

Prevalence of refractive error in Indigenous and non-Indigenous Australians: a systematic review and meta-analysis

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ABSTRACT

Aims This study aimed to compare the prevalence of (1) presenting vision loss from refractive error, (2) subtypes of refractive error and (3) rates of spectacle coverage and use between Indigenous and non-Indigenous Australians in urban and rural locations.

Methods Joanna Briggs Institute guidance for systematic reviews of prevalence studies was followed. Medline, Embase, Web of Science and relevant grey literature were searched. All studies reporting refractive error prevalence in Australian populations were included. Pooled prevalence estimates were derived using meta-analyses with a random-effects model.

Results 17 studies were included (22 450 adults and 13 493 children). Pooled prevalence of bilateral distance vision loss from refractive error was 7.5% (95% CI, 4.6% to 11.1%) and 4.5% (95% CI, 2.7% to 6.8%) among Indigenous and non-Indigenous adults, respectively ($p=0.126$). Bilateral blindness occurred in 0.19% (95% CI, 0.00% to 0.75%) and 0.01% (95% CI, 0.00% to 0.09%) of Indigenous and non-Indigenous adults, respectively ($p=0.265$). Myopia, astigmatism and anisometropia were similar among Indigenous and non-Indigenous children (6.2% vs 5.3% ($p=0.750$), 5.2% vs 5.6% ($p=0.928$) and 4.1% vs 5.0% ($p=0.661$), respectively). Narrative synthesis of studies suggested Indigenous people had lower spectacle coverage and lower use of the spectacles they owned.

Conclusions Vision loss from refractive error is common in Australia, with Indigenous people particularly affected by lower spectacle coverage and use. National strategies for addressing this should be considered, such as the national spectacle subsidy scheme.

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INTRODUCTION

Refractive error is the leading cause of vision loss and the second leading cause of blindness globally, affecting over 123 million people worldwide.¹ In Australia, it is the leading cause of vision loss among both Indigenous and non-Indigenous populations, despite being treatable with spectacles.^{2–4} Vision loss from refractive error is associated with significant morbidity and costs to patients and society.^{5–10}

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Indigenous Australians suffer disproportionately from vision loss. However, direct comparisons of the prevalence and treatment of vision loss from refractive error between Indigenous and non-Indigenous Australians are lacking.

WHAT THIS STUDY ADDS

⇒ Pooled prevalence of bilateral distance vision loss and blindness from refractive error was 1.7 and 19 times higher in Indigenous adults, respectively, but these differences were not statistically significant. Rates of refractive error subtypes were similar in Indigenous and non-Indigenous children. Indigenous adults and children had lower coverage and use of spectacles.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Strategies to improve national spectacle access and use are needed, particularly for Indigenous Australians.

Consequently, refractive error is one of the five priority eye diseases identified by the Royal Australian and New Zealand College of Ophthalmologists in their ‘Vision 2023 and Beyond’ strategic plan.¹¹ Likewise, the World Health Assembly has endorsed a target 40% increase in global treatment coverage of refractive error by 2030.¹²

In Australia, historical research suggests that Indigenous people have better visual acuity (VA) and lower rates of myopia and astigmatism than non-Indigenous people.¹³ However, the 2016 National Eye Health Survey (NEHS) is the only study that has directly compared vision loss from refractive error between these groups, reporting higher rates of vision loss and lower spectacle coverage among Indigenous adults.^{14 15} Beyond this, comparisons of refractive error rates and treatment between these groups are lacking.



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Furthermore, other gaps remain in our knowledge about refractive error in Australia. No temporal analysis has been performed on vision loss from refractive error and spectacle coverage. No study has compared rates of refractive error subtypes between urban and rural Australians, despite international evidence indicating that urban living is a risk factor for myopia.¹⁶ Finally, age-related and gender-related differences in refractive error have been underexplored.

To address these gaps, we conducted the first systematic review and meta-analysis to compare rates of vision loss from refractive error, refractive error subtypes, spectacle coverage and spectacle use between Indigenous and non-Indigenous Australians. Differences across age, gender, location and time were explored.

METHODS

This review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and the Joanna Briggs Institute (JBI) guidance for systematic reviews of prevalence studies.^{17 18} A single deviation from our preregistered protocol (PROSPERO ID: CRD42022340197) was made (online supplemental appendix A). Two reviewers (AK and JT) independently screened studies for eligibility (title and abstract screening followed by full-text reviews, using Rayyan software), extracted data and assessed risk of bias. Discrepancies were resolved by consensus or arbitration with a third reviewer (HR).

Search strategy

The PRISMA-S checklist was used to improve transparency of the search strategy.¹⁷ MEDLINE (Ovid), Embase and Web of Science were searched from inception to March 2025 using the strategy in online supplemental appendix B, with no limits or filters. Records were imported into and deduplicated using EndNote V.20. Multiple grey literature sources were searched (online supplemental appendix B). Reference lists of reviews and included reports were screened for additional reports.

Eligibility criteria

We included studies reporting the prevalence of (1) distance or near vision loss from refractive error diagnosed through an improvement in presenting distance or near VA, respectively, with pinhole testing or corrective lenses or (2) any refractive error subtype diagnosed through autorefractometry, retinoscopy or subjective refraction. Studies were excluded if diagnoses were based on medical records or self-report. Studies of Indigenous and non-Indigenous Australian populations of all ages were included. Studies of non-Indigenous ethnic subgroups or non-screening populations (ie, those attending specialist clinics requiring a referral) were excluded. Where necessary, corresponding authors were contacted for clarification of diagnostic methods and/or missing data.

