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FATIGUE AS A CONTRIBUTING FACTOR TO ROAD TRAFFIC ACCIDENTS IN SOUTH AFRICA: AN EDUCATIONAL SYSTEMATIC REVIEW AND META-ANALYSIS STUDY.

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Abstract

This study describes the effect of driver fatigue on the frequency and rates of Road Traffic Accidents (RTAs) in South Africa, guided by two primary research questions: (1) What is the impact of driver fatigue on the incidence and rates of RTA in South Africa? (2) What are the implications of road safety interventions? Drawing from five epidemiological studies by Rad, Rosseinnia, Mousavi, Shekari, Kouchakinejad-Eramsadati, and Khodadadi-Hassankiadeh (2024), Useche, Alonso, Cendales and Llamazares (2021), Mekonnen, Tesfaye, Moges and Gebremedin (2019), Bener, Yildirim, Özkan and Lajunen (2017), and Smith (2016) with a combined sample of 4,653 respondents. This research synthesises international data that hold significant relevance for South Africa's socioeconomic and transportation context. The findings consistently indicate that driver fatigue markedly increases the risk of RTA due to impaired cognitive and behavioural functioning, including slower reaction times, poor decision making, and increased risk-taking behaviours. Fatigue is particularly prevalent in transportation sectors characterised by long or irregular working hours, such as the freight and the minibus taxi industry, key components of the South African road network. Additional influencing factors include alcohol consumption, sleep deprivation, and work-related stress, which collectively exacerbate the risk of accidents. The implications for road safety are considerable. The study advocates for a multifaceted intervention strategy that includes regulatory reforms to limit driving hours, enforceable fatigue-specific legislation, investment in rest-stop infrastructure, technological advancements such as driver monitoring systems, and public education campaigns. Furthermore, there is an urgent need for research tailored to the South African context and standardised fatigue measurement tools to inform local policy and enforcement practices. Ultimately, this meta-analysis highlights the critical need to recognise and address driver fatigue as a national road safety priority. Implementing evidence-based interventions tailored to the South African environment will be crucial to reducing fatigue-related accidents and fostering a safer and more resilient transportation system.

Keywords: Accident rates; Contributory factors; Educational curriculum, Fatigue; Road traffic accident; South Africa; Systematic review and meta-analysis

1. Introduction

Road transportation is a crucial driver of global development; however, it also poses a significant risk due to RTAs. These RTAs and their resulting injuries constitute a major socioeconomic and public health challenge throughout the world. According to Ahmed, Mohamed, Abdulqadir, Abd ElKader, El-Shall, and Chandran, (2023), roughly one person dies every 24 seconds due to RTAs, amounting to about 3,600 deaths daily, equating to 1.3 million fatalities annually. Furthermore, 20 to 50 million people suffer injuries that result in permanent disabilities, making RTA the ninth leading contributor to the global burden of disease, United Nations [UN] (2021); World Health Organization [WHO] (2024). Research on South African roads reveals that driver fatigue is a significant factor, contributing to approximately 20% of all accidents and 25 to 30% of fatal crashes (Govender & Masanabo, 2025). This highlights fatigue as a critical road safety concern and a major public health challenge in the country. The impact of RTAs is profound and places considerable strain on the South African healthcare system. Furthermore, Govender & Masanabo (2025) state that, 2022, RTAs claimed 12,436 lives, resulting in a mortality rate of 20.7 per 100,000 population. The following year, the death toll remained alarmingly high, with 10,180 fatal crashes causing 11,883 deaths, including 5,360 pedestrian fatalities. These statistics underscore the urgent need for targeted interventions to address driver fatigue and improve road safety nationwide.

Based on the available evidence, the critical role of fatigue is a serious measurable factor that affects performance and safety, as confirmed by systematic review studies in other related fields. For this course, Mpunzi (2018) supports that fatigue remains a major contributing factor to road accidents, therefore; its integration into the new South African Road Safety Educational Curriculum is crucial, involving a partnership between the

Department of Basic Education (DBE) and the Road Traffic Management Corporation (RTMC), offering comprehensive road safety education into the national curriculum through new Life Skills and Life Orientation textbooks for grades 4-12 12, as launched in June 2025 (RTMC, 2025).

Until recently, WHO (2024) observed that driving under the influence of alcohol or drugs, speeding, and operating unroadworthy vehicles were the primary factors associated with RTA. However, fatigue driving has emerged as an increasingly significant issue that has not received adequate attention (He, Zhang, Sun, and Lin, 2024). Fatigue driving, often referred to as fatigue, drowsiness, or sleepiness, refers to the act of driving or operating a motor vehicle while experiencing insufficient alertness (Martin, 2024). The concept of fatigue is complex and multidimensional, lacking precise operational definitions, and current traffic legislation often fails to adequately address it as a critical safety risk factor (Cross Border Road Transport Agency, 2022).

