QUEEN'S UNIVERSITY BELFAST

Vision impairment and traffic safety outcomes in low-income and middle-income countries: a systematic review and meta-analysis

Piyasena, P., Olvera-Herrera, V. O., Chan, V. F., Clarke, M., Wright, D. M., MacKenzie, G., Virgili, G., & Congdon, N. (2021). Vision impairment and traffic safety outcomes in low-income and middle-income countries: a systematic review and meta-analysis. *The Lancet. Global health*, *9*(10), E1411-E1422. https://doi.org/10.1016/S2214-109X(21)00303-X

Published in:
The Lancet. Global health

Document Version:
Publisher's PDF, also known as Version of record

Queen's University Belfast - Research Portal:
Link to publication record in Queen's University Belfast Research Portal

Publisher rights
Copyright 2021 the authors. Published by Elsevier Ltd.
This is an open access article published under a Creative Commons Attribution-NonCommercial-NoDerivs License (https://creativecommons.org/licenses/by-nc-nd/4.0/), which permits distribution and reproduction for non-commercial purposes, provided the author and source are cited.

General rights
Copyright for the publications made accessible via the Queen's University Belfast Research Portal is retained by the author(s) and / or other copyright owners and it is a condition of accessing these publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy
The Research Portal is Queen's institutional repository that provides access to Queen's research output. Every effort has been made to ensure that content in the Research Portal does not infringe any person's rights, or applicable UK laws. If you discover content in the Research Portal that you believe breaches copyright or violates any law, please contact openaccess@qub.ac.uk.

Open Access
This research has been made openly available by Queen's academics and its Open Research team. We would love to hear how access to this research benefits you. – Share your feedback with us: http://go.qub.ac.uk/oa-feedback

Download date:13. Jul. 2024

Vision impairment and traffic safety outcomes in low-income and middle-income countries: a systematic review and meta-analysis

Prabhath Piyasena, Victoria Odette Olvera-Herrera, Ving Fai Chan, Mike Clarke, David M Wright, Graeme MacKenzie, Gianni Virgili, Nathan Congdon

Summary

Background Road traffic injuries are a major public health concern and their prevention requires concerted efforts. We aimed to systematically analyse the current evidence to establish whether any aspects of vision, and particularly interventions to improve vision function, are associated with traffic safety outcomes in low-income and middle-income countries (LMICs).

Methods We did a systematic review and meta-analysis to assess the association between poor vision and traffic safety outcomes. We searched MEDLINE, Embase, PsycINFO, CINAHL, Web of Science, Cochrane Database of Systematic Reviews, and the Cochrane Central Register of Controlled Trials in the Cochrane Library from database inception to April 2, 2020. We included any interventional or observational studies assessing whether vision is associated with traffic safety outcomes, studies describing prevalence of poor vision among drivers, and adherence to licensure regulations. We excluded studies done in high-income countries. We did a meta-analysis to explore the associations between vision function and traffic safety outcomes and a narrative synthesis to describe the prevalence of vision disorders and adherence to licensure requirements. We used random-effects models with residual maximum likelihood method. The systematic review protocol was registered on PROSPERO, CRD-42020180505.

Findings We identified 49 (1·8%) eligible articles of 2653 assessed and included 29 (59·2%) in the various data syntheses. 15 394 participants (mean sample size n=530 [SD 824]; mean age of 39·3 years [SD 9·65]; 1167 [7·6%] of 15 279 female) were included. The prevalence of vision impairment among road users ranged from 1·2% to 26·4% (26 studies), colour vision defects from 0·5% to 17·1% (15 studies), and visual field defects from 2·0% to 37·3% (ten studies). A substantial proportion (range 10·6–85·4%) received licences without undergoing mandatory vision testing. The meta-analysis revealed a 46% greater risk of having a road traffic crash among those with central acuity visual impairment (risk ratio [RR] 1·46 [95% CI 1·20–1·78]; p=0·0002, 13 studies) and a greater risk among those with defects in colour vision (RR 1·36 [1·01–1·82]; p=0·041, seven studies) or the visual field (RR 1·36 [1·25–1·48]; p<0·0001, seven studies). The I^2 value for overall statistical heterogeneity was 63·4%.

Interpretation This systematic review shows a positive association between vision impairment and traffic crashes in LMICs. Our findings provide support for mandatory vision function assessment before issuing a driving licence.

Funding None.

Copyright © 2021 The Author(s). Published by Elsevier Ltd. This is an Open Access article under the CC BY-NC-ND 4.0 license.

Lancet Glob Health 2021

Published Online August 16, 2021 https://doi.org/10.1016/S2214-109X(21)00303-X

School of Medicine, Dentistry and Biomedical Sciences, Institute of Clinical Science, Centre for Public Health, Royal Victoria Hospital, Queen's University, Belfast, UK (P Piyasena PhD, V O Olvera-Herrera MPH, V F Chan PhD, Prof M Clarke DPhil, D M Wright PhD, Prof G Virgili MD, Prof N Congdon MD); **School of Optometry, College of Health Sciences, University of KwaZulu-Natal, Durban, South Africa** (V F Chan); **Riemann Limited, London, UK** (G MacKenzie DPhil); **Clearly Initiatives, London, UK** (G MacKenzie); **Department of Preventive Ophthalmology, Zhongshan Ophthalmic Centre, Sun Yat-sen University, Guangzhou, China** (Prof N Congdon); **Orbis International, New York, NY, USA** (Prof N Congdon)

Correspondence to: Prof Nathan Congdon, School of Medicine, Dentistry and Biomedical Sciences, Institute of Clinical Science, Centre for Public Health, Royal Victoria Hospital, Queen's University, Belfast BT12 6BA, UK **ncongdon1@gmail.com**

Introduction

As the leading global cause of death among people aged 5–29 years, road traffic injuries are a major public health concern, and without sustained action could become the seventh leading global cause of death for all ages by 2030.[1,2] Road traffic injuries caused 1·35 million deaths worldwide in 2016,[3] and the burden is especially great in low-income and middle-income countries (LMICs), with annual fatality rates per 100 000 population of 24·1 in low-income countries, compared with 9·2 in high-income countries (HICs).[3] Globally, although only 60% of cars are driven in LMICs, 93% of traffic deaths occur in these countries.[1] In LMICs, 30–86% of hospital admissions for trauma are due to road crashes.[4] Furthermore, the continuous expansion of cities, rapid urban migration, and growing rates of private car ownership are adding to a rapidly growing burden.[5] The socioeconomic effect of road traffic injuries is profound: 40–75% of those injured or killed in road traffic crashes in LMICs are their family's principal earners.[6] Road traffic crashes cost LMICs 1–2% of their gross national product annually, exceeding the total amount received from development aid.[7]

The main domains of visual function necessary for safe driving are visual acuity, visual field, colour vision, stereo vision, and contrast sensitivity.[8] In HICs, research has shown that vision problems such as glare and field loss are likely to be associated with increased risk of crashes

Research in context

Evidence before this study

The visual ability of road users is fundamental to traffic safety, but, despite the high burden of traffic crashes and associated mortality in low-income and middle-income countries (LMICs), evidence for an association between vision function and traffic safety outcomes is scarce. This fact makes it difficult to advocate that policy makers should develop effective vision-based road crash prevention strategies. We searched MEDLINE (Ovid) and the Cochrane Database of Systematic Reviews from database inception up to April 2, 2020, for systematic reviews and meta-analyses of vision interventions to reduce traffic crashes. We identified 12 reviews and three meta-analyses based mainly on studies from high-income countries. This search confirmed a major gap in evidence syntheses for vision and traffic safety in LMICs, which we sought to address.

Added value of this study

To our knowledge, this study is the first systematic review and meta-analysis of the association between vision function and traffic safety outcome in LMICs. We assessed 29 studies that described prevalence of vision disorders among drivers, 14 studies on adherence to vision-related driving licensure requirements, and 20 studies of the association of vision function with traffic safety outcomes. With use of data from these 20 studies, we did a meta-analysis on 39 vision-related parameters and risk of involvement in a traffic crash.

Implications of all the available evidence

People with poor central visual acuity are 46% more likely to have a road traffic crash than people with normal vision and there is a significant association between colour vision or visual field defects and safety outcomes. In addition, we identified a high prevalence of vision disorders among drivers and poor adherence to vision-related driving licensure requirements in some LMICs. There appears to be a significantly elevated risk of road traffic crashes for people with poor central visual acuity, colour vision, and visual field defects, but the cross-sectional nature of these studies, and the absence of randomised trials of interventions to improve vision, limits inference of cause and effect. Data from LMICs, particularly for younger drivers who might be at higher risk and women, are scarce.

