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REVIEW

The cost of injury and trauma care in low- and middle-income countries: a review of economic evidence

Hadley K H Wesson,[1,2] Nonkululeko Boikhutso,[3] Abdulgafoor M Bachani,[1] Karen J Hofman[4] and Adnan A Hyder[1]*

[1]International Injury Research Unit, Bloomberg School of Public Health, Johns Hopkins University, 615 North Wolfe Street, Baltimore, MD 21205, USA, [2]Department of Surgery, Virginia Commonwealth University Medical Center, 1200 East Broad Street, Richmond, VA 23298, USA, [3]University of Witwatersrand Faculty of Health Sciences, School of Public Health, 27 St Andrews Road, Parktown, Johannesburg 2193, [4]Medical Reserach Council, Wits Rural Public Health and Health Transitions Research Unit, School of Public Health, University of Witwatersrand, 7 York Road, Parktown 2193, Johannesburg, South Africa

*Corresponding author. International Injury Research Unit, Bloomberg School of Public Health, Johns Hopkins University, 615 North Wolfe Street, Suite E-8132, Baltimore, MD 21205, USA. E-mail: ahyder@jhsph.edu

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Introduction Injuries are a significant cause of mortality and morbidity, of which more than 90% occur in low- and middle-income countries (LMICs). Given the extent of this burden being confronted by LMICs, there is need to place injury prevention at the forefront of public health initiatives and to understand the costs associated with injury. The aim of this article is to describe the extent to which injury-related costing studies have been conducted in LMICs.

Methods A review of literature was performed to explore costing data available for injury and/or trauma care in LMICs. Study quality was described using recommendations from the Community Guide's quality assessment tool for economic evaluations.

Results The review identified 68 studies, of which 13 were full economic evaluations. Cost of injury varied widely with mean costs ranging from US$14 to US$17 400. In terms of injury-prevention interventions, cost per disability adjusted life year averted for injury-prevention interventions ranged from US$10.90 for speed bump installation to US$17 000 for drunk driving and breath testing campaigns in Africa. The studies varied in quality, ranging from very good to unsatisfactory.

Discussion There is a lack of injury-related economic evidence from LMICs. Current costing research has considerable variability in the costs and cost descriptions of injury and associated prevention interventions. The generalizability of these studies is limited. Yet the economic burden of injury is high, suggesting significant potential for cost savings through injury prevention. A standardized approach to economic evaluation of injury in LMICs is needed to further prioritize investing in injury prevention.

Keywords Injury, trauma, economic evaluation, costs, developing countries

KEY MESSAGES

- The economic burden of injury and trauma care is high in LMICs, suggesting significant potential for cost savings through injury prevention.
- A standardized approach to economic evaluation of injury in LMICs is needed to further prioritize investing in injury prevention.

Introduction

Injuries are a significant cause of mortality and morbidity, accounting for ~5.8 million or 10% of global deaths per year (World Health Organization, 2008). The magnitude of the burden of injury is alarming when compared to other diseases: there are 32% more deaths from injuries than from AIDS, tuberculosis (TB) and malaria combined (World Health Organization, 2008). More than 90% of these injury-related deaths occur in low- and middle-income countries (LMICs).

Given the extent of this burden being confronted by LMICs, there is need to place injury prevention at the forefront of public health initiatives. Yet this is not happening. Efforts to promote injury prevention have not received the attention and prioritization of diseases such as HIV/AIDS, TB and malaria. If injury mortality and morbidity data have failed to convince policy-makers to invest in injury prevention, there is a need to explore alternative ways to advocate for injury prevention. One approach is to consider the costs associated with injury and the cost-effectiveness of injury-prevention interventions.

Nearly half of injury-related mortality occurs in individuals aged 15 to 44 years during their most economically productive years (Nilsen *et al.*, 2006). This makes the financial burden of injuries far exceed the immediate medical costs associated with the injury. As such, more comprehensive injury-related cost studies that describe not only medical costs, but also those related to the consequences of injury to the individual, family and society, such as productivity losses, can be used to inform policies and interventions at the local and national levels.

In addition to describing the cost of injuries, there is also a need to describe the cost-effectiveness of injury-prevention initiatives. While a key first step in injury prevention requires obtaining evidence on the effectiveness of interventions, potential effectiveness is only part of a policy-maker's decision to invest in a prevention programme (Zaza *et al.*, 2005). With limited resources and competing health needs, the costs of an intervention in relation to the benefits must also be taken into account.

The increased use of cost calculations to implement injury-prevention efforts has been encouraged by the World Health Organization (WHO) and the Disease Control Priorities Project (DCPP) (World Health Organization, 2011a; Jamison *et al.*, 2006). While systematic reviews have explored the cost-effectiveness of injury prevention in high income countries (HICs), this represents less than 10% of the global burden of injury and conclusions drawn from reviews from HICs may not be transferable to LMICs (Gyllensvard, 2010; Waters *et al.*, 2004; Scuffham, 2008).

There is a need to review the literature in the context of LMICs; to the best of our knowledge, this has not previously been done. The aim of this article is thus to describe the extent to which injury-related costing studies have been conducted in LMICs. The specific objectives of this article are 3-fold: to summarize the body of economic evidence on injury in LMICs; to assess the quality of cost-effectiveness studies using standard methods to highlight the role of economic data as a tool for injury-prevention advocacy; and to provide recommendations regarding economic evaluations in LMICs.