Data collection and risk-of-bias assessment

The following were collected into standardised, prepiloted forms: study period, location, design, participant

characteristics, diagnostic methods and criteria, and outcomes of interest. The 2011 Australian Statistical Geographical Classification-Remoteness Area (ASGC-RA) was used to classify location as urban ('major cities of Australia') or rural (other ASGC-RA classifications).¹⁹

Risk-of-bias assessments and quality scores were obtained using a JBI Critical Appraisal Checklist, described previously (online supplemental appendix C).^{18 20} Overall quality of pooled prevalence estimates was assessed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach modified for observational studies.²¹

Study outcomes

Primary outcomes were:

1. Prevalence of presenting distance vision loss (VA<6/12) or blindness (VA<6/60) from refractive error. Most studies did not distinguish between uncorrected (no spectacle ownership) and undercorrected (ownership of inappropriate powered spectacles) errors, precluding separate meta-analyses of these.
2. Spectacle coverage rate (proportion of participants whose vision loss from refractive error is corrected with appropriate spectacles):

$$\text{Spectacle coverage} = 100 \times \frac{n1}{n1+n2}$$

where $n1$ is the number who use distance spectacles and achieve bilateral presenting distance VA $\geq$ 6/12, and $n2$ is the number with bilateral vision loss (VA<6/12) due to uncorrected or undercorrected errors.¹⁴

Secondary outcomes were:

3. Prevalence of refractive error subtypes: myopia (spherical equivalent (SE) $\leq$ -0.5 D in any eye), hyperopia (SE $\geq$ 2.0 D), astigmatism (cylinder $\geq$ 1.0 D) and anisometropia ($\geq$ 1.0 D difference in SE between eyes).
4. Prevalence of corrected, undercorrected or uncorrected near vision loss from refractive error, diagnosed through an improvement in near vision with corrective lenses.

Data synthesis and analysis

Pooled prevalence and 95% CIs were calculated for vision loss from refractive error and refractive error subtypes in Indigenous and non-Indigenous subgroups. Further subgroup analyses by age, gender, location (urban vs rural) and time were performed if there were at least two studies per subgroup. In cases of insufficient study numbers, results were explored descriptively. Temporal trends were assessed through subgroup analysis of pre-2000 and post-2000 studies (based on median year of data collection). The year 2000 was selected to achieve a balanced distribution of studies in each subgroup.

Meta-analyses were performed using Freeman-Tukey double arcsine transformation with a random-effects model to allow for between-study variation.¹⁸ Between-study heterogeneity was assessed by the I^2 statistic and characterised as low ($\leq$ 50%) or high ($>$ 50%). Publication bias was unassessed, given the known limitations of

these assessments on proportional data.²² Analyses were performed in Stata (STATA V.16, Stata, Texas, USA).

RESULTS

Study selection

Of the 938 unique database records identified, 39 reports from 17 studies were included (online supplemental figure S1 and online supplemental appendix D). The prevalence of (1) distance vision loss from refractive error and/or (2) refractive error subtypes was reported in nine studies of adults (21 122 and 10 687 adults, 5990 and 1653 of whom were Indigenous, respectively)^{2 3 15 23–28} and nine studies of children (6946 and 11 799 children, 1694 and 485 of whom were Indigenous).^{3 29–36}

Quality assessment

Risk-of-bias assessments for Indigenous and non-Indigenous subgroups revealed no difference in mean quality scores (64% vs 68%, $p=0.60$) (online supplemental figure S2 and table S1). Most studies did not perform or meet their sample size estimations (JBI checklist item 3).^{23–25 27 29–34 36} Most did not perform an assessment of coverage bias (item 5)^{27 29–34 36} or identify potential differences between responders and non-responders which could affect refractive error prevalence, such as differences in age,^{2 15 23 25} educational attainment,¹⁵ use of glasses²⁵ or rates of vision problems.²⁴ The overall quality of evidence using the GRADE framework was moderate for vision loss from refractive error in adults and low for refractive error subtypes in children (online supplemental table S2).

Study characteristics

In adults, distance vision loss from refractive error was reported in three studies of Indigenous participants,^{2 23 24} three of non-Indigenous participants^{25–27} and two with both groups^{3 15} (table 1). Studies reporting near vision loss did not test for improvement with refractive correction; they therefore could not attribute this impairment to refractive error and these results were excluded.^{3 15 26} Refractive error subtypes were only reported in one Indigenous (Central Australian Ocular Health Study (CAOHS))² and three non-Indigenous studies,^{25 26 28} explored descriptively.

In children, distance vision loss from refractive error was only reported in one Indigenous (National Indigenous Eye Health Survey (NIEHS))³ and one non-Indigenous (Sydney Myopia Study (SMS))³⁵ study (table 2). Eight studies reported on refractive error subtypes, among participants in preschool,³⁶ primary school^{29 31–35} or children ranging from preschool to high school.³⁰

Vision loss from refractive error in adults

Indigenous adults had a higher prevalence of bilateral vision loss (7.5% vs 4.5%) and bilateral blindness (0.19% vs 0.01%) from refractive error than non-Indigenous adults, although these were not statistically significant ($p=0.126$ and $p=0.265$, respectively) (figure 1 and

table 3). Unilateral vision loss from refractive error was lower among Indigenous adults than non-Indigenous adults (7.9% vs 12.0%, $p=0.047$). Vision loss from refractive error prevalence was similar in urban and rural populations. Bilateral vision loss from refractive error was comparable between male (4.8%, 95% CI, 2.9% to 7.3%) and female sex (5.0%, 95% CI, 3.1% to 7.4%) ($p=0.919$).

There were no differences in the overall pooled prevalence of bilateral vision loss or blindness between pre-2000 and post-2000 studies. However, pre-2000 studies included only non-Indigenous adults. Further temporal trends were explored descriptively, as follows.

