The prevalence of refractive error and visual impairment among New Zealand children in a community with significant socioeconomic disadvantage: is current preschool vision screening effective?

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ABSTRACT

AIM: To examine the prevalence of refractive error and visual impairment and evaluate the efficacy of B4 School Check (B4SC) vision screening, in a cohort of predominantly New Zealand Māori and Pacific children from a community with socioeconomic disadvantage.

METHOD: A cross-sectional investigation of children in the Welcome-to-School study. Participants received a comprehensive eye examination at six to seven years of age. Refractive error and amblyopia were identified and compared with B4SC vision screening results.

RESULTS: One-hundred and fourteen children were assessed: 21.9% Māori, 57.9% Pacific and 20.2% Other. Over 30% of children had significant refractive error. Eighty-nine percent received a B4SC; 26.3% of children who passed the B4SC had significant refractive error. Seven children (6.1%) had amblyopia risk factors: none passed the B4SC, four were referred, one was identified for rescreening and two were not screened.

CONCLUSION: Refractive errors were common in this cohort. For those screened, the B4SC was effective at identifying children with amblyopia risk factors but poor at detecting refractive errors potentially affecting academic performance. The efficacy of the programme was limited by the number of children screened, inequity of screening and the mismatch between the aims of the vision screening test and the overall rationale for the B4SC.

On a typical day, around 70% of classroom time is spent performing academic tasks which require visual input.[1] Uncorrected refractive errors account for up to 96% of visual impairment in school-aged children and are associated with the development of amblyopia and strabismus.[2] Amblyopia or 'lazy eye' is a reduction in best corrected visual acuity (VA) in the presence of an amblyopia risk factor and in the absence of ocular pathology.[3] Amblyopia risk factors include anisometropia (difference in refractive error between the two eyes), bilateral high refractive error, visual pathway obstruction and strabismus ('squint' or turned eye).[3] Amblyopia treatment is most effective before seven years of age, thus it is important to identify children with amblyopia risk factors at a young age.[4] Additionally, lesser amounts of uncorrected

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hyperopia and astigmatism (irregular curvature of the cornea or lens causing blurred vision) have been associated with reduced performance in tests of early literacy, reading ability and academic achievement.[5–7]

Studies of refractive error distribution have been conducted in many countries and the prevalence, particularly of myopia, varies considerably by geographic location.[8] Population-based studies of children in Australia have shown overall refractive error prevalence of 12–14%, with higher prevalence of hyperopia and astigmatism in young school-aged children, and increased myopia prevalence in older children.[8,9] Unfortunately, similar contemporary refractive error data do not exist for New Zealand children and it is not known whether ethnic differences exist, particularly for children of Māori and Pacific ethnicities. Distance VA screening is commonly used worldwide to detect reduced vision in children. It is effective in detecting myopia but poor at detecting significant hyperopia and astigmatism as children with these conditions often achieve sufficient distance VA to pass a screening.[10] Therefore, understanding the refractive error profile of New Zealand children is essential to ensure screening strategies identify children who will benefit from refractive correction.

Preschool children in New Zealand receive a universal, free, well child check, the *B4 School Check* (B4SC), at four years of age which aims to identify behavioural, developmental and other health concerns which could negatively impact on their ability to learn in the school environment.[11] The B4SC has excellent coverage, with 96.7% of eligible children and 94.5% of children living in high deprivation communities in the Auckland region completing the check in 2017.[12] As part of the B4SC, vision-hearing technicians measure distance VA using the Parr vision chart[13] with the specific aim of identifying children who may have amblyopia.[11] Recent studies of children assessed following referral from the B4SC vision screening show high numbers of false positive referrals and low positive predictive value;[14,15] however, there are currently no data for children who passed the B4SC or did not receive screening.

The aims of this study were, therefore, to determine the prevalence of refractive error and visual impairment in a cohort of six- to seven-year-old children in the multicultural community of Tāmaki, and to evaluate the efficacy of the B4SC vision screening programme in this community.

Methods

Participants

Welcome-to-School (WTS) was a multidisciplinary collaborative study of children from schools in the Manaiakalani Community of Learning in Tāmaki: the Auckland suburbs of Glen Innes, Point England and Panmure Bridge. Children were recruited into the WTS project on school entry at five years of age. Children received a comprehensive health, developmental, educational and social assessment and appropriate referrals and linkages made. These same children and whānau were contacted by the WTS research nurse approximately a year later at six to seven years of age. This project was discussed and informed consent for formal vision assessment obtained.

Data collection

Data were collated from a parental questionnaire, a health and developmental assessment, school entry educational assessment, oral health assessment and formal speech and language assessment. Demographic data included their address, NZDepIndex (an area based measure of socioeconomic deprivation)[16] and ethnicity, defined as per New Zealand statistics Level 1.[17] B4SC results were obtained from the Well Child Manager within Planning and Funding at Auckland District Health Board.