Methods

We searched Medline/PubMed (National Library of Medicine, 2013), EconLit (American Economic Association, 2013), Econbase (Elsevier Inc., 2013a), Embase (Elsevier Inc., 2013b) the Cochrane Library (The Cochrane Collection, 2013) and the National Health Service Economic Evaluation Database (National Institute for Health Research, 2013) to identify articles published before February 2013 that pertained to costs associated with injury in LMICs using key words presented in the Appendix. Citations and reference lists were reviewed to identify any additional studies (Littell *et al.*, 2008). Since this was a review of published literature only, the 'grey' literature was not searched.

We assessed each study for inclusion using three criteria. First, included studies had to use costing data from LMICs. We defined a LMIC according to the World Bank's classification of a country with a gross national income per capita of less than US$12 195 in 2011 (World Bank, 2011). Second, studies had to describe either injuries, an injury classification (i.e. road traffic injures (RTIs), burns, falls, drowning and violence), or trauma care defined as pre-hospital and hospital-based trauma care services (World Health Organization, 2008). Third, studies had to use either a cost-related partial evaluation or full economic evaluation. We included cost-related partial evaluations in our review because they represent important initial work in LMICs to describe the economic burden of injury (Drummond *et al.*, 2005). These partial economic evaluations were grouped into four categories: 1) 'cost description' which examined only costs without a comparison to alternative outcomes; 2) 'cost analysis' which compared alternatives in terms of costs only; 3) 'cost-outcome description' which examined both costs and outcomes, but did not compare alternatives; and 4) 'outcome analysis' which compared alternatives in terms of outcome only (Drummond *et al.*, 2005). Full economic evaluations included cost-effectiveness analysis, cost-utility analysis and cost-benefit analysis (Drummond *et al.*, 2005).

Review articles, commentaries and editorials were excluded. Studies that did not report the currency unit for the reported costs were excluded. To avoid double counting, duplicate data presented in multiple publications were excluded; in these instances, the earlier publication was included. For the

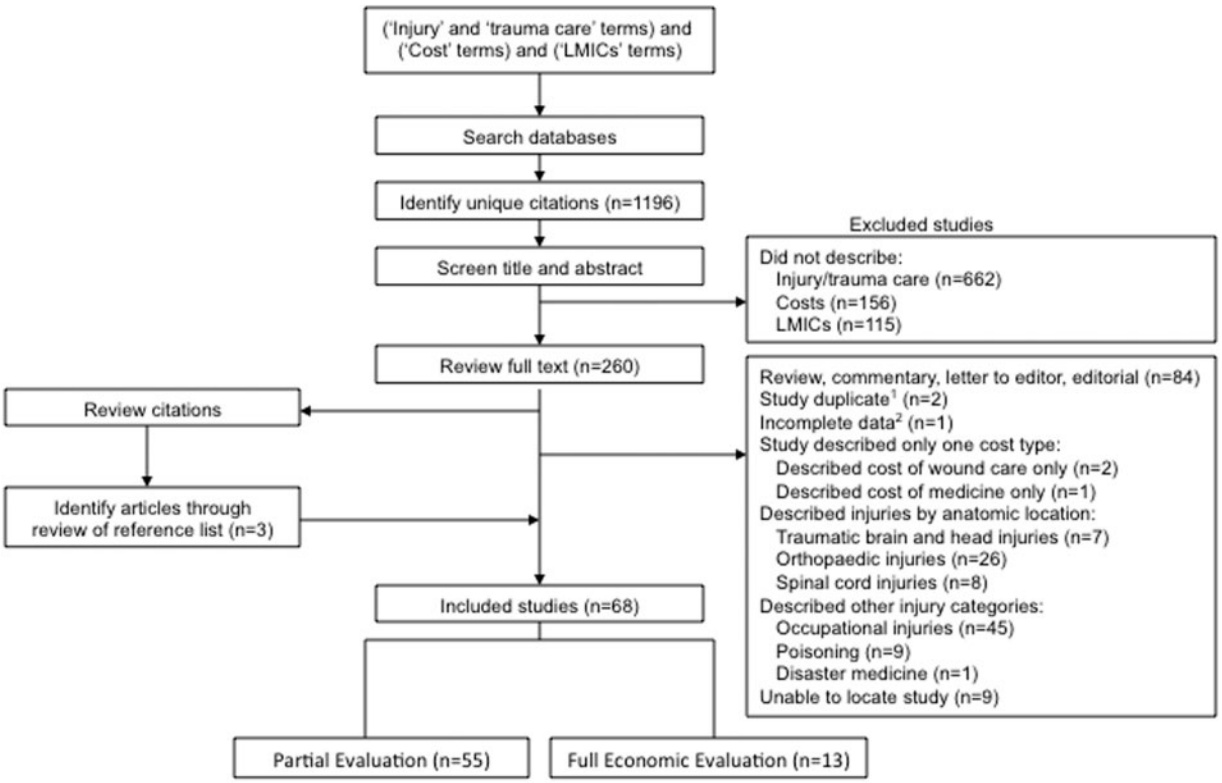
purposes of this review, we excluded poisoning, occupational injuries and disaster-related injuries given that the underlying causes of these injury classifications and the associated costs were too broad for the scope of this review. Injuries that were defined according to an anatomical location were excluded. This included head (including traumatic brain injuries), spinal cord and orthopaedic-related injuries. Studies that looked at only one type of cost, such as the cost of a particular dressing or wound care, were excluded as these costs were too narrow for this review.