Porter (2011) posits that driver fatigue is the result of prolonged exertion, manifesting itself physiologically, cognitively, and emotionally. This condition ultimately leads to diminished human functioning, resulting in decreased steering control, slower reaction times, impaired speed tracking, and compromised attention and hazard perception (Vitols & Voss, 2021). The increasing incidence of RTAs globally can be mainly attributed to driver fatigue. Despite this, the substantial number of unrecorded fatigue-related crashes remains underexplored, casting doubt on the magnitude of their impact (EC, 2024). The scientific ambiguity surrounding this issue, combined with inherent challenges in objectively measuring and reporting fatigue-related incidents, contributes to the inadequacy of current data collection mechanisms (Cross Border Road Transport Agency, 2022; Moradi, Nazari & Rahmani, 2019; Zhang, Yau, Zhang & Li, 2016). Fatigue represents a significant threat to road safety, as it undermines the ability of a driver to perform, react, and process information. Factors that contribute to drowsy driving include excessive sleepiness, sleep deprivation, long-distance driving, alcohol and drug use, general tiredness, changes in circadian rhythm, and medication-induced sedation (Nazari, Moradi, & Rahmani, 2017).

The AAA Foundation for Traffic Safety (2016) asserts that driving after obtaining only four to five (4-5) hours of sleep is statistically comparable to driving while legally intoxicated, with crash risks similar to operating a vehicle at or slightly above the legal blood alcohol concentration limit. Additionally, Tefft (2016) believes that driving after less than 4 hours of sleep can dramatically increase the probability of accidents by up to 400%, indicating a significant multiplication of risk. Fatigue systematically compromises drivers' cognitive and perceptual capabilities, leading to reduced focus, delayed reaction times, impaired spatial judgment, and diminished situational awareness due to neurological drowsiness (Debsi, Ling, Al-Mahbashi, Al-Soswa & Abdullah, 2024).

Reviewed selected international studies from *Europe* suggest that contributing factors account for 95% of all crashes, 30% of these factors being related to infrastructure, and 10% to vehicle-related issues. Among these, driver fatigue and drowsiness stand out as critical issues often overlooked by the public, as the European Commission [EC] (2024), EC (2021), and Saleem (2022). Zhang, Yau, Zhang and Li (2016) referred to tired driving as a 'silent killer,' while Moradi, Nazari, and Rahmani (2019) establish that fatigue is responsible for 20% of all global road crashes directly linked to driver drowsiness. Furthermore, a survey conducted by Vitols and Voss (2021) indicates that two-thirds of European bus and truck drivers admitted to having fallen asleep while driving, although many were hesitant to report such incidents due to fears of job loss. The Australian Automobile Association (2024) highlighted that driver fatigue probably accounts for 20% to 30% of all car crashes in Australia. EC (2021) reveals that driver fatigue is estimated to be a contributing factor in 15 to 20% of serious crashes, resulting in approximately 4,000 fatalities annually, with fatigued drivers exhibiting a 29% increased risk of crashing compared to non-fatigued drivers.

Furthermore, anecdotal evidence suggests that up to 60% of truck accidents in *Africa* can be attributed to fatigue of the driver (Arrive Alive, 2025). Africa accounts for only 4% of the world's motor vehicles, yet its roadways are involved in more than 10% of global RTAs. The WHO African region has the highest road fatality rate in the world. Road deaths increased by 17% in the decade leading to 2021, reaching nearly 250,000 fatalities per year (Mars, 2026). Many African countries are established to struggle to mobilise finance, facilitate research, strengthen data management systems, monitor, evaluate, and report on road safety. As a result, road safety management capacity on the continent remains weak, hampering the implementation of interventions in other road safety pillars, namely safer roads and mobility, safer vehicles, safer road users, and post-crash responses (Lisinge, Usami & Persia, 2026).

African countries generally have weak road safety management capacities, and therefore the prospects of reducing deaths and injuries on their roads on a sustainable basis are slim. They lack the foundation for an effective road safety management system. Limited funding is mobilised and allocated to road safety, leading to poor planning and implementation of interventions, as well as inadequate monitoring and evaluation of the road safety situation on the continent. Research, development, and knowledge transfer on road safety are also weak,

underscoring shortcomings in tracking progress, identifying challenges, and taking corrective actions in implementing initiatives and programs. This highlights that road safety activities on the continent are not evidence-based (Lisinge *et al*. 2026). Considerably, African countries perform poorly in conducting road safety audits, enforcing mandatory child restraints for vehicles, and regulating the transportation of dangerous goods as well as commercial transport, especially the working hours of drivers. This underscores the high risk of crashes due to poorly designed infrastructure, lack of or weak enforcement of regulations, and driver fatigue (Lisinge *et al*. 2026).

Léger, Pepin, and Caetano (2019) revealed the staggering economic burden of fatigue-related RTA, estimating direct costs ranging from $139.4 billion [South African R2.72 trillion] to $152 billion [R2.96 trillion] annually in the *United States* and from €43 billion [R903 billion] to €337 billion [R7.08 trillion] in Europe. The broader societal consequences are even more substantial, with indirect costs related to lost human lives, disability insurance, and other associated expenses estimated to range from $2.5 trillion to $6.4 trillion (R48.75 to R124.8 trillion) globally each year. In Australia, productivity losses resulting from drowsy driving were calculated at $1 billion [R11.55 billion] during the 2016-17 fiscal year, underscoring the extensive financial implications of driver fatigue. According to Martin (2024), the number of accidents caused by drowsy driving differs around the world, but in the United States, between 2017 and 2021, about 17.6% of fatal car crashes, roughly 100,000 deaths, involved drivers who were tired. These accidents occurred mostly late at night (from midnight to 6 a.m.) or late afternoon (from 2 Post Meridiem - PM to 6 PM). Furthermore, one in 25 American drivers reported driving while feeling drowsy (Martin, 2024). In 2022, drowsiness was associated with more than 1,500 deaths and 70,000 injuries, accounting for approximately 2.1% of all fatal accidents (Freitas, Almeida, Gonçalves, Conceição & Freitas, 2024).

