The impact of uncorrected/under-corrected refractive error on drivers: a systematic review

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ABSTRACT

Background: Decreased visual acuity in drivers, resulting from uncorrected refractive error (URE), may have detrimental impacts on specific driving tasks.
Objective: To summarise relevant evidence investigating the negative impact(s) of uncorrected refractive error and the impact of correcting refractive error on licensed drivers.
Design: Systematic review.
Participants: Licenced drivers 16 years and older, globally.
Methods: We systematically searched 12 databases and the reference lists of retrieved studies. The methodology employed adhered to the PRISMA statement. Consolidated Standards of Reporting Trials (CONSORT) Guidelines and the Critical Appraisal Skills Programme (CASP) tools were used to assess the quality of full text articles in the review synthesis. We used a descriptive narrative to report the findings of the review.
Main Outcome Measures: Outcomes measures included, Psychosocial (behavioural, well-being and quality of life), and driving performance (frequency of road accidents/ crashes, reduced driving distance and frequency, driving distance and frequency, driving cessation-including impacts on social/ emotional development, sign recognition, night driving) and impact of RE correction (sign recognition, viewing odometer, night/ day time driving).
Results: The search yielded 12164 studies, of which 9 met the inclusion criteria. Studies included 6 cross-sectional and 3 case control designs. The lack of randomised control trials (RCTs) in the determination of the impact of refractive error reduces the granularity of the data that is presented. The three case control studies provides a strong case for refractive error blur impacting on driving performance. The simulation of blur, while it can be argued in not a precise replication of the reality of uncorrected refractive error, addressed two significant issues. These are the limitations of self-reported accident and driving experience data and the ethical dilemma that arises from asking subjects to drive uncorrected
Conclusions: The lack of evaluation and analysis of the refractive error component in studies looking at the impact on drivers of poor vision, is a lost opportunity to quantify an easily addressed issue and a lost advocacy opportunity. Majority of the studies found a positive relationship between URE and RTAs. Cessation of driving is a significant indicator of the impact of UREs on drivers. This has both economic and quality of life implications for individuals.

INTRODUCTION

Driving is a highly visual and cognitive task in which vision may provide much of the sensory input needed to drive safely (Green et al.2013). Cognitive skills needed to drive safely include memory, visual perception, visual processing, visual search, visuospatial skills, attention, sequencing, planning, and judgment and decisions making (American Medical Association,2012) . The task of driving is suggested to have a 90-95% reliance on good vision (Hills, 1980) and impaired vision is suggested to be associated with increased driver discomfort, difficulty, and crash risk (Owsley, 2010). With increasing age, an individual's visual system and visual perception also change, having implications for safe driving (Andersen,2012) . In addition to age, there are other factors that contribute to safe driving, including physical abilities and reaction time because they also weaken with age (Johnson,2009). For example, individuals in theirs 40's may develop presbyopia (loss of near vision due to the thickening of the lens), which may impact their ability to process visual information as individuals with the condition may shift focus from monitoring the road ahead to monitoring the instrument panel.

The relationship between visual performance and driving tasks can be explored through understanding the influence of refractive error on visual acuity. A refractive error (myopia, hyperopia or astigmatism) occurs when the eye is not able to correctly focus images on the retina. The result is blurred vision, which is sometimes so severe that it creates functional blindness for affected individuals (Sawada, 2007). Uncorrected refractive errors, associated with low visual acuity (Willis, 2012), have a negative impact on quality of life and vision-related activities of daily living, including driving (Coleman, 2006; Lamourex, 2009; Nirmalan, 2005; Rahi, 2008; West, 2002). Difficulties related to driving include focussing on distant objects such as oncoming vehicles or traffic lights at a distance, near objects in the vehicle such as the speedometer, distortion of focus on objects (near and far) and adjusting focal length between objects in the near and far field of view (Charlton et al., 2010).

Many studies have suggested that poor visual acuity is a risk factor for specific driving performance tasks such as road-sign recognition and road hazard avoidance (Higgins et al., 1998), however some studies have shown no or minimal associations between acuity deficits and motor vehicle crash rates in the elderly (Green et al., 2013; Owsley & McGwin, 2010). Odeoye et al. (2007), however, concluded that poor visual acuity was associated with road traffic accidents. Evidence suggests that visual impairment influences driving patterns and some older drivers with acuity impairment engage in self- regulation, avoiding risky driving situations or quit driving (Owsley et al., 1999; Freeman et al., 2005; Brabyn et al., 2005 and Keay et al., 2009) . Driving can provide older adults with the ability to be mobile, to interact socially, feel a sense of independence, self-worth, and control and can also influence their health and well-being (Donorfio et al., 2009; Oxley et al., 2010 and Windsor et al., 2007). A study by Lafont et al. (2008) showed that vision difficulties (at near and at far) were associated with driving cessation. Driving cessation has furthermore been shown to have a myriad of negative effects including reduced social functioning (Owsley et al., 1999; Edwards et al., 2009), social isolation (Marottoli et al., 2009) and increased depressive symptoms (Windsor et al., 2007; Fonda et al., 2001 and Ragland et al., 2005).