Information regarding the study design and findings in terms of costs and outcomes was extracted and tabulated. To maximize comparisons among studies, we standardized costs when applicable. All costs were converted to US dollars (US$) for 2010 using gross domestic product (GDP) deflators and purchasing power parities (Shemilt *et al.*, 2009).

For partial evaluation studies, mean costs were reported in the units described by the individual study, such as the cost per hospitalization or the cost per injury. The cost per hospitalization differed from cost of injury depending on whether the study included costs that would be incurred outside of the injured patient's hospital admission. To describe this, the types of costs presented by the partial evaluation studies were tabulated into three categories: direct medical costs, direct non-medical costs and indirect costs. Medical costs are those costs incurred during the hospital inpatient stays, out-patient stays, hospital stay, medicine, surgery, emergency department visits, prostheses and wound-care dressings, radiological, laboratory and specialist consultation costs. Direct non-medical costs included administration costs (which included the medico-legal costs, cost administration, costs of police activity and insurance administration, funeral costs, transportation, non-medical material costs, and food and accommodation of the patient and/or family members. Indirect costs include loss of income, cost of premature death, pain and suffering and the cost of restricted activity (Drummond *et al.*, 2005).

We tabulated the median and range of reported mean costs for partial evaluation studies, describing this in terms of those studies that reported costs as (1) direct medical costs only, (2) direct medical and non-medical costs and (3) direct medical and non-medical costs and indirect costs. To further compare costs among partial economic studies, when applicable, costs were reported as a percentage of GDP per capita for 2010, as reported by the World Bank (World Bank, 2013).

For full economic studies, costs were reported in units of costs per disability-adjusted life year (DALY) averted, per death averted and per years of life gained, as defined by the individual study. We described the quality of these studies using recommendations from the Community Guide's quality assessment tool for economic evaluations (Community Guide, 2010). Of note, because this tool is designed for full economic evaluations, we did not apply the Community Guide to the partial evaluations. Quality was systematically assessed across five categories: study design, cost data, outcome measure, effects and analysis. A quality score was assigned to each study using the Community Guide quality assessment criteria. For full



[1] Denotes publications that used data from the same study. In these instances, the first publication was cited.
[2] Currency unit not reported, thus data could not be included

Figure 1 Literature review flowchart

Table 1 Partial evaluation studies of the costs of injuries, treatment and prevention in LMICs ($n = 55$)

Author, year	Study location	Study setting	Study sample	Outcome	Cost (US$ 2010)	Unit (mean cost per)	Cost as a % of GDP/ capita	Direct medical costs	Direct non-medical costs	Indirect costs
1. RTIs ($n = 25$)										
Cost description										
Jadaan, 1989	Jordan	Urban (one hospital)	N/A	N/A	$99	Per hospitalization	2%	X		
Arokiasamy and Krishnan, 1994	Malaysia	National	2354 fatal RTIs	N/A	$129 000	Per injury	1484%			X
Al-Masaeid *et al.*, 1999	Jordan	Urban and Rural	552 fatal RTIs	N/A	$4200	Per fatality	96%	X	X	X
Olukoga, 2004	South Africa	Urban and Rural	N/A	N/A	Minor: $3970	Per injury	55%	X	X	X
					Major: $14 800		200%			
					Fatal: $64 700		890%			
Anh *et al.*, 2005	Vietnam	National	26 925 RTIs	N/A	$8,770	Per injury	717%	X	X	X
De Leon, 2005	Philippines	National	N/A	N/A	Minor: $1560	Per injury	73%	X	X	X
					Major: $16 100		752%			
					Fatal: $75 900		3546%			
Hassan *et al.*, 2005	Kenya	Urban (one hospital)	136 RTIs	N/A	$140	Per hospitalization	18%	X		
Jianping *et al.*, 2006	China	Urban	420 RTIs	N/A	$720	Per hospitalization	16%	X		
Yan-Hong *et al.*, 2006	China	National	N/A	N/A	$766 million	Total RTI costs	N/A	X	X	X
Hung *et al.*, 2008	Vietnam	Urban	656 MCIs	N/A	$10	Per motorcycle helmet	1%	N/A		
Riewpaiboon *et al.*, 2008	Thailand	Urban (one hospital)	200 RTIs	N/A	$3000	Per hospitalization	65%	X	X	X
Reddy *et al.*, 2009	India	Urban (five hospitals)	95 RTIs	N/A	$23 100	Per hospitalization	35%	X	X	
Juillard *et al.*, 2010	Nigeria	Urban	127 RTIs	N/A	$28	Per injury	2%	X		X
Mashreky *et al.*, 2010	Bangladesh	Urban and Rural (16 hospitals)	7732 RTIs	N/A	$110	Per hospitalization	16%	X	X	
Perez-Nunez *et al.*, 2010	Belize	National	964 RTIs	N/A	$10 300	Per injury	254%	X	X	X
Kudebong *et al.*, 2011	Ghana	Rural	556 MCIs	N/A	$2220	Per injury	168%	X	X	X
Li *et al.*, 2011	China	Urban	550 bicycle injuries	N/A	$4330	Per injury	98%	X		X
Razzak *et al.*, 2011	Pakistan	Urban (five hospitals)	341 RTIs	N/A	$355	Per injury	35%	X	X	X
Perez-Nunez *et al.*, 2011	Mexico	Urban (four hospitals)	60 RTIs	N/A	$810	Per hospitalization	9%	X	X	X
Sangowawa *et al.*, 2011	Nigeria	Urban	44 MCCs	N/A	$75	Per injury	5%	X		X
Nguyen *et al.*, 2012b	Vietnam	Urban (one hospital)	477 RTIs	N/A	$363	Per injury	30%	X	X	X
Cost analysis										
Bishai *et al.*, 2003	Uganda, Pakistan	National	N/A	N/A	Uganda: $0.12	Per road safety	0.02%	N/A		
					Pakistan: $0.09		>0.01%			
Hendrie *et al.*, 2004[c]	8 LMICs[a]	Urban	Retail stores and internet vendors	N/A	Car seat: $100	Per safety device	N/A	N/A		
					Booster seat: $219					
					Bicycle helmet: $16					
Hijar *et al.*, 2004	Mexico	Urban (four hospitals)	233 RTIs	N/A	Uninsured: <$25	Per hospitalization	<0.3%	X	X	
					Insured: >$123		>1.3%			