Five studies between 1992 and 2016 reported on vision loss from refractive error in non-Indigenous adults (table 1).^{3 15 25–27} In chronological order, the reported prevalence of bilateral vision loss was 7.5% (1992–1994),²⁵ 2.4% (1992–1996),²⁶ 5.6% (1997–2000),²⁷ 3.7% (2008)³ and 4.0% (2015–2016).¹⁵ Bilateral blindness occurred in 0.16%,²⁵ 0.11%,²⁶ 0.03%,²⁷ 0%³ and 0%.¹⁵ Unilateral vision loss (reported in four studies) occurred in 17.0%,²⁵ 13.9%,²⁷ 8.8%³ and 8.3%,¹⁵ while unilateral blindness occurred in 0.91%,²⁵ 0.43%,²⁷ 0%³ and 0%.¹⁵

Among Indigenous adults, five studies were conducted between 1995 and 2016 (table 1).^{2 3 15 23 24} In chronological order, the prevalence of bilateral vision loss from refractive error (reported in three studies) was 11.0% (2005–2008),² 5.3% (2008)³ and 6.7% (2015–2016).¹⁵ Bilateral blindness occurred in 0% (1995–2007),²⁴ 0.38% (2005–2006),²³ 1.0%,² 0.25%³ and 0%.¹⁵ Unilateral vision loss (reported in two studies) occurred in 7.7%³ and 7.9%,¹⁵ while unilateral blindness occurred in 0%,²⁴ 0.38%,²³ 1.4%,² 0.25%³ and 0%.¹⁵

Refractive error subtypes in adults

There were too few studies to conduct a meta-analysis of refractive error subtype prevalence in adults, so these were explored descriptively using the definitions provided in individual studies. In the CAOHS,² Indigenous adults over 40 in rural Australia had a prevalence of myopia ($SE<-0.5$ D) of 10.1%, hyperopia ($SE>0.5$ D) of 39.3% and astigmatism (cylinder >1.0 D) of 5.6% (table 1). These rates in non-Indigenous adults over 40 were 16.8%, 36.7% and 6.6% in a mixed urban and rural study (Melbourne Visual Impairment Project (MVIP))²⁶ and 14.4% (myopia) and 57.0% (hyperopia) in an urban study (Blue Mountains Eye Study I (BMES I)).²⁵

Vision loss from refractive error and refractive error subtypes in children

The NIEHS³ reported that 1.8% of Indigenous children (mean age 9.5 ± 2.9 years) had vision loss from refractive error in at least one eye. This was lower than the combined prevalence of 2.9% among 6-year-old and 12-year-old non-Indigenous children in the SMS³⁵ ($p=0.020$, post hoc χ^2 test of independence).

There were no significant differences in pooled prevalences of myopia (6.2% vs 5.3%, $p=0.750$), astigmatism

Table 1 Characteristics of studies reporting the prevalence of vision loss from refractive error or refractive error subtypes in Indigenous and non-Indigenous adults

Author, study name	Study period	Location	Sampling method	Refractive method	Type of vision loss from refractive error reported	Prevalence (%)*	Refractive error subtypes reported	Prevalence (%)†
Indigenous								
Wright <i>et al.</i> ²³	2005–2006	NT (rural)	Community-based census	Pinhole testing	Unilateral blindness Bilateral blindness	0.38 0.38	Nil	
Clark <i>et al.</i> , ²⁴ Goldfields Eye Health Survey	1995–2007	Eastern Goldfields, WA (rural)	Clinic-based consecutive sampling	'Refracted' but unclear method	Unilateral blindness Bilateral blindness	0.00 0.00	Nil	
Landers <i>et al.</i> , ² Central Australian Ocular Health Study	2005–2008	Central Australia, NT (rural)	Clinic-based consecutive sampling	Retinoscopy or autorefraction refined by subjective refraction	Unilateral blindness Bilateral VL Bilateral blindness	1.40 10.99 1.01	Myopia (SE< -0.5 D) Myopia (SE< -1.0 D) Hyperopia (SE>0.5 D) Astigmatism (Cyl>1.0 D)	10.1 3.9 39.3 5.6
Taylor <i>et al.</i> , ³ National Indigenous Eye Health Survey (NIEHS)	2008	National (9% urban, 91% rural)	Random cluster sampling	Autorefraction if VA improves with pinhole testing	Unilateral VL Unilateral blindness Bilateral VL Bilateral blindness	7.74 0.25 5.30 0.25	Nil	
Keel <i>et al.</i> , ¹⁵ National Eye Health Survey (NEHS)	2015–2016	National (43% urban, 57% rural)	Random cluster sampling	Autorefraction if VA improves with pinhole testing	Unilateral VL Unilateral blindness Bilateral VL Bilateral blindness	7.94 0.00 6.67 0.00	Nil	
Non-Indigenous								
Attebo <i>et al.</i> , ²⁵ Blue Mountains Eye Study I (BMES I)	1992–1994	Blue Mountains region, NSW (urban)	Community-based census	Autorefraction refined by subjective refraction	Unilateral VL Unilateral blindness Bilateral VL Bilateral blindness	17.00 0.91 7.52 0.16	Myopia (SE< -0.5 D) High myopia (SE≤ -4.0 D) Hyperopia (SE>0.5 D) High hyperopia (SE>5.0 D) Astigmatism (Cyl≥0.75 D) Anisometropia‡ (≥1.0 D in SE)	14.4 3 57.0 2.7 37.0 14.1
Liou <i>et al.</i> , ²⁶ Melbourne Visual Impairment Project	1992–1996	VIC (69% urban, 31% rural)	Random cluster sampling	Autorefraction refined by subjective refraction	Bilateral VL Bilateral blindness	2.42 0.11	Myopia (SE< -0.5 D) Myopia (SE< -1.0 D) High myopia (SE< -5.0 D) Hyperopia (SE>0.5 D) Astigmatism (Cyl>1.0 D) Anisometropia‡ (>0.5 D in SE)	16.8 12.8 2.1 36.7 6.6 10.6
Foran <i>et al.</i> , ²⁷ BMES II	1997–2000	Blue Mountains region, NSW (urban)	Community-based census	Autorefraction refined by subjective refraction	Unilateral VL Unilateral blindness Bilateral VL Bilateral blindness	13.88 0.43 5.56 0.03	Nil	
Taylor <i>et al.</i> , ³ NIEHS	2008	National (rural only)	Random cluster sampling	Autorefraction if VA improves with pinhole testing	Unilateral VL Unilateral blindness Bilateral VL Bilateral blindness	8.82 0.00 3.68 0.00	Nil	

Continued

Table 1 Continued

Author, study name	Study period	Location	Sampling method	Refractive method	Type of vision loss from refractive error reported	Prevalence (%)*	Refractive error subtypes reported	Prevalence (%)†
Kee <i>et al.</i> , ¹⁵ NEHS	2015–2016	National (40% urban, 60% rural)	Random cluster sampling	Autorefractometer if VA improves with pinhole testing	Unilateral VL Unilateral blindness Bilateral VL Bilateral blindness	8.30 0.00 4.00 0.00	Nil	
Lee <i>et al.</i> , ²⁸ Raine Study	2010–2012	Perth, WA (urban)	Clinic-based consecutive sampling	Cycloplegic autorefractometer	Nil		Myopia (SE _≤ -0.5 D) High myopia (SE _≤ -5.0 D)	25.8 1.5

*Reported to two decimal places given the low prevalence of blindness.

