents in the study about road traffic exposure is an important aspect hardly explored before in study setting context. We conducted this survey during school. It was undertaken with the permission of the school principal and class teacher. We believe it was a learning process for the school and adolescents. We took the amount of time equal to one subject period, which was 30 to 40 minutes. In some schools we had to utilize their recess. We also offered them some snacks in order to account their participation. To maintain a trusting relationship, we had a debriefing session with them to learn about their enjoyment of the whole process.

The study IV (No.F.2.81/2012-GENL/3198/JPMC and Aga Khan University 2022-7490-2155) was conducted in the emergency rooms of city's major hospitals, which were busy and sensitive clinical area, therefore, verbal assent was obtained from the emergency staff and patients or their next of kin before proceeding to collecting information on a questionnaire. I was not involved in the conduct of the study and got a waiver of ethics for the secondary data analysis for study for of this thesis.

5 RESULTS

5.1 Study I: Country level economic disparities in child injury mortality

Table 4: Mean injury mortality rate in 1-4 years according to income groups of countries and region, 2010

Countries grouped by income levels within regions	**Injury mortality rate per 100,000**
OECD	9.5
High-income countries n=29	8.9
Upper-middle-income countries n= 3	15.7
North Africa/Middle East	29.4
High-income countries n=6	22.2
Upper-middle-income countries n=5	29.9
Lower-middle-income countries n=8	30.1
Sub-Saharan Africa	119.7
High-income countries n=1	296.1
Upper-middle-income n=4	23.7
Lower-middle-income n=12	183.6
Low-income n=29	94.1
Latin America and the Caribbean	39.4
High-income n=3	18.0
Upper-middle-income countries n=16	22.0
Lower-middle-income countries n=9	32.2
Low-income countries n=1	650.3
Eastern Europe/Central Asia	33.0
High-income countries n=8	5.9
Upper-middle-income countries n=12	29.9
Lower-middle-income countries n=7	48.5
Low-income countries n=2	60.5
Asia East, S. East and Pacific	31.0
High-income countries n=2	11.4
Upper-middle-income countries n=4	10.7
Lower-middle-income countries n=15	31.5
Low-income countries n=5	39.9
South Asia	43.3
Lower-middle-income countries n=3	38.6
Low-income countries n=3	71.7

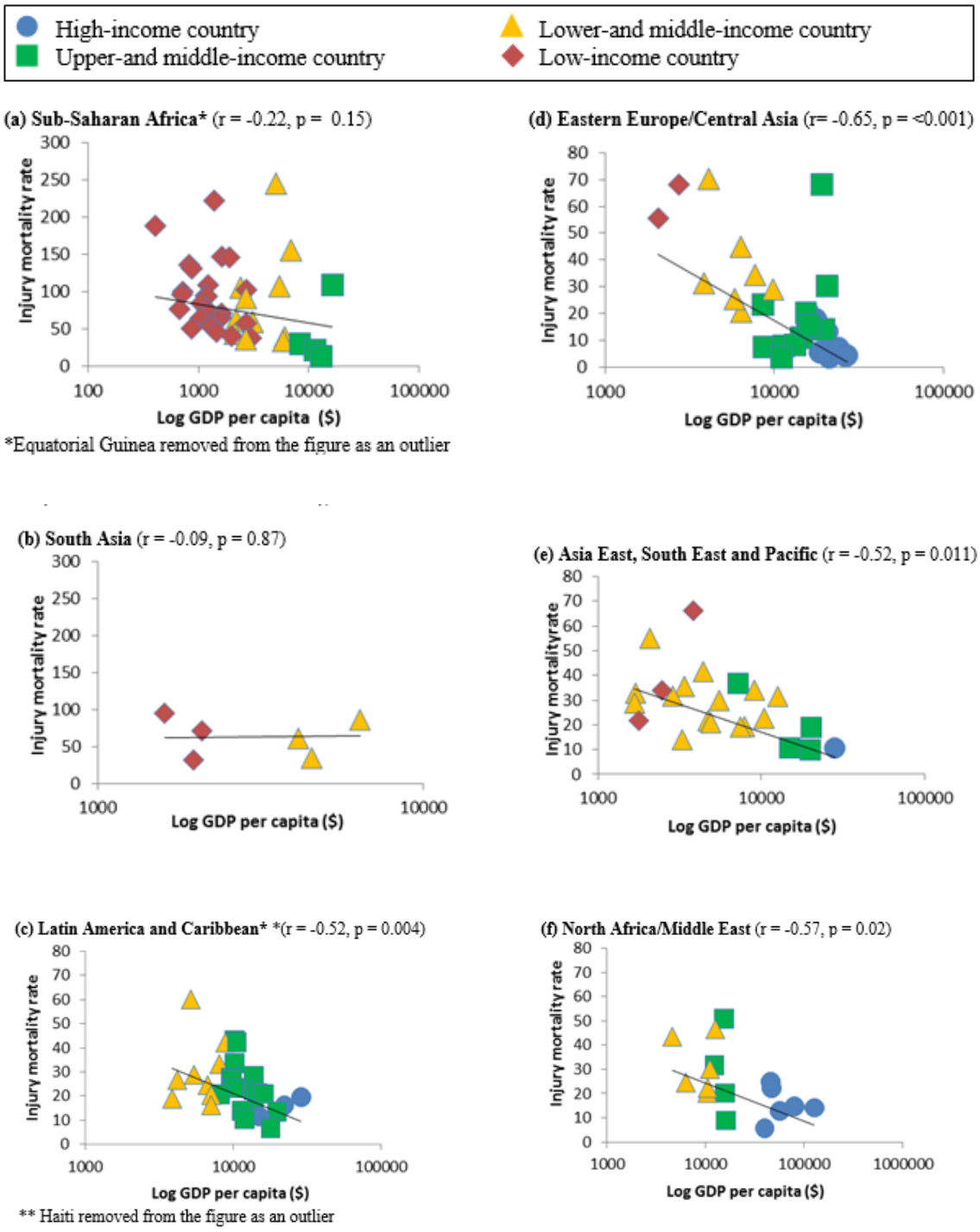
Sub-Saharan Africa and South Asia had the highest rates of injury mortality in children 1-4 years of age. Within each region, the rates were inversely related to the income groups, with the highest rates observed in low-income countries and the lowest rates in the high-income