In most countries, there are set visual acuity requirements for a person to be issued with a driver’s licence. Where visual acuity is low due to the presence of a refractive error, drivers are required to wear a prescribed correction to meet the required acuity levels. However despite there being laws and legal regulations in place and negative reports on poor vision and driving, several studies have found that individuals continue driving without appropriate correction for refractive error (Adeoye et al., 2007; Bekibele, 2007; Erdogan et al., 2011; Keeffe et al., 2002). As alluded to earlier, decreased visual acuity, resulting from uncorrected refractive error, may have detrimental impacts on specific driving tasks (Higgins et al., 1998). In a study conducted by Keeffe et al. (2002), uncorrected refractive error was the cause of reduced visual acuity in 80% of current drivers whose acuity levels were below the widely adopted legal limit of 20/40 (Zerbardast et al., 2015). The Salisbury Eye Evaluation study found that subjects with uncorrected refractive error had difficulty with driving and demonstrated more frequent driving cessation. Refractive blur was found to have a negative impact on driving performance under day and particularly night-time conditions in a study investigating the impact of a range of levels of refractive blur on day and night-time driving performance. This study involved using real-world tasks including road sign recognition, recognition and avoidance of road hazards and judging gaps while maintaining lane control and an appropriate speed on a closed road circuit (Wood et al., 2014). However, despite the impairment caused by refractive errors and their high prevalence, associations between these conditions, crash involvement and driving performance are largely unknown (Charlton et al., 2010). This systematic review therefore sets out to evaluate the evidence available on the negative impact(s) of uncorrected/undercorrected refractive error on driver’s vision, drivers visual function and driving performance (road accidents/crashes, driving cessation-including impacts on social/emotional development), psychosocial (behavioural, well-being and quality of life) and the impact of correcting refractive errors such as on sign recognition, viewing odometer and night/day time driving. .

METHODS

This systematic review followed the reporting items for systematic reviews as described in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al. 2009).

Eligibility Criteria

We included studies that sampled licensed drivers who were 16 years and older, globally. Studies that were of interest included those that focused on refractive error correction through spectacles or contact lenses. Outcomes measures included, Psychosocial (behavioural, well-being and quality of life), and driving performance (frequency of road accidents/ crashes, reduced driving distance and frequency, driving distance and frequency, driving cessation-including impacts on social/ emotional development, sign recognition, night driving) and impact of RE correction (sign recognition, viewing odometer, night/ day time driving). We included randomised control trials (RCTs), cohort (prospective and retrospective), cross-sectional population-based studies and qualitative studies.

Information Sources and Search Strategy

The search strategy was devised by an Information Specialist (IS) who developed a set of terms for the outcomes to be assessed and a set of terms to limit the search to the study designs of interest. Where possible search strategies contained a filter to remove studies on children being captured by the search.

The following databases were searched:MEDLINE, PubMed, EMBASE, the Cochrane Library, CINAHL, Global Health, PsychINFO, Web of Science (SCI, SSCI, A&HCI, CPCI-S, CPCI-SSH), Open Grey, New York Academy of Medicine Grey Literature Report, Clinicialtrials.gov, the World Health Organization (WHO) International Clinical Trials Registry Platform (ICTRP).
The databases were searched from 1994 to April 2018 and no language limits were applied. See Appendices for details of search strategies used.
The IS pre-screened the results to remove records which were not relevant to the scope of the review and forwarded the results to two reviewers who independently screened the remaining results.

Study Selection

The Endnote referencing system was used to import citations from the bibliographic databases for the screening of titles and abstracts for eligibility. The IS pre-screened the results and removed duplicate records which were not relevant to the scope of the review. Two reviewers independently screened the remaining title and abstracts and the full text of retained studies were obtained for appraisal. Two independent reviewers critically appraised the full text studies using the inclusion criteria predetermined for the study.

Qualitative Assessment and Data Extraction

A tool designed for assessment of reporting selected studies was used for checking unbiasedness in terms of the methodology, validity of results, relevance and applicability.

