Road Traffic Crashes Among Motorized Two-Wheeler Riders in Low- and Middle-Income Countries: Epidemiology and Risk Factors, With a Focus on Morocco.

Abstract:

Motorized two-wheeler (MTW) riders are among the most vulnerable road users worldwide, and low- and middle-income countries (LMICs) bear a disproportionate share of the resulting deaths and injuries. This review synthesizes epidemiological evidence on MTW-related road traffic crashes across world regions, with a focused analysis of Morocco, where national crash and fatality counts have risen year-on-year since 2022. Drawing on World Health Organization statistics alongside country-level studies from the Americas, Asia, Europe, and Africa, we document a consistent pattern: MTW riders account for a rising and disproportionate share of road deaths, particularly in rapidly motorizing LMICs where infrastructure, enforcement, and post-crash care have not kept pace with the growth of two-wheeler use. In Morocco specifically, National Road Safety Agency (NARSA) data show injury crashes rising from 113,625 in 2022 to 142,247 in 2024, with two- and three-wheeler users now accounting for more than 40% of road deaths. We organize the risk factors identified across this literature into four domains: human factors (inexperience, speeding, alcohol and drug use, distraction), environmental factors (weather, lighting, road design, urban/rural context), vehicle and mechanical factors, and safety equipment use, with helmet non-use emerging as a recurring and modifiable contributor to fatal head injury across nearly every country reviewed. We conclude by discussing policy implications specific to Morocco's context and the methodological limitations of the underlying evidence base, including data-quality concerns common to LMIC crash-reporting systems.

Keywords: motorized two-wheeler riders; road traffic injury; epidemiology; risk factors; low- and middle-income countries; Morocco

1.Introduction

Road traffic injury kills an estimated 1.19 million people every year and is the leading cause of death worldwide for people aged 5 to 29 (World Health Organization [WHO], 2023). Within this toll, riders of powered two- and three-wheelers are consistently among the most vulnerable road users: they account for roughly one-fifth of all road traffic deaths globally, and nine in ten of these deaths occur in low- and middle-income countries (LMICs), where the pace of motorization has outstripped the development of road infrastructure, vehicle-safety regulation, and emergency and rehabilitative care (WHO, 2023). Unlike in many high-income countries, where motorcycling is often a recreational or lifestyle choice, motorized two-wheelers (MTW) in most LMICs function as essential, affordable transport for commuting, informal-sector commerce, and delivery work ; a structural role that shapes both how widely they are used and how difficult it is to regulate or restrict their use (Job &Wambulwa, 2020).

Morocco illustrates this pattern clearly. The country's National Road Safety Agency (Agence Nationale de la SécuritéRoutière, NARSA) has recorded a rising trend in both crash frequency and fatality counts since 2022, and riders of two- and three-wheeled vehicles now make up a growing

share of the country's road deaths. Yet despite this trend, peer-reviewed epidemiological research specifically on MTW crashes in Morocco remains sparse relative to the scale of the problem, and much of what is known nationally is documented in institutional reports rather than the international academic literature.

This review has three aims. First, we synthesize the international epidemiological literature on MTW-related road traffic crashes, organized by world region, to establish the global and comparative context within which Morocco's situation sits. Second, we present a focused, detailed account of the available epidemiological data on MTW crashes in Morocco specifically, drawing on national statistical reports. Third, we synthesize the risk factors identified across this literature into four recurring domains :human, environmental, vehicle-related, and safety-equipment-related and discuss which of these appear most directly relevant, and most amenable to intervention, in the Moroccan context specifically.

2. Methodology

2.1 Review Design

This study employed a narrative synthesis approach to review the epidemiological evidence on motorized two-wheeler (MTW) road traffic crashes, with a focused analysis on Morocco. A narrative synthesis was selected over a systematic review or meta-analysis for three reasons: (1) the underlying literature is highly heterogeneous in terms of study design (police-recorded statistics, hospital case series, toxicological analyses, and cross-sectional surveys), case definitions, reporting periods, and population denominators, making quantitative pooling methodologically inappropriate; (2) the review aimed to describe and compare patterns across diverse world regions rather than generate a single pooled effect estimate; and (3) the inclusion of institutional reports and gray literature (particularly from Morocco's National Road Safety Agency) was essential to capture the full scope of available evidence, given the limited peer-reviewed literature in some settings.