countries. The exception is Sub Saharan Africa where the highest rate was in the only high-income country in that region (Table 4).

The disparity in rates was observed between regions; the rates of same income-groups between regions have variations. High-income countries of Eastern Europe/Central Asia had the lowest rates of 5.9 per 100,000 while the only high-income country of Sub Saharan Africa had rate of 296 per 100,000 and high income countries of North Africa/Middle East had 22.2 per 100,00 rate. Low-income countries of Sub Saharan Africa had rate of 94.1 per 100,000 compared to 39.9 per 100,000 in Asia East, South East and Pacific (Table 4).

There is a graded association between country GDP level and injury mortality rates of 1-4 years across regions, with the highest rates observed in low-income countries and the lowest in the high-income group. The negative correlation between country level GDP and injury mortality was observed in in the four regions: Latin America and the Caribbean ($r = -0.52$, p 0.004), Eastern Europe/Central Asia ($r = -0.65$, $p < 0.001$), Asia East, South-East and Pacific ($r = -0.52$, p 0.011) and North Africa/Middle East ($r = -0.057$, p 0.02). The two regions with the highest rates; Sub Saharan Africa and South Asia did not show correlation (Figure 7).

Figure 7: Association between country gross domestic product per capita (log scale) and child injury mortality rate per 100,000 (children 1 – 4 years) in six GBD regions, 2010



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5.2 Study II: Global trends in adolescents' road traffic injury mortality, 1990–2019

Between 1990 and 2019, the mean mortality rate for adolescents age 15-19 years was the highest for motor vehicle occupants followed by pedestrians in HICs (11.7 versus 2.2), UMICs (8.5 versus (6.3) and LMICs (4.8 versus 3.4). For low-income levels, the mean mortality rate for pedestrians (6.0) in adolescents 15-19 years was higher than that for motor vehicle occupants (5.4). Although the noticeable difference was that pedestrian rate was low in HICs while other income-levels had double burden of mortality for pedestrians and motor vehicle occupants as the rates are comparable. The mortality was high for 15-19 years motorcyclists in LMICs and LICs. In 10-14 years, the mortality is higher in pedestrians in all income levels except in HICs where the mortality is higher in motor vehicle occupants (Table 5).