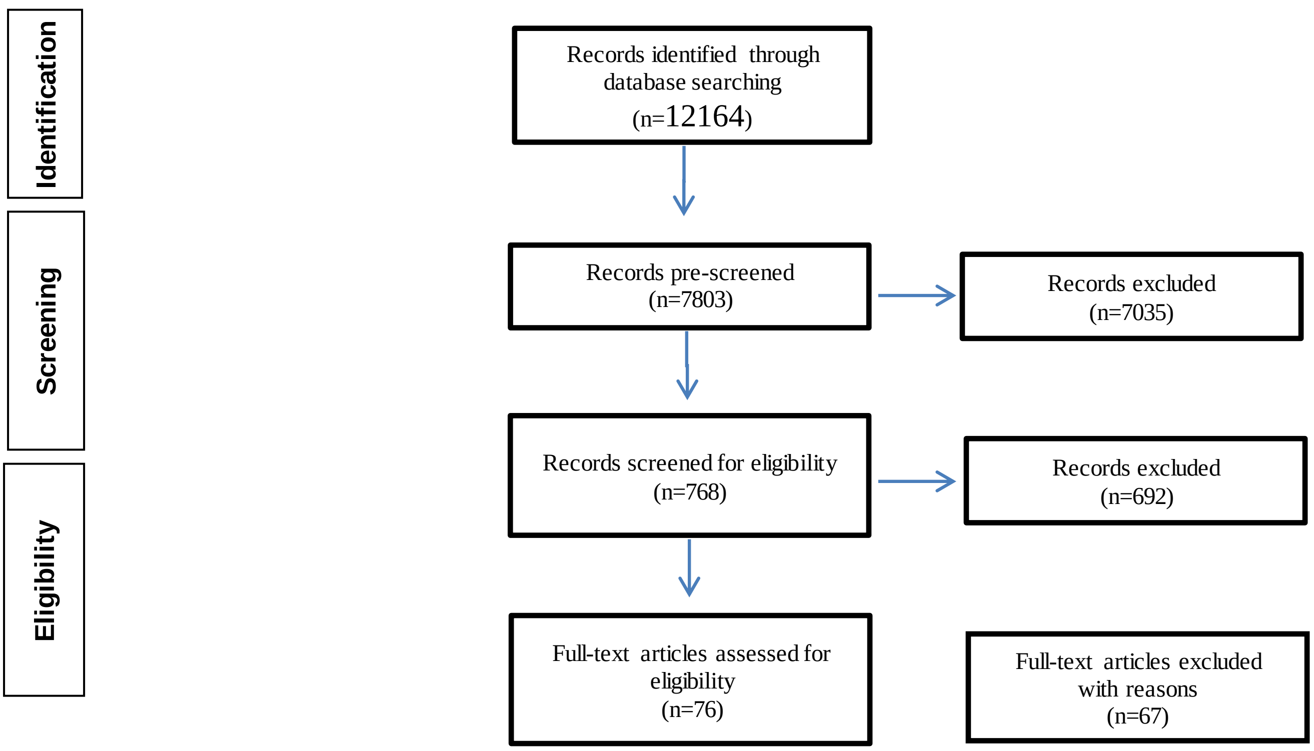
For this reason, an appraisal tool for health research of reporting systematic reviews and clinical trials, Critical Appraisal Skills Programme (CASP) tool (CASP, UK; Oram, 2012) was used. Different checklists were adapted to suit our research and ultimately, the final tool used for this study consisted of 15 questions with answers on a scale of 0 (not relevant or bad) to 2 (good). Two independent reviewers critically compared their quality appraisal scores and differences were settled through mutual agreement.

A profound data extraction sheet was used to extract desirable information from the selected studies. Extracted information included: first author, year of publication, title, country in which the study was performed, study design, sample size, type of refractive error, refractive error correction, main outcome measures, study findings, conclusions and limitations. Data were independently extracted and analytically compared by two reviewers and all disagreements were solved amicably through discussion. A third reviewer was consulted should they have failed to agree.

RESULTS

Study selection

The search yielded a total of 12,164 records, after 4,361 duplicates were removed the Information Specialist (IS) pre-screened 7,803 records and removed 7,035 records which were not relevant to the scope of the review. There were a large number of irrelevant papers as the search captured the many prevalence and incidence papers available in these topic areas. However, these types of papers are not relevant to this review as they do not have measureable outcomes on the impact of corrected or uncorrected refractive errors. The reviewers screened the remaining 768 records and discarded a further (692) records as not meeting the inclusion criteria. A total of (76) full text reports were obtained for further assessment. After reading the full text, 9 studies met the inclusion criteria and 67 were excluded as not relevant (Figure 1). We included articles that were published in English and excluded those that were only available in other languages (Appendix 1: search strategy).



