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Safety of young children on motorized two-wheelers around the world: A review of the global epidemiological evidence

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ABSTRACT

The safety of children younger than 10 years on motorized two-wheeled vehicles (MTWs) in low- and middle-income countries receives substantial attention from global road safety advocates. However, there is little empirical evidence available to describe the magnitude of the problem. Therefore, we constructed a population-level database of road traffic injury statistics disaggregated by age (<5, 5–9, 10+ years) and mode of transport. Our database included mortality data from 44 countries and 5 Indian cities, and hospital admissions from 17 countries. The MTW fleet in these settings ranged from 2% to 70% of all registered vehicles. We find that children under 5 years averaged 0.05% (SD 0.13%) of all road traffic deaths, and 5–9 year olds averaged 0.11% (SD 0.25%). Even in regions with high prevalence of MTWs, young children comprised at most 1.5% of all road traffic deaths and 5.8% of all MTW deaths. Young children were a slightly larger proportion of all road traffic deaths in countries where MTWs were more common. However, after adjusting for population age structure, this effect was no longer evident. The percentage of child road traffic injuries that are due to MTWs increased with increasing MTW use, but at a much lower rate. Our findings suggest that children may be at lower risk from MTW crashes than previously assumed, and certainly at a lower risk than as pedestrians. Further studies are needed to explain the underlying mechanisms that regulate risk of road users.

1. Introduction

There appears to be near unanimous consensus among global road safety advocates that the safety of young children on motorcycles in low- and middle-income countries is of grave concern. Thus, a recent World Health Organization (WHO) report to the Ministry of Transport of Vietnam advises, "WHO encourages adults not to transport children on motorcycles unless absolutely necessary. If this is the case, then both WHO and UNICEF promote the use of standardized, correctly fitted, helmets for children as a harm reduction strategy." [1] (Bold in original) Similarly, a report from the WHO South East Asia Regional Office recommends, "Governments at the national, provincial and municipal levels should consider policies … that would obviate the need for transporting children on motorcycles" [2].

These policy statements are primarily referring to infants and children younger than 10 years (hereafter referred to as "young children") who are often transported as passengers on motorized two-wheeled vehicles (MTWs) in many parts of the world. Anecdotal mentions of such use of MTWs have been reported from South, East, and Southeast Asia [1,2] (including Malaysia [3] and Vietnam [4]), sub-Saharan Africa (including Cameroon [5] and Uganda [6]), North Africa and the Middle East (including Iran [7]), Latin America (including Brazil [8]), among others. MTW riders are inherently vulnerable in crashes because, unlike most motor vehicles, MTWs do not have a steel protective shell. Head injuries are the most common cause of death in MTW crashes. Therefore, the promotion of helmet use has been a primary thrust of MTW safety policy worldwide [9]. Unfortunately, providing protective head gear for infants is difficult for several reasons, including the fact that the size and shape of the human head evolve rapidly during the first four years of life [10]. Although helmets exist for older children (aged 5–10) for different purposes, helmet use in this age group of MTW riders is relatively rare in most of the world [2,11]. Therefore, it is natural that road safety advocates worry about the vulnerability of young children in MTW crashes.

However, despite the apparent importance of the issue and the strong public positions taken by international agencies, there is surprisingly little empirical evidence supporting the urgency of addressing the safety of children on MTWs. Public debates related to the health of children usually inspire strong emotions and a tendency to view issues as a matter of values that are so fundamental that they are beyond rational debate [12]. Thus, advocates for the safety of children on MTWs have

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Table 1
Global vehicle and motorized two-wheeler (MTW) fleet in 2010.

Global region	Population (1000s)	Fleet			Ownership (per 1000 people)	
		Vehicles (1000s)	MTWs (1000s)	MTWs (% of veh)	Vehicles	Motorcycles
Southeast Asia	612,705	171,133	129,224	76	279	211
South Asia	1,628,745	126,398	88,869	70	78	55
East Asia	1,363,753	211,958	104,412	49	155	77
Western Sub-Saharan Africa	339,896	18,118	6746	37	53	20
Caribbean	27,962	7425	2674	36	266	96
Andean Latin America	53,078	5105	1546	30	96	29
Tropical Latin America	207,069	65,737	16,746	25	317	81
Southern Latin America	62,103	18,826	4716	25	303	76
North Africa & Middle East	402,319	74,426	17,306	23	185	43
Eastern Sub-Saharan Africa	342,560	4925	921	19	14	3
Central Latin America	231,953	47,985	6781	14	207	29
Western Europe	425,264	271,574	28,615	11	639	67
Eastern Europe	209,827	65,604	4845	7	313	23
Central Europe	118,070	50,547	3509	7	428	30
High Income Asia Pacific	186,282	110,877	6906	6	595	37
Australasia	26,170	19,288	773	4	737	30
Southern Sub-Saharan Africa	68,589	11,564	430	4	169	6
High Income North America	354,776	280,345	8525	3	790	24
Central Sub-Saharan Africa	93,636	791	16	2	8	0
Central Asia	47,448	11,017	154	1	232	3
Oceania	2041	552	6	1	271	3
Grand total	6,804,247	1,574,198	433,719	28	231	64