†Reported to one decimal place, where possible.

‡Refers to a significant difference in the SE between eyes.

Cyl, cylinder; NSW, New South Wales; NT, Northern Territory; SE, spherical equivalent; VA, visual acuity; VIC, Victoria; VL, vision loss; WA, Western Australia.

(5.2% vs 5.6%, $p=0.928$) and anisometropia (4.1% vs 5.0%, $p=0.661$) between Indigenous and non-Indigenous children (table 4). Myopia was similar among children in urban compared with rural locations (6.7% vs 5.5%, $p=0.725$). Hyperopia was lower in Indigenous children and male sex (table 4). Children aged 10 or more years were more myopic and less hyperopic than children under 10 (table 4). In the meta-analyses of myopia prevalence, the Indigenous subgroup only contained studies that used cycloplegic refraction, whereas the non-Indigenous subgroup contained a mix of cycloplegic and non-cycloplegic studies. All other subgroups for the myopia analyses contained a mix of cycloplegic and non-cycloplegic studies. In contrast, all studies included in the meta-analyses of hyperopia prevalence used cycloplegic refraction.

Spectacle coverage

The NEHS (2015–2016)¹⁵ was the only study comparing spectacle coverage between Indigenous and non-Indigenous populations, finding lower coverage among Indigenous adults (82.7% vs 93.5%)¹⁴ (online supplemental table S3). In the NIEHS (2008),³ fewer Indigenous adults wore distance spectacles (26% vs 49%, $p<0.001$), but coverage rates were not explicitly reported. The CAOHS (2005–2008)² noted that only 9.0% of Indigenous adults with myopia or hyperopia owned spectacles, without reporting a coverage rate. In three studies of non-Indigenous adults, coverage rates were calculated as 89.1% (BMES I, 1992–1994),²⁵ 95.6% (MVIP, 1992–1996)²⁶ and 91.9% (BMES II, 1997–2000)²⁷ (online supplemental table S3).

No studies directly investigated spectacle coverage among children. However, four reported the proportion with refractive error subtypes who were either previously prescribed or currently wearing spectacles.^{29 30 35} Cox *et al.*³⁰ reported that 17.4% of Indigenous and 18.4% of non-Indigenous children with refractive error subtypes were previously prescribed spectacles. Hopkins *et al.*²⁹ reported corresponding rates of 17.6% and 20.7%, respectively. Read *et al.*³¹ reported that none of the 34 Indigenous children with a refractive error subtype had spectacles. In the SMS (2003–2005),³⁵ 14.5% of 6-year-old and 54.7% of 12-year-old non-Indigenous children with refractive error wore spectacles.

Vision loss from uncorrected versus undercorrected refractive error

Six studies of adults differentiated between bilateral vision loss from uncorrected versus undercorrected errors. In the NEHS (2015–2016),¹⁵ 34% (40/116) and 20% (25/124) of vision loss from refractive errors in Indigenous and non-Indigenous adults, respectively, were uncorrected (with the remainder being undercorrected). In the CAOHS (2005–2008),² all 19 Indigenous adults bilaterally blind from refractive error lacked spectacles. Similarly, Wright *et al.* (2005–2006)²³ reported no spectacle use among any

Table 2 Characteristics of studies reporting the prevalence of vision loss from refractive error and refractive error subtypes in Indigenous and non-Indigenous children

Author, study name	Study period	Location	Sampling method	Refractive method	Type of vision loss from refractive error reported	Prevalence (%) ^a	Refractive error subtypes reported	Prevalence (%) ^b
Indigenous								
Taylor <i>et al.</i> ³ National Indigenous Eye Health Survey	2008	National (9% urban, 91% rural)	Random cluster sampling	Non-cycloplegic autorefraction if VA improves with pinhole	Unilateral VL Unilateral blindness Bilateral VL Bilateral blindness	0.94 0.06 0.89 0.06	Nil	
Hopkins <i>et al.</i> ²⁹	Unspecified	QLD (mixed†)	Convenience sampling from schools	Cycloplegic retinoscopy	Nil		Myopia (SE ≤ -0.5 D) Hyperopia (SE ≥ 2.0 D) Astigmatism (Cyl ≥ 1.0 D) Anisometropia§ (≥ 1.0 D in SE)	1.7 5.1 3.4 4.0
Cox <i>et al.</i> ³⁰	Unspecified	QLD (rural)	Convenience sampling from schools	Cycloplegic autorefraction	Nil		Myopia (SE ≤ -0.5 D) High myopia (SE ≤ -6.0 D) Hyperopia (SE ≥ 2.0 D) Astigmatism (Cyl ≥ 1.0 D) Anisometropia§ (≥ 1.0 D in SE)	7.2 0.0 3.6 9.9 4.5
Read <i>et al.</i> ³¹	Unspecified	QLD (rural)	Convenience sampling from schools	Cycloplegic autorefraction	Nil		Myopia (SE ≤ -0.5 D) High myopia (SE ≤ -6.0 D) Hyperopia (SE ≥ 2.0 D) Astigmatism (Cyl ≥ 1.0 D) Anisometropia§ (≥ 1.0 D in SE)	12.0 0.0 3.1 4.1 5
Non-Indigenous								
Hanks and Chapman ³²	1986	Port Macquarie, NSW (rural)	Stratified random sampling	Non-cycloplegic retinoscopy	Nil		Myopia (SE ≤ -0.5 D) Hyperopia (SE ≥ 1.5 D) Astigmatism (Cyl ≥ 1.0 D)	2.0 4.0 2.0
Junghans <i>et al.</i> ³³	1990–1994	Sydney, NSW (urban)	Convenience sampling from schools	Non-cycloplegic retinoscopy refined by subjective refraction	Nil		Myopia (SE ≤ -0.5 D) High myopia (SE ≤ -4.0 D) Hyperopia (SE ≥ 1.5 D) Hyperopia (SE ≥ 2.0 D) Astigmatism (Cyl > 1.0 D) Anisometropia§ (> 1.0 D in SE)	6.6 0.4 6.1 2.0 2.0 1.4
Junghans and Grewther ³⁴	1998–2004	Sydney, NSW (urban)	Convenience sampling from schools	Non-cycloplegic retinoscopy refined by subjective refraction	Nil		Myopia (SE ≤ -0.5 D) High myopia (SE ≤ -4.0 D) Hyperopia (SE ≥ 1.5 D)	8.4 0.8 6.2