See Online for appendix

among older drivers.[9,10] However, the effect of poor vision on the safety of road users in LMICs, in which many drivers do not undergo vision testing, is poorly understood.[11] Although it has been established by traffic safety research groups that uncorrected vision problems are common among drivers in LMICs, and that reduced visual acuity appears to be associated with crash risk, the difficulty in establishing reliable measures of crash outcomes and the paucity of trials in these settings have been major barriers to inference of cause and effect.[12]

The scientific community has yet to gather the necessary evidence to show to policy makers that modest investments to improve vision would save lives on the road.[13] Information on licensure requirements and rates of compliance in LMICs remains scarce. This systematic review was designed to fill these gaps in the evidence base. We examined the hypothesis that interventions to improve vision function are associated with better traffic safety outcomes, while also assessing the prevalence of various vision disorders among drivers in LMICs as well as adherence rates with local vision-related licensure requirements. We aimed to systematically analyse the evidence to establish whether any aspect of vision, and particularly interventions to improve vision function, are associated with traffic safety outcomes in LMICs. The review also identifies information gaps, and highlights areas in which additional research is needed.

Methods

Search strategy and selection criteria

For **study protocol** see https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42020180505

We did a systematic review and meta-analysis, in which we used Cochrane guidance on systematic reviews and the PRISMA guidelines to conduct and report the review (appendix p 1).[14–16]

We searched MEDLINE, Embase, PsycINFO, CINAHL, Web of Science, Cochrane Database of Systematic Reviews, and the Cochrane Central Register of Controlled Trials in the Cochrane Library, from database inception to April 2, 2020. A broad search strategy was developed under consultation with an information specialist to capture road users and traffic safety outcomes and a list of search terms as recommended by the Cochrane Effective Practice and Organisation of Care Group was used to identify studies from LMICs.[17] The full search strategy is shown in the appendix (p 3). Database searches were performed by PP and VOO-H under guidance of the information specialist.

We included any interventional or observational studies assessing whether vision is associated with traffic safety outcomes, studies describing prevalence of poor vision among drivers, and adherence to licensure regulations in LMICs. Eligible participants were road users in LMICs, including drivers, cyclists, pedestrians, and those using public transit, with special attention to individuals whose income was derived from driving a vehicle. We excluded studies from high-income countries. The primary outcome of this review was any traffic-crash-related injury to any road user that had potential to cause morbidity and mortality. We also included surrogate outcomes such as hard braking, or accelerometer-measured events, mostly based on self-reported data. The exposure of interest was poor vision functions of drivers. The study protocol is available online

Data collection and analysis

Two reviewers (PP, VOO-H) independently checked titles and abstracts retrieved by our searches against the review's eligibility criteria, resolving disagreements by discussion. The full text of all potentially eligible articles was retrieved, and data extraction was done by two reviewers (PP and VOO-H) if eligibility was confirmed. Data were extracted into a Microsoft Excel spreadsheet by adapting the data extraction forms and guidelines of Cochrane, including country, setting, year, study design, sample size, participant characteristics, type of vehicle and driver, measure of visual acuity or other vision-related domains, and reported outcomes. One reviewer extracted the data and a second verified it.

Risk of bias and quality of studies were assessed using the appropriate tool for each study: the National Institutes of Health (USA) quality assessment tool for observational cross-sectional studies and the relevant tool from the Critical Appraisal Skills Programme for other study designs.[18,19]

Data synthesis

We first described study characteristics, such as study design, country, setting, type of driver, and category of vehicle, and then provided meta-analyses of the findings for reported outcomes, using odds ratios or risk ratios (RRs) for binary outcomes. We also did a narrative synthesis of the prevalence of vision disorders among drivers and rates of compliance with vision-related licensure requirements.

Statistical analysis

Statistical heterogeneity was assessed across the studies. When meta-analyses were appropriate, a random-effects model was applied using Stata-SE, version 17.0. The suite of commands was used to fit random-effects models with the residual or restricted maximum likelihood method to estimate τ^2, which produces an unbiased, non-negative estimate of between-study variance.[20] We used reported RRs comparing risk of crashes among drivers with poor vision function against those with good vision function. If RRs were not reported, we calculated them using other data in the publications (appendix p 32). Separate meta-analyses were applied for visual acuity, colour vision, and visual field outcomes. If sufficient data were available, we did subgroup analyses for individuals whose income derived from driving a vehicle in an LMIC.

Small-study bias was assessed using Harbord's test[21] and by plotting data in a contour-enhanced funnel-plot with a non-parametric trim-and-fill method[22] of imputation of potentially missing data from small studies. Multivariate meta-regression to assess confounding was attempted; however, modelling was not successful due to an insufficient number of studies and scarcity of necessary primary data within studies (appendix p 34). The systematic review protocol was registered on PROSPERO, CRD-42020180505.

Role of the funding source

There was no funding source for this study.

Results

The electronic database search yielded 2653 titles and abstracts, and 49 (1·8%) eligible studies were selected for full review, among which 20 (40·8%) did not meet criteria for inclusion (figure 1).

The 29 included studies were cross-sectional and observational in design; no randomised trials or other studies of interventions were identified. Only one (3·4%) study was done in a low-income country, Ethiopia.[23] 22 (75·9%) studies were from lower-middle-income countries: 11 in Nigeria,[11,12,24–32] nine in India,[33–41] and

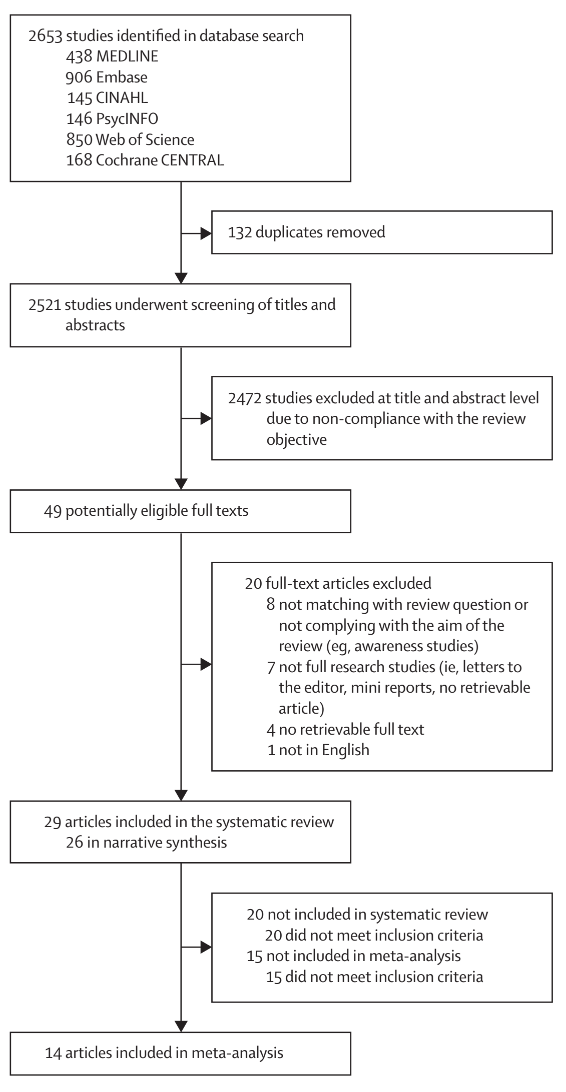

Figure 1: **Search strategy and results**
Reported according to the PRISMA guidelines. Some studies did not report vision disorder prevalence data or licensure requirement but provided vision and traffic safety risk ratio data for the meta-analysis. Some studies contributed to both the narrative review and meta-analysis.