2.2 Search Strategy

A targeted literature search was conducted between January 2025 and July 2025 across the following electronic databases:

- PubMed/MEDLINE
- Scopus
- Web of Science
- Google Scholar (for gray literature and institutional reports)
- WHO IRIS (World Health Organization Institutional Repository for Information Sharing)

The search strategy combined keywords from three thematic clusters:

Theme	Search Terms
Population	"motorized two-wheeler" OR "motorcycle" OR "motorbike" OR "powered two-wheeler" OR "moped" OR "scooter" OR "three-wheeler*"
Outcome	"road traffic crash" OR "road traffic accident" OR "traffic collision" OR "road traffic injury"

	OR "road traffic death" OR "fatal" OR "mortality"
Context	"low- and middle-income country" OR "LMIC" OR "developing country*" OR "Morocco" OR "North Africa" OR "MENA" OR "Africa" OR "Asia" OR "Americas"

Boolean operators (AND/OR) were applied to combine terms within and across clusters. No date restrictions were applied to maximize coverage of foundational studies, though priority was given to literature published from 2000 onward to reflect contemporary epidemiological patterns. Reference lists of included studies and relevant review articles were also hand-searched for additional citations (citation tracing).

2.3 Inclusion and Exclusion Criteria

Studies were included if they met the following criteria:

Inclusion Criteria:

• Peer-reviewed original research, systematic reviews, or institutional reports presenting epidemiological data on MTW-related road traffic crashes

• Reported on at least one of: crash incidence, mortality, injury severity, or risk factors among MTW riders

• Conducted in a low- or middle-income country (as defined by the World Bank classification at the time of the study) OR provided regional data that included LMICs

• Published in English, French, or Arabic

• Available in full text

Exclusion Criteria:

• Studies limited exclusively to high-income country settings without relevance to LMIC comparisons

• Opinion pieces, editorials, or commentaries without primary data

• Studies focused solely on non-motorized two-wheelers (bicycles) or four-wheeled vehicles

• Conference abstracts without sufficient methodological detail

• Duplicate publications

2.4 Data Extraction and Synthesis

From each included study or report, the following information was extracted when available:

• Author(s), year, and country/region

• Study design and data sources (police records, hospital data, death registries, surveys)

• Study period and sample size

• Key epidemiological measures (crude crash counts, mortality rates, proportion of road deaths attributable to MTW riders, injury patterns)

• Risk factors examined and their associations with crash occurrence or severity

• Helmet use rates and enforcement context

Extracted data were organized using a structured data-charting form developed for this review. Given the narrative synthesis design, findings were grouped thematically by world region (Sections 3.2–3.6) and then by risk factor domain (Section 5), following the framework adapted from Lin and Kraus (2009) and expanded to include environmental and vehicle-related factors. This framework was chosen because it has been widely used in motorcycle injury research and provides a clear, policy-relevant structure for organizing diverse evidence.

2.5 Moroccan Data Sources

For the Morocco-specific analysis (Section 4), data were obtained from:

• NARSA (Agence Nationale de la SécuritéRoutière): Annual road-safety barometers, technical fact sheets, and provisional indicator reports for 2022–2024

• WHO Global Status Report on Road Safety (2023): For comparative mortality estimates

• Ministry of Health, Morocco:Cross-referenced mortality registry data where available

These institutional sources were prioritized because peer-reviewed epidemiological research on MTW crashes in Morocco remains sparse, and NARSA represents the most complete national data repository available.

2.6 Quality Considerations

Systematic quality appraisal was not performed because of the heterogeneity of study designs and the inclusion of institutional reports without standardized quality metrics. However, the following quality-relevant characteristics were noted for each source where available:

• Data source (police vs. hospital vs. vital registration)

• Reporting completeness (whether underreporting was discussed)

• Study period and sample representativeness

• Case definition clarity

These considerations are reflected in the limitations discussion (Section 8) and in the narrative treatment of data reliability throughout the text (e.g., Section 4.1, Section 6).