Table 5: Descriptive statistics of the road mortality rate of years 1990- 2019 by type of road user and country income level for adolescents by age groups (n=30)

Income	Age	Mortality by Road User Type			
		Pedestrians	Cyclists	Motorcyclists	Motor vehicle road users
Mean (Standard Deviation)					
High-income countries	15-19 years	2.2 (0.8)	0.5 (0.2)	2.8 (1.2)	11.7 (3.9)
	10-14 years	1.2 (0.6)	0.5 (0.2)	0.2 (0.1)	1.7 (0.6)
Upper-middle-income countries	15-19 years	6.3 (0.9)	0.6 (0.1)	2.0 (0.2))	8.5 (0.6)
	10-14 years	3.6 (0.5)	0.3 (0.1)	0.6 (0.1)	3.2 (0.2)
Lower middle-income countries	15-19 years	3.4 (0.6)	0.6 (0.1)	4.1 (0.4)	4.8 (0.6)
	10-14 years	2.5 (0.4)	0.4 (0.1)	0.6 (0.1)	1.7 (0.2)
Low-income countries	15-19 years	6.0 (1.3)	0.7 (0.1)	4.5 (0.3)	5.4 (0.5)
	10-14 years	3.7 (1.0)	0.5 (0.1)	0.7 (0.1)	1.8 (0.3)

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Only high-income countries had the most pronounced decline in mortality rates in all road users of age 15-19 and 10-14 years, though the reduction for mortality in cyclists is not statistically significant Also reduction in mortality of motorcyclists aged 10-14 is statistically significant. Upper middle-income countries showed declined in the mortality of pedestrians of both ages. Low and lower middle-income showed statistically insignificant decrease in all the road users (Tables 6 and 7).

Table 6: Poisson regression of road traffic mortality rates and years (1990-2019) by type of road user and country income level in adolescents 15-19 years of age

Income levels	Mortality rates by Road users				
	All road injuries IRR (95% CIs)	**Pedestrian injuries IRR (95% CIs)**	**Cyclist injuries IRR (95% CIs)**	**Motorcyclist injuries IRR (95% CIs)**	**Motor vehicle injuries IRR (95% CIs)**
High-income countries	0.96 (0.95,0.97)	0.96 (0.93,0.99)	0.96 (0.90,1.02)	0.96 (0.93,0.98)	0.96 (0.95,0.98)
Upper- middle-income countries	0.99 (0.98,1.00)	0.98 (0.96,0.99)	0.99 (0.94,1.04)	1.00 (0.98,1.02)	0.99 (0.97,1.01)
Lower-middle-income countries	0.99 (0.98,1.00)	0.98 (0.96,1.00)	0.99 (0.94,1.04)	0.99 (0.97,1.01)	0.99 (0.97,1.01)
Low-income countries	0.99 (0.98,1.00)	0.98 (0.97,1.00)	0.99 (0.93,1.05)	0.99 (0.96,1.02)	0.99 (0.98,1.01)

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Table 7: Poisson Regression of road traffic mortality rates and years (1990-2019) by type of road user and country income level in adolescents 10-14 years of age

Income levels	Road users				
	All road injuries IRR (95% CIs)	**Pedestrian injuries IRR (95% CIs)**	**Cyclist injuries IRR (95% CIs)**	**Motorcyclist injuries IRR (95% CIs)**	**Motor vehicle injuries IRR (95% CIs)**
High-income countries	0.95 (0.93,0.98)	0.94 (0.90,0.98)	0.95 (0.88,1.01)	0.95 (0.86,1.04)	0.96 (0.93,0.99)
Upper- middle-income countries	0.98 (0.96,0.99)	0.97 (0.95,0.99)	0.99 (0.93,1.04)	0.99 (0.95,1.04)	0.98 (0.95,1.02)
Lowe -middle-income countries	0.98 (0.97,1.00)	0.98 (0.95,1.01)	0.99 (0.92,1.06)	0.99 (0.94,1.04)	0.99 (0.96,1.02)
Low income-countries	0.99 (0.97,1.00)	0.98 (0.96,1.01)	0.98 (0.91,1.06)	0.99 (0.93,1.04)	0.99 (0.97,1.02)

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5.3 Study III: Association of adolescents' independent mobility with road traffic injuries in Karachi, Pakistan: a cross sectional study

There were 1264 adolescents of age 10-19 years. A majority were girls (60%). Majority walk to school (72%). Overall, 21% of the adolescents reported lifetime RTIs 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.