	Country	Total sample size	Sex	Age, years	Identity of cohort	Visual acuity (in better, worse, or both eyes; any visual acuity cutoff, ≤6/9 to ≥6/24)	Monocular blindness	Uncorrected refractive errors	Cataract	Glaucoma	Corneal opacity	Posterior segment pathologies	Colour vision defects	Visual field defects
Abebe and Wondmikun, 2010[23]	Ethiopia	1879	6·3% female, 93·7% male	33·5 (NR)	Drivers in vehicle parks	..	..	..	..	..	..	..	4·5% (65·9% deuteranopes, 34·1% protanopes)	..
Abraham and Umanah, 2011[24]	Nigeria	291	100% male	41·5 (23–65)	Commercial vehicle drivers in a city	26·1% (≤6/9 in worse eye; 14·4% in better eye)	2·1% (<3/60 in worse eye)	2·4%	2·4%	..	..	..	2·2%	4·4% (at least one eye), 2·1% (for both eyes)
Adekoya et al, 2009[25]	Nigeria	399	100% male	44·7 (41–50)	Commercial vehicle drivers in a city	2·8% (<6/18 in better eye), 11·5% had less than FRSC* standard	3·3%	1·5% (better eye), 2·5% (second eye)	2·0–2·5%		0·5%	0·5% (ARMD, optic atrophy)	4·3%	5·5%
Boadi-Kusi et al, 2016[42]	Ghana	520	100% male	39·2 (20–75)	Commercial vehicle drivers in a town	2·5% (<0·2 logarithm of minimal angle of resolution or <6/9)	1·0%	60·0% (including presbyopia 39·6%)	..	..	..	..	7·1% (protanopes 45·9%, deuteranopes 35·1%, and tritanopes 18·9%)	..
Chakrabarty et al, 2013[33]	India	146	100% male	NR	Drivers in a refresher training	10·9% (visual acuity cutoff not defined)	..	..	..	..	..	..	17·1%	2·7–6·2%
Chidi-Egboka et al, 2015[26]	Nigeria	328	100% male	46·0 (20–70)	Commercial vehicle drivers in a capital	9·2% (better eye), 12·0% (second eye)*	..	2·7% (better eye), 6·4% (second eye)	0·3–0·9%	0·9%	..	0·6–1·2%	9·5% (both eyes)	19·5% (better eye), 20·4% (second eye)
Dairo et al, 2019[27]	Nigeria	340	100% male	52·5 (24–72)	Commercial vehicle drivers in one state	27·1% (right eye), 26·4% (left eye), 15·3% (both eyes; <6/9)	..	..	..	..	..	..	..	..
Erdogan et al, 2011[48]	Turkey	200	100% male	41·4 (23–60)	Drivers registered in a Drivers' Association	..	..	21·5%	..	..	..	..	2·2%	..
Ghasemi et al, 2015[49]	Iran	200	100% male	42·5 (NR)	Truck drivers (commercial and military)	1·5% (military), 2·0% (commercial; binocular visual acuity <20/30)	..	..	..	..	..	..	1·0% (military), 3·0% (commercial)	..
Isawumi et al, 2011[28]	Nigeria	99	100% male	45·9 (NR)	Commercial vehicle drivers in motor parks	6·1% (<6/18 in either eye, WHO definition)	5·0%	31·3%	24·3%	13·6% (glaucoma suspected)	6·6%	..	6·1%	37·3% (<120°)
Jayaseelan and Veeramani, 2017[34]	India	148	100% male	32 (NR)	Truck drivers in drivers' camps at highways	45·9% (<6/9 all, both eyes), 25·0% (<6/18)	..	31·1%	9·4%	4·7%	4·0%	2·7% (ARMD), 6·8% (retinopathies)	2·0%	..
Kshastri et al, 2016[35]	India	195	100% male	46·4 (22–65)	Inter-state truck drivers	5·6% (<6/18, better eye), 8·7% (second eye)	..	4·8% (presbyopia)	39·6% (any lens opacity)	6·9%	..	..	..	..

(Table continues on next page)

	Country	Total sample size	Sex	Age, years	Identity of cohort	Visual acuity (in better, worse eye, or both eyes; any visual acuity cutoff, ≤6/9 to ≥6/24)	Monocular blindness	Uncorrected refractive errors	Cataract	Glaucoma	Corneal opacity	Posterior segment pathologies	Colour vision defects	Visual field defects
(Continued from previous page)														
Murthy et al, 2019[36]	India	100	4% female, 96% male	65·2 (40–82)	Drivers with glaucoma identified in an eye clinic	NR	..	..	..	67·0% (primary open angle glaucoma) 33·0% (primary angle closure glaucoma)	..	..	..	69·0% (early), 2·0% (advanced)
Ojabo et al, 2020[29]	Nigeria	122	100% male	33·8 (NR)	Commercial divers in a motor park	1·2% (<6/12)	..	..	..	..	..	..	..	..
Oladehinde et al, 2007[12]	Nigeria	215	100% male	41·5 (21–75)	Registered commercial drivers in a local government area	3·2% (<6/18, better eye)	..	17·2% (8·8% presbyopia)	14·4%	5·6%	1·4%	2·9%	0·5% adjusted with sample size	10·2% (one eye)
Omolase et al, 2012[30]	Nigeria	90	100% male	45·2 (22–70)	Commercial drivers identified in community	2·2% (<6/18, better eye), 8·9% (second eye)	..	3·6% (presbyopia)	33·3% (lens opacity)	4·4%·	..	..	..	..
Onabolu et al, 2012[31]	Nigeria	524	100% male	46·8 (19–66)	Commercial motor vehicle drivers	11·6% (<6/18; 6/18 to 6/60, 8·2% right eye, 9·4% left eye)	Counting fingers and no perception of light 2·3% to 2·9%	4·2%	3·6%	2·3%	1·0%	0·6%	..	..
Ovenseri-ogomo and Adofo, 2011[43]	Ghana	206	100% male	39·2 (18–68)	Commercial drivers in a municipality park	6·8% (<6/18, better eye)	..	32·0%	8·2%	..	..	..	Difficulty in seeing colour lights 0·5%	Constricted field 6·8%
Owoaje et al, 2005[32]	Nigeria	299	100% male	27·5; 85% 20–39	Commercial motorcyclists	8·1% (out of road traffic accidents n=136, visual acuity cutoff not defined)	..	10·4% (hyperopia)	..	..	..	..	..	..
Pepple and Adio, 2014[11]	Nigeria	400	100% male	37·8 (25–62)	Commercial drivers in a motor park	1·8% (cutoff not given, WHO, 1984 definition of visual impairment)	3·5%	8·4% (myopia and hyper-metropia) 22·9% (presbyopia)	14·1%	11·5%	0·4%	5·7%	4·5%	4·0%
Rajendra et al, 2013[37]	India	140	NR	NR (21 to >60)	Truck drivers in their rest stops	15·0% (<6/18)	..	28·5% (31·4% presbyopia)	..	..	..	..	..	..
Sabherwal et al, 2020[38]	India	4059	100% male	34 (17–74)	Truck drivers in an eye camp	26·4%* (cutoff not given)	..	26·4% (any refractive error in at least one eye; 8·8% distant correction, 24·3% near correction)	..	..	..	..	..	..

(Table continues on next page)

	Country	Total sample size	Sex	Age, years	Identity of cohort	Visual acuity (in better, worse eye, or both eyes; any visual acuity cutoff, ≤6/9 to ≥6/24)	Monocular blindness	Uncorrected refractive errors	Cataract	Glaucoma	Corneal opacity	Posterior segment pathologies	Colour vision defects	Visual field defects
(Continued from previous page)														
Sharma et al, 2014[39]	India	59	100% male	28·4 (18–55)	Truck drivers in a transport company	16·9% (either eye) 5·1%* (both eyes); WHO criteria for visual impairment	..	..	..	..	..	..	..	..
Verma et al, 2016[41]	India	387	NR	NR (20–60)	Bus drivers and renewal applicants in transport companies	10·0% (<6/18, both eyes; left 12·0%, right 16·0%)	..	..	..	..	..	..	14·4%	2·0–21·9%
Verma and Bharadwaj, 2015[40]	India	1041	100% male	32 (18–60)	Truck drivers on national highways	19·9% (<6/18)	..	18·8%	1·0%	..	0·3%	..	1·3%	..
Zhang et al, 2009[46]	China	1539	52·5% female, 47·5% male	14·6 (NR)	Rural schoolchildren who use bicycles	3·9% (worse than 6/18 in better eye)	..	12·3% (worse than –4D both eyes)	..	..	..	..	..	..

Data are mean (range) or as specified. Yan et al, 2018,[45] Yan et al 2016,[44] and Zhang et al 2017[47] are not included in this table since there are no data on prevalence of visual impairment among the commercial vehicle drivers. ARMD=age-related macular degeneration. NR=not recorded. *Federal Road Safety Commission. standard: <6/9 in better eye and <6/24 in second eye.