Countries are grouped into GBD-2010 regions [25].
Regions are sorted by proportion of vehicle fleet that is MTWs.

had a tendency to frame facts as "everybody knows" without supporting empirical evidence.

The goal of our study is to review the empirical evidence on the safety of young children on MTWs globally. In particular, we focus on a cluster of questions that affect public policy:

- Are young children more vulnerable than adults in MTW crashes and do children require additional safety considerations?
- Are MTW crashes an important risk factor for child health around the world? Should public health professionals focus special attention on the issue?
- Are child MTW passengers a large proportion of road traffic deaths around the world? Does the road safety community need to focus special attention on the issue?
- Do countries with more MTWs have higher child road traffic death rates? Should transport planners steer societies away from developmental trajectories that involve large MTW fleets?

In this paper, we summarize the literature on what is known about the biomechanical tolerance of young children to impact forces, and briefly review the global burden of road traffic injuries among young children. We develop a database of population-level MTW and road traffic injury statistics and explore the epidemiological evidence related with MTW injuries among young children in countries across global regions.

1.1. Biomechanics of injuries in young children

Despite large advances in knowledge about human injury tolerance, the vulnerability of children relative to adults remains poorly understood. Over the last century, substantial efforts have been directed at studying the capability of the human body to withstand external forces and accelerations. The body regions most vulnerable in MTW crashes (head, torso, and extremities) are commonly involved in many other types of injury events and have been a central focus of many biomechanical investigations. Studies have focused on analyzing real-world injury incidents, conducting experiments on human volunteers, animals, and cadavers, and developing and validating mechanical and computational models. Among these, cadaver experiments have been particularly important because they can be subjected to injury-inducing forces and have proven especially useful for understanding the response of adult hard tissue. However, child cadavers have been rarely used for biomechanical research due to ethical and logistical constraints [13].

Children are not miniature adults from a biomechanical standpoint. Human body segments grow at different rates during childhood leading to large differences between the relative geometric and inertial properties of children and adults [14]. For instance, the infant head is 25% of its standing height but the adult head is only 11% [15]. The infant head reaches 90% of the size of the adult head by the age of four [10]. Similarly, the mechanical properties of human tissue evolve considerably during childhood [16–18]. Experiments on human tissue suggest that the elastic and viscous components of the complex shear modulus (a measure of how much the tissue distorts during impact) of frontal brain tissue increases significantly with age affecting the mechanical response of the brain to impact forces [17]. Furthermore, the frontal bone of the skull in infants consists of two halves that are connected by a dense connective tissue (suture) that fuses by the age of six. Since sutures have a much lower elastic modulus, the pediatric skull case can undergo large shape changes without permanent injury [16]. Nevertheless, the empirical evidence on age-dependent mechanical characteristics of skull and brain tissue is still weak, and it remains unclear if children are more or less vulnerable to head injuries than adults. The biomechanics of the neck, thorax, and extremities of children is similarly poorly understood [13].

In practice, therefore, injury thresholds used in the design and development of protective equipment, such as helmets, are based on the biomechanical tolerances of adults. The benchmark for estimating the probability of head injuries is the head injury criteria (HIC), which uses a time-averaged weighted integral of linear acceleration measured at the center of gravity of the head [19]. Helmet test standards use methods that are even simpler. The US design standard for motorcycle helmets (FMVSS 218) requires that accelerations never exceed 400 g and do not exceed 200 g for more than 4 ms during a guided free fall of a helmeted head-form from a height of 1.8 m [20]. Other agencies require similar tests with peak accelerations limited to 275–300 g [20]. There have been substantial efforts to adapt these testing methods to the needs of child helmets but there is relatively little consensus on key test parameters, such as the mass of the test head-form and acceleration thresholds for injury [21].