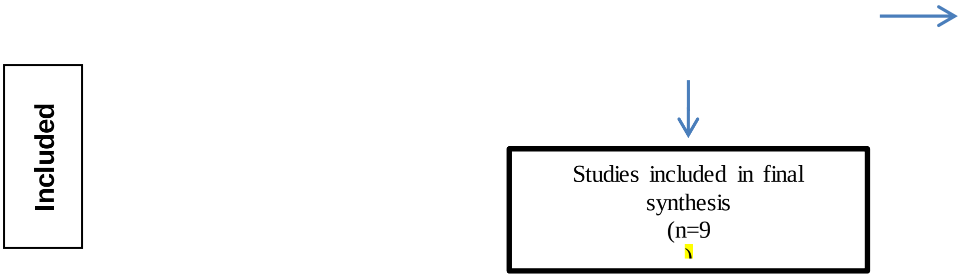


Figure 1.Flow diagram showing the selection process for inclusion of studies in the systematic review

Synthesis of results and assessment of robustness

Due to the vast diversity of the selected studies in terms of characteristics such as sample size, study designs, study setting, intervention and outcome measure, introverted narrative synthesis of the results is reported. We presented this systematic review in four main categories: 1) studies that were selected and the screening process, 2) characteristics of the studies and exploring their relationships, 3) quality assessment of studies as it was applied from CASP, and 4) synthesis of results on different impact factors.

Study characteristics

We selected nine studies that met the inclusion criteria for the systematic review (Table 1). Of the selected studies, six were cross-sectional (Biza *et al.,* 2013; Boadi-Kusi *et al*., 2015; Chu *et al.,* 2009; Oladehinde *et al.,* 2007; Pepple *et al.,* 2014; Zebardast *et al.*, 2015) and 3 were case-control (Keeffe *et al., 2002;* Sagberg *et al.,* 2005, Wood *et al., 2009*). No study included more than one study design.

Table 1: Study designs and impact measurement

Design	**Driving performance** (frequency of road accidents/ crashes, reduced driving distance and frequency, driving distance and frequency, driving cessation-including impacts on social/ emotional development, sign recognition, night driving) (11)	**Psychosocial** (behavioural, well-being and quality of life) (2)	**Impact of RE correction (sign recognition, viewing odometer, night/ day time driving) (4)**
Case-control study (3)	Keeffe (2002), Sagberg (2005); Wood (2009) (CL, Sp)		Wood (2009) (CL, Sp)

Cross-sectional (8)	Biza (2013); Boadi-Kusi (2015); Chu (2009) (CL, Sp); Oladehinde (2007); Pepple (2014); Zebardast (2015);	Zebardast (2015) Pepple(2014),	Chu (2009) (CL, Sp);

Sp - spectacles used for correction; CL – contact lenses used for correction

Out of the nine studies considered in this review, two were conducted in Australia (Chu *et al.*, 2009; Wood *et al.*, 2009), two in Ethiopia (Biza *et al.*, 2013; Keeffe *et al.*, 2002), one in Ghana (Boadi-Kusi et al., 2015), two were conducted in Nigeria (Oladehinde *et al.*, 2007; Pepple *et al.*, 2014), onw in Norway (Sagberg, 2006) and one in the USA (Zebardast *et al.*, 2015). These studies were published between 2009 and 2015 with sample sizes ranging from 39 in the case-control study by Wood et al (2009) to 4,448 in the case-control study conducted by (Sagberg *et al.*, 2006).

Random sampling techniques was reported in five studies (Biza *et al.*, 2013; Boadi-Kusi et al.,2015; Chu *et al.* 2009; 2013; Keeffe *et al.*, 2002; Sagberg, 2005). Four studies either did not clarify the sampling method or was non-random. Studies examined the following impact issues (Table 2):