***Table:* Prevalence of vision disorders among drivers in the study sample, not population adjusted**

two in Ghana,[42,43] and there were six from upper-middle-income countries (20·7%): four in China[44–47] and one each in Turkey[48] and Iran.[49]

Among the 29 included studies, 20 (69·0%) assessed the association between vision function and traffic safety outcomes (appendix p 11), 26 (89·7%) reported prevalence of vision disorders among drivers (appendix p 19), and 14 (48·3%) described adherence with driving licensure requirements (appendix p 26). Several studies reported multiple outcomes. Among 20 studies reporting on vision and traffic safety outcomes, 14 (70·0%) qualified for our meta-analysis of the association between visual impairment and road traffic crashes. No studies were found assessing interventions to improve vision function.

The 29 included studies enrolled 15 394 participants (mean sample size n=530, SD 824, range 23–4059) with a mean age of 39·3 years (SD 9·65, range 14·6–65·2). Only five studies included women (1167 [7·6%] women of 15 279 included individuals with known sex or gender).[23,36,44–46] Most included studies (22 [75·9%] of 29) described vision and traffic safety outcomes among commercial drivers of trucks, buses, or taxis (appendix p 11). Two studies assessed safety outcomes on driving simulators,[44,45] one enrolled patients from a glaucoma clinic,[36] one assessed self-reported crashes among schoolchildren riding bicycles in China,[46] and one included motorcycle delivery drivers.[32]

Studies used both Snellen and logarithm of the minimum angle of resolution charts and most (16 [61·5%] of 26) used WHO definitions of visual impairment. Prevalence of visual impairment among drivers, at cutoffs of ≤6/9 to ≥6/24 in the better eye or worse eye or second eye reported in 26 studies across seven countries ranged from 1·2%[29] to 26·4%.[38] In Nigeria, visual impairment among commercial drivers in 11 (37·9%) studies ranged from 1·2%[29] to 26·1%,[24] and in Ghana from 2·5%[42] to 6·8%.[43] Monocular blindness ranging from 1·0% to 5·0% was reported among drivers in five studies in Nigeria[11,24,25,28,31] and one in Ghana[42] (table, appendix p 19).

18 studies provided prevalence of the main causes of visual impairment among drivers. Prevalence of uncorrected refractive errors (including presbyopia) ranged from 1·5% to 31·3% in the better-seeing or second eye in Nigeria;[11,12,24–26,28,31,32] 21·5% in Turkey;[48] 32·0%[43] to 60·0%[42] in Ghana; 12·3% in China,[46] and 4·8%[35] to 31·1%[34] in India. Murthy and colleagues reported glaucoma prevalence in India of 69·0% early, 29·0% moderate, and 2·0% advanced among drivers of any kind of vehicle in a glaucoma clinic.[36] Prevalence of glaucoma among non-clinic-based driver cohorts varied from 0·3%[25] to 11·5%.[11] Cataract prevalence among commercial drivers in eight studies from Ghana, India, and Nigeria ranged from 0·3[40] to 33·3%[30] (appendix p 19).

Colour vision defects were assessed in 15 (57·7%) of 26 studies, and ranged from 0·5%[17] to 9·4%[26] in six studies in Nigeria, while Omolase and colleagues reported no colour vision defects among Nigerian commercial drivers.[30] In Ethiopia, Abebe and Wondmikun reported a prevalence of 4·5%.[23] In India, colour vision defects ranged from 1·3%[40] to 17·1%[33] in four studies, while in Iran, colour vision defects were present in 1·0% of military drivers and 3·0% of commercial drivers,[49] and in Ghana 7·1%[42] of commercial drivers had protanopic colour vision defects. Overall from these 15 studies, the range of colour vision defects was 0·5% to 14·4%.

Although terminology was not defined consistently, the prevalence of visual field defects among drivers varied from 2·0%[41] to 37·3%[28] in ten studies, from 4·0%[11] to 20·4% (second eye) in Nigeria,[26] 6·8% in Ghana (constricted field),[43] while in India, Verma and colleagues reported peripheral defects in 2·0% and altitudinal defects among 21·9%.[41] There were very few data for prevalence of other vision anomalies among drivers in LMICs: abnormal stereopsis was reported among 18·2% in Nigeria[12] and 15·4% in Ghana,[42] while one study found a 4·0% prevalence of abnormal contrast sensitivity in India[41] (appendix p 19).

A substantial proportion of drivers in included studies received licences without undergoing vision testing, although vision testing was mandatory in all countries included in this review. The proportion who did not receive vision testing ranged from 10·6% in Ghana[42] to 85·4% in Nigeria.[25] In India, legal licence renewal was bypassed by 45·0% of drivers[36] and only 47·5% of drivers needing glasses or spectacles had them.[38] Vision testing during renewal of driving licences was reported to be inadequate in Ethiopia,[23] India,[33,34,36,38] Ghana,[42,43] and Nigeria[11,12,25,26,29,30,32] (appendix p 26).

Among 14 articles assessed for methodological quality and risk of bias (appendix p 9), the most common issues were: (1) absence of sample size justification (35·8%); (2) inability to measure vision function of drivers before assessing safety outcomes (100·0%); (3) inadequate time to assess exposure and outcome (50·0%); (4) limitations of cross-sectional design (100·0%); and (5) failure to mask study personnel (100·0%; figure 2).

Among 20 studies eligible for the meta-analysis, six (30·0%) were excluded: one enrolling patients in a glaucoma clinic,[36] two reporting insufficient data to calculate RRs,[29,43] and two with outcomes incompatible with the objective of the meta-analysis.[44,45] Another study contributed no RR data as visual impairment was assessed based on self-report.[47] For the remaining 14 studies, 39 sub-components describing visual acuity (assessed in 13 studies), colour vision (seven studies) and visual field (seven studies), and traffic safety outcomes were used to calculate summary estimates (appendix p 32). Inadequate data were available for meta-analyses of stereopsis[12,42] or contrast sensitivity.[41]

The overall meta-analytic estimate (RR) of the effect of different types of visual impairment on adverse road safety outcomes was 1·41 (95% CI 1·26–1·59; Z=6·61; p<0·0010). We observed an overall statistical heterogeneity of I^2=63·4% (p=0·0002; H^2=2·73; Q=77·1). According to our review protocol, we reported data separately by type of visual perceptual parameter.

Among the seven studies (35·0%; n=4348 participants) that reported defects in colour vision, most assessed colour vision using Ishihara pseudochromatic colour plates,[11,12,23,26,28,41] while Boadi-Kusi and colleagues[42] used the Hardy-Rand-Rittler pseudochromatic plate. The heterogeneity among included studies was moderate (I^2=64·0%; p=0·0031). Most studies concluded that colour vision defects presented variable amounts of increased risk of traffic crashes. The included studies showed a RR range of 0·85–2·47, with summary estimate of 1·36 (95% CI 1·01–1·82, test for overall effect Z=1·95; p=0·041), showing moderate increased risk (figure 3).

Among seven studies (35·0%, n=2119 participants) that reported visual field defects, methods of measuring visual fields included direct confrontation,[24–26,41] automated perimetry,[12] Epson 910,[28] and supra-threshold Optifield KP-910[11,24] automated perimetry. The summary RR was 1·36 (95% CI 1·25–1·48, test for overall effect Z=7·28; p<0·0001) indicating a 36% increase in crash risk among