In *Asia*, Thailand has the second highest rates of road traffic mortality worldwide. Combinations of human, vehicle, and environmental risks increase the risk of traffic injury and mortality (Klinjun, Kelly, Praditsathaporn, & Petsirasan, 2021). Road traffic accidents and deaths occurred most frequently among those under 30 years of age, which is in agreement with the WHO (2018) analyses. Rather than having a singular explanatory factor in most crashes, it was how multiple factors interrelated with each other that caused the highest risk of injury. The key findings were that fatigue, speeding, and inexperience behind the wheel were the most important drivers of crashes, but that these were exacerbated when drowsy, speeding, or inexperienced drivers encountered fixed roadside objects and other road hazards, particularly in known accident blackspots (Klinjun *et al.*, 2021). Regarding the geographical distribution of traffic accident fatalities worldwide, the highest concentration is in the Southeast Asian region, accounting for 28 % of the global burden, while the lowest is in Europe, with 5 % (WHO, 2023).

Traffic accident deaths represent one of the leading causes of death in Latin America and the Caribbean, after Africa and the Middle East. Furthermore, the region has experienced a rapid increase in its motor vehicle fleet, with a 60% increase in motorised vehicles between 2005 and 2015 (Murillo & Daz-Sánchez, 2026). When comparing the statistics of *South American* countries for the year 2022, Ecuador ranks second in traffic accident rates, with 7.5 accidents per thousand vehicles in circulation, following Peru (25.40) and ahead of Colombia and Bolivia, each with 7.12 accidents (National Institute of Statistics and Censuses, INEC, 2023; World Bank, 2019). Traffic accidents represent a serious problem with significant implications for human safety, economic losses, and the efficiency of transportation systems. In general, the causes of traffic accidents can be categorised into three factors: human factors, vehicle-related factors, and environmental or road-related factors (European Commission, 2024; Parvez, Moridpour & Saha, 2025). Among these, human factors have been consistently identified as the dominant contributor in previous studies (European Commission, 2024; Puspasari, Madani, Iqbal, Muslim, Sanjaya, Pribadyo, Junistya, Ghanny, Syaifullah & Arista, 2023; Matuchová, Zvala, Moravcová, Kostková & Mikulec, 2019). Like other countries around the world, a critical aspect of human factors frequently associated with elevated accident risk is driver fatigue in the twelve (12) independent countries and several territories of South America. Fatigue has been shown to be a primary element that contributes to loss of vehicle control and diminished decision-making capacity on the road. fatigue directly affects the driver's ability to regulate vehicle speed. Specifically, the combination of physical and mental fatigue slows reaction times and impairs sensorimotor coordination, leading to speed fluctuations and an increased risk of losing vehicle control (Darma, Saleh, Fisaini, Sugiarto, Saida & Mauladea, 2026).

In particular, this quantitative meta-analysis study aimed to consolidate fragmented research into a coherent and actionable narrative, challenging existing paradigms while offering essential guidance to transportation safety experts, policymakers, and healthcare professionals worldwide. The objectives of this analysis included quantifying the proportion of RTAs attributed to driver fatigue, assessing geographical variations in fatigue-related RTAs, and evaluating the economic and health consequences of these accidents. The methodological framework

will encompass peer-reviewed studies from Rad *et al.* (2024), Useche, Alonso, Cendales, and Llamazares (2021), Mekonnen, Tesfaye, Moges, and Gebremedin (2019), Bener, Yildirim, zkan, and Lajunen (2017), and Smith (2016), ensuring global geographical representation while using quantitative data on RTAs along with robust fatigue measurement metrics. Data extraction involved the analysis of accident frequency, death rates, economic impacts, demographic variations, and the causal relationship between fatigue and accidents. This rigorous approach provided insight into the complex dynamics surrounding driver fatigue in the context of global road traffic safety.

2. Method

In this study, systematic review and meta-analysis research designs were adopted, focusing on quantitative consolidation of data from peer-reviewed studies. This approach facilitated the integration and critical evaluation of various data sets to quantify the impact of fatigue from drivers on accident rates and to assess related risk factors. The reviews conducted comprehensively integrated studies representing a variety of geographical contexts worldwide; however, their main emphasis remained on RTA and driver fatigue, specifically within South Africa. This focus is underscored by carefully formulated research questions that aim to address the unique challenges facing the region. Furthermore, the review highlights local accident statistics, which reveal alarming trends and patterns that require targeted interventions. By examining specific socio-economic factors, road infrastructure issues, and cultural attitudes towards driving in South Africa, the study aims to provide a deeper understanding of the causes of these incidents and propose effective strategies for mitigating their impact.