3. Global and Regional Epidemiology of MTW-Related Crashes

3.1 Global burden

Road traffic injury has been recognized by the WHO as a leading global public health concern for over a decade, and projections have long suggested that, absent stronger intervention, it would climb rather than fall in the ranking of causes of death worldwide (Toroyan, 2009). Riders of powered two- and three-wheelers bear a disproportionate share of this burden: earlier WHO-based estimates placed motorcyclists at around one-quarter of global road deaths, with a per-kilometer fatality risk many times higher than that of car occupants (Ncube et al., 2016), and the most recent WHO data confirm that this group still accounts for roughly one-fifth of all road deaths worldwide, concentrated overwhelmingly: approximately 90%, in LMICs (WHO, 2023). This concentration is not incidental: rapid, under-regulated motorization, the affordability of two-wheelers relative to cars and public transport, and road-safety governance that has not kept pace with vehicle-fleet growth are recurring explanations across the regional literature reviewed below (Job &Wambulwa, 2020; Rodrigues et al., 2013).

3.2 The Americas

In the Americas, fatality trends associated with two-wheeled vehicles rose substantially over the 2000s and 2010s, with the steepest increases documented in the Andean sub-region, particularly Ecuador, and in Meso-America, where Costa Rica recorded a 60% rise in motorcyclist deaths over the period studied (Rodrigues et al., 2013). That analysis linked these regional increases to accelerating motorization, the relative affordability of motorcycles compared with cars or public transport, and road-safety policy that had not adapted to the growing two-wheeler fleet, noting that poorer and more unequal countries within the region fared worse on motorcyclist mortality specifically.

3.3 Asia

Asia hosts some of the highest motorcycle-fatality burdens documented anywhere, disproportionately affecting young men and frequently linked to weak helmet-law enforcement (Manan & Várhelyi, 2012; Oxley et al., 2013). Cambodia recorded the highest motorcyclist mortality rate in Southeast Asia, with deaths per registered motorcycle rising roughly 30% between 2007 and 2011, speed-related crashes accounting for close to half of these deaths, and more than 80% of fatalities involving unhelmeted riders (Roehler et al., 2014). In Vietnam, motorcyclists and their passengers account for approximately 53% of road deaths (Luot et al., 2020), while in Malaysia (which records the highest road-mortality risk in the ASEAN region) motorcyclists represent over half of all road fatalities, young men aged 16 to 20 are especially overrepresented, and most crashes involve angular or lateral collisions in which the motorcyclist is often found responsible (Manan & Várhelyi, 2012; Oxley et al., 2013).

Iranian data covering 2011–2017 found that motorcyclists accounted for over 23,000 of some 122,000 total road deaths, with male riders vastly overrepresented, the highest mortality among 18 to 24-year-olds, head trauma as the leading cause of death, and helmet use recorded in only 37.4% of fatal cases (Barzegar et al., 2020). In India, a study of single-vehicle motorcycle crashes in Tamil Nadu between 2009 and 2017 recorded over 16,000 crashes and more than 7,000 deaths, disproportionately among men aged 26–64, with roughly a third of victims lacking a valid driving licence and head trauma the most common fatal injury (Sivasankaran et al., 2021); a separate autopsy-based study in South Delhi found that motorcyclist deaths accounted for over 5% of all autopsy cases, again concentrated among young men, with heavy vehicles involved in around a third of fatal collisions and helmet use recorded

in barely half of cases (Subhashini, 2019). In Thailand, motorcyclists account for up to 84% of road deaths and the country records among the highest motorcyclist mortality rates in the world, with the associated economic costs (medical care, lost productivity, disability) estimated at roughly three times the country's motorcycle export revenues over a recent three-year period (Kanitpong et al., 2024; Santikarn et al., 2022).