(continued)

Table 1 Continued

Author, year	Study location	Study setting	Study sample	Outcome	Cost (US$ 2010)	Unit (mean cost per)	Cost as a % of GDP/ capita	Direct medical costs	Direct non-medical costs	Indirect costs
Outcome analysis										
Naci and Baker, 2008	Turkey	Urban	N/A	N/A	$360,571	Years of potential life lost	N/A	N/A		
2. Burn Injuries ($n = 12$)										
Cost description										
Nursal *et al.*, 2003	Turkey	Urban (one hospital)	109 burns	N/A	$6310	Per hospitalization	601%	X		
Mashreky *et al.*, 2008	Bangladesh	N/S (61 health facilities)	791 burns	N/A	$267	Per hospitalization	675%	X	X	
Kai-Yang *et al.*, 2009	China	Urban (one hospital)	178 paediatric burns	N/A	$1070	Per hospitalization	24%	X		
Ogundipe *et al.*, 2009	Nigeria	Urban (one hospital)	69 burns	N/A	$297	Per hospitalization	21%	X		
Yin *et al.*, 2010	China	Urban (one hospital)	201 elderly burns	N/A	$3860	Per hospitalization	87%	X		
Ahachi *et al.*, 2011	Nigeria	Urban (one hospital)	52 burns	N/A	$1390	Per hospitalization	96%	X		
Allorto *et al.*, 2011	South Africa	Urban (one hospital)	450 burns	N/A	$9800	Per hospitalization	135%	X		
Sahin *et al.*, 2011	Turkey	Urban (one hospital)	43 burns	N/A	$15 400	Per hospitalization	153%	X	X	
Alinia *et al.*, 2013	Iran	Urban (one hospital)	723 firework burns	N/A	$227	Per hospitalization	2%	X		
Cost analysis										
Hendrie *et al.*, 2004[c]	8 LMICs[a]	Urban	Retail stores and internet vendors	N/A	Smoke alarm: $61.8	Per safety device	N/A	N/A		
Cost-outcome description										
Zhou *et al.*, 2003b	China	Urban (one hospital)	40 burns treated with:	Plasma concentration		Per hospitalization		X		
			1. Glutamine	1. 591	1. $9200		207%			
			2. Control	2. 399	2. $10 100		228%			
Muangman *et al.*, 2010	Thailand	Urban	70 burns treated with:	Time to wound closure:		Per hospitalization		X	X	
			1. Siler sulfadiazine	1. 13.7 days	1. $94		2%			
			2. Aqualcel Ag	2. 10 days	2. $53		1%			
3. Injuries from Violence ($n = 4$)										
Cost description										
Mansingh and Ramphal, 1993	Jamaica	Urban (one hospital)	640 violent injuries	N/A	$36 to $56	Per hospitalization	0.7–1.1%	X		
Mendonca *et al.*, 2002	Brazil	Urban	9220 violent injuries	N/A	$285	Per hospitalization	3%	X		
Allard and Burch, 2005	South Africa	Urban (one hospital)	21 firearm injuries	N/A	$17,400	Per hospitalization	239%	X		
Ward *et al.*, 2009	Jamaica	National	8468 violent injuries	N/A	$59.2 million	Per injury	N/A	X	X	X

(continued)

Table 1 Continued

Author, year	Study location	Study setting	Study sample	Outcome	Cost (US$ 2010)	Unit (mean cost per)	Cost as a % of GDP/ capita	Direct medical costs	Direct non-medical costs	Indirect costs
4. Injury, not specified ($n=15$)										
Cost description										
Kaya *et al.*, 1999	Turkey	Urban (one hospital)	347 injuries	N/A	$2,190	Per hospitalization	209%	X		
McDonald *et al.*, 1999	Jamaica	Urban (one hospital)	22,311 injuries	N/A	$97	Per hospitalization	2%	X		
Zhao *et al.*, 2002	China	Urban (eight hospitals)	5876 injuries	N/A	$624	Per hospitalization	14%	X		
Gurses *et al.*, 2003	Turkey	Urban (one hospital)	91 paediatric injuries	N/A	$493	Per hospitalization	47%	X		
Thanh *et al.*, 2003	Vietnam	Urban and rural	1740 non-fatal unintentional injuries	N/A	$17	Per injury	1%	X	X	X
Mock *et al.*, 2003	Ghana	Urban and rural	1609 injuries	N/A	Urban: $38	Per injury	3%	X		
					Rural: $14		1%			
Li *et al.*, 2005	China	Rural	902 injuries	N/A	$1033	Per injury	23%	X	X	X
Melione and Mello-Jorge, 2008	Brazil	Urban (one hospital)	976 injuries	N/A	$188	Per hospitalization	2%	X		
Joshi and Shrestha, 2009	Nepal	Urban (six health centres)	505 injuries	N/A	$128	Per injury	24%	X		
Rodrigues *et al.*, 2009	Brazil	National	N/A	N/A	$868 million	Total cost of injury	N/A	X	X	X
Soyer *et al.*, 2009	Turkey	Urban (one hospital)	146 paediatric injuries	N/A	$169	Per emergency room visit	16%	X		
Bildik *et al.*, 2010	Turkey	Urban (one hospital)	118 injuries	N/A	$78	Per hospitalizaiton[b]	1%	X		
Plummer *et al.*, 2010	Jamaica	Urban	715 injuries	N/A	$357	Per hospitalization	7%	X		
Nguyen *et al.*, 2012a	Vietnam	Urban (one hospital)	892 injures	N/A	$366	Per injury	30%	X	X	X
Outcome analysis										
Zhou *et al.*, 2003a	China	National	N/A	N/A	$12.6 million	years of lost productivity	N/A	N/A		