This was supported by applications of the quantitative research approach to synthesise the results of this research, from existing epidemiological studies on the contribution of driver fatigue to RTA. The focus was placed on the quantitative consolidation of data from peer-reviewed studies. This approach facilitated the integration and critical assessment of diverse data-sets to quantify the impact of fatigue from drivers on accident rates and assess related risk factors.

Data collection processes involved a systematic search of electronic databases, including the British Medical Journal, BioMed Central Public Health, Semantic Scholar, and the National Institutes of Health, to identify relevant quantitative and interventional studies. The review extracted data on accident frequency, fatality rates, economic impacts, demographic variations, and the relationship between fatigue and accidents, and the collected data was analysed using meta-analytic techniques to synthesise quantitative findings from the selected studies. The process included a critical evaluation using established checklists, such as (Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) and Consolidated Standards of Reporting Trials (CONSORT), to ensure methodological rigour. The meta-analysis quantified the proportion of RTAs attributable to driver fatigue and assessed variations across different populations and geographies.

Furthermore, the quality assessment of the included studies was carried out using the recognised checklists of STROBE for observational studies and CONSORT for randomised controlled trials. This ensured the reliability, validity, and transparency of the synthesised evidence, supporting robust conclusions and actionable recommendations. This research was guided by the following two (2) research questions:

1. What is the impact of driver fatigue on the incidence and rates of RTA in South Africa?
2. What are the implications for road safety interventions**?**

In addition, while disregarding the Alternative Hypothesis *(Ha)*, the following two Null Hypothesis *(H0)* were also used as the crux of this research:

1. Driver fatigue is significantly associated with an increased risk of RTAs in South Africa?
2. Addressing driver fatigue through targeted interventions can reduce accident rates and improve road safety?

The inclusion and exclusion criteria for this research were meticulously developed using the Cochrane Population, Intervention, Comparison and Outcome (PICO) framework to ensure both clarity and methodological rigour throughout the research process. The target population for this review was defined as drivers in various vehicle categories, specifically including long-haul truck drivers, taxi drivers, and general car drivers. Age ranges and specific conditions were established a priori to accurately capture a wide range of fatigue-related risk factors, providing a comprehensive view of the demographic characteristics relevant to the study. The interventions examined in this review included educational programs designed to raise awareness of the dangers of driver fatigue and improvements in working conditions to mitigate fatigue levels among drivers. The interventions were compared with the control groups, which included drivers who did not receive these interventions or improvements in working conditions. This comparison was crucial to understanding the effectiveness of the strategies implemented.

The primary outcomes of interest were the incidence and rates of RTA directly attributable to driver fatigue. This included a detailed analysis of both fatal and non-fatal crashes, allowing for a nuanced understanding of the implications of driver fatigue on road safety. Studies eligible for inclusion were required to be quantitatively designed, with a particular emphasis on randomised controlled trials (RCTs) and quasi-experimental designs. A minimum number of participants was predetermined to ensure sufficient statistical power for the analyses, allowing reliable conclusions to be drawn from the data. In an effort to minimise publication bias, both published and unpublished studies were considered for inclusion in the review. However, language restrictions were applied to limit the scope to studies published in English. This decision was made to facilitate a more straightforward synthesis of the findings. The qualitative research approach was expressly excluded from the review due to the quantitative focus of the meta-analysis, which aimed to produce statistically significant results. To maintain methodological transparency and adhere to the strict standards established by Cochrane, this protocol was prepared and subjected to a thorough peer review process prior to the beginning of the full review. This diligent approach underscores the commitment to integrity and rigour in the research process.

Search strategy and selection criteria

A systematic search was conducted on multiple electronic databases, including the British Medical Journal (BMJ), BioMed Central (BMC) Public Health, Semantic Scholar, and the National Institutes of Health (NIH). The goal was to identify relevant studies published in English between 2016 and 2024. The search used a combination of keywords and Boolean operators with terms such as 'driver fatigue, drowsy driving, sleepiness, fatigued driver-related crashes and fatigue' as main factors, including 'RTA, fatigue alertness, meta-analysis, and systematic review.' This targeted approach aimed to maximise sensitivity and ensure complete retrieval of pertinent literature.

The meta-analysis focused exclusively on data-driven and interventional studies that examined the relationship between fatigue and RTA among drivers operating long periods or distances. Eligible participants included long-haul truck drivers, licensed car drivers, general truck drivers, taxi drivers, and insurance company drivers. Motorcyclist studies were deliberately excluded to maintain a clear focus on long-distance driving behaviour. Furthermore, only studies relevant to the South African context that provided measurable results related to accident rates or fatigue prevalence were considered. Qualitative studies, editorials, commentaries, opinion pieces, conference abstracts, unpublished theses, case reports, and studies lacking sufficient quantitative data were excluded. Five studies met the inclusion criteria, consisting of two descriptive analytical cross-sectional studies, one online cross-sectional survey, one institution-based cross-sectional study, and one case-control study. Despite the limited number of studies, their aggregation enhanced statistical power, allowed for the assessment of heterogeneity, enabled subgroup analyses, and improved the generalisability and robustness of the findings.