Table 8: Adjusted odds ratios (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, 1.89)	-	-	-
Mixed travel pattern, i.e., alone or with parents	0.84 (0.40, 1.71)	-		-
Parental permission to cross main roads alone				
No	-	1	-	-
Yes	-	**1.39 (1.04, 1.86)**	-	-
Parental permission to travel on public buses alone				
No	-	-	1	-
Yes	-	-	1.34 (0.93, 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, 3.06)
Alone or with young person	-	-	-	**2.61 (1.42, 5.13)**
Mixed; both with parents and alone	-	-	-	**2.50 (1.38, 4.89)**

Adjusted for age sex, type of school, transport to home from school, travel time to school

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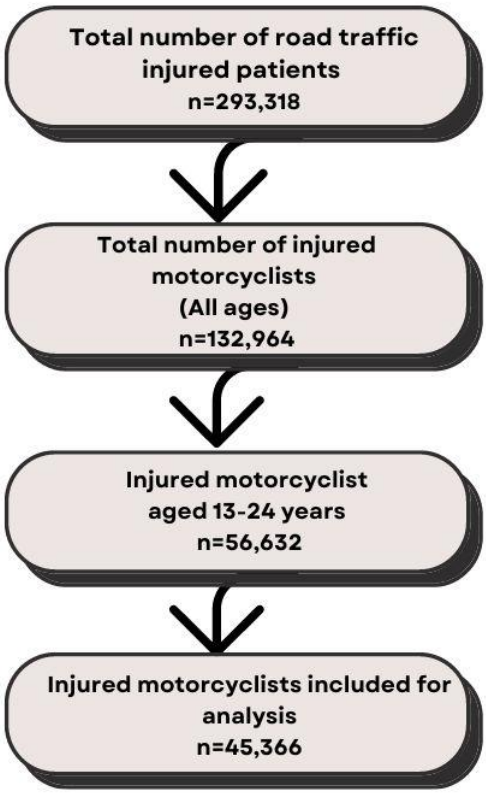
In the adjusted analysis, adolescents with parental permission to cross main roads (aOR 1.39; 95% CI 1.04 to 1.86) had significantly higher odds of RTIs. Unaccompanied adolescents with any activity outside the home on the previous weekend (aOR 2.61; 95% CI 1.42 to 5.13) or with a mixed pattern of weekend activities, either accompanied or alone (aOR 2.50; 95% CI 1.38 to 4.89) had significantly higher odds of RTIs (Table 8).

5.4 Study IV: Association of age and severe injury in young motorcycle riders: a cross-sectional study from Karachi, Pakistan

Figure 8: Study participants for study IV



There were 45,366 motorcycle riders of age 13-24 years that were included in the analysis (Figure 8). There were 10,115 (22.6%) motorcycle riders aged 13-17 years, 9,899 (21.9%) aged 18-19 years, and 25,352 (55.5%) aged 20-24 years. Female riders made up less than 1% in the current study.

The adjusted odds of severe injury were higher in the 13–17-year age group (aOR 1.25 95% CIs 1.11, 1.42) and in the 18–19-year age group (aOR 1.26; 95% CIs 1.10, 1.43) than in the 20-24 year age group (Table 9).

Table 9: Adjusted associations of age with severe injury in young motorcycle riders (n=45,366)

Variable	Severe injury (ISS<16) n = 43367	Severe injury (ISS>=16) n = 1999	Adjusted OR (95% CIs)
Age group			
20-24 years	24289 (56.0)	1063 (53.2)	1
18-19 years	9435 (21.8)	464 (23.2)	1.26 (1.10, 1.43)
13-17 years	9643 (22.2)	472 (23.6)	1.25 (1.11, 1.42)

Adjusted for sex, profession, time of crash, day of the crash, season, road structure, crash location, helmet use, patient's transfer vehicle and hospital

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6 DISCUSSION

The thesis added evidence on global epidemiology of injuries in both children 1-4 years and adolescents 10-19 years with particular focus in Pakistan- a lower middle-income country. The highest injury rates for children 1-4 years were in Sub Saharan Africa and South Asia.The rate of adolescents' mortality due to road traffic injuries has decreased from 1990 to 2019, but this decrease is not as apparent in low and middle-income countries compared to high- income countries. Some specific associations of road traffic injuries in adolescents were also assessed in the LMIC context. Independent mobility is associated with RTIs and early driving age 13-19 years compared to 20-24 years is associated with severe motorcycle injuries in Pakistan.