Table 2: Impact issues examined in the selected studies

Driving Performance	
Frequency of crash/accident (8)	Biza (2013); Boadi-Kusi(2015); Keeffe (2013); Oladehinde (2007); Pepple (2014); Wood (2009);
Reduced/ceased driving (3)	Keeffe (2013); Zebardast (2015) (*SR);
Crash/accident (4)	Keeffe (2013) (*SR); Sagberg (2005) (*SR); Wood (2009); Zebardast (2015)
Sign recognition (3)	Chu et al (2009), Wood (2009)
Night driving (3)	Chu (2009)
Psychosocial	
Quality of life (2)	Pepple(2014),;Zebardast (2015)
well-being (2)	Pepple(2014); Zebardast (2015)
RE Correction (positive impacts)	
Sign recognition (3)	Chu (2009) (*SR); Wood (2009) (*SR)
Viewing odometer (Day) (3)	Chu (2009) (*SR); Wood (2009) (*SR)
RE Correction (negative impacts)	
Night driving (1)	Chu (2009)
Viewing odometer (Night) (1)	Chu (2009) (*SR)

*SR – Self-reported

Quality assessment and assessment of risk

CASP tools were used to identify the main general constraint of the studies. The Cochrane Handbook for Systematic Intervention was used as the recommended tool. We classified studies according to randomisation sequence generation, allocation concealment, blinding of participants, detection bias, incompleteness bias, reporting bias and other sources of bias should there be any. Among all the studies that showed refractive error correction with spectacles or contact lenses, all studies had the outcome of interest measured after the intervention. Sample size calculation was explicitly stated in only one study (Biza *et al.*, 2013). Management of missing data was unclear in all nine studies selected.

Risk of Bias

Allocation (Selection Bias). No allocation of concealment was stated in detail, which might lead to a greater risk of bias. Studies which had a random method of selection (Biza *et al.*, 2013; Boadi-Kusi et al., 2015; Chu *et al.* 2009; Keeffe *et al.*, 2002; Sagberg, 2005) were classified as low risk. All other studies were classified as high risk because they used a non-random method of selection and allocation.
Blinding (Performance Bias and Detection Bias). All of the studies were unclear on blinding/masking of the participants and assessors and were neither classified as high risk nor low risk.
Incomplete outcome data. Missing outcome data during the study due to attrition in the analysis raise possibility of risk and bias. Not much information was provided in all studies.
Selective reporting (Reporting Bias). Protocols were unavailable for all studies.
Other potential Source of bias. No other sources of bias were identified.

Synthesis of results
The findings are reported under the following headings: 1. Driving performance (frequency of road accidents/ crashes, reduced driving distance and frequency, driving distance and frequency, driving cessation-including impacts on social/ emotional development, and sign recognition) 2. Psychosocial (behavioural, well-being and quality of life) and 3) Impacts of RE correction (sign recognition, viewing odometer and night/ day time driving).

- ***Driving performance***

Nine studies that were included in the final synthesis reported on driving performance: 3 were case-control studies (Keeffe *et al.*; 2002 and Sagberg, 2005; Wood *et al.*, 2009) and 6 were cross-sectional studies (Biza *et al.*, 2013; Boadi-Kusi et al., 2015; Chu *et al.*, 2009; Oladehinde *et al.*, 2007; Pepple *et al.*, 2014; Zebardast, 2015)

A case-control study in Australia (Wood *et al.*, 2009) assessed the general driving performance of drivers on conventional visual acuity (VA) and the change over a period of time. In this study, Wood *et al.* (2009) considered the effects of visual status, driver age and the presence of secondary distracter tasks on driving performance. The composite driving score was significantly worse when participants drove with the blur or cataract simulations, and worse for the cataract compared to the blur condition. The blur condition was the stimulation of uncorrected refractive error through the addition of plus lenses over the best correction. All ages were affected by the simulated cataracts and blur as well as the distracter tasks but cataract stimulation had a greater impact. This highlights the importance of contrast sensitivity in driving performance.

A population based, stratified random cluster sampling method was used in a study by Keeffe *et al.* (2002). Of those who had accidents almost 10% reported that the accident was due to vision and those with impaired vision were more likely to have an accident or attribute the accident to poor vision. Of those who stopped driving, 11% gave impaired vision as their reason and those with impaired vision were more likely to give impaired vision as a reason. As the vision worsened the proportion attributing their stopping driving to impaired vision increased from 4.6% if VA was 6/12 or better to 33% with VA <6/12 and 43% with VA <6/18. Of those who reported limiting their driving in these conditions, 57% said that they did so because of their vision. Of those visually impaired, 80% had refractive error. The likelihood of self-reported accidents did not differ between those with good vision and those with impaired vision. The authors concluded that although many older drivers with impaired vision limit their driving in adverse conditions and some drivers with impaired vision stop driving, there are a significant number of current drivers with impaired vision.