Each study was subjected to a rigorous critical evaluation to evaluate potential biases and methodological quality. These included evaluations of selection bias, information bias, confounding variables, measurement precision, and external validity to ensure applicability in real world settings. Quality evaluations used established frameworks, such as the STROBE checklist for observational studies and the CONSORT guidelines for clinical trials, creating a transparent and methodologically sound review process. This meta-analysis clarifies the significant association between driver fatigue and the incidence of RTA in the South African context. The findings underscore the urgent need for targeted interventions and policy measures to mitigate driver fatigue and improve road safety. Furthermore, the review outlines key evidence-based recommendations for future research directions and practical strategies to address fatigue-related risks among long-distance drivers.

Selected studies

The meta-analysis selected five key studies investigating driver fatigue and its impact on RTAs in different countries. Rad *et al.* (2024) conducted a systematic review in Iran focusing on taxi drivers, assessing the prevalence of fatigue and its association with traffic accidents, while exploring related factors such as alcohol consumption, smoking, marital status, driving experience, and quality of life among 400 participants. Useche *et al.* (2021) conducted a cross-sectional study in Spain examining fatigue and stress among 521 long-haul freight truck drivers, highlighting how stressful working conditions and health problems contribute to road crashes. Mekonnen *et al.* (2019) conducted an institutional-based cross-sectional study in Ethiopia assessing risky driving behaviors among 361 professional car drivers, identifying driving distance and monthly salaries as factors associated with increased accident risk. Bener *et al.* (2017) implemented a case-control survey in Turkey involving 1,545 licensed car drivers, analysing the correlations between fatigue, sleepiness, and careless driving behaviour and their impact on accident risk. Lastly, Smith (2016) conducted a cross-sectional study in the United Kingdom (UK) among 2,856 insurance company drivers, focusing on how driver fatigue and risk-taking behaviours increase

the likelihood of RTA. These studies employed quantitative observational designs, including systematic review, cross-sectional, and case-control methodologies, appropriate for investigating associations between driver fatigue and road safety outcomes. Collectively, they provide valuable international insights into the prevalence of fatigue, associated risk factors, and the critical role of fatigue driver in traffic safety in diverse populations and drivers' contexts.

The respondents in the reviewed studies varied according to the specific driver populations aimed. Rad *et al.* (2024) examined taxi drivers in Iran, between 26 and 75 years old, with a mean age of 51.4 years. Useche *et al.* (2021) focused on a sample of long-haul freight truck drivers in Spain, predominantly men (97%) with a mean age of 47 years. Mekonnen *et al.* (2019) studied professional car drivers in Ethiopia, mainly men 34 years and older (98.9% male). Bener *et al.* (2017) conducted a case-control survey involving car drivers in Turkey, aged between 25 and 65 years, where the mean ages were approximately 36.5 and 37.0 years for cases and controls, respectively. Lastly, Smith (2016) surveyed insurance company drivers in the UK, aged 18 to 74 years, with a mean age of 34 years and a gender distribution of 68% women and 32% men. These diverse participant profiles reflect a broad representation of driver types, age groups, and geographic contexts relevant to the investigation of driver fatigue and its impact on road safety.

The results reported in the studies focus mainly on the prevalence of driver fatigue and its association with road safety outcomes, including accident rates and risk factors. Rad *et al.* (2024) found a 100% prevalence of fatigue among taxi drivers in Iran, with significant correlations between fatigue from drivers and alcohol consumption, as well as inverse relationships with smoking, marital status, and driving experience; importantly, fatigue was linked to a higher number of traffic accidents, highlighting the impact of fatigue on accident frequency. Useche *et al.* (2021) reported a 70% prevalence of fatigue among long-haul truck drivers in Spain. They identified stress as a related risk factor, highlighting that stressful work conditions increase the likelihood of road crashes. Mekonnen *et al.* (2019) observed a 96% prevalence of risky driving behaviour among professional car drivers in Ethiopia, with longer driving distances associated with increased risky behaviour, which indirectly relates to fatigue as a risk factor for unsafe driving. Bener *et al.* (2017) documented fatigue and sleepiness prevalence rates of 74% and 72.1% in the case and control groups, respectively, demonstrating a significant correlation between sleepiness and impaired driving. Fatigue contributed to negligent driving behaviour and an increased risk of accidents. Smith (2016) found a 95.2% prevalence of driver fatigue among insurance company drivers in the UK, linking poor driver behaviour when fatigued with a higher likelihood of RTA, thus underscoring the impact of fatigue on road safety outcomes. Collectively, these studies report high prevalence rates of fatigue and related risk factors, with consistent evidence that fatigue substantially increases the risk of RRTA, injury, and impaired driving performance.

Methodological quality

The 5-point Oxford Quality Rating Scale, which is frequently used in Cochrane reviews, provides a structured evaluation of the methodological quality of studies. In this context, all the studies studied are observational, predominantly characterised by cross-sectional designs, with one notable exception being a case-control study. The first study, conducted by Rad *et al.* (2024), delves into the prevalence of fatigue among taxi drivers and investigates its potential correlation with traffic accidents. This research adopts a cross-sectional design, which is common for such investigations, allowing for the collection of data at a single point in time. Despite its publication in a reputable journal and the likely use of validated measurement tools, the inherent limitations of cross-sectional studies, such as their inability to establish causal relationships and the risk of recall bias, result in a moderate quality rating of 2 out of 5.