6.1 Injury mortality in 1-4 years children

Study 1 shows that injury mortality in children 1-4 years is distributed unequally between regions' income levels. The injury mortality rates are much higher in low and lower middle-income countries as compared to upper middle and high-income countries. Due to competitive priorities in child health amongst resource poor countries, injury prevention policies and measures in LMICs are compromised and either not implemented or not enforced as these have in high-income countries (131). Universally implemented laws in HICs such as child-resistant packaging and car safety seat use have brought down the mortality in HICs (132). This points to the need for effective country-level response programs. Efforts to reduce inequalities must start from a child's early years. Integrating injury prevention into multi-sector child survival efforts has the potential to assist in meeting many SDGs directly and indirectly including to halve RTIs, end preventable deaths in under-5 children, reducing inequality within and among countries, end poverty and the access to safe, housing and transport systems (45).

6.2 Focusing on road traffic injuries in adolescents

The study II indicates the trend of reduction but the burden of mortality due to motor vehicle injuries is high in adolescents 15-19 years at all income levels as it is a licensing age for driving universally and many adolescents start driving. Additionally, the pedestrians' mortality in adolescents 15-19 years was also high for UMICs, LMICs and LICs. The inequalities in injuries burden in adolescents imply compromises in road safety at the levels of built environment, the vehicles and the individuals (133-135). Adolescents living in families with lower socioeconomic statuses have increased exposure to unsafe roads and unsafe vehicles (136). The undisciplined traffic, poor enforcement, limited public awareness, less availability and use

of safety equipment, lack of prehospital care, and compromised trauma care are few of the reasons for the high mortality rates (137, 138) in these countries. The introduction of new vehicles to fulfill the demand for affordable public transportation may bring risks that were not expected. For example, three-wheeled scooter taxis (qinqi, tuk-tuks, jeepneys, rickshaws) that are flourishing in many LICs and LMICs are particularly susceptible to topple over due to over-loading and/or being driven at too high a speed (139, 140). These vehicles are not used in HICs and thus very little work has been done on their design, safety, and crash-worthiness. The reduction in traffic mortality in HICs occurred despite increase in motor vehicles over the last century because of huge commitment to safety such as safer products and safe road environments (141-143). The interventions are designed and implemented based on the available epidemiology of RTIs in high-income countries. Low and lower-middle-income countries could learn much from the experience of the high-income countries regarding best strategies in injury prevention and control (66, 144).

6.3 Specific risk factors associated with road traffic injuries in Karachi, Pakistan- the low- middle-income countries context

We explored some of the risk factors related to road traffic injuries in Karachi. Our study III established two measures of independent mobility, i.e., engaging in weekend activities outside the home and crossing main roads are associated with RTIs among adolescents. In cities of LMICs, there is a lack of safe social and physical environment. Due to large internal migration from rural areas, neighbors are unfamiliar with each other in Karachi. The unavailability of parks and playgrounds in neighborhood further cause barrier to create mutually trusting social environment. Living and playing near busy streets and vehicles driving at high speeds increase the risk of child pedestrian RTIs (145, 146). The road environment is not designed to facilitate pedestrians and cyclists. There is a lack of traffic signals for pedestrian crossings and separate lanes for cyclists. There are limited walkways and crosswalks for pedestrians (147). Moreover, motor vehicle drivers also do not give way to pedestrians in road crossings (148). Short distances are covered by travelling on motorized vehicles. Security concerns and high rates of RTIs mentioned are the biggest barriers for adolescents'' independent mobility (149, 150).

Our study IV determined that motorcyclists aged13-17 years and 18-19 years had significantly higher odds of severe injury as compared to motorcyclists aged 20-24 years. In the absence of mass urban transit systems, the use of two wheelers has increased substantially in LMICs due to their low cost and this has taken place at the expense of the users' safety (151). A range of pre-crash and crash-related factors may contribute to high rates of injuries among users of

motorcyclists such as unprotected structure of motorcycle and lack of helmet use. Besides the mixed and busy traffic environment in which motorcyclists operate, an undefined number of young and inexperienced riders might be underage (152). The legal age limit for riding a motorcycle in Pakistan is 18 years while our study showed that boys as young as 13 years are injured as riders of two wheelers. This echoes an earlier study that attributed unsafe riding practices and under-age driving without a driving license as causes for motorcycle injuries (153). There is a pressing need to understand reasons for underage driving and the ways to deal with this problem.