3.4 Europe

European road deaths overall have declined over the past two decades, but MTW-related mortality has not followed the same trajectory and has risen in several countries even as the aggregate trend improved; by the mid-2010s, powered two-wheelers accounted for roughly 18% of all EU road deaths, and vulnerable road users (including cyclists) collectively accounted for nearly half (A. Morris et al., 2018; A. P. Morris et al., 2018). Germany saw a substantial overall decline in road deaths over twenty years, alongside a shift in the relative injury burden between motorcyclists and car occupants (Koch et al., 2023). In France, MTW-related deaths fluctuated considerably from the mid-1990s onward, including a marked rise around the mid-2000s, with the most common fatal scenarios involving either head-on collisions during opposing left turns or single-vehicle loss-of-control crashes in bends (Shankar & Varghese, 2006). In Italy, the metropolitan Milan area recorded a substantial rise in MTW-related deaths between 2001 and 2012, with motorcyclists eventually recording the highest mortality of any vehicle-occupant category and multiple-system trauma the leading cause of death (Amadasi et al., 2015), while stronger enforcement of road-safety law and mandatory helmet use on motorway sections contributed to a decline in fatal crashes on Italian motorways between 2001 and 2013 even as urban hotspots like Milan remained a concern (Torre et al., 2015). Greece recorded over 800 road deaths annually between 2012 and 2016, a substantial share involving two-wheelers, placing it among the highest-mortality EU member states for this user group (Anagnostou & Cole, 2020) ,a pattern plausibly linked, as in Turkey, to rising motorcycle sales outpacing safety adaptation (Öztürk & Eken, 2009).

3.5 Sub-Saharan Africa

Across Africa, road traffic injury is a major public-health problem disproportionately affecting vulnerable road users, including pedestrians, cyclists, and MTW riders, a pattern worsened by rapid motorization, poor road infrastructure, weak enforcement, and limited access to emergency care (Toroyan, 2009). In Ghana, MTW-related crashes account for roughly a third of all road accidents, with 2020 alone recording over 1,000 deaths and nearly 4,700 injuries, a situation compounded by the growing and often unregulated use of motorcycles for commercial transport, disproportionately affecting people aged 15–29 (Marnah&Manortey, 2022); hospital-based data from Kumasi's Komfo Anokye Teaching Hospital similarly show road-crash trauma forming a substantial share of emergency caseload with significant economic implications (Biney et al., 2013). In Tanzania, MTW-related crashes rose markedly across the 2010s, with Dar esSalaam alone reporting that motorcycle crashes account for 40% of all road accidents in the capital (Kinyaga, 2022). In Ethiopia, motorcycle crashes accounted for 55% of road-crash injuries at a major hospital, again concentrated among men aged 20–29 (Oltaye et al., 2021), while in Benin, MTW collisions (frequently with trucks or pedestrians and disproportionately fatal at night) contributed to one of the highest road-mortality rates in the region,

with over 1,600 crashes and 62 deaths recorded in urban areas during 2016–2017 (Agossou et al., 2020).

3.6 North Africa and the Middle East

The North Africa and Middle East region, commonly grouped as MENA, shows a consistently high burden of motorcycle-related injury, particularly during summer months, with head and lower-limb trauma the most frequent injuries and motorcycle-crash mortality rates across the region ranging from roughly 0.5% to 4.5% (Alghamdi et al., 2024). In Tunisia, official 2019 police-recorded road deaths stood at 1,421, but a multi-source data-linkage study combining police and health records found the true toll was closer to 2,240; a substantial undercount concentrated among men aged 26–45 (Saïdi et al., 2022), a discrepancy consistent with wider concerns about underreporting in LMIC crash-surveillance systems (Soltani et al., 2024). Algeria similarly records a high concentration of road crashes in dense urban centers such as Constantine, linked to population density and commercial activity (Abdelali et al., 2024). In Egypt, motorcycle crashes were the leading cause of trauma-related death in Alexandria between 2000 and 2010, with incidence rates of 38 to 51 per 100,000 population and victims disproportionately young men aged 15–29 (Wahab, 2012), a pattern corroborated by hospital-based findings from Mansoura's emergency trauma service showing frequent severe injury among motorcycle-crash patients (Fouda et al., 2016).