Vision assessment

Two authors (RF and JB) conducted comprehensive eye examinations of the participating children in their schools. Vision assessment comprised measurement of distance VA using the Electronic Amblyopia Treatment Study (e-ATS) protocol presented on an Electronic Visual Acuity (EVA) testing system (JAEB Centre for Health Research)[18] viewed at 3m; and near VA using the Sloan Letter Near LogMAR acuity chart (Good-Lite Company) viewed at 40cm. Binocular vision assessment included the cover test for detection and measurement of strabismus, near point of convergence using

Table 1: Definition of significant refractive error.[21]

Refractive error (either eye)	Refractive error (D)
Myopia*	≤-0.50
Hyperopia*	≥+2.00
Astigmatism	≥0.75

*Spherical equivalent.

the Royal Air Force (RAF) rule (Good-Lite Company),[19] ocular motility assessment and measurement of near stereoacuity using the Randot Preschool Stereotest at 40cm (2012, Stereo Optical Company Inc).[20]

Non-cycloplegic autorefraction was measured with the Spot Vision Screener VS100 (Welch Allyn Inc) and the Nidek ARK-30 Type R (Nidek Co Ltd). Following cycloplegia (a minimum of 40 minutes after instillation of one drop of cyclopentolate 1% and when pupils were no longer reactive), autorefraction was repeated and cycloplegic retinoscopy was performed.

Ocular health was evaluated by assessment of pupillary reactions, slit lamp evaluation of the anterior segment and binocular indirect ophthalmoscopy.

Definitions

Significant refractive error (refractive error requiring glasses; Table 1) and visual impairment (Table 3) were defined according to the Refractive Error Studies in Children group.[21] Amblyopia risk factors were defined as presence of refractive error thought to induce amblyopia, visual pathway obstruction or strabismus (Table 2).[3] Convergence insufficiency was defined as exophoria greater at near than distance and receded near point of convergence.[22]

Analysis

Each participant was assessed for significant refractive error, amblyopia risk factors and ocular pathology. The results were compared with their B4SC vision screening results. Data analysis was conducted using IBM SPSS Statistics (Version 25, IBM Corporation, US). Descriptive statistics were used to summarise the data. The chi-squared test was used to compare the prevalence of significant refractive error between different ethnic groups.

Ethics approval was attained from the Central Health and Disability Ethics Committee of the New Zealand Ministry of Health with an amendment to the protocol (15/CEN/224/AM04). The research followed the tenets of the Declaration of Helsinki and parental consent for a comprehensive vision assessment was obtained for all participants.

Table 2: Definition of amblyopia risk factors.[3]

	Refractive error (D)
Anisometropia	
Myopia*	≥2.50
Hyperopia*	≥1.50
Astigmatism	≥1.50
Bilateral refractive error	
Myopia*	≥2.50
Hyperopia*	≥3.50
Astigmatism	≥1.50
Visual pathway obstruction	
Strabismus	

*Spherical equivalent.

Table 3: Visual Impairment categories.[21]

	Visual Acuity (LogMAR)
No visual impairment either eye	0.2 (6/9.5) or better both eyes
Visual impairment one eye	0.2 (6/9.5) or better one eye only
Mild visual impairment	0.3 (6/12) to 0.5 (6/19) better eye
Moderate visual impairment	0.6 (6/24) to 0.9 (6/48) better eye
Severe visual impairment	Worse than 1.0 (6/60) better eye

Results

Study population

120 children were enrolled in WTS. Consent for vision assessment was obtained for 115 children: full consent for 113 children and consent for examination without cycloplegia for two children. Vision testing was completed for 114 children: one child left their school before vision assessment was completed.

Demographic characteristics

All children lived in a community with significant socioeconomic disadvantage; NZDepIndex quintile 5. The mean age at testing was 6.72 years (range 6.14–7.24 years). There were more boys than girls in the cohort and the majority were of New Zealand Māori or Pacific ethnicities (Table 4).

Refractive error

Thirty-six participants (31.6%) had significant refractive error, most commonly astigmatism (29 participants, 80.6% of refractive errors, all 'with-the-rule' with the steepest meridian vertically). Seven participants (6.1%) had amblyopia risk factors: two anisometropia, four bilateral astigmatism and one bilateral hyperopia. Two of these participants also had strabismus.

There was no difference in the prevalence of refractive errors between ethnic groups (Table 5; chi-squared, z=2.866, df=2, p=0.239).

Visual impairment

No participant had binocular distance visual impairment; all participants had unaided distance VA of 0.2 logMAR or better in at least one eye and 97.4% of participants had unaided distance VA of 0.2 logMAR or better in both eyes (Table 6). Causes of distance visual impairment were astigmatism (1, 0.9%), myopia (1, 0.9%) and anisometropia (1, 0.9%). Binocular near visual impairment was identified in 14 participants and a further 11 participants had monocular near visual impairment.