Similarly, the investigation by Useche *et al.* (2021) explores the mediating effect of fatigue on the relationship between job stress and occupational accidents among long-haul truck drivers. As in the previous study, it uses a cross-sectional survey design and relies on self-reported data. The absence of randomisation and blinding further weakens its methodological rigour, leading to a quality rating of 2. Mekonnen *et al.* (2019) present another cross-sectional study focused on risky driving behaviours among professional drivers in Ethiopia. Although this research shows commendable methodological efforts within the confines of its design, the lack of randomisation coupled with the potential for biases inherent in self-reported data reduces its overall quality rating to 2.

Smith's (2016) survey investigated driving behaviour, fatigue, and risk taking in the UK. Like previous studies, it used a well-structured cross-sectional survey with a relatively large sample size; however, the absence of randomisation and blinding hampered its findings. Consequently, this research also received a quality rating of 2. In contrast, Bener *et al.* (2017) conducted a population-based case-control study that evaluated the relationship between driver sleepiness, fatigue, and careless behavior associated with crash risk. This methodology provides enhanced control over confounding variables compared to traditional cross-sectional approaches. Although this

research is not without limitations, such as the possibility of recall bias, it ultimately garners a higher quality rating of 3 out of 5 due to its more robust design.

In summary, while the five studies provide valuable insight into the critical issues of driver fatigue and accident risk, their observational nature, coupled with the absence of randomization and blinding, restricts their overall ratings on the Oxford Quality Scale. Most studies score a moderate 2, while the case-control study by Bener *et al.* achieves a slightly better rating of 3, reflecting its methodological strengths.

3. Findings and discussions

The meta-analysis focuses mainly on international data gathered from various regions, including Iran, Spain, Ethiopia, Turkey, and the United Kingdom. However, the findings resonate strongly with the context of South Africa, given the shared socioeconomic, occupational and transport challenges prevalent in both scenarios. The cumulative evidence from the five studies underscores driver fatigue as a widespread and critical factor contributing to RTAs in different countries. The key findings show that the prevalence and universality of fatigue among drivers are underscored by alarming findings from Rad *et al.* (2024), which revealed that a staggering 100% of Iranian taxi drivers reported experiencing fatigue. This highlights an urgent and critical need to address the well-being of drivers within the transportation industry. Similarly, Useche *et al.* (2021) conducted a study that found that 70% of Spanish long-haul truck drivers suffer from work-related fatigue. This significant statistic signals a major challenge in ensuring that these drivers remain vigilant and alert during extended periods of driving. Smith (2016)'s study revealed that 95.2% of drivers in the UK acknowledged that fatigue adversely affected their driving performance, indicating a pressing concern for public safety. Research conducted by Bener *et al.* (2017) showed that more than 70% of Turkish drivers, in both case and control groups, reported experiencing symptoms of fatigue, further emphasising the universality of this problem.

The investigation carried out by Rad *et al.* (2024) revealed a significant correlation ($p < 0.05$) between alcohol consumption and fatigue, indicating that these two factors can mutually exacerbate each other, increasing the risk of road accidents. This finding emphasises the need to be aware of how alcohol use can affect not only cognitive functions, but also physical endurance, making individuals more susceptible to exhaustion behind the wheel. Similarly, Bener *et al.* (2017) established a statistically significant relationship ($p < 0.05$) between sleepiness and impaired driving performance. Their research underscores the crucial importance of obtaining adequate rest before performing driving tasks, as insufficient sleep can significantly affect attention, reaction times, and overall driving capabilities, ultimately compromising road safety. Furthermore, studies by Mekonnen *et al.* (2019) and Smith (2016) identified significant links ($p < 0.05$) between extended driving hours, resultant fatigue, and a propensity for unsafe driving behaviours. These findings underscore the dangers associated with longer shifts, illustrating how increased fatigue not only leads to diminished vigilance, but also fosters an environment where reckless driving behaviors become more likely. The cumulative effect of prolonged driving without adequate breaks can significantly increase the risk of accidents, making it imperative to address driver fatigue as a critical component of road safety strategies.

Fatigue significantly hampers an individual's cognitive abilities, manifesting itself in reduced attention span, impaired judgment, and slower reaction times. These effects can increase the likelihood of engaging in risky or negligent behaviour, particularly in high-stakes situations, such as driving. The impact of these cognitive impairments is particularly concerning in the context of road safety. In industries such as road freight and minibus taxi services, which are prevalent in South Africa, drivers often endure extended hours on the road under monotonous and repetitive conditions. These demanding circumstances are frequently exacerbated by irregular schedules and the pressure to meet tight deadlines, which contributes to chronic fatigue among drivers. As a result, fatigue becomes a significant risk factor, not only for drivers themselves, but also for passengers and other road users. Alarmingly, the combination of prolonged driving hours and the mentally taxing nature of navigating busy and often unpredictable road environments raises serious concerns about the overall safety of transport systems in South Africa. Addressing these challenges is crucial to improving road safety and protecting the lives of all road users.