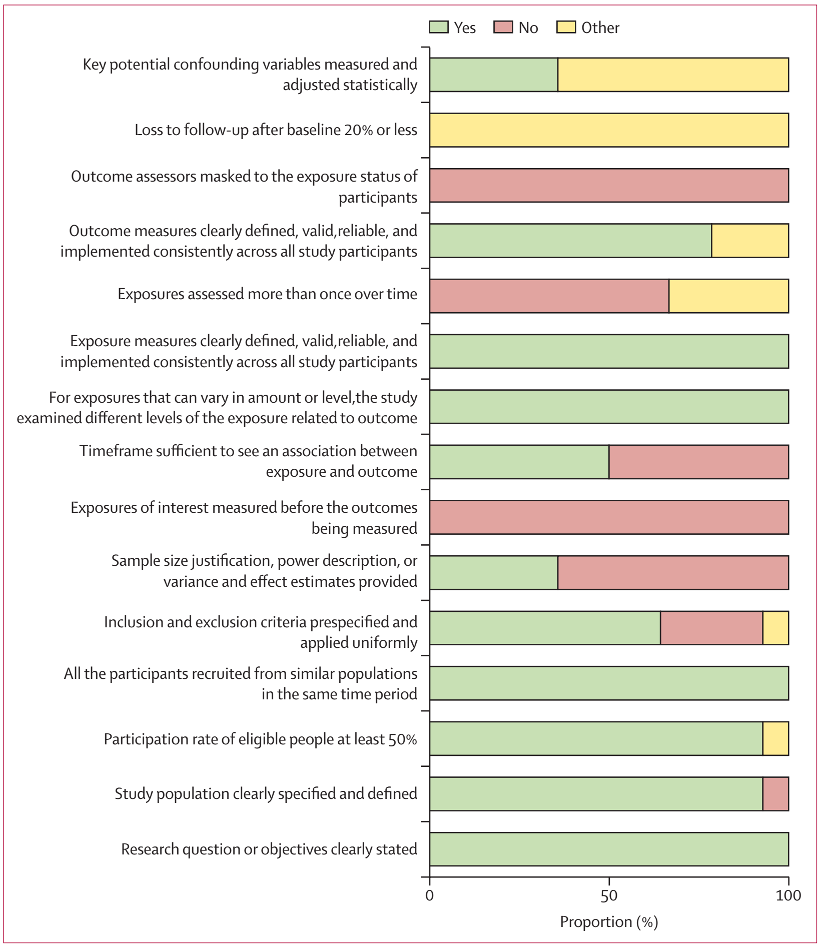

Figure 2: **Methodological quality assessment of studies included in the meta-analysis**
Other indicates factors that cannot be determined, are not reported, or are not applicable as per criteria defined in the quality assessment tool, details given in the appendix p 9.

	Exposure		Control		Weight (%)	Risk ratio (95% CI)
	Yes	No	Yes	No		
Colour vision defects						
Abebe et al (2010)[23]	27	58	371	1423	4·3%	1·54 (1·11–2·12)
Boadi-Kushi et al (2015)[42]	13	24	104	379	3·2%	1·63 (1·02–2·61)
Boadi-Kushi et al (2015)[42]	9	8	108	395	3·1%	2·47 (1·53–3·98)
Chidi-Egboka et al (2015)[26]	6	25	58	239	1·8%	0·99 (0·47–2·11)
Isawumi et al (2011)[28]	2	4	18	75	0·8%	1·72 (0·52–5·75)
Oladehinde et al (2007)[12]	1	3	56	155	0·4%	0·94 (0·17–5·22)
Pepple and Adio (2014)[11]	10	8	172	211	3·4%	1·24 (0·81–1·90)
Verma et al (2016)[41]	33	23	228	103	5·1%	**0·86 (0·68–1·08)**
Heterogeneity: τ^2=0·09, I^2=64·0%, H^2=2·78						1·36 (1·01–1·82)
Homogeneity: θi=θj: Q(7)=21·53; p=0·0030						
Visual field defects						
Abraham et al (2013)[24]	2	11	70	208	0·7%	0·61 (0·17–2·22)
Adekoya et al (2009)[25]	7	15	76	301	2·2%	1·58 (0·83–3·00)
Chidi-Egboka et al (2015)[26]	17	47	47	217	3·1%	1·49 (0·92–2·42)
Chidi-Egboka et al (2015)[26]	16	51	48	213	3·0%	1·30 (0·79–2·14)
Isawumi et al (2011)[28]	14	23	8	40	1·8%	2·27 (1·07–4·83)
Oladehinde et al (2007)[12]	7	15	50	143	2·1%	1·23 (0·64–2·37)
Oladehinde et al (2007)[12]	1	4	56	154	0·4%	0·75 (0·13–4·39)
Pepple and Adio (2014)[11]	9	7	173	211	3·3%	1·25 (0·80–1·95)
Verma et al (2016)[41]	6	0	255	126	5·2%	1·39 (1·12–1·73)
Verma et al (2016)[41]	77	8	255	126	6·0%	1·35 (1·23–1·49)
Heterogeneity: τ^2=0·00, I^2=0·0%, H^2=1·00						**1·36 (1·25–1·48)**
Homogeneity: Q(9)=4·34; p=0·89						
Visual impairment						
Abraham et al (2013)[24]	2	3	70	216	1·0%	1·63 (0·55–4·87)
Adekoya et al (2009)[25]	6	21	77	295	1·8%	1·07 (0·52–2·23)
Adekoya et al (2009)[25]	8	24	75	292	2·2%	1·22 (0·65–2·30)
Boadi-Kushi et al (2015)[42]	3	7	114	386	1·2%	1·32 (0·50–3·44)
Boadi-Kushi et al (2015)[42]	7	23	110	370	2·1%	1·02 (0·52–1·99)
Chidi-Egboka et al (2015)[26]	8	22	56	242	2·2%	1·42 (0·75–2·69)
Chidi-Egboka et al (2015)[26]	11	27	53	237	2·6%	1·58 (0·91–2·76)
Isawumi et al (2011)[28]	8	5	12	74	2·1%	4·41 (2·24–8·69)
Isawumi et al (2011)[28]	5	17	10	67	1·2%	1·75 (0·67–4·59)
Kshatri et al (2016)[35]	2	9	35	149	0·7%	0·96 (0·26–3·47)
Kshatri et al (2016)[35]	4	13	33	145	1·3%	1·27 (0·51–3·15)
Oladehinde et al (2007)[12]	6	1	51	157	3·8%	3·50 (2·38–5·14)
Omolase et al (2012)[30]	1	1	17	71	0·6%	2·59 (0·61–11·04)
Omolase et al (2012)[30]	2	8	16	66	0·7%	1·02 (0·28–3·82)
Onabolu et al (2012)[31]	6	55	89	374	1·7%	0·51 (0·23–1·12)
Owoaje et al (2005)[32]	19	12	117	151	4·4%	1·40 (1·03–1·92)
Owoaje et al (2005)[32]	36	34	100	129	4·7%	1·18 (0·90–1·54)
Pepple and Adio (2014)[11]	2	5	180	213	0·9%	0·62 (0·19–2·02)
Verma et al (2016)[41]	36	2	225	124	6·0%	1·47 (1·32–1·64)
Zhang et al (2009)[46]	20	40	277	1066	3·9%	1·62 (1·11–2·35)
Zhang et al (2009)[46]	55	134	242	972	4·9%	1·46 (1·14–1·87)
Heterogeneity: τ^2=0·10, I^2=69·2%, H^2=3·25						**1·46 (1·20–1·78)**
Homogeneity: θi=θj: Q(20)=45·31; p=0·0010						
Overall						**1·41 (1·26–1·59)**
Heterogeneity: τ^2=0·06, I^2=63·4%, H^2=2·73						
Homogeneity: θi=θj: Q(38)=77·06; p<0·0001						
Test of group differences: $Q_b(2)$=0·43; p=0·81						

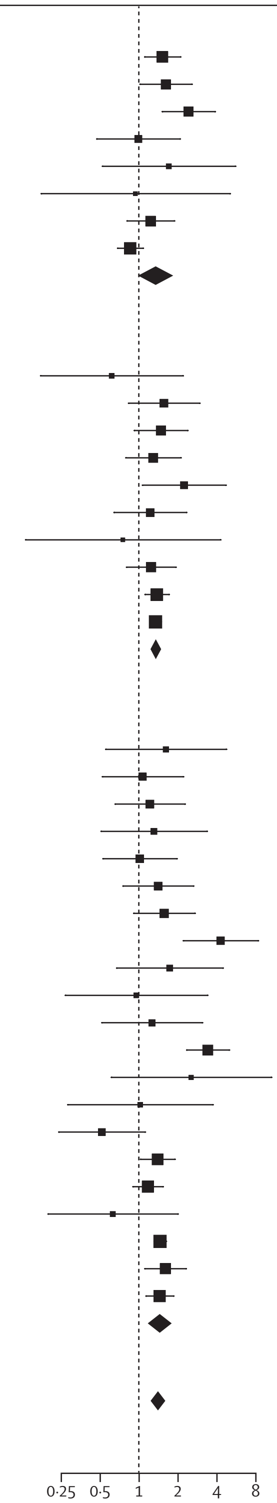

Figure 3: **Association between colour vision defects, visual field defects, and visual impairment of road users and road traffic crashes**
Some papers are cited more than once as they have reported vision related outcomes using different cutoff levels.

those with field defects. No variation in effect sizes was attributable to heterogeneity (I^2=0%; p=0·89; figure 3).