4. Road Traffic Crashes Among MTW Riders in Morocco

4.1 Data sources and reliability

Road-crash statistics in Morocco are compiled primarily by NARSA, which centralizes reports from the police and gendarmerie and cross-references them against hospital admission records and mortality registers maintained by the Ministry of Health, an approach intended to link injury severity to the circumstances of each incident. These national statistics feed periodic publications such as the road-safety barometer, and are supplemented internationally by WHO and International Transport Forum datasets. As with most national crash-surveillance systems, however, the reliability of these figures depends on the reporting capacity of security agencies and the completeness of medical records, requiring careful validation and harmonization of data formats (Chand et al., 2021); several studies have documented divergence between police-recorded fatality counts and WHO modeled mortality estimates in comparable settings, plausibly reflecting underreporting, which argues for a measure of caution when making cross-national comparisons (Soltani et al., 2024).

4.2 National trends, 2019–2024

Comprehensive national data for 2019–2021 illustrate the disruptive effect of the COVID-19 pandemic on Morocco's road-safety trajectory. NARSA recorded 3,622 road deaths in 2019, a total that fell sharply to 3,005 in 2020 amid pandemic-related mobility restrictions, before rebounding to 3,685 in 2021; already exceeding pre-pandemic levels within a single year. Injury crashes followed a similar pattern, rising from 84,585 in 2020 to 114,626 in 2021 as traffic volumes recovered (International Transport Forum [ITF], 2023). Motorized two- and three-wheeler riders were not exempt from this rebound, though a precise year-by-year breakdown for this group is not available: the ITF's own benchmarking analysis relies on a 2017–2019 average of 1,102 annual powered-two-wheeler deaths as its pre-pandemic reference point, explicitly noting that the 2020–2021 figures are

too distorted by pandemic-era mobility disruption to serve as a reliable annual benchmark (ITF, 2023). This is itself informative: it means the sharp rise in MTW deaths documented from 2022 onward cannot be decomposed into a precise year-by-year trajectory across 2019–2021. The true speed of the underlying increase once mobility normalized likely cannot be recovered from published sources. Consequently, the analysis that follows focuses on the 2022–2024 period, for which consistent and comparable annual data are available.

NARSA recorded 113,625 injury crashes and 3,499 deaths on Moroccan roads in 2022. Of these deaths, close to six in seven victims were men and roughly one in seven women; 889 victims were under 25; 1,398 were users of two- or three-wheeled motorized vehicles; and 888 were pedestrians, more than a fifth of whom were aged 65 or older. Following a temporary decline associated with COVID-19-era mobility restrictions, crash frequency and severity resumed an upward trend. Provisional 2023 figures showed a 7% year-on-year increase in urban crashes specifically, and consolidated 2024 data recorded a further rise to 142,247 injury crashes and 4,024 deaths, indicating that both the frequency and the severity of road incidents have been worsening in tandem (NARSA, 2024) (see Table 1).

Table 1. National road-crash indicators, Morocco, 2022 vs. 2024 (NARSA)

Indicator	2022	2024
Injury crashes (total)	113,625	142,247
Road deaths (total)	3,499	4,024
Deathsamong 2-/3-wheeler users	1,398 (2022)	>40% of all deaths (2024)
Deathsamong pedestrians	888 (2022)	—
Victimsunderage 25	889 (2022)	—
Vulnerable road users, share of deaths	69% (2021)	—

Source: NARSA (2022, 2024) Dashes indicate figures not separately reported for that year in the sources reviewed.

4.3 Regional and temporal distribution

NARSA's statistics distinguish crashes occurring within urban areas, which are more numerous but generally less severe, from those occurring outside built-up areas, which are less frequent but carry a higher fatality rate owing to higher travel speeds. Notable regional disparities also exist: the Marrakech-Safi and Souss-Massa regions recorded significant increases in crashes during 2024–2025, plausibly linked to tourism intensity and inter-regional travel. A seasonal pattern is also apparent, with crash frequency peaking during periods of high mobility; in response, NARSA launched a summer intervention program in 2025 aimed at intensifying preventive measures and enforcement during these peak periods (NARSA, 2024).