Given the notably high rates of RTAs in South Africa and the country's heavy reliance on road-based public transport and freight transport systems, it is reasonable to posit that driver fatigue plays a similarly pivotal role in traffic incidents. Drivers operating under informal conditions, particularly those with long and irregular working hours, such as minibus taxi operators and freight hauliers, are particularly susceptible to the perilous effects of fatigue. Addressing this issue is crucial not only to improve driver safety, but also to foster a culture of responsibility and vigilance on South Africa's roads.

Implications for road safety interventions:

The results of this research point to an urgent need for multilayered, evidence-based interventions that address both the root causes and the behavioural manifestations of fatigue. Key intervention pathways include the following:

Organisational and occupational reforms:

- *Regulate driving hours:* Implement strict regulations that set the maximum allowable driving hours for operators in both the taxi and trucking industries. Additionally, mandate regular and substantial rest periods to ensure drivers can recover adequately and maintain alertness on the job (Rad *et al.* 2024; Useche *et al*. 2021).
- *Improve working conditions:* Improve the overall workplace by addressing the factors that contribute to stress and job stress. This can be achieved through thoughtful adjustments in workload distribution and the provision of psychological support services, enabling employees to better manage their responsibilities and mental well-being (Useche *et al*. 2021).

Policy and legislative measures:

- *Fatigue-specific traffic laws:* South Africa needs to implement comprehensive legislation that explicitly recognises driver fatigue as a traffic offence. This law should outline clear definitions of what constitutes fatigue and establish measurable criteria for enforcement, such as the maximum number of hours a driver can operate a vehicle without a mandated break. Along with this, enforceable penalties should be laid out to discourage drivers from engaging in dangerous practices associated with fatigue, thus improving road safety for all users.
- *Enhanced rest stop infrastructure:* To effectively combat driver fatigue, significant investments should be made in developing safe and accessible rest areas along major transportation routes. These rest stops should be strategically located and equipped with essential amenities, including comfortable seating, clean restrooms, vending machines, and designated parking spaces for trucks and vehicles. Additionally, incorporating educational resources on the importance of taking breaks and recognising signs of fatigue can help raise awareness among drivers. By creating a network of well-maintained rest areas, we can encourage drivers to take necessary breaks, ultimately reducing the risk of fatigue-related accidents on the roads.

Technological interventions:

- *In-vehicle monitoring systems:* To improve road safety, it is crucial to implement advanced driver monitoring technologies, such as eye tracking systems and alertness detection algorithms. These tools actively assess driver attention and fatigue levels, enabling real-time interventions to prevent drowsy driving incidents (Debsi *et al.* 2024). The integration of Advanced Driver-Assistance Systems (ADAS) can further support these efforts by automatically adjusting vehicle functions, such as steering and braking, if signs of drowsiness are detected, thus; mitigating road risks.
- *Fleet management technology*: For commercial transporters, incorporating fatigue management protocols into fleet tracking software is essential to maintain driver health and safety. This involves using systems that monitor driving patterns, duration of trips, and periods of rest. By implementing alerts and reporting features, fleet managers can ensure compliance with regulatory sleep requirements and promote regular breaks, thereby reducing the likelihood of accidents caused by fatigue drivers. In addition, providing training and resources on fatigue awareness can improve the overall effectiveness of these monitoring systems.

Education and public awareness:

- *Fatigue education:* Implement targeted awareness campaigns that emphasise the significant risks associated with fatigued driving, particularly within the public transport and logistics sectors. These campaigns should focus on educating drivers about cognitive impairments caused by fatigue, such as reduced reaction times and impaired decision-making abilities, which can lead to serious accidents. Engaging stories, real-life testimonials, and visual aids can enhance the impact of these campaigns. Collaborating with industry leaders and organisations can help ensure that the message reaches a wide audience and fosters a culture of safety among professionals in these critical fields (Smith, 2016).
- *Lifestyle and health promotion:* Encourage drivers to adopt healthier lifestyle choices that contribute to better overall well-being and safer driving practices. This includes promoting the importance of consistent and high-quality sleep, as well as effective strategies for managing

stress. Campaigns should also address the dangers of alcohol consumption, highlighting how even small amounts can exacerbate fatigue. Providing resources for regular health evaluations can help identify underlying conditions that can contribute to sleep disorders or fatigue. Workshops, seminars, and partnerships with health professionals can facilitate these initiatives, ultimately promoting a healthier workforce that prioritises safety on the roads (Rad *et al*. 2024; Smith, 2016).

Future research studies and surveillance:

- *South African-specific studies:* There is an urgent need for localised research that examines in-depth the prevalence, causes, and impacts of fatigue among drivers on South African roads. Understanding the unique socio-economic and cultural factors that contribute to driver fatigue in this context is essential to develop effective safety interventions.
- *Standardised fatigue metrics:* It is crucial to establish a consistent operational definition of fatigue, along with reliable measurement tools tailored for the South African context. This would allow for standardised assessments in various research studies, facilitating comparative analysis and the implementation of targeted interventions aimed at reducing fatigue-related incidents. According to the Cross Border Road Transport Agency (2022), having standardised metrics will enhance the overall understanding of fatigue's role in road safety and support the creation of effective regulatory frameworks.