13 (65·0%) studies reported effects of impaired central visual acuity on traffic safety outcomes (n=3747 participants). Mean prevalence of visual impairment was 7·3% (SD 7·07, 95% CI 2·52–12·10). The summary estimate revealed a 46% increased risk of road traffic crash among those with visual impairment (RR 1·46 [95% CI 1·20–1·78], test for overall effect Z=4·55; p=0·0002), with a moderate level of heterogeneity (I^2=69·2%; p<0·0010; figure 3).

A substantial association between poor central visual acuity and traffic crashes was present at a visual acuity cutoff of ≤6/18 in either eye (RR 1·61 [95% CI 1·10–2·36], test for overall effect Z=2·68; p=0·015, six studies), with a moderate level of heterogeneity (I^2=72·5%; p<0·0025; appendix p 28). A post-hoc analysis including only commercial vehicle drivers showed a significant association between central visual acuity and traffic safety outcomes (RR 1·46 [95% CI 1·11–1·93], test for overall effect Z=2·98; p=0·0077, 11 studies) with moderate heterogeneity (I^2=68·7%; p=0·0004; appendix pp 29–30). There was no effect of age on traffic safety outcomes (<40 years RR 1·41; *vs* ≥40 years RR 1·48; p<0·072 for the difference; appendix p 31).

The visual inspection of the contour-enhanced funnel plot (figure 4) suggested that a few smaller and non-significant study results might be missing in the right portion of the plot. Using the trim-and-fill methods, there was little difference between the observed (RR 1·41) and imputed (RR 1·53) estimates, and the imputed data were in the direction of a greater effect. This result was confirmed by Harbord's test for small study bias, which was not significant (p=0·13).

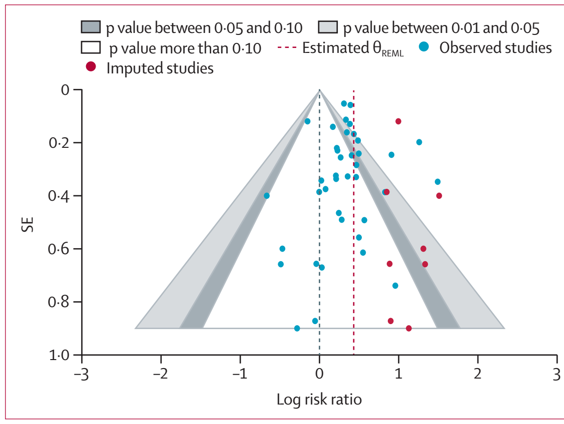

Figure 4: **Contour enhanced funnel plot for assessment of publication bias**
REML=restricted maximum likelihood.

Discussion

Visual functioning of road users is fundamental to traffic safety. This systematic review and meta-analysis highlights that vision impairment significantly increases the risk of road traffic crashes in LMICs, especially among commercial vehicle drivers, who are an important group of high-intensity users. It also shows that vision disorders are common among road users in LMICs, as is poor adherence to driving licensure standards in terms of vision requirements in some settings. These findings suggest the need for tighter controls on the licensing of drivers based on vision, and highlight the need for trials on interventions to improve vision function and road safety in LMICs.

Among 1·35 million people killed annually by road traffic crashes, 93% of deaths occur in LMICs.[50] The importance of traffic regulations is illustrated by the reduction of traffic deaths and injuries by 13% in the WHO European Region between 2010 and 2016 through enactment and enforcement of road safety legislations by political and technical commitment.[51] The Global Burden of Diseases, Injuries, and Risk Factors Study 2017 showed that, although mortality from road traffic injuries decreased globally over time, it did not in south Asia and southern Latin America.[50] The economic burden of road traffic crashes is increasing in LMICs[52] and exceeds that in HICs due to increases in urbanisation,[53] road infrastructure, and access to private vehicles.[54] Sustainable Development Goal 3·6 aims to "halve the number of global deaths and injuries from road traffic accidents" by 2020, echoing the Stockholm Declaration target of reducing road deaths by 50% by 2030.[55] These goals will not be achievable in LMICs without concerted effort.

Under-reporting of road crashes in low-income countries has led to important gaps in the evidence base,[56] and consequently lower prioritisation of strategies to reduce the burden of traffic-related morbidity and mortality. Our review found only one article from a low-income country.[23] We identified 12 systematic literature reviews and three meta-analyses on vision and traffic safety (appendix p 38), mainly of studies from HICs, and one from LMICs that reviewed studies of traffic safety published up to 1994, but did not report on vision.[57] Three meta-analyses from HICs describe effectiveness of cataract surgery in reducing driving-related difficulties (reduced by 88% following surgery),[58] association of useful field of vision as a valid vision parameter of driving performance,[59] and scarcity of randomised trials on the effect of vision screening on safety outcomes among older drivers.[60] Such data are needed, or similarly absent, for LMICs.

We found evidence for a significantly elevated risk of traffic crashes with impaired central visual acuity in LMICs, as has been observed in studies in HICs.[61,62] However, strategies from HICs that might help with this factor cannot be directly implemented in LMICs without evidence for what works in these settings.[55,63] Furthermore, studies in HICs have largely focused on older drivers and the results might not be relevant to the younger driving populations in LMICs.[60,64] For instance, participants in the study by McGwin and colleagues[62] in

Panel 1: Gaps in the evidence base on vision and traffic safety in low-income and middle-income countries

- Insufficient evidence on young drivers, who are at the greatest risk of crashes in many countries, as well as women.
- Absence of randomised trials of the effects of traffic safety of interventions that improve vision (hindering ability to make strong inferences of cause and effect with respect to vision impairment and traffic crash risk).
- Insufficient evidence on pedestrians and drivers of private vehicles, a rapidly growing group in low-income and middle-income countries.
- Insufficient evidence on motorcyclists, three-wheeled taxi drivers, users of electric bicycles, and drivers of other smaller and potentially more vulnerable vehicles.
- Poor uniformity of definitions of traffic safety outcomes, including an absence of denominator data for participant populations, and inconsistencies in classification of vision function.

the USA were aged from 55 to 85 years, whereas those included in the LMIC studies in this review had a mean age of 39·8 years. Very little data for women were available.

Johnson and Keltner's 1983 study in the USA, one of the largest studies of visual fields and drivers in HICs, reported that among 10 000 drivers, those with binocular visual field loss had crash and conviction rates twice as high as those without such loss.[65] This finding is consistent with the current review, in which the summary estimate of the number of crashes due to visual field defects was 36% higher (RR 1·36). With respect to colour vision, people with protanopic colour vision defects are not allowed to obtain a commercial vehicle licence in some HICs due to their inability to identify red traffic lights. This factor might partly explain the high number of people with colour vision defects who had traffic crashes (nine [52·9%] of 17)[42] in LMIC studies compared with those in HICs (14% among those with difficulty in seeing traffic lights).[66]

The observed moderate level of statistical heterogeneity of the current meta-analysis could have arisen due to variations in effect sizes within observational studies, due to different levels of diagnostic test accuracy of vision tests, different cutoff points of vision parameters, and different definitions of primary outcome that had been assigned by study investigators. Time gap between traffic crash and data collection might have also influenced effect estimates through recall bias. We have presented our main results based on subgroup level analyses, taking heterogeneity into account, and not purely based on effect estimates derived in pooling all studies together.