Sagberg (2005) investigated the impact of a range of medical conditions on the outcome measure of crash involvement while driving. The sample was randomly drawn from an insurance database and administered a questionnaire. By comparing drivers with and without the condition, relative risk for being at fault for the crash for each health condition was estimated. The use of glasses or lenses by drivers had a significant risk (OR=1.26) and specifically for myopia (OR=1.22) and were thus significantly associated with crash involvement. No relationship was found between risk and the severity of refractive error.

Oladehinde *et al.* (2007) in their study intended to analyse the effect of the visual functions on the occurrence of road traffic accidents (RTA) in four major motor parks in Nigeria. The study showed a significant correlation between uncorrected visual acuity impairment in the better eye and RTA ($P < 0.05$), with a risk ratio of 3.5. A significant proportion of drivers with visual impairment had refractive error (8.4%) however none of these drivers were wearing corrective glasses. The main outcome in the study was that poor visual acuity is robustly associated with RTA and of those who were visually impaired 8.4 % was due to URE.

A cross-sectional descriptive study was conducted by Biza *et al.* (2013) to determine the impact of visual impairment and other factors on the road traffic accident among vehicle drivers in Southwest Ethiopia. 'The authors concluded that uncorrected binocular vision impairment was strongly associated with road traffic accidents. Of the sampled drivers, there was a significant percentage of URE for both left and right eye (7.6% and 8.8% respectively) with 3.2% of them having less than what is required to obtain a driving license (VA of 6/12). All drivers must have their eyes tested before obtaining a driving license but it was shown in this study that a significant proportion (9.6%) did not have their eyes examined. Among all drivers in this study, none of the drivers with refractive errors were wearing appropriate correction.

In a study by Pepple and Adio (2014) in Nigeria, 8.4% of the participants were classified as having RE, majority being myopic. All participants in this study were males and a significant number (20%) of them did not undergo any prior driving test. Three percent of the sample was driving without a license. A significant number (69.1%) of the drivers did not have their eye tested prior to issuance of the driving license. The relationship between RE and RTA in this study was not *statistically significant (P=0.46, X2=0.3, RR=0.62).* The authors depended on self-reported accidents.

Chu *et al.* (2009) investigated the subjectivity of driving difficulties experienced when wearing a range of common presbyopic contact lens (monovision contact lenses and bifocal/multifocal contact lenses) and spectacle correction (PALs and bifocal spectacles). A sample of 255 drivers, aged 45 to 70 years, with valid licenses and who were presbyopic, was recruited through local optometry practices. According to the authors "multifocal contact lens wearers were significantly less satisfied with aspects of their vision during night-time driving than daytime driving, particularly with disturbances from glare and haloes. Progressive spectacle wearers noticed more distortion of peripheral vision, while bifocal spectacle wearers reported more difficulties with tasks requiring changes of focus and those who wore no optical correction for driving reported problems with intermediate and near tasks. Overall satisfaction was significantly higher for progressive spectacles than bifocal spectacles for driving."

It must be noted however, overall, ratings of satisfaction during daytime driving were relatively high for all correction and that those without correction had more problems such as reading street directions or signs.

Zebardast (2015) compared the effects of URE and non-refractive visual impairment (VI) on performance and disability measures in a cross sectional population based study. They looked at timed performance of mobility and near vision tasks, self-reported driving cessation, and self-reported visual difficulty using the Daily Vision (ADV) scale. It was deduced in this study that individuals with RE have slower walking speeds, slower near task performance and more frequent driving cessation ($P<0.05$). When considering the impact of VI due to RE and other conditions, the impact of VI due to RE had a lesser impact on deficits on mobility measures and driving cessation.

Boadi-Kusi et al. (2015) investigated the relationship between some visual functions: colour vision defects, abnormal stereopsis, visual acuity and the occurrence of road traffic accident (RTAs) among commercial vehicle drivers in the central region of Ghana, and assessed their knowledge of these anomalies in the major commercial towns within the central region of Ghana. The study involved 520 male commercial vehicle drivers. Their results indicate that there was no statistically significant association between abnormal stereopsis (OR=0.89 95% CI: 0.44-1.80, p=0.56), poor vision due to refractive error (_2 = 3.090, p=0.388) and the occurrence of RTAs.

- ***Psycho-social impacts***

Psycho-social impacts were addressed in two studies: one case-control (Sagberg, 2005) and one cross-sectional (Zebardast *et al.* 2015). Pepple (2005) found that presbyopia was present in 22.9% of the participants and was reported as very distressing to older commercial motor vehicle drivers who sign movement registers and other documents in Transport Companies. RE (excluding presbyopia) was prevalent in 8.4% of the drivers and myopia in 90% of those with RE.