Continued

Table 2 Continued

Author, study name	Study period	Location	Sampling method	Refractive method	Type of vision loss from refractive error reported	Prevalence (%) [*]	Refractive error subtypes reported	Prevalence (%) [†]
Oiaimi <i>et al</i> , ³⁵ Sydney Myopia Study	2003–2005	Sydney, NSW (urban)	Random cluster sampling	Cycloplegic autorefraction	Unilateral blindness Bilateral blindness VL in any eye	0.00 0.00 2.01 (G1), 3.61 (G7)	Myopia (SE≤ −0.5 D) Hyperopia (SE≥2.0 D) Astigmatism (Cyl≥1.0 D) Anisometropia§ (≥1.0 D in SE)	1.5 (G1), 12.9 (G7) 13.2 (G1), 5.0 (G7) 4.8 (G1), 6.7 (G7) 1.6 (G1), 4.1 (G7)
Pai, ³⁶ Sydney Paediatric Eye Disease Study	2007–2009	Sydney, NSW (urban)	Random cluster sampling	Cycloplegic autorefraction and retinoscopy if autorefraction failed	VL in any eye [¶]	4.46 [¶]	Myopia (SE≤ −0.5 D) High myopia (SE≤ −4.0 D) Hyperopia (SE≥2.0 D) High hyperopia (SE≥6.0 D) Anisometropia§ (≥1.0 D in SE)	4.1 0.1 18.6 0.7 5.6
Hopkins <i>et al</i> , ²⁹	Unspecified	QLD (mixed [‡])	Convenience sampling from schools	Cycloplegic retinoscopy	Nil		Myopia (SE≤ −0.5 D) Hyperopia (SE≥2.0 D) Astigmatism (Cyl≥1.0 D) Anisometropia§ (≥1.0 D in SE)	4.0 8.1 1.9 5.7
Cox <i>et al</i> , ³⁰	Unspecified	QLD (rural)	Convenience sampling from schools	Cycloplegic autorefraction	Nil		Myopia (SE≤ −0.5 D) High myopia (SE≤ −6.0 D) Hyperopia (SE≥2.0 D) Astigmatism (Cyl≥1.0 D) Anisometropia§ (≥1.0 D in SE)	2.4 0.0 10.1 17.8 7.1

^{*}Reported to two decimal places given the low prevalence of blindness.

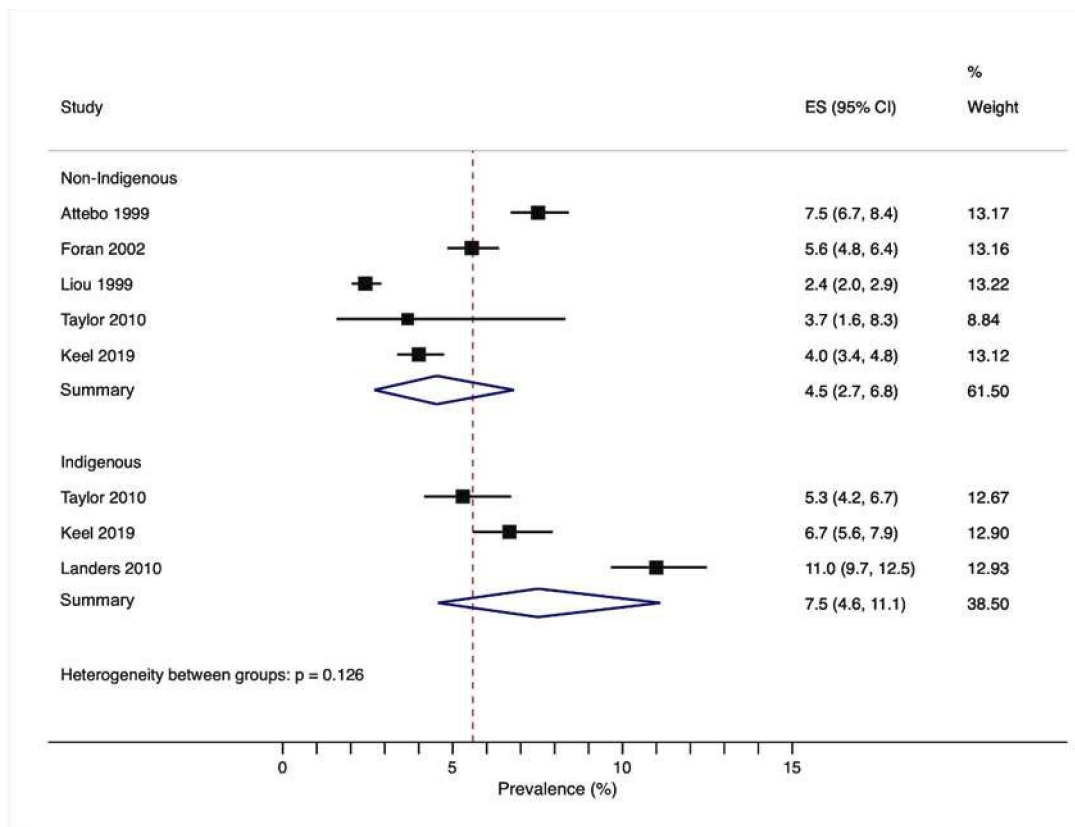
[†]Reported to one decimal place.