Our study has some limitations. The absence of data from randomised controlled trials and reliance on observational studies to show causal connection between visual impairment and traffic safety outcomes is sub-optimal. Most studies were from the African region, and record a high prevalence of visual impairment and blindness, minimising the generalisability of review outcomes. Participant-reported outcomes and different methods used to collect vision-related data affect the internal validity of the primary data. Most studies described visual acuity without spectacle correction and there could be more than one underlying pathology causing visual impairment. Evidence was scarce on other road users and surrogate outcomes. Some authors selected participants in public motor parks (ie, public car parking facilities), and there is a propensity for self-selection of those who have had a crash. We have minimised the limitations of confounding at the stages of statistical analysis and interpretation. However, effects of unidentified confounding on our results are a main weakness for the ability to draw conclusions and there

Panel 2: Implications for research, policy, and practice

- Randomised trials, perhaps using a step-wedge design to avoid ethical issues around withholding interventions that are known to improve vision, and done in real-world driving environments with recording of crash and near-crash events, could provide the best evidence to inform policy and practice in low-income and middle-income countries (LMICs) by providing robust data for cause and effect and reliable estimates of the size of any benefits from these interventions.
- Studies that recruit currently under-represented categories of drivers, especially women, might provide more generalisable results.
- Considering the so-called Five Pillar Approach for road safety (ie, road safety management, safer roads and mobility, safer vehicles, safer road users, or post-crash response), a more transdisciplinary approach to research is needed to generate strategies to reduce the mortality burden of road traffic crashes in LMICs.[67]
- Studies that generate scientific evidence on safe and specific visual acuity cutoffs in licensure requirements, which would not be purely based on visual impairment definitions and guidelines given for eye health in general. Enactment and strict enforcement of a traffic safety evidence based visual acuity cutoff might be a pragmatic approach to pre-licensure screening, given that many studies in this review reported that drivers do not adhere to vision screening standards when obtaining licences.
- Referral for early treatment after screening of the preventable causes of vision impairment identified in these studies is needed.
- Collaboration with commercial drivers' regulatory bodies, transport ministries, traffic police departments, licence issuing authorities, and eye care professionals from the health sector will be important in successful implementation of proposed strategies.

was insufficient primary data to assess these factors through a meta-regression analysis (appendix p 38).

This review provides evidence for a clear association between vision impairment and traffic crashes in LMICs, and provides support for mandatory vision function assessment before issuing driving licences, especially for drivers of commercial vehicles. However, there are still several gaps in the evidence base for LMICs that need to be filled to fully inform policy and practice (see panels 1, 2) and establishing robust systems to collect good quality data in these countries should be a priority. Although vision testing was mandatory in all countries included in this review, enforcement challenges are sometimes further increased in LMICs if policies are lax, or when existing tighter regulations are unenforced, such as inadequate vision testing during licence renewal in Ghana, Ethiopia, Nigeria, and India. Randomised trials of interventions to improve vision and their effect on driving safety are needed in LMICs to identify strategies to promote policies of more thorough vision screening of drivers and interventions that will improve the vision of drivers.

Contributors

NC, MC, GM, VFC, DMW, VOO-H, and PP contributed to conceptualisation, review design, protocol writing, conducting the review, data analysis, interpretation of the results, and manuscript preparation. PP and VOO-H did the database searches, title and abstract screening, data extraction from full articles, and synthesis as co-reviewers. GV contributed to re-analysis of the data and interpretation. NC, GV, MC, GM, VFC, DMW, VOO-H, and PP provided revisions, edited earlier versions of the manuscript, and approved the final version for submission. VOO-H and PP had full access to all the data in the study, verified the extracted data, and had final responsibility for the decision to submit for publication.

Declaration of interests

NC works as director of research for Orbis International, an organisation working on global eye health, including vision and traffic safety. NC is supported by the Ulverscroft Foundation, UK. GM reports personal fees for consulting on regulatory compliance in Japan, the UK, and the USA for Adlens, a manufacturer of eyewear, outside the submitted work. All other authors declare no competing interests.

Data sharing

All datasets generated and analysed are available in the Article and appendix.

Acknowledgments

We thank Richard Fallis at the Library of Queen's University, Belfast, UK for support in developing the proposed search terms and strategy.

References

1 WHO. Global status report on road safety 2018. Geneva: World Health Organization, 2018. https://www.who.int/violence_injury_prevention/road_safety_status/2018/en/ (accessed March 18, 2021).

2 United Nations Sustainable Development Knowledge Platform. The Sustainable Development Goals. https://www.sustainabledevelopment.un.org/sdgs (accessed March 18, 2021).

3 WHO. Global Health Observatory Data: number of road traffic deaths. Geneva: World Health Organization, 2016. https://www.who.int/gho/road_safety/mortality/traffic_deaths_number/en/ (accessed March 18, 2021).

4 Gobyshanger T, Bales AM, Hardman C, McCarthy M. Establishment of a road traffic trauma registry for northern Sri Lanka. *BMJ Glob Health* 2020; **5:** e001818.

5 Li J, Liu Q, Sang Y. Several issues about urbanization and urban safety. *Procedia Eng* 2012; **1:** 615–21.

6 Silcock C, Jacobs A. Socio economic aspects of road accidents in developing countries. *Transp Res Lab* 1997; **R6237:** 1–33.

7 Murray C, Lopez A. Alternative versions of the future: projecting mortality and disability, 1990–2020. The Global Burden of Disease. *Lancet* 1997; **349:** 1498–504.

8 Thorslund B, Strand N. Vision measurability and its impact on safe driving—a literature review. *Scand J Optom Vis Sci* 2016; **9:** 1–9.

9 Rubin GS, Ng ES, Bandeen-Roche K, Keyl PM, Freeman EE, West SK. A prospective, population-based study of the role of visual impairment in motor vehicle crashes among older drivers: the SEE study. *Invest Ophthalmol Vis Sci* 2007; **48:** 1483–91.

10 Owsley C, Wood JM, McGwin G Jr. A roadmap for interpreting the literature on vision and driving. *Surv Ophthalmol* 2015; **60:** 250–62.

11 Pepple G, Adio A. Visual function of drivers and its relationship to road traffic accidents in Urban Africa. *Springerplus* 2014; **3:** 47.

12 Oladehinde MK, Adeoye AO, Adegbehingbe BO, Onakoya AO. Visual functions of commercial drivers in relation to road accidents in Nigeria. *Indian J Occup Environ Med* 2007; **11:** 71–75.

13 Johnson CA, Wilkinson ME. Vision and driving: the United States. *J Neuroophthalmol* 2010; **30:** 170–76.

14 Higgins JPT, Thomas J, Chandler J, et al. Cochrane handbook for systematic reviews of interventions. Version 6.2, 2021. Cochrane, 2021. https://training.cochrane.org/handbook/current (accessed March 18, 2021).

15 Moher D, Shamseer L, Clarke M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst Rev* 2015; **4:** 1.

16 Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med* 2009; **6:** e1000097.

17 Cochrane Colloboration. Low and middle income country filters. Cochrane Effective Practice and Organisation of Care Cochrane Colloboration. https://www.epoc.cochrane.org/lmic-filters (accessed March 18, 2021).

18 Critical Appraisal Skills Programme. CASP checklists. 2020. http://www.casp-uk.net/casp-tools-checklists (accessed March 18, 2021).

19 National Institutes of Health, USA. Quality assessment tool for observational cohort and cross-sectional studies. https://www.nhlbi.nih.gov/health-pro/guidelines/in-develop/cardiovascular-risk-reduction/tools/cohort (accessed March 18, 2021).

20 Cooper H, Hedges L, Valentine J, Raudenbush S, eds. Analyzing effect sizes: random-effects models. In: The handbook of research synthesis and meta-analysis. New York, NY, USA: Russells Stage Foundation, 2009: 295–316.

21 Harbord RM, Egger M, Sterne JA. A modified test for small-study effects in meta-analyses of controlled trials with binary endpoints. *Stat Med* 2006; **25:** 3443–57.

22 Duval S, Tweedie R. Trim and fill: a simple funnel-plot-based method of testing and adjusting for publication bias in meta-analysis. *Biometrics* 2000; **56:** 455–63.

23 Abebe Y, Wondmikun Y. Defective color perception among car drivers in Addis Ababa, Ethiopia. *Traffic Inj Prev* 2002; **3:** 294–97.

24 Abraham E, Umanah IN. Prevalence of visual impairment among commercial motor vehicle drivers in Uyo, South–South Nigeria. *J Environ Occup Sci* 2011; **2:** 55–60.

25 Adekoya BJ, Owoeye JFA, Adepoju FG, Ajaiyeoba AI. Visual function survey of commercial intercity vehicle drivers in Ilorin, Nigeria. *Can J Ophthalmol* 2009; **44:** 261–64.

26 Chidi-Egboka N, Bolarinwa O, Awoyemi A. Visual function test among commercial drivers in a north central state of Nigeria. *Health Sci J*. 2015; **9:** 1–7.

27 Dairo MD, Okechukwu-Nwankpa UP, Nwankpa R. Survey on visual acuity among intra-city commercial vehicle drivers in Ibadan, southwestern Nigeria. *J Public Health Africa* 2019; **10:** 789.