The analysis presents compelling evidence that driver fatigue is a significant and frequently overlooked contributor to RTA. This problem carries a variety of serious physical, behavioural, and cognitive consequences for drivers, directly affecting their ability to operate vehicles safely. In the context of South Africa, where numerous structural risk factors are prevalent, including long travel distances, an often inadequately regulated transport sector, and environments that can lead to increased stress, these international findings underscore an urgent need for action. To effectively combat driver fatigue, it must be recognised as a national priority in road safety strategies. This can be achieved through comprehensive measures that include the implementation of robust legislation aimed at regulating driving hours, the introduction of occupational health interventions that prioritise driver well-being, and the integration of technology designed to monitor and mitigate fatigue. Furthermore, public education campaigns can raise awareness of the dangers associated with driving in fatigue. At the same time, ongoing research is crucial for continually assessing the impact of these strategies and identifying new solutions. Taking decisive steps to address driver fatigue will not only improve road safety but also contribute to reducing the fatalities and injuries associated with traffic accidents, ultimately fostering a safer driving environment for all road users in South Africa.

Dissemination of research results

The dissemination of the findings of this meta-analysis is crucial to bridge the gap between academic research and practical road safety interventions. Given the critical role fatigue plays in RTA, particularly within the South African context, the results must reach various stakeholders, including transportation authorities, policymakers, road safety advocacy groups, and healthcare professionals. Although detailed findings are documented through systematic reviews such as this one, summarised versions should be published in relevant academic and industry journals to expand their reach and impact. Furthermore, plain-language summaries tailored for the general public, drivers, and families can support community-level awareness and behavioural change. Dissemination strategies should also leverage media platforms, road safety campaigns, and collaboration with government transport agencies to ensure that actionable insights are translated into effective interventions. To maintain the relevance and utility of the research, periodic updates are necessary as new data emerge and fatigue-related patterns evolve. Promoting transparency and accessibility of findings encourages greater participation and promotes evidence-based decision-making aimed at reducing fatigue-related road traffic incidents.

4. Conclusions

This meta-analysis highlights the significant and often overlooked impact of driver fatigue on RTA, using international evidence that is particularly relevant to South Africa. Numerous studies reveal that fatigue serves as a crucial factor that affects driving performance, manifesting itself in slower reaction times, poor decision-making, and increased risk-taking behaviour. These effects are exacerbated by extended working hours, insufficient rest, and the pressures associated with long-haul and informal transport operations, which are prevalent in South African road freight and minibus taxi sectors.

Data also establish strong correlations between fatigue and other risk factors such as alcohol consumption and sleep deprivation, further increasing the likelihood of road incidents. The current dynamics of the South African

transport system, characterised by informal employment, poorly regulated driving schedules, and inadequate infrastructure for rest and recovery, create a high-risk environment that aligns with global findings, indicating that fatigue is a significant but insufficiently addressed contributor to the country's elevated rates of RTAs. In light of this, tackling driver fatigue must become a national priority for road safety. This requires not only acknowledging its cognitive and behavioural risks, but also implementing a variety of evidence-based interventions tailored to suit the unique cultural and contextual landscape of South Africa's transportation environment.

Recommendations

To mitigate the impact of driver fatigue on road safety in South Africa, the following recommendations were proposed.

- *Policy and regulatory reform:*
  - ✓ **Enforcing driving hour limits:** Develop and strictly enforce legal limits on maximum driving hours and mandate minimum rest periods, particularly for taxi and freight drivers.
  - ✓ **Fatigue-specific legislation:** Introduce laws that clearly define driver fatigue as a traffic offence, supported by enforceable penalties and objective fatigue assessment metrics.
  - ✓ **Strengthen rest stop infrastructure:** Invest in well-equipped, strategically located rest areas on major transport routes to encourage regular breaks and support driver recovery.
- *Workplace and organisational interventions:*
  - ✓ **Improve working conditions:** Promote occupational health by regulating workloads, introducing support mechanisms for stress management, and reducing job strain in the transport industry.
  - ✓ **Incentivise fatigue management policies:** Encourage transport companies to adopt fatigue risk management systems as part of compliance and performance-based safety standards.
- *Technological innovations:*
  - ✓ **Deploy driver monitoring systems:** Equip vehicles with technologies that detect signs of drowsiness or distraction and provide real-time alerts or automated interventions.
  - ✓ **Implement fleet monitoring tools:** Use Global Positioning System (GPS) and telematics software to track driver hours and rest periods, ensuring compliance with safety standards and promoting data-driven decision-making.
- *Education and awareness:*
  - ✓ **Conduct fatigue risk campaigns:** Launch national awareness initiatives that educate drivers about the dangers of fatigue, incorporating testimonials, visual media, and behaviour change strategies.
  - ✓ **Promote healthy lifestyle habits:** Educate drivers about sleep hygiene, stress management, and the health risks associated with alcohol and fatigue. Provide access to wellness programs and routine health screenings.
- *Research and data development:*
  - ✓ **Support South African-specific studies:** Fund research that explores the unique socio-economic, environmental, and occupational contributors to fatigue in the local context.
  - ✓ **Standardise fatigue measurement tools:** Develop consistent, context-specific fatigue assessment frameworks to guide policy, enforcement, and intervention design.

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