RTI: road traffic injury; N/A: not applicable; N/S: not specified.

[a] Eight LMICs include: Albania, China, Philippines, Brazil, Thailand, Venezuela, Vietnam, and South Africa. As this study describes costs of both burn and RTI prevention, it is listed in both sections but counted once.

[b] Cost reported as median.

[c] Study listed twice under RTI and burn injury, respectively.

economic evaluation studies that did not require expert opinion, the respective categories were labelled as not applicable and the quality assessment score was adjusted to account for this. The score was then converted into ratings of very good, good, satisfactory and unsatisfactory. Following the Community Guide's recommendations that stipulate studies with an unsatisfactory score should be discarded, we assessed studies that achieved a score of satisfactory or higher to then determine if the intervention was cost-effective (Community Guide, 2010). For those studies that reported costs in terms of life year saved or DALY averted, the interventions were described as very cost-effective, cost-effective or not cost-effective using World Health Organization Choosing Interventions that are Cost Effective (WHO-CHOICE) guidelines. These guidelines define a 'very cost-effective' intervention as an intervention that produces a healthy year of life for less than the GDP per capita, a 'cost-effective' intervention as producing a health year of life for less than three times GDP per capita and a 'non-cost-effective' intervention as producing a health year of life for more than three times GDP per capita (World Health Organization, 2003).

Given the lack of generalizability among studies, we did not conduct a meta-analysis (Drummond and Pang, 2001). We used the results to summarize the strength of the body of the evidence regarding injury in LMICs and identify research gaps.

Table 2 Type of injury costs variables included in partial economic studies

Cost Variables	Partial economic studies ($n=49$)[a]
Direct medical cost ($n=48$)	
Hospital stay	21
Pre-hospital care	2
Emergency department visit	6
Surgical services	11
Specialist consultation	4
Rehabilitation/physical therapy	3
Out-patient follow-up	3
Wound care/prostheses	11
Laboratory investigations	8
Radiological investigations	9
Blood and blood products	2
Medicine	16
Not specified	25
Direct non-medical costs ($n=21$)	
Administrative	6
Transportation	10
Property damage	6
Food	5
Accommodation	5
Funeral cost	3
Not specified	4
Indirect costs ($n=21$)	
Income loss	15
Cost of premature death	8
Pain and suffering	3
Restricted activity (not work related)	2
Not specified	3

[a] Includes studies that reported unit cost as per injury, hospitalization and total injury.

Results

Sixty-eight of the initially identified 1196 unique citations met our inclusion criteria (Figure 1). Fifty-five studies were partial evaluations and 13 were full economic evaluations. Nearly half of partial evaluation studies were hospital based ($n=27/55$; 49%), of which the majority were single-centre studies ($n=21/27$; 78%). Fifteen studies described injuries in general; in terms of types of injury, the majority of studies described RTIs ($n=31/68$; 46%), followed by burn injuries ($n=11/68$; 16%). Six studies described trauma care, of which four described pre-hospital trauma care. While most studies were conducted in urban settings ($n=51$), used national data ($n=6$), or used data from both urban and rural areas ($n=8$), three studies were exclusively set in rural areas.

Partial evaluation studies included 48 cost description studies, two cost-outcome description studies, three cost-analysis studies, and two outcome analysis studies that focused on RTIs, burns, violence and injuries (Table 1). Costs were presented in units of cost per hospitalization ($n=30$ including one study of emergency room visits), cost per injury ($n=17$),

Table 3 Median and range of injury costs per hospitalization and per injury described by cost description studies ($n=41$; US$ 2010)[a]

Injury type	Direct medical costs per hospitalization			Direct medical and non-medical costs per hospitalization			Direct medical, direct non-medical, and indirect costs per injury		
	Studies (n)	Median cost (range)	Median cost as % of GDP (range)	Studies (n)	Mean cost (range)	Median cost as % of GDP (range)	Studies (n)	Median cost (range)	Median cost as % of GDP (range)
Injury (not specified)	9	$178.5 (14–2190)	11% (1–209%)	0	–	–	3	$91 (17–366)	16% (1–30%)
RTI	3	$140 (99–720)	16% (2–18%)	3	$117 (<25–23 100)	9% (<0.3–1680%)	10	$4200 (355–10 300)	98% (9–717%)
Burn	7	$1390 (227–9800)	87% (2–601%)	3	$181 (53–15 400)	21% (1–153%)	0	–	–
Violence	3	$ 285 (36–17 400)	3% (0.7–239%)	0	–	–	0	–	–
Total	**22**	**$291 (14–17 400)**	**15% (0.7–239%)**	**6**	**$125 (<25–15 400)**	**9% (<0.3–1680%)**	**13**	**$4085 (17–10 300)**	**97% (1–717%)**