28 Isawumi MA, Adeoti CO, Ubah JN, Oluwatimilehin IO, Raji RA. Ocular status of commercial drivers in Osun State, Nigeria. *Afr J Med Med Sci* 2011; **40:** 405–11.

29 Ojabo CO, Adeniyi OS, Ojo BA. An assessment of visual acuity of commercial vehicle drivers in Makurdi, Benue State. *Curr J Appl Sci Technol* 2020; **39:** 61–67.

30 Omolase CO, Afolabi OT, Omolase BO, Ihemedu CO. Community medicine and health education ocular status of commercial drivers in a Nigerian community. *J Community Med Health Educ* 2012; **2:** 2–5.

31 Onabolu OO, Bodunde OT, Otulana TO, et al. Visual acuity of commercial motor drivers in Ogun State of Nigeria. *Niger Postgrad Med J* 2012; **19:** 225–29.

32 Owoaje ET, Amoran OE, Ohnoferi OE. Incidence of road traffic accidents and pattern of injury among commercial motorcyclists in a rural community in south western Nigeria. *J Community Med Prim Care* 2005; **17:** 7–12.

33 Chakrabarty N, Lakshman A, Gupta K, Bhatnagar A. Visual challenges among drivers: a case study in Delhi, India. *Int J Innov Res Sci Eng Technol* 2013; **2:** 3074–83.

34 Jayaseelan CX, Veeramani P. Analysis of vision screening of truck drivers in a truck parking campus located in a busy national highway. *Indian J Clin Experimental Ophthalmol* 2017; **3:** 296–99.

35 Kshatri JS, Pradhan PC, Patro S, Tripathy RM. Ocular status of inter-state commercial drivers: a cross sectional study in Odisha, India. *Int J Ophthalmic Res* 2016; **2:** 6–11.

36 Murthy GJ, Deshmukh AV, Mallidi AR, Murthy PR, Kattige JS, Murthy VR. Renewal of driving license in India and glaucoma: a study of prevalent practice and its lacunae. *Indian J Ophthalmol* 2019; **67:** 240–46.

37 Rajendra J, Krishna B, Satyanarayana U. Refractive errors and color blindness among truck drivers: a pilot study. *J Dr NTR Univ Health Sci* 2013; **2:** 89–91.

38 Sabherwal S, Sood S, Chinnakaran A, Majumdar A, Dasgupta S. The prevalence of refractive errors and spectacle uptake in truck drivers: a North Indian cross-sectional study. *J Clic Ophthalmol Res* 2020; **8:** 51–55.

39 Sharma PK, Ganguly E. Morbidity profile of long distance truck drivers in Hyderabad city, India. *J Dr NTR Univ Health Sci* 2014; **3:** 234–37.

40 Verma R, Bharadwaj P. Assessment of visual function of truck drivers travelling on national highway of Central India: a prospective study. *Int J Sci Stud* 2015; **3:** 140–42.

41 Verma A, Chakrabarty N, Velmurugan S, Bhat P, Kumar H, Nishanthi B. Assessment of driver vision functions in relation to their crash involvement in India. *Curr Sci* 2016; **110:** 1063–72.

42 Boadi-Kusi SB, Kyei S, Asare FA, Owusu-Ansah A, Awuah A, Darko-Takyi C. Visual function among commercial vehicle drivers in the central region of Ghana. *J Optom* 2016; **9:** 54–63.

43 Ovenseri-Ogomo G, Adofo M. Poor vision, refractive errors and barriers to treatment among commercial vehicle drivers in the Cape Coast municipality. *Afr Health Sci* 2011; **11:** 97–102.

44 Yan X, Zhang X, Zhang Y, Li X, Yang Z. Changes in drivers' visual performance during the collision avoidance process as a function of different field of views at intersections. *PLoS One* 2016; **11:** e0164101.

45 Yan X, Zhang X, Xue Q. How does intersection field of view influence driving safety in an emergent situation? *Accid Anal Prev* 2018; **119:** 162–75.

46 Zhang M, Congdon N, Li L, et al. Myopia, spectacle wear, and risk of bicycle accidents among rural Chinese secondary school students: the Xichang Pediatric Refractive Error Study report no. 7. *Arch Ophthalmol* 2009; **127:** 776–83.

47 Zhang X, Yang Y, Chen Y, et al. Road traffic crashes among farm vehicle drivers in southern China: a cross-sectional survey. *Traffic Inj Prev* 2017; **18:** 83–87.

48 Erdoğan H, Ozdemir L, Arslan S, et al. Prevalence of refraction errors and color blindness in heavy vehicle drivers. *Int J Ophthalmol* 2011; **4:** 319–22.

49 Ghasemi M, Hoseini Yazdi SH, Heravian J, Jafarzadehpur E, Rezaee M. Comparison of visual status of Iranian military and commercial drivers. *Iran Red Crescent Med J* 2015; **17:** e19751.

50 James SL, Lucchesi LR, Bisignano C, et al. Morbidity and mortality from road injuries: results from the Global Burden of Disease Study 2017. *Inj Prev* 2020; **26** (suppl 1)**:** i46–56.

51 Passmore J, Yon Y, Mikkelsen B. Progress in reducing road-traffic injuries in the WHO European region. *Lancet Public Health* 2019; **4:** e272–73.

52 Zakeri R, Nosratnejad S. Economic Burden of road traffic injuries in low and middle income countries versus high income countries: a systematic review. *BMJ Open* 2017; **7** (suppl 1)**:** bmjopen-2016-015415.172.

53 Staton C, Vissoci J, Gong E, et al. Road traffic injury prevention initiatives: a systematic review and metasummary of effectiveness in low and middle income countries. *PLoS One* 2016; **11:** e0144971.

54 Alam K, Mahal A. The economic burden of road traffic injuries on households in South Asia. *PLoS One* 2016; **11:** e0164362.

55 Stockholm Declaration. Third global ministerial conference on road safety: achieving global goals 2030. Geneva: World Health Organization, 2020. https://www.roadsafetysweden.com/contentassets/b37f0951c837443eb9661668d5be439e/stockholm-declaration-english.pdf (accessed March 18, 2021).

56 Heydari S, Hickford A, McIlroy R, Turner J, Bachani A. Road safety in low-income countries: state of knowledge and future directions. *Sustainability* 2019; **11:** 1–29.

57 Odero W, Garner P, Zwi A. Road traffic injuries in developing countries: a comprehensive review of epidemiological studies. *Trop Med Int Health* 1997; **2:** 445–60.

58 Subzwari S, Desapriya E, Scime G, Babul S, Jivani K, Pike I. Effectiveness of cataract surgery in reducing driving-related difficulties: a systematic review and meta-analysis. *Inj Prev* 2008; **14:** 324–28.

59 Clay OJ, Wadley VG, Edwards JD, Roth DL, Roenker DL, Ball KK. Cumulative meta-analysis of the relationship between useful field of view and driving performance in older adults: current and future implications. *Optom Vis Sci* 2005; **82:** 724–31.

60 Desapriya E, Harjee R, Brubacher J, et al. Vision screening of older drivers for preventing road traffic injuries and fatalities. *Cochrane Database Syst Rev* 2014; **2:** CD006252.

61 Caberry T, Wood J, Watson B, King M. Self awareness of driving impairments in patients with cataract and glaucoma. Australasian road safety research, policing and education conference; Gold Coast, QLD; Oct 25–27, 2006 (abstr E215375).

62 McGwin G Jr, Chapman V, Owsley C. Visual risk factors for driving difficulty among older drivers. *Accid Anal Prev* 2000; **32:** 735–44.

63 Peden M, Hyder A. Road traffic injuries are a global public health problem. *BMJ* 2002; **324:** 1153.

64 Azami-Aghdash S, Aghaei MH, Sadeghi-Bazarghani H. Epidemiology of road traffic injuries among elderly people; a systematic review and meta-analysis. *Bull Emerg Trauma* 2018; **6:** 279–91.

65 Johnson CA, Keltner JL. Incidence of visual field loss in 20,000 eyes and its relationship to driving performance. *Arch Ophthalmol* 1983; **101:** 371–75.

66 Cole BL. Colour blindness and driving. *Clin Exp Optom* 2016; **99:** 484–87.

67 Road Safety Factsheet. Sustainable Development Goals. The Royal Society for the Prevention of Accidents. 2020. https://www.rospa.com/media/documents/road-safety/factsheets/sustainable-development-goals-factsheet.pdf (accessed March 18, 2021).