[‡] Urban and rural data not reported separately.

[§] Refers to a significant difference in the SE between eyes.

[¶]Reported what proportion of children with vision loss had a refractive error subtype (myopia, hyperopia or astigmatism) but could not attribute refractive error as the cause. Cyl, cylinder; G, grade; NSW, New South Wales; QLD, Queensland; SE, spherical equivalent; VA, visual acuity; VL, vision loss.

A



B

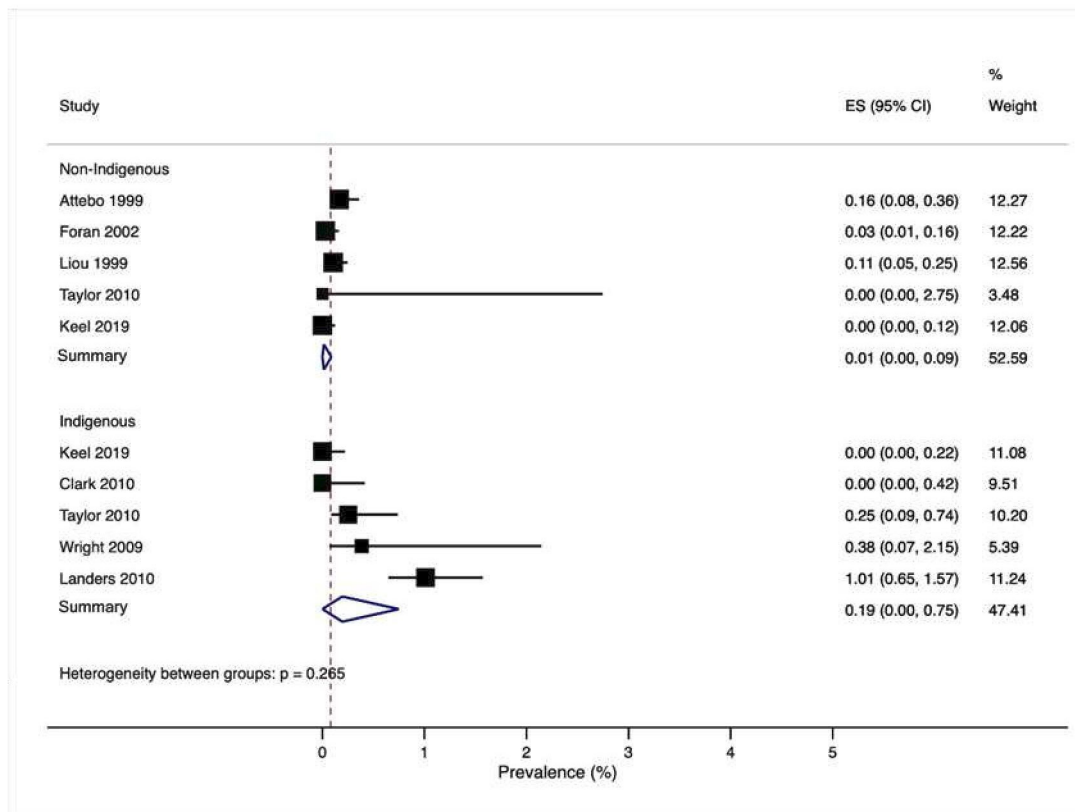


Figure 1 Forest plots of the prevalence of (A) bilateral vision loss and (B) bilateral blindness from refractive error in non-Indigenous and Indigenous adult subgroups. ES, effect size.

Table 3 Pooled prevalence of vision loss from refractive error in adults by Indigenous status and location

Type of VL by subgroup	Studies (n)	Participants (n)	Pooled prevalence % (95% CI)	Heterogeneity I ² (%)*	P value
Unilateral VL					
Indigenous status					0.047
Indigenous	2	2927	7.9 (6.9 to 8.9)	–	
Non-Indigenous	4	10388	12.0 (8.0 to 16.7)	97.6	
Location					–
Rural	0	–	–	–	
Urban	2	7154	15.4 (14.6 to 16.3)	–	
Unilateral blindness					
Indigenous status					0.989
Indigenous	5	5990	0.2 (0.0 to 1.0)	91.9	
Non-Indigenous	4	10388	0.2 (0.0 to 0.9)	94.2	
Location					0.913
Rural	4	5900	0.2 (0.0 to 1.3)	94.9	
Urban	3	9153	0.3 (0.0 to 1.0)	94.6	
Bilateral VL					
Indigenous status					0.126
Indigenous	3	4810	7.5 (4.6 to 11.1)	94.7	
Non-Indigenous	5	15132	4.5 (2.7 to 6.8)	97.0	
Location					0.979
Rural	3	4564	5.2 (1.1 to 12.2)	98.7	
Urban	4	10542	5.2 (3.0 to 8.0)	96.4	
Bilateral blindness					
Indigenous status					0.265
Indigenous	5	5990	0.19 (0.00 to 0.75)	88.6	
Non-Indigenous	5	15132	0.01 (0.00 to 0.09)	55.8	
Location					0.358
Rural	5	7373	0.2 (0.0 to 0.7)	90.6	
Urban	4	12424	0.1 (0.0 to 0.1)	52.3	

*Reported when there were three or more studies in the meta-analysis
VL, vision loss.

Indigenous adult with vision loss from refractive error. In contrast, 54% (BMES I, 1992–1994),²⁵ 60% (MVIP, 1992–1996)²⁶ and 55% (BMES II, 1997–2000)²⁷ of vision loss from refractive errors were uncorrected in three studies of non-Indigenous adults.

Among children, the NIEHS³ was the only study that differentiated between uncorrected and under-corrected errors, with 73% of bilateral vision loss from refractive error in Indigenous children being uncorrected. Three other studies reported on the use of inappropriately powered spectacles in children. Hopkins *et al*²⁹ found that over 50% of Indigenous and non-Indigenous children wore spectacles with prescriptions ≥ 0.5 D different from their measured refractive error. Junghans *et al.* (1990–1994)³³ observed this in 21% of non-Indigenous children. In the SMS (2003–2005),³⁵ one-third of 6-year-old and 12-year-old non-Indigenous children wearing spectacles had no subtype of refractive error.