[a] Excludes three studies that reported costs as a unit of total costs (Rodrigues *et al*., 2009; Ward *et al*., 2009; Yan-Hong *et al*., 2006), three studies that reported the costs of safety programmes or devices (Bishai *et al*., 2003; Hendrie *et al*., 2004; Hung *et al*., 2008), one study that reported only indirect costs (Arokiasamy and Krishnan, 1994) and two studies that reported only direct medical costs and indirect costs (Joshi and Shrestha, 2009; Juillard *et al*., 2010).

Table 4 Full economic evaluation studies of injuries and trauma care in low- and middle-income countries ($n = 13$)

Author, year	Study location	Study setting	Study sample	Intervention	Cost (US$ 2010)	Unit (Cost per)	Cost-effectiveness
1. Road traffic injuries (n = 6)							
Harris, 2005 (Harris and Olukoga, 2005)	South Africa	Urban	Model using data from 7567 injured patients	Seat belt enforcement	$17 400	Per death averted	N/A
Bishai, 2006 (Bishai and Hyder, 2006)	LMICs	Urban	Model using data from Bangladesh, Brazil, China, Ghana, and Philippines	1. Traffic enforcement	$78.8	Per DALY averted	Very cost-effective
				2. Speed bumps at locations that cause 25% of junction deaths	$10.9	Per DALY averted	Very cost-effective
				3. Motorcycle helmet legislation and enforcement	$575	Per DALY averted	Very cost-effective
Bishai, 2008 (Bishai *et al.*, 2008)	Uganda	Urban	Model using data from 10 police stations	Enhanced traffic enforcement	$30	Per life year saved	Very cost-effective
Pham, 2008 (Pham *et al.*, 2008)	Vietnam	Urban	414 households	Willingness to pay among 63% of respondents	$9.38	Per motorcycle helmet	N/A
Chisholm, 2012 (Chisholm and Naci, 2012)	AFRO, SERO	Urban and rural	Model	1. Speed cameras	AFRO: $4230; SERO: $5540	Per DALY averted	AFRO and SERO: Very cost-effective
				2. Drink-driving and breath testing campaigns	AFRO: $5670; SERO: $9530	Per DALY averted	AFRO and SERO: Cost-effective
				3. Seatbelt use[a]	AFRO: $11600; SERO: $8730	Per DALY averted	AFRO and SERO: Very cost-effective
				4. Motorcycle helmets[a]	AFRO: $17000; SERO: $5920	Per DALY averted	AFRO: Cost-effective; SERO: Very cost-effective
				5. Bicyclist helmets[a,b]	AFRO: $3130; SERO: $12800	Per DALY averted	AFRO: Very cost-effective; SERO: Cost-effective
Ditsuwan, 2013 (Ditsuwan *et al.*, 2013)	Thailand	Urban and rural	Model	1. Selective breath testing	$367	Per DALY averted	Very cost-effective
				2. Random breath testing	$403	Per DALY averted	Very cost-effective
				3. Mass media campaign	$291	Per DALY averted	Very cost-effective
				4. Selective breath testing with mass media	$353	Per DALY averted	Very cost-effective
				5. Random breath testing with mass media	$376	Per DALY averted	Very cost-effective

(continued)

Table 4 Continued

Author, year	Study location	Study setting	Study sample	Intervention	Cost (US$ 2010)	Unit (Cost per)	Cost-effectiveness
2. Drowning ($n=1$)							
Rahman, 2012 (Rahman *et al.*, 2012)	Bangladesh	Rural	76918 children in 3 rural regions	Drowning prevention programme including a preschool education system and a child swim programme	362	Per DALY averted	Very cost-effective
3. Pre-hospital trauma care ($n=4$)							
Hauswald, 1997 (Hauswald and Yeoh, 1997)	Malaysia	Urban	Model using data from 467 injury-related deaths	Development of pre-hospital system, based on a North American model	$596,000	Per death averted	N/A
Arreola-Risa, 2004 (Arreola-Risa *et al.*, 2004)	Mexico	Urban	20 pre-hospital providers	PHTLS training	$1020	Per death averted	N/A
Arreola-Risa, 2007 (Arreola-Risa *et al.*, 2007)	Mexico	Urban	35 pre-hospital providers	EMT training	$212	Per death averted	N/A
Jayaraman, 2009 (Jayaraman *et al.*, 2009)	Uganda	Urban	Model using estimates of 9000 lay first responders	Pre-hospital training	$1820	Per death averted	N/A
4. Hospital-based trauma care ($n=2$)							
Gosselin, 2008 (Gosselin and Heitto, 2008)	Cambodia	Urban (one hospital)	957 injured patients	Surgical care for traumatic injuries	$30	Per DALY averted	Very cost-effective
Gosselin, 2010 (Gosselin *et al.*, 2010)	Nigeria and Haiti	Urban (two hospitals)	6745 injured patients	1. Surgical care in Nigeria	$174	Per DALY averted	Very cost-effective
				2. Surgical care in Haiti	$226	Per DALY averted	Very cost-effective

AFRO: World Health Organization African Region; DALY: Disability-adjusted life year; EMT: Emergency Medical Technician; LMICs: Low- and middle-income countries; PHTLS: PreHospital Trauma Life Support; SEARO: World Health Organization South-East Asia Region

[a] Legislation and enforcement

[b] In children less than 15 years old.

cost per fatality ($n=1$), cost per safety intervention or device ($n=3$), years of potential life lost ($n=1$), years of lost productivity ($n=1$) and total cost of injury ($n=2$).