6.4 Methodological consideration

Ecological comparisons beyond the individual level are critical to address inequalities in injuries for policy purposes and to affect child and adolescent safety. Comparison of total injury burden at regional and country- level income levels by both unintentional and intentional injuries in under-5 children highlights the problem of injuries. Previous literature covered only unintentional injuries. The global changes in RTI mortality in adolescents by road user type at all income level was assessed for the first time. Use of both primary and secondary data were strengths of our study.

The ecological and cross-sectional nature of designs in our studies have inherent limitations. We cannot ascertain causation and can only draw inferences. However, these two designs are useful to have snapshot of health outcomes. The ecological design in study I and II helped us to identify country-income level determinant. The cross-sectional design is helpful to collect data from busy settings like hospitals and schools where complex designs are difficult to carry out. The ICD classification that GBD study use for injuries is extensive, however it does not entail the details of the motor vehicle occupant. The information if the motor vehicle occupant was driver or a passenger (of rear or front seat) is critical to know for adolescents, which may limit our capacity to design interventions accordingly. The self-reported lifetime injury in study III, was susceptible to recall bias. The long recall period may have led to under-reporting of injury. The surveillance system from which the data is derived may have missed capturing all reported injuries in the hospitals. The motivation of capturing road traffic injured victims was at the discretion of research assistants, and it was not part of hospital data capture system in study IV.

7 CONCLUSIONS

There are reductions in mortality of adolescents aged 10-14 years and 15-19 years among all income groups, but with differences in both the magnitude of the injury as well as the type of road user. The mortality is high for vulnerable road users such as pedestrians and motorcyclists compared to motor vehicle occupants globally and at all country income levels excluding high-income countries. Adolescents in Karachi, Pakistan who were allowed to cross main roads alone and who were engaged in weekend activities alone were associated with road traffic injuries. In addition, adolescents age 13-17 and 18-19 years had higher odds of severe road traffic injuries compared to those aged 20-24 years among motorcyclists in Karachi, Pakistan.

8 IMPLICATION FOR RESEARCH AND PRACTICE

8.1 Research

Findings from paper I and II underscores the need to research the contextual differences in high-income countries of different regions with huge variations in rates to explore what other factors contribute in countries performing better than the rest.

The evidence for injury is just the tip of iceberg and in-depth details are required regarding mechanisms and factors associated with child injury mortality in low and middle-income countries. Surveillance of injuries from hospitals can be starting point of documenting injuries. The foremost research need is to have policy analysis, feasibility studies and economic analysis to prioritize injury interventions in these resource constraints countries. There is also critical need to study the effect of interventions on mortality in low and middle-income countries.

We intend to build on with the findings generated from studies III and IV in Karachi by filling the gaps identified from current studies such as factors associated with underage driving, weaknesses in driving licensing process and shortcomings of built environment.

8.2 Policy

Upper-middle-income and high-income countries should continue investing on injury prevention in children and adolescents and further decrease the rate of injuries by taking the best country example. High-income countries need to focus on the interventions for occupants of motor vehicles and may have potential to benefit from graduated driver license program which aims for all new drivers to limit driving by many strategies until the driver gains experience. The program have been shown to be successful in reducing crashes in young drivers (154).

The inequalities in injury mortality underscore the need for creating political will for injury prevention in adolescents by presenting it as a public health problem in the low and middle-income countries. It may be practical to integrate evidence based proven strategies into existing policies and/or legislation. The low and middle-income countries need to revamp legislations, enforcement and built environment for vulnerable road users, pedestrians and motorcyclists. The interventions such as slow speeding around schools, eliminating one-way streets around schools, installing walkways in school routes, volunteer traffic wardens for schools, and walking buses for schools, helmet use and seat belt for the adolescents.

In Pakistan, the legislations for injuries specific to children are not comprehensive and enforcement of existing legislations is very low. The findings from this thesis will help making public health case of injury prevention in children and adolescents. The involvement of pediatricians and public health advocates in creating political will for injury prevention in children and adolescents will be valuable.