Spectacle ownership and use

Among adults, 29% of Indigenous vs 74% of non-Indigenous participants in the NEHS (2015–2016)¹⁵ who owned reading spectacles brought these to the study exam ($p < 0.001$, post hoc analysis). In the NIEHS (2008),³ 71% of Indigenous versus 83% of non-Indigenous adults brought their reading spectacles to the exam ($p = 0.010$, post hoc analysis) and 62% of Indigenous adults brought their distance spectacles. In the BMES I (1992–2004),²⁵ 97% of non-Indigenous adults brought their reading or distance spectacles.

Among children, Hopkins *et al*²⁹ reported that 0% (0/32) of Indigenous versus 60% (52/87) of non-Indigenous children brought their spectacles to the exam ($p < 0.001$, post hoc analysis). Read *et al*³¹ reported that only 33% (1/3) of Indigenous children brought their spectacles. In the NIEHS (2008),³ 14% of Indigenous children brought their distance spectacles. Pai

Table 4 Pooled prevalence of refractive error subtypes in children by Indigenous status, gender, location and age

Refractive error type by subgroup	Studies (n)	Participants (n)	Pooled prevalence % (95% CI)	Heterogeneity I ² (%)*	P value
Myopia					
Indigenous status					0.750
Indigenous	3	485	6.2 (1.2 to 14.4)	88.8	
Non-Indigenous	7	11 314	5.3 (3.9 to 7.0)	90.7	
Location					0.725
Rural	3	624	5.5 (1.4 to 11.8)	87.4	
Urban	4	10 580	6.7 (4.9 to 8.7)	93.3	
Gender					0.862
Male	4	5168	6.9 (5.0 to 9.0)	87.7	
Female	4	5358	6.6 (4.4 to 9.2)	92.2	
Mean age					<0.001
<10 years	8	8582	4.2 (2.6 to 6.3)	93.3	
≥10 years	3	3209	11.7 (8.8 to 14.8)	75.6	
Hyperopia					
Indigenous status					0.011
Indigenous	3	485	3.9 (2.3 to 5.8)	0.0	
Non-Indigenous	4	6737	11.1 (5.9 to 17.7)	97.7	
Gender					0.001
Male	2	3167	10.3 (9.3 to 11.4)	–	
Female	2	2948	12.9 (11.7 to 14.2)	–	
Mean age					0.028
<10 years	5	4736	9.7 (5.5 to 14.9)	95.9	
≥10 years	2	2478	4.9 (4.1 to 5.8)	–	
Astigmatism					
Indigenous status					0.928
Indigenous	3	485	5.2 (2.3 to 9.2)	64.1	
Non-Indigenous	4	4798	5.6 (2.0 to 10.8)	93.6	
Mean age					0.204
<10 years	5	2797	4.8 (2.4 to 7.9)	87.1	
≥10 years	2	2478	6.9 (5.9 to 7.9)	–	
Anisometropia					
Indigenous status					0.661
Indigenous	2	292	4.1 (2.0 to 6.7)	–	
Non-Indigenous	4	6737	5.0 (3.0 to 7.3)	90.0	
Mean age					0.860
<10 years	4	4543	4.4 (1.9 to 7.7)	94.4	
≥10 years	2	2478	4.0 (3.3 to 4.9)	–	

*Reported when there were three or more studies in the meta-analysis.

(2007–2009)³⁶ reported that 75% of non-Indigenous children with spectacles for hyperopia brought them to the exam.

DISCUSSION

To the best of our knowledge, this is the first systematic review and meta-analysis of refractive error in Australia. We report that refractive error is common among Australian adults and children and highlight the need for improved access and use of appropriate spectacles, particularly among Indigenous people.

Refractive error in adults

By applying our prevalence estimates to census data,³⁷ approximately 540 000 non-Indigenous and 20 000 Indigenous Australians over 40 have bilateral vision loss from refractive error. This compares to an estimated 130 000 non-Indigenous Australians over 40 years of age with bilateral vision loss from cataract, the second leading cause of vision loss in Australia.³⁸ This represents a substantial proportion of Australians who, through the provision of appropriate spectacles, could potentially regain private drivers' licences (requiring a VA≥6/12 in the better eye) and may experience improvements in quality of

life, education, income and life expectancy.⁵ From an economic perspective, considering the annual cost of US\$28 905 per person over 40 with bilateral vision loss,¹⁰ refractive error costs society upwards of US\$9.5 billion per year. This is despite treatment being non-invasive and highly cost-effective.³⁹

The pooled prevalences of bilateral vision loss and blindness from refractive error were approximately 1.7-fold and 19-fold higher in Indigenous adults, respectively. The lack of statistical significance may be due to an underpowered meta-analysis, as suggested by the low number of studies and our wide CIs.⁴⁰ Indeed, the NEHS's within-study comparison found a statistically higher prevalence of bilateral vision loss from refractive error in Indigenous adults (6.7% vs 4.0%, $p < 0.001$).¹⁴ Additionally, there were too few studies to calculate the age-adjusted prevalence of vision loss from refractive error. The mean age of the included Indigenous study populations ranged from 42 to 55 years, compared with 59 to 67 years for the non-Indigenous populations. Since the prevalence of vision loss from refractive error increases with age,^{15 26} age adjustment may have revealed a greater difference in prevalence between the Indigenous and non-Indigenous subgroups than reported in our unadjusted analysis. Our findings should be interpreted in view of these limitations, which also highlight the need for further epidemiological research on refractive error in Australia.

The pooled prevalence of unilateral vision loss from refractive error was lower among Indigenous adults, driven by high rates among non-Indigenous adults in the BMES I (1992–1994, 17.0%)²⁵ and BMES II (1997–2000, 13.9%).²⁷ The remaining studies in this analysis were the NIEHS (2008)³ and NEHS (2015–2016),¹⁵ which reported similar rates among Indigenous (7.7% and 7.9%, respectively) and non-Indigenous adults (8.8% and 8.3%). This suggests that our result was skewed by the two older studies, rather than reflecting true differences in anisometropia. This is supported by our similar pooled prevalence estimates of anisometropia among Indigenous and non-Indigenous children.