Zebardast *et al.* (2015) conducted a population based study to compare the effects of URE and non-refractive VI on performance and disability measures. Inferior vision due to URE and VI were both associated with probability of driving cessation with higher odd ratios (OR=2.1, 95% CI 1.13–3.6) for URE. Individuals with URE were likely to have stopped driving since there was a stronger association than with VI. The authors suggest that VI is associated with greater disability than URE across a wide variety of functional measures and should be expected to have different levels of outcome when measuring impact.

- ***Impact of RE correction***

Correction of refractive error was reported to be from mainly spectacles or contact lenses, where either could result in positive or negative impacts. Different day time measures were used and in some studies it was shown they effect either day (Chu *et al*., 2009; Kaido *et al*., 2013; Zur and Shinar 1998; Wood *et al*., 2009) or night time driving (Chu *et al*., 2009; Kaido *et al*., 2013; Zur and Shinar 1998). Four studies showed impact following correction: one was a case-control (Wood *et al*., 2009) and three were cross-sectional studies (Chu *et al*., 2009; Kaido *et al*., 2013; Zur and Shinar 1998).

✓ *Positive impacts*

Wood et al. (2009) demonstrated that the presence of simulated visual impairment and distracter responsibilities besmirched driving performance and there was a significance interaction between the two. Normal vision (the one with optimum distance refractive correction) was significantly better than blur and simulated cataract on sign detection ($P<0.05$) and on the self-reported sum of pairs of numbers presented on dashboard monitor. There was also a positive impact on the use of glasses and contact lenses on viewing of street signs.

✓ *Negative impacts*

Effects of presbyopia on driving experience was investigated in Chu et al. (2009), with participants being categorized into five different age-matched groups. This study was conducted both during the day and night and the results showed different driving difficulties on drivers based on time of day. The study showed that effects of using corrective lenses has an overall negative impact on drivers ($P<0.05$) in most of the groups for both day and night driving. There was an overall group effect for clarity of sign recognition with the normal group reporting significantly more difficulty. Night driving and viewing of the odometer was still worse than the group with normal vision.

DISCUSSION AND CONCLUSION

None of the RCT papers met the inclusion criteria. This is a major deficit in terms of evaluating the link between uncorrected refractive error and road traffic accidents. Randomised controlled trials are the gold standard for determining whether a cause-effect relationship exists such as uncorrected refractive error causes road traffic accidents. According to Sibbald and Roland (1998), RCTs have several important features which include:

- “Random allocation to intervention groups.
- Patients and trialists should remain unaware of which treatment was given until the study is completed-although such double blind studies are not always feasible or appropriate.
- All intervention groups are treated identically except for the experimental treatment.
- Patients are normally analysed within the group to which they were allocated, irrespective of whether they experienced the intended intervention (intention to treat analysis).
- The analysis is focused on estimating the size of the difference in predefined outcomes between intervention groups”.

The lack of randomised control trials (RCTs) in the determination of the impact of refractive error reduces the granularity of the data that is presented however three studies were case control studies, which, while not providing the certainty of RCTs, is a stronger study design to cross sectional studies. It allows for risk approximation by calculating the odds ratio but the magnitude of the association is influenced by the characteristics of the subjects chosen for the control group.

Majority (6 out of 9) of the studies were cross-sectional studies which do not allow for a causal relationship to be established and as such should be interpreted with caution. They are popular in studies dealing with refractive error/vision impairment and driving because of the relative ease with which they can be performed as well as the affordability of such studies.

Of the nine studies included in this review, the three case control studies were: Keeffe *et al., 2002;* Sagberg *et al.,* 2005, and Wood *et al., 2009.* Wood et al. (2014) provides a strong case for refractive error blur impacting on driving performance. The simulation of blur, while it can be argued in not a precise replication of the reality of uncorrected refractive error, addressed two significant issues. These are the limitations of self-reported accident and driving experience data and the ethical dilemma that arises from asking subjects to drive uncorrected while evidence is clear that this at the minimum effects their capacity to read signs and must surely put them at risk of accidents. An alternative will be to recruit a sample with different refractive errors and then test their driving skills with and without prescription in a controlled environment. This however raises questions regarding the value of a controlled environment that does not duplicate all the nuances of the situation one is faced with when driving on regular roads. However, it could be argued they also allow more complex tasks to be administered through simulation as well as introduction of different weather and other conditions and seem the most viable option.