4.4 Vulnerable road users and the rising share of MTW riders

Vulnerable road users (pedestrians, cyclists, and MTW riders) made up the majority of Moroccan road deaths in 2021, accounting for 69% of the total, of whom 39% were riders of two- or three-wheeled motorized vehicles. This group's share of total road deaths rose further to over 40% by 2024, prompting targeted responses including the distribution of certified helmets and stronger enforcement

against illegally modified vehicles. Taken together, Morocco's national data depict a worsening trajectory since 2022: rising crash and fatality counts, a growing and disproportionate share of deaths among MTW riders, and persistent regional disparities, closely mirroring the broader LMIC pattern documented in Sections 3.3 through 3.6.

5. Risk Factors for MTW Crashes: A Four-Domain Synthesis

The regional and national statistics above document the scale of the problem but not its causes. Across the studies reviewed, contributing factors cluster into four recurring domains: human factors, environmental factors, vehicle and mechanical factors, and safety equipment use.

5.1 Human factors

Inexperience is a frequently cited contributor to MTW crashes, particularly among younger and newer riders who have not yet mastered the simultaneous demands of traffic observation, braking, and gear control that motorcycling requires (Lin & Kraus, 2009). Rider and driver error more broadly is a major contributor: motorcyclists more often display diagnostic failures in traffic (misjudging a situation), while other drivers more often show detection failures, particularly at intersections, with right-of-way violations by other road users a frequent precipitating cause of MTW crashes (Tmejová et al., 2022).

Speed is consistently identified as a major determinant of crash severity. In Kentucky, excessive speed was linked to worse injury outcomes among motorcyclists, with speed, cornering, and evasive maneuvers all strongly correlated with injury and death (Cheng et al., 2014); in Western Australia, riding above the speed limit was associated with worse patient outcomes, including a higher risk of head trauma (Cunningham et al., 2012); and a detailed reconstruction of fatal motorcycle crashes found that risk and severity climbed sharply between the rider's initial reaction point and the critical moment of impact as speed increased (Murphy & Morris, 2020).

Alcohol and drug use substantially impair riding capacity and are linked to a marked increase in crash risk. In France, alcohol was identified as a contributing factor in 27 fatalities among riders of two- and three-wheeled vehicles in a single year, disproportionately among riders aged 25–39 and disproportionately at night. In Brazil, close to half of motorcyclists involved in crashes reported having consumed alcohol and/or drugs beforehand (Pires et al., 2022), and toxicological analysis in Porto Alegre found that most road-crash victims were motorcyclists, with a meaningful share testing positive for alcohol or marijuana and a strong association between alcohol dependence and intoxication at the time of the crash (Breitenbach et al., 2011). In Norway, roughly a quarter of motorcyclists killed in crashes tested positive for alcohol or illicit substances, an association that strengthened on weekend evenings (Christophersen & Gjerde, 2015), and a study of trauma-center admissions found that motorcyclists were more likely than car drivers to test positive for drug use, with cannabis the most frequently detected substance (Renzi et al., 2021). Separately, blood alcohol concentrations at or above 0.08 g/L have been associated with a more than tenfold increase in the probability of death in single-motorcycle crashes relative to sober riders (Islam, 2023). Mobile phone use is a further contributor to crash risk: distraction has been documented among more than a third of road users generally, including roughly one in ten MTW riders specifically (A. Morris et al., 2018; A. P. Morris et al., 2018).

5.2 Environmental factors

Adverse weather (rain, snow, or fog) increases collision risk for all road users but poses a particularly acute hazard for motorcyclists, given the inherent instability and reduced traction of two-wheeled vehicles. Analyses of road and environmental conditions in fatal single-vehicle motorcycle crashes have found that nighttime hours are associated with elevated crash risk, plausibly compounded by reduced visibility in poor weather (Sharon et al., 2025), a finding consistent with earlier work showing that rain-slicked surfaces reduce tire grip and complicate balance and control for riders (Manan et al., 2017).