The findings of study in Karachi make the strong case of safe built environment for adolescents who can be mobile in roads without supervision. Therefore, number of known road safety strategies can be recommended such as proper walkways for pedestrians, pedestrian signals, road crossings, pedestrian right of crossing the road, seat belt use, designated bus stops, and regulations for public transport. Helmet use and the regulation of drivers' training and licensing for motorcyclists are the two important policy points for adolescents in Karachi, Pakistan.

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11 APPENDIX

Table 1: Countries located in regions and super regions as defined in GBD 2010

GBD Super Region	GBD Region	Country
OECD	Asia Pacific, High Income	Brunei Darussalam, Japan, Republic of Korea (South Korea), Singapore
	Australasia	Australia, New Zealand
	Europe, Western	Akrotiri and Dhekelia, Aland Islands, Andorra, Austria, Belgium, Channel Islands, Cyprus, Denmark, Faeroe Islands, Finland, France, Germany, Gibraltar, Greece, Greenland, Holy See, Iceland, Ireland, Isle of Man, Israel, Italy, Liechtenstein, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, San Marino, Spain, Sweden, Switzerland, United Kingdom
	Latin America, Southern	Argentina, Chile, Falkland Islands (Malvinas), Uruguay
	North America, High Income	Canada, Saint Pierre et Miquelon, United States of America
Eastern Europe/Central Asia	Asia, Central	Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Mongolia, Tajikistan, Turkmenistan, Uzbekistan
	Europe, Central	Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, Kosovo, Montenegro, Poland, Romania, Serbia, Slovakia, Slovenia, The Former Yugoslav Republic of Macedonia
	Europe, 5Eastern	Belarus, Estonia, Latvia, Lithuania, Republic of Moldova, Russian Federation, Ukraine
Sub-Saharan Africa	Sub-Saharan Africa, Central	Angola, Central African Republic, Congo, Democratic Republic of the Congo, Equatorial Guinea, Gabon
	Sub-Saharan Africa, East	Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Madagascar, Malawi, Mayotte, Mozambique, Rwanda, Somalia, Sudan, Uganda, Tanzania (United Republic of), Zambia
	Sub-Saharan Africa, Southern	Botswana, Lesotho, Namibia, South Africa, Swaziland, Zimbabwe
	Sub-Saharan Africa, West	Benin, Burkina Faso, Cameroon, Cape Verde, Chad, Cote d'Ivoire, Gambia, Ghana, Guinea,

		Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Saint Helena, Sao Tome and Principe, Senegal, Sierra Leone, Togo
North Africa/Middle East	North Africa/Middle East	Algeria, Bahrain, Egypt, Iran (Islamic Republic of), Iraq, Jordan, Kuwait, Lebanon, Libyan Arab Jamahiriya, Morocco, Occupied Palestinian Territory, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, Turkey, United Arab Emirates, Western Sahara, Yemen
South Asia	Asia, South	Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan
	Asia, Southeast	Cambodia, Christmas Island, Cocos Islands, Indonesia, Lao People's Democratic Republic, Malaysia, Maldives, Mauritius, Mayotte, Myanmar, Philippines, Reunion, Seychelles, Sri Lanka, Thailand, Timore-Leste, Viet Nam
East Asia and Pacific	Asia, East	China, Democratic People's Republic of Korea (North Korea), Hong Kong, Taiwan
	Oceania	American Samoa, Cook Islands, Fiji, French Polynesia, Guam, Kiribati, Marshall Islands, Micronesia (Federated States of), Nauru, New Caledonia, Niue, Northern Mariana Islands, Palau, Papua New Guinea, Pitcairn, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, Wallis and Futuna Islands
Non-OECD Latin America/Caribbean	Caribbean	Anguilla, Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, Bermuda, British Virgin Islands, Cayman Islands, Cuba, Dominica, Dominican Republic, French Guiana, Grenada, Guadeloupe, Guyana, Haiti, Jamaica, Martinique, Montserrat, Netherlands Antilles, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Saint Martin, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Turks and Caicos Islands, US Virgin Islands
	Latin America, Andean	Bolivia, Ecuador, Peru
	Latin America, Central	Colombia, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Venezuela
	Latin America, Tropical	Brazil, Paraguay

Source: Institute for Health Metrics and Evaluation (IHME). Global Burden Of Diseases (GBD)