Binocular function

Three participants (2.6%) had binocular vision abnormalities. Two (1.8%) had strabismus for which they were under care: one was referred following the B4SC and the other did not receive a B4SC and was referred following the WTS assessment. A third participant had convergence insufficiency.

Table 4: Demographic characteristics.

	n (%)
Gender	
Female	51 (44.7)
Male	63 (55.3)
Ethnicity	
NZ Māori	25 (21.9)
Pacific (Tongan, Samoan, CI Maori, Other)	66 (57.9)
Other (NZ European, Asian, European)	23 (20.2)

Table 5: Prevalence of refractive error and amblyopia risk factors.

	NZ Māori n (%)	Pacific n (%)	Other n (%)	Total n (%)
Myopia ≤-0.50	0 (0)	4 (6.1)	0 (0)	4 (3.5)
Hyperopia ≥+2.00	3 (12.0)	4 (6.1)	0 (0)	7 (6.1)
Astigmatism ≥0.75	8 (32.0)	16 (24.2)	5 (21.7)	29 (25.4)
Any refractive error	**11 (44.0)**	**20 (30.3)**	**5 (21.7)**	**36 (31.6)**
Amblyopia risk factors	**2 (8.0)**	**5 (7.6)**	**0 (0)**	**7 (6.1)**

Note: Three participants had myopia and astigmatism and one participant had hyperopia and astigmatism.

Ocular health evaluation

No anterior or posterior segment pathology was detected.

Efficacy of the B4SC vision screening

A significant number of children (13, 11.4%) did not receive a B4SC vision screening; one (0.9%) declined screening while 12 (10.5%) were unable to be contacted or scheduled (Table 7). A similar number (12, 10.5%) were identified for rescreening (borderline or inconclusive result), which had not been completed. No child with amblyopia risk factors passed the B4SC vision screening; however, two did not receive screening and one was identified for rescreening but did not receive follow-up. These children, therefore, remained undiagnosed at the time of WTS data collection. Eight children (7.0%) were referred from B4SC vision screening; six of these had significant refractive error and four also had amblyopia risk factors.

Vision correction

Only five of the 36 participants with significant refractive error (13.9%) and four of the seven participants with amblyopia risk factors (57.1%) were wearing glasses at the time of our assessment. More than half of the participants with significant refractive error (21/36, 58.3%) passed their B4SC vision screening and none of these had glasses at the time of our assessment.

Discussion

Almost one-third of six- to seven-year-old children in Tāmaki had significant refractive errors likely to affect reading development and academic achievement,[5–7] most of which were previously undetected. Over 80% of refractive errors were astigmatism, a prevalence similar to that seen in studies of specific populations of school-aged children in the Americas but lower than countries in the Western Pacific region.[8] The prevalence of myopia (3.5%) and hyperopia (6.1%) were low, similar to that seen in six-year-old children in Australia[9] and much lower than myopia prevalence reported in East Asian countries.[8]

The prevalence of unaided distance visual impairment in this cohort was low. All participants had VA of 0.2 logMAR or better in at least one eye and only three

Table 6: Prevalence of unaided distance and near visual impairment.

	Unaided distance VA n (%)	Unaided near VA n (%)
No visual impairment either eye	110 (97.4)	88 (77.9)
Visual impairment one eye	3 (2.6)	11 (9.7)
Mild visual impairment	0 (0)	13 (11.4)
Moderate visual impairment	0 (0)	1 (0.9)
Severe visual impairment	0 (0)	0 (0)

Table 7: B4SC vision screening outcomes, significant refractive error and amblyopia risk factors.

B4SC outcome	Cohort n (%)	Significant refractive error n (%)	Amblyopia risk factors n (%)
Pass bilaterally	80 (70.2)	21 (58.3)	0 (0)
Rescreen	13 (11.4)	4 (11.1)	1 (14.3)
Referred	8 (7.0)	6 (16.7)	4 (57.1)
Declined	1 (0.9)	0 (0)	0 (0)
Not screened	12 (10.5)	5 (13.9)	2 (28.6)
Total	114 (100.0)	36 (31.6)	7 (6.1)

participants (2.6%) had monocular visual impairment, a level similar to that reported in six-year-old Australian children.[23] Children with higher levels of astigmatism (>1.50D) can frequently achieve unaided distance VA of 0.2 LogMAR or better,[10] which was the source of the disparity between refractive error prevalence and visual impairment in this cohort. Correction of astigmatism of 0.75D or more is, however, recommended in published guidelines, even in children without symptoms.[24]