Poor lighting and reduced visibility are similarly significant contributors. Research in Japan aimed at reducing motorcycle fatalities in collisions with fixed objects identified inadequate lighting as a key correlate of single-vehicle motorcycle deaths, since poor illumination impairs a rider's ability to detect and react to obstacles (Zulherman et al., 2022). Comparable findings from Taiwan link insufficient intersection lighting and unclear traffic-control signalling to a higher likelihood of severe MTW injury (Lin et al., 2022). Poor lighting cuts both ways: it reduces a rider's ability to detect hazards and reduces other drivers' ability to detect the rider, distorting judgments of distance, speed, and trajectory that are especially consequential at intersections, during lane changes, and in low-light conditions generally (Fotios & Castleton, 2015; Jägerbrand&Sjöbergh, 2016).

Road design and maintenance also shape MTW crash risk substantially. Poor pavement condition (potholes, rutting, loose gravel)can cause loss of control, particularly at higher speeds, while tight bends or decreasing-radius curves demand riding skill that not all motorcyclists possess; curved road segments have been specifically linked to elevated single-vehicle motorcycle fatality risk (Manan et al., 2017). Poor lane markings similarly complicate a rider's ability to maintain safe positioning and following distance, and unpaved surfaces are associated with a higher likelihood of severe head and neck injury; curve alignment together with speed limits above roughly 60 km/h have both been identified as critical contributors to MTW crashes (Zulherman et al., 2022). The urban-rural setting matters as well: research in Taiwanese university districts ,commercial in character despite their institutional label, found that greater traffic volume increased crash risk and severity for riders (Lin et al., 2022), while injuries sustained in rural settings tend to be more severe than urban ones, plausibly reflecting higher rural travel speeds and longer emergency-response times (Xiong et al., 2016); in Myanmar, straight urban roads were linked to a higher incidence of crashes while rural crash risk was linked instead to winding, poorly maintained roads (Lwin et al., 2016). Rural areas often lack adequate road markings, compounding rider risk, while dense urban traffic and high pedestrian volumes constitute a distinct risk factor of their own.

5.3 Vehicle and mechanical factors

Mechanical defects account for only a small share of MTW crashes: one detailed study found defects in just 5% of examined vehicles, and even these did not necessarily contribute causally to the crash, with tire- and wheel-related problems the most common issue identified (A. Morris et al., 2018; A. P. Morris et al., 2018).Where mechanical factors are implicated, faulty braking systems, worn tires, and suspension problems can meaningfully compromise a rider's ability to control the vehicle, particularly in emergency maneuvers; a detailed review of motorcycle-safety research identified front and rear brake defects specifically as contributing factors in some crashes, alongside inadequate tire pressure and wear, both of which compromise vehicle stability especially under abrupt maneuvers or difficult

conditions (Konlan& Hayford, 2022) .Functioning headlights, indicators, and rear lighting are similarly important for rider visibility and signalling intent to other road users, particularly in low-light conditions, making regular maintenance of these systems a meaningful, low-cost safety measure.

5.4 Safety equipment use

Helmet use is not primarily a measure to prevent crashes from occurring but a critical determinant of injury severity once a crash has happened, particularly for head trauma. The Iranian mortality study cited above found that only 37.4% of fatally injured motorcyclists were wearing a certified helmet, with head trauma responsible for more than half of all deaths in the sample , a pattern the authors read as strong evidence that low helmet uptake contributes substantially to the high incidence of severe head injury in this population, and that broader helmet use could plausibly reduce both injury severity and mortality in MTW crashes (Barzegar et al., 2020). This pattern of low helmet use accompanying high rates of fatal head injury recurs across several of the country-level studies reviewed above (e.g., Sivasankaran et al., 2021; Subhashini, 2019), reinforcing helmet-law enforcement as one of the most consistently evidenced, modifiable levers available to road-safety policy in this area.