In terms of the breakdown of the costs of injury, of the applicable partial evaluation studies—excluding outcome analysis studies ($n=2$) and studies that reported the costs of safety devices ($n=4$)—all but one study ($n=48/49$) reported direct costs. Twenty-one studies (42%) reported direct non-medical costs and 21 other studies (42%) reported indirect costs. Sixteen studies (32%) reported all three types of costs. As shown in Table 2, costs included within these categories varied widely. For example, while 21 studies included the cost of hospital stay, two studies defined in terms of direct medical costs only as hospital stay, while five studies defined direct medical costs as hospital stay, surgical services, laboratory investigations and medicine. Twenty-five studies (51%) did not specify how direct medical costs were defined. Twenty-one studies (42%) reported indirect costs, of which six defined indirect costs as income loss only.

The range of injury costs per hospitalization and per injury varied widely (Table 3). Of the 22 studies that reported only direct costs per hospitalization, the median cost was US$291, but costs ranged from US$14 to US$17 400. The median cost as a percentage of GDP was 15%. In terms of specific types of injuries, the highest reported median direct medical costs were for burn injuries. Six studies reported direct medical and non-medical costs, ranging from less than US$25 to US$15 400. Thirteen studies reported direct medical, direct non-medical and indirect costs; the median cost of these studies was US$4085 or 97% of GDP per capita.

Three partial evaluation studies described the cost of safety interventions or devices, including road safety, car and booster seats, motorcycle and bicycle helmets, and smoke detectors, ranging from US$0.09 for a national road safety programme to US$219 for a booster seat.

Thirteen full economic evaluations explored costs associated with RTIs, drowning, and pre-hospital and hospital-based trauma care (Table 4). Some studies calculated cost per outcome using primary data ($n=6$) and others applied secondary data from other published studies to epidemiological models ($n=7$). Different units were used to describe effectiveness, including cost per death averted ($n=5$), cost per DALY averted ($n=6$), cost per life year saved ($n=1$) and willingness to pay ($n=1$). Costs per death averted ranged from US$30 for enhanced traffic enforcement to US$596 000 for a citywide pre-hospital system based on a North American emergency response model. The cost per DALY averted from injury-prevention interventions ranged from US$10.9 for speed bump installation to US$12 800 for legislation and enforcement of motorcycle helmets in the WHO's African (AFRO) region. In terms of hospital-based surgical care for trauma victims, costs ranged from US$30 to US$226 per DALY averted in Cambodia and Haiti, respectively.

Based on the Community Guide's criteria, two full economic evaluation studies were unsatisfactory in their methods to explore the costs associated with injuries (Table 5). Of the studies that achieved a rating of satisfactory or greater and reported costs per DALY averted, the level of cost-effectiveness was described ($n=7$; Table 4). These studies show many interventions to be very cost-effective, such as legislation and enforcement of bicycle helmets in the AFRO region, speed bumps at junctions with 25% or more mortality, and surgical trauma care in Cambodia, Nigeria and Haiti.

Table 5 Quality assessment of full economic studies on costs of injury in LMICs[a]

Quality indicator	Full economic evaluation ($n=13$)		
	Described	Not described	Not applicable
Study design			
Study population	12	1	–
Study question(s)	13	–	–
Alternative interventions	7	6	–
Study perspective specified	6 (7 inferred)	–	–
Societal perspective specified	4 (3 inferred)	6	–
Time frame defined	12	1	–
Analytic horizon defined	3	10	–
Costs			
Data sources reported	12	1	–
Data sources appropriate	10	3	–
Quantities of resources reported	13	–	–
Programme costs included	9	4	–
Cost of illness included	6	7	–
Future costs discounted	7	6	–
Price base-year reported	11	2	–
Outcome measures			
Outcome measures specified	13	–	–
Outcome measures consistent	11	2	–
Future outcomes discounted	6	7	–
Outcomes included other effects	6	7	–
Effects			
Effect information provided	13	–	–
Criteria reported	6	7	–
Expert opinion appropriate	1	–	12
Analysis			
Analytical model reported	10	3	–
Sensitivity analysis of discounted rate	6	7	–
Sensitivity analysis of effect size	10	3	–
Sensitivity analysis of any other parameter	8	5	–
Summary measure used correctly by study	9	4	–
Rating			
Very good		5	
Good		1	
Satisfactory		5	
Unsatisfactory		2	

[a] Based on the *Community Guide* Quality Assessment Criteria.

Discussion

Our study found that there are a relatively significant number of studies that have explored the cost of injury or the cost of hospitalizations from injury in LMICs. Yet only 13 studies performed full economic evaluations in 14 of 144 LMICs as classified by the World Bank. It is difficult to generalize the costs of injury at a regional or global level, as the currently available data are country and context-specific and heterogeneous in their definitions of costs.