Sagberg et al. (2005) used insurance claims data to determine if subjects were involved in an accident. It could be argued that this data is more precise than that of a questionnaire based self-reported data which all of the other studies used except in Wood et al. (2009). Most individuals will report accidents to the insurance for reimbursement purposes but may not give an accurate recollection of their accident history in responding to a study questionnaire. In a study comparing self-report of accidents and state records McGwin G Jr et al. (1998) found that self-reported accidents had a moderate level of agreement with state recorded crashes. It is therefore important that state records be accessed and cross referenced with individual responses to ensue increased accuracy of the analysis and conclusions regarding the impact of uncorrected refractive error on RTA.

Besides Broadi-Kusi et al. (2015), Keefee et al. (2002) and Zebardast et al. (2015); all of the papers did not clearly describe the methods for defining refractive error. The dependence on self-reported refractive status, current prescription or pinhole evaluation of refractive error, does not provide an accurate reflection of refractive error and prevents the classification of the type of refractive error. Some of the studies excluded used the current prescription as an indicator of refractive error without further examination. This is erroneous as the prescription may be an under-correction and as such comparing spectacles to normal vision may not be an accurate reflection as the spectacle prescription could be an indicator of mild vision impairment due to under-correction.

Wood et al. (2009) also assessed both mesopic (low light levels) and photopic (bright or well-lit) conditions and indicate that performance degrades under mesopic conditions. This highlights the need for clinicans and licensing authority to respond more precisely to the need for refractive correction. Vision testing for drivers should be conducted under both of these conditions. If a significant difference in performance between the different time of day occurs, those drivers that do a lot of night time driving, especially commercial drivers, may need a different correction for night driving. Traffic authorities should ensure that policies are developed that provide guidelines on these issues.

Most studies that we found in our initial search on drivers have focussed on vision impairment without quantifying the relative contribution of different possible causes. No distinction is made between ocular disease and refractive error and as such could not be included in this study. This is a lost opportunity as quantifying refractive error would have provided a strong motivation for advocacy efforts aimed at employers and governments given the ease of correction and the often affordable interventions available in most settings. While some studies did not quantify refractive error and was excluded in our analysis this data can be extrapolated for future use as studies have shown that refractive error is the major cause of VI and VI can be considered as a proxy indicator of the effect of uncorrected refractive error on driving if the local prevalence figures for URE are known.

The RTA are not the only measure of the impact of RE. Evidence exists of the fact that individuals stop driving when they perceive that their vision reduces (Zebardast et al. (2015). This has significant impact on the quality of life and ability to either earn or live independently and further studies quantifying this especially economically will be of great value.

Of the seven studies that investigated the relationship between URE and RTA only two did not find a significant relationship. Broadi-Kusi et al. (2015) found no impact of refractive error on RTA among commercial drivers in Ghana. The majority of their subjects were hyperopic and the outcome can be explained by Sagberg et al. (2005) found that myopia is the only refractive error that is clearly related to increased risk. Sagberg (2005) offered the following explanation "This may imply that myopia is a more serious problem than hyperopia. A possible explanation may be that uncorrected myopia always will result in a blurred retinal image, whereas uncorrected moderate hyperopia can be compensated to some extent by accommodation, at least in young persons”.

It will be useful for future studies to ensure that the sample size is large enough to provide a significant sample of myopes and hyperopes. They should then be analysed as two separate cohorts in addition to the overall analysis of the impact of uncorrected refractive error from the aggregated data.

Those studies (Chu et al.(2009) that investigated the performance of correction for refractive error versus normal vision raise interesting questions about the nature of vision correction for drivers and the need for further work in this area to address issues of glare etc. that impact on the performance of spectacles and contact lenses. However, these results are no indication of the value of vision correction for refractive error as the results should be seen in the context of those papers that have indicated that uncorrected refractive error impacts negatively on driving performance compared to correction. Not achieving par with normal vision is not ideal but preferred over no correction.

This systematic review elicited the following key issues:

-There is a dearth of RCTs examining the relationship between URE and the impact on drivers.
-Studies need to classify myopia and hyperopia and provide analysis for these cohorts separately given the differences between the two group of subjects in terms of URE impact.
- The lack of evaluation and analysis of the refractive error component in studies looking at the impact on drivers of poor vision, is a lost opportunity to quantify an easily addressed issue and a lost advocacy opportunity.
-Majority of the studies found a positive relationship between URE and RTAs.
-Cessation of driving is a significant indicator of the impact of UREs on drivers. This has both economic and quality of life implications for individuals.

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