While the pooled prevalence of bilateral vision loss from refractive error was similar in pre-2000 and post-2000 studies, this meta-analysis was limited as pre-2000 studies only included non-Indigenous adults. A descriptive exploration of studies suggests that the prevalence of vision loss from refractive error in non-Indigenous adults has declined over time, consistent with an analysis in the NEHS.¹⁵ As proposed in the NEHS, this may be due to increased utilisation of optometry services among non-Indigenous Australians over the past two decades.¹⁵ This trend was not observed among Indigenous adults, suggesting a potential growing disparity in spectacle coverage between Indigenous and non-Indigenous people.

Refractive error in children

Comparing the NIEHS³ and SMS,³⁵ there appears to be a lower prevalence of vision loss from refractive error

among Indigenous compared with non-Indigenous children. This should be interpreted cautiously, as only two studies were involved in this analysis. Our meta-analysis revealed that myopia, astigmatism and anisometropia are equally common in both groups. While hyperopia was more common in non-Indigenous children, this was not observed by two within-study comparisons.^{29 30} Furthermore, aside from Pai,³⁶ hyperopia prevalence had overlapping CIs among Indigenous and non-Indigenous subgroups (online supplemental figure S3). This suggests the higher estimate in non-Indigenous children may be due to inclusion of the younger preschool non-Indigenous participants in Pai's study.

Spectacle coverage and use

Based on the available evidence, Indigenous adults have, over time, had consistently lower access to spectacles than non-Indigenous adults. This includes a lower spectacle coverage in the NEHS's within-study comparison¹⁵ and lower rates of indirect measures of coverage such as fewer Indigenous adults wearing distance spectacles,³ most with myopia or hyperopia not owning spectacles² and a higher proportion of their vision loss from refractive error being uncorrected (no spectacle ownership)^{2 15 23} compared with the greater proportion of undercorrected errors in non-Indigenous adults (ownership of spectacles, but inappropriately powered).^{15 25–27} Preliminary data from the Australian Eye and Ear Health Survey suggest a potential increase in refractive error coverage in adults, but did not differentiate between Indigenous and non-Indigenous participants.⁴¹

Spectacle coverage in children has not been directly studied, representing a gap in Australian research. Indirect measures include the proportion with refractive error subtypes who have either been prescribed or wear spectacles, which was low in both Indigenous (0.0–17.6%)^{29–31} and non-Indigenous (18.4–54.7%)^{29 30 35} children. In the NIEHS,³ most vision loss from refractive error in Indigenous children was uncorrected, further indicating low coverage in this group.

Indigenous adults and children who reportedly owned glasses were less likely to bring them to study exams, suggesting that spectacles, when available, may be underused in Indigenous communities. The reasons for this are likely multifactorial and may include limited access to affordable repair or replacement services for damaged spectacles, particularly in rural areas; the lack of Indigenous input into frame design; the failure to explain refractive errors and their treatment in a culturally appropriate manner when prescribing spectacles; and a reliance on lower-quality, incorrectly powered over-the-counter spectacles due to the unaffordability or inaccessibility of culturally appropriate optometry services.^{42–44}

Research and policy implications

In recent years, efforts have been made to reduce the disparity in spectacle coverage between Indigenous

and non-Indigenous, as well as rural and urban, populations. These include the expansion of the Visiting Optometry Scheme (VOS), which provides spectacles for all Indigenous populations and rural non-Indigenous populations.⁴⁵ The gap in episodes of service under the VOS for Indigenous and non-Indigenous people has steadily closed: 7000 vs 23500 episodes (2009), 19000 vs 20,000 (2015) and 26500 vs 21,800 (2020).⁴⁵ Despite this, the spectacle needs of Indigenous people remain largely unmet, with the number of subsidised spectacles dispensed in 2020 being less than half their requirement.⁴⁵ Multiple spectacle subsidy schemes exist across Australia, but inconsistencies in patient eligibility, product range and costs are thought to limit accessibility for Indigenous Australians. The implementation of a National Spectacle Subsidy Scheme providing Indigenous people with timely access to quality-assured, cost-certain spectacles may help reduce their burden of untreated refractive error.^{46 47} Ensuring such a scheme is collaboratively designed and implemented, ideally within Aboriginal Medical Services, could further increase spectacle supply and use among Indigenous people. This may improve access to spectacle replacements, satisfaction with frames and understanding of the importance of their use.^{42–44} Such culturally tailored strategies have proven successful in select regions but have yet to be implemented nationwide.^{43 47} As seen with other initiatives addressing Indigenous eye health disparities,⁴⁸ these strategies may also prove to be cost-effective for the government.

Implementing a national preschool vision screening programme could further improve spectacle coverage among children.⁴⁹ Regular eye exams by paediatric-trained optometrists are also essential, considering that 21–50% of Indigenous and non-Indigenous children using spectacles either had no refractive error or an incorrect prescription.^{29 33 35}

Limitations

Low study numbers precluded several prespecified meta-analyses, including the prevalence of refractive error subtypes in adults, vision loss from refractive errors in children, near vision impairment from refractive error and the sensitivity analysis excluding low-quality studies. Although including low-quality studies improves comprehensiveness, it may have compromised the precision of prevalence estimates. A covariate to study cohort ratio of <1:10 precluded meta-regression.⁵⁰ While most studies were recent, five were conducted pre-2000 and may not reflect current Australian populations. Our temporal analysis should be interpreted with caution, given the limited number of studies and absence of Indigenous participants in older studies. Lastly, most of our meta-analyses had considerable heterogeneity, which is expected given the nature of proportional data and should be interpreted conservatively.²²

CONCLUSIONS

Vision loss from refractive error is common in Australia, with a gap in spectacle coverage and use among Indigenous people. Policymakers should explore strategies for refractive error, including national spectacle subsidy and preschool vision screening programmes.

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