Our review showed LMIC injury-related costing research may not reflect the distribution of the burden of injury across regions and injury type. For example, only 12% of the studies included in our review were conducted in Southeast Asia, although the region accounts for 36% of injury-related deaths among LMICs (Figure 2) (World Health Organization, 2008). Conversely, 28% of studies were conducted in the Western Pacific Region although the region accounts for only 18% deaths from injury. In terms of injury type, only 4 of 68 studies examined the costs associated with intentional injuries, although they make up 26% of DALYs lost to injuries in LMICs (World Health Organization, 2008). In terms of demographics, only three studies used primary data collected from a rural setting, despite estimates that more than half of people in LMICs live in rural areas (The World Bank, 2012). Some studies set in urban referral hospitals may have captured injuries that occur in rural areas given the nature of referral hospitals, but this was not been specifically studied.

Unfortunately, a lack of representative data is not limited to these studies; even data from the WHO are limited. For example, estimates from the WHO on injuries per DALY for LMICs show that of the 144 LMICs, 74 countries (52%) lacked complete, country-specific data for these calculations, and therefore used modelled estimates (World Health Organization, 2011b).

In addition to gaps in data collection, our review found considerable variability in the costs and cost descriptions of injury. Costs and outcomes were often not reported nor measured in a systematic way. As there are no standard definitions for direct medical, direct non-medical and indirect costs, studies were left to their own discretion to decide which cost variables to include. Some studies did not even describe which cost variables were included in their estimates. This limits the ability to generalize costs across studies.

In addition to the limitations of the reported data, our review was limited in that we only searched published literature; additional costing studies may be available among the grey and unpublished literature. The study was further limited in that our search was conducted using English-language-based databases.

Despite these limitations, the economic burden of injury is indisputable. As shown in our review, the median cost of direct medical costs from injury was US$291 or 15% of GDP per capita. This estimate increased 14-fold to US$4085 or 97% of GDP per capita when studies included direct medical, direct non-medical and indirect costs. This shows not only the devastating financial impact of injury, but also the need to invest in injury prevention. Yet in a time of global budget constraints and competing social sector priorities, policy-makers and public health planners are increasingly faced with having to maximize available resources, and cost-effectiveness of interventions or programmes often comes into play.

Our review showed encouraging findings among the cost-effectiveness studies that achieved a quality-assessment rating of satisfactory or higher: many interventions could be cost-effective or very cost-effective in decreasing the burden of injury. These interventions include traffic enforcement, installation of speed bumps, motorcycle helmet legislation, breath testing campaigns and drowning prevention programmes. The provision of surgical care was also shown to be very cost-effective, suggesting a significant potential for cost savings through injury prevention and trauma care. Care, however, should be used when generalizing these interventions to national, regional and global contexts. This is also important as seven studies adopted a societal perspective and six used a provider perspective, highlighting heterogeneity among the

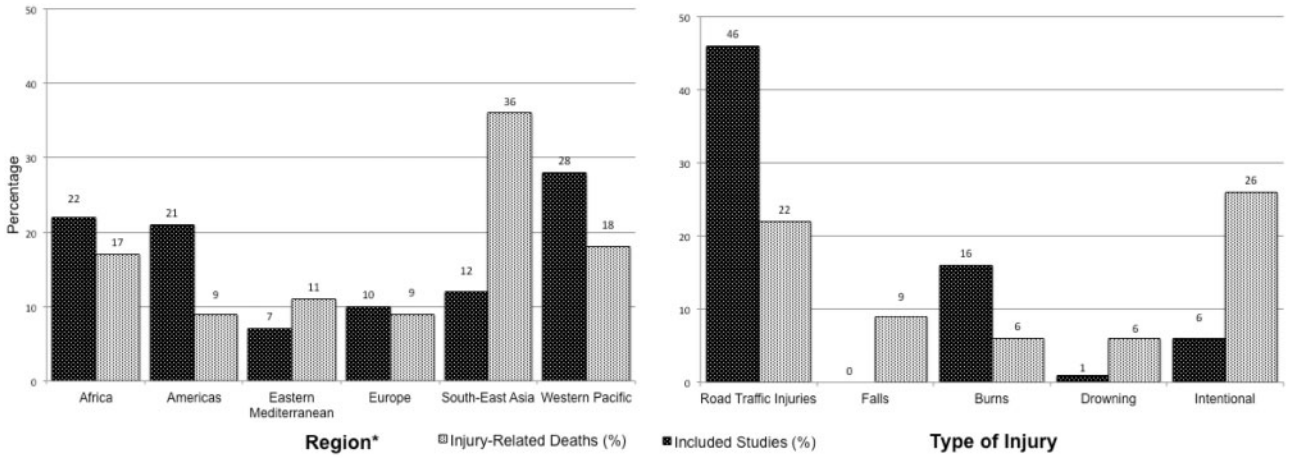


Figure 2 Comparison between the number of papers published on costs of injury in LMICs (%) and injury-related deaths in LMICs by region and type of injury[1]
Source: WHO, Global Burden of Disease 2004 Update.
[1]As a percentage of total injuries
*Region defined using WHO classification

costs included in each study. This concern is not unique to our review and prior literature has explored why results from economic studies may not be reproducible in different settings and times (Drummond and Pang, 2001; Sculpher *et al.*, 2004).

Costs are often considered the 'tie-breaker' when decisions are made regarding how and where to prioritize health interventions. To make an impact in the future, we need to better understand the costs of injury and injury prevention in LMICs. Through multi-sectoral collaboration with Departments of Health, Transport and other stakeholders, injury prevention advocates in LMICs can generate economic data to advocate for greater investments in injury prevention. This may finally enable injury prevention to be placed on regional, national and district policy agendas.

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Conflict of interest

None declared.

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