Although most children in New Zealand receive a B4SC vision screening, inequities are evident and a significant number of children in this cohort failed to benefit from this health initiative. While the screening was effective in detecting amblyopia, it was ineffective in detecting refractive error in this population with predominantly astigmatism. Consequently, many children in this cohort started school with uncorrected refractive errors potentially impacting their academic performance.[5–7] Therefore, for these children, the current B4SC vision screening did not meet the overall aim of the B4SC to detect conditions that may adversely affect a child's ability to learn in the school environment. Additionally, 10.5% of children in this cohort were not screened and a further 11.4% were recommended for rescreening, which was not performed before school entry. Many of these children with uncompleted screenings had amblyopia risk factors and significant refractive error. In 2017, in the Auckland and Waitemata District Health Board catchment areas, 5.3% of children from high deprivation households did not receive a B4SC vision screening and 7.5% were recommended for rescreening whereas in the most advantaged areas 4.9% were not screened and 4.3% were recommended for rescreening.[12] Differing models are required to ensure all children receive screening and appropriate eyecare prior to school entry, irrespective of ethnicity and the community they live in.[25]

For this cohort living in socioeconomic deprivation, accessing eyecare services appears to have been problematic. Six children with significant refractive error were referred from the B4SC vision screening, but only four were wearing glasses. Moreover, nearly 60% of children with significant refractive error passed the screening and none of these children were wearing glasses at our assessment, suggesting no access to eyecare following screening. This is consistent with a UK study that found seven year old children from lower socioeconomic groups were less likely to have seen an eyecare specialist than those from more advantaged groups.[26] Previous studies have noted financial, logistical, social and perceptual issues prevent families from obtaining a vision assessment following a failed screening.[27] Additionally, there is increasing evidence that cultural factors including racism and lack of trust in healthcare systems influence access and utilisation by Māori and Pacific whānau.[28] Optometry services in New Zealand are not government funded, and while limited subsidies are available for prescription glasses, the process can be difficult to navigate. Cost should not be a barrier for good care for children and funding for eyecare services should be available for all children. Culturally appropriate coordination is necessary to ensure children who

are referred or identified for rescreening receive follow up and to assist whānau in accessing services.

The false positive referral rate from the B4SC vision screening in this cohort was low, with 75% of those referred having significant refractive error. This is contrary to previous retrospective reviews of B4SC vision screening referrals in New Zealand which found only 30–50% of children referred from vision screening had diagnosed vision conditions.[14,15] The reasons for this disparity are unclear: screening and referral processes appear to differ between district health boards and higher prevalence of the condition in the target population improves the positive predictive value of the test, which may explain the differences between the studies.

Three children in this cohort presented with binocular vision abnormalities. Children with co-existing significant refractive error had been identified and referred for treatment. VA screening, however, is unlikely to identify children with intermittent or alternating strabismus without significant refractive error. Convergence insufficiency is also unlikely to be detected by VA screening and is associated with symptoms such as discomfort, loss of concentration, slow reading and need to re-read when completing near tasks.[22]

Limitations of this study include the small sample size, which reduces the power to detect statistically important differences, particularly for comparing differences between ethnic groups. The children in this study received their B4SC vision screening at four to five years of age while formal vision assessment was conducted at six to seven years of age, so the magnitude of refractive error may have changed between the two assessments. Previous studies, however, suggest that astigmatism remains stable or reduces across this age range.[29] Although this was a prospective cohort study, there was no control group and it is unclear whether the effects are a result of socioeconomic status, ethnicity or other factors.

Further investigation is necessary to determine the refractive error profile across a broader cross-section of New Zealand children and to establish methods of vision screening most effective for this population. A previous study found autorefraction superior to VA screening for detection of astigmatism,[30] and the prevalence of near visual impairment was greater than distance visual impairment in this cohort, suggesting alternative screening strategies may be more appropriate to detect refractive error in the New Zealand population. The current Well Child Tamariki Ora review provides an opportunity to re-examine the rationale for the preschool vision screening and follow-up protocol. Additionally, research addressing attitudes and beliefs towards the B4SC vision screening and vision correction in children is required.

In conclusion, almost one third of children in this ethnically diverse cohort with known socioeconomic disadvantage had significant refractive error. The current B4SC vision screening was effective in detecting amblyopia but poor at detecting significant refractive error. As the goal of the B4SC is to detect and intervene on issues which could adversely impact educational outcomes, this research highlights a mismatch between the current vision screening protocol and the intent of the B4SC programme, particularly for socioeconomically disadvantaged Māori and Pacific children. This mismatch, in combination with the differential reach of the B4SC, is likely to be increasing inequities. This study suggests that urgent attention is required to review the B4SC vision screening protocol to ensure it is appropriate and equitable, so all children receive high-quality vision screening and eyecare to improve their health, educational and social outcomes.

Competing interests:
Nil.
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