6. Synthesis: Cross-Cutting Patterns and Morocco-Specific Considerations

Three patterns recur across this literature regardless of region. First, MTW riders are consistently overrepresented among road deaths relative to their share of vehicle-kilometerstraveled, a pattern documented from Cambodia to Ghana to Italy to Morocco. Second, this overrepresentation is systematically worse in LMICs, where rapid, under-regulated motorization has outpaced infrastructure investment, helmet-law enforcement, and emergency-care capacity, a structural explanation that fits Morocco's own trajectory closely, given the rising share of MTW deaths documented by NARSA since 2022. Third, data-quality concerns recur across LMIC settings specifically: the Tunisian data-linkage study's finding that true road deaths ran roughly 58% higher than police-recorded figures (Saïdi et al., 2022) is a direct methodological caution for interpreting Morocco's own NARSA-based statistics, which likewise rely primarily on police reporting cross-referenced with health records of variable completeness.

Morocco's specific profile (a rising trend since 2022, MTW riders and pedestrians together accounting for the large majority of vulnerable-road-user deaths, marked regional disparities linked to tourism and interregional travel, and a seasonal peak that has prompted a dedicated summer intervention program) fits within, rather than departs from, this broader regional pattern. What the international literature adds is a more granular picture of which risk factors are likely doing the causal work: given the documented roles of speed, alcohol, low helmet uptake, poor lighting, and road-surface quality elsewhere in the MENA region and in comparable LMICs, these are the most plausible priority targets for Morocco's own road-safety interventions, pending confirmatory local research.

7. Implications for Policy and Practice in Morocco

Several interventions follow directly from the risk-factor synthesis above and from Morocco's own documented crash profile. Given the consistent association between low helmet use and fatal head injury across the international literature, continued and expanded helmet distribution and enforcement (already underway via NARSA's certified-helmet program) remains one of the most directly evidenced priorities. Given the recurring role of road design and lighting, targeted infrastructure investment at

high-risk urban junctions and pedestrian crossings, consistent with Morocco's existing Sustainable Urban Mobility Plans, is likely to yield disproportionate returns relative to broader, less targeted measures. Given the regional and seasonal concentration of crashes documented in Sections 4.3 and 4.4, NARSA's summer intervention program and region-specific enforcement in high-tourism areas such as Marrakech-Safi and Souss-Massa represent a reasonable, evidence-consistent allocation of limited enforcement resources. Finally, given the data-quality concerns raised in Section 6, investment in linking police, hospital, and mortality-registry data (as piloted successfully elsewhere in the region (Soltani et al., 2024)) would improve the accuracy of the very statistics on which future policy and research will depend.

8. Limitations

This review has several limitations that follow from its narrative, rather than systematic, design. It does not apply a documented, reproducible search protocol or formal risk-of-bias appraisal to the underlying studies, and the country-level literature reviewed is highly heterogeneous in case definition, data source (police records, hospital case series, toxicology panels), and time period, limiting direct quantitative comparability across countries. Coverage of the international literature, while broad, cannot be considered exhaustive, and is likely to reflect some publication bias toward countries and research groups with greater academic infrastructure, potentially underrepresenting the true burden in the least-studied settings. Peer-reviewed, Morocco-specific epidemiological literature on MTW crashes remains limited, meaning the Moroccan analysis in Section 4 relies substantially on institutional (NARSA) reporting rather than independently peer-reviewed research; this is itself informative about the state of the field, but it means the usual protections of peer review (independent replication, methodological scrutiny) have not been applied to the primary national data source used here.

9. Conclusion

Motorized two-wheeler riders remain among the most vulnerable road users worldwide, and this vulnerability is markedly concentrated in low- and middle-income countries where motorization has outpaced infrastructure, enforcement, and care systems. Morocco's own crash and fatality trends since 2022, and the rising share of deaths among two- and three-wheeler users specifically, place the country squarely within this broader pattern rather than as an outlier. The international literature synthesized here converges on four recurring risk domains ; human, environmental, vehicle-related, and safety-equipment-related, with low helmet uptake standing out as a particularly well-evidenced and directly modifiable contributor to fatal injury. Strengthening Morocco's road-safety response along these evidenced lines, while simultaneously investing in the data-linkage infrastructure needed to track progress accurately, offers a realistic path toward reducing a toll that, on current trends, continues to grow.

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