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SCIENTIFIC PAPERS

THE INCIDENCE OF REDUCED VISUAL ACUITY AND SQUINT IN PRE SCHOOL CHILDREN AGED THREE IN AUSTRALIA.

Orthoptic Association of Australia Study.

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Abstract

Three thousand and twenty 3 year old children attending pre schools throughout Australia were screened by orthoptists. Testing included visual acuity (VA), using Sheridan Gardiner single letters at 6 meters and cover test. The incidence of reduced VA (6/9 or worse testing with SG singles) when testing in a classroom situation was 14.7%. A difference of more than one line in VA between the two eyes occurred in 14.9% of the children. (6.5% of the children could not do the SG singles VA test at 6 meters). The incidence of strabismus was 2.4%.

Children who were found to have reduced VA together with those with strabismus may be considered to be 'at risk' of having or developing amblyopia. Such risk can only be ruled out by having the child referred for a full ocular examination in a clinical setting. Without regulated pre school assessment many 'at risk' three year old children may not be identified until such time as the child is routinely screened at school. By then valuable time for the treatment has been lost.

Key Words: *Pre school vision screening, visual acuity, amblyopia, strabismus.*

INTRODUCTION

Reduced visual acuity detected during pre school and school screening has been reported to have been secondary to amblyopia and/or strabismus in numerous cases in studies in the literature[1-9].

Amblyopia, the reduction in visual acuity (VA) in one or both eyes in the presence of organically normal eyes, is known to be caused by deprivation during post natal visual system development. The effects of deprivation are most marked in the sensitive period between the ages of three months and three years, then to a decreasing extent, up to the age of eight years[10-13]. The sensitive period is the time when amblyopia is most amenable to treatment and, the earlier the commencement of treatment the better the visual outcome[10-13].

Amblyopia is the commonest cause of visual disability in childhood[14]. In a citation by De Becker et at,[15] it was shown that at pre school age, amblyopia was found to affect between 1.2% to 5.6% of children. Other studies reported higher incidence[4,5]. The incidence of strabismus ranged from 1.4% to 6% in pre school children[1,3,4,6-8] and the combined prevalence of strabismus and amblyopia was reported to be around 5%[9].

Although amblyopia has been recognised for well over two centuries[16,17] it was not until 1925

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that the idea of vision screening appeared in the literature[18]. From 1925 to World War II, vision screening was primarily concerned with the detection of refractive errors, eye safety and incipient blindness[19].

According to Simons and Reinecke[19], amblyopia screening per se did not receive serious attention from the ophthalmic profession in the USA until the mid 1950's. By 1965 an article in the Readers Digest[20] entitled "A Hidden Threat to Children's Eyes" estimated that only 0.2% of three to six year old children in the USA were being screened.

Today vision screening is common in developed countries. Debate on screening in the literature includes; what is the ideal age at which to screen, what methods should be employed to screen VA in children, what is the place of refraction in pre school screening, what constitute the criteria for referral to eye professionals and who should do the screening.

A number of publications advocated screening before school age[4,21,22]. For example, a paper in the Lancet[4] reported on screening of 1506 pre school children. They concluded that there were 50% fewer visual problems overall in children who had undergone pre school screening[4]. On the other hand, some literature stated abnormalities who were missed during pre school screening programmes[5,23]. In these studies most of the children with serious visual disruption had presented for examination without any screening. Shaw et al[23] stated that, following pre school screening, there had been no significant improvement in the age at which amblyopia had been detected over the previous 13 years. They attributed their finding to the fact that there was no existing test that was adequate for pre school screening.

Responses to the question of which methods should have been employed to screen VA in children, ranged from chart based tests, single letters and preferential looking to contrast sensitivity tests and visually evoked responses[21].

The place of refraction in pre school screening had also been discussed extensively in the literature. Some literature suggested that refraction during the first year of life gave the best predictive value of those children likely to develop amblyopia. Those with +3.50D or more in any one meridian often did not attain and retain normal VA even with occlusion[5,23]. On the other hand some papers argued that, as refraction was not a direct test for either amblyopia or strabismus, and as many children have only minimal hypermetropia there may be many under referrals if clinicians relied on refraction results[21].

The question of what constituted the level of VA for referral was another debate that was not resolved. The American Academy of Paediatrics referral criteria was 6/12 or worse in one or both eyes below 5 years old and 6/9 or worse for older children[24]. In many other publications, predominantly those from Britain, the referral criteria was VA less than or equal to 6/9 in one or both eyes[7,15,22,25]. There appeared to be consensus that children with more than one line difference in VA should be referred[7,15,22,24,25].

The other consensus in the literature on pre school screening was the finding that orthoptists were more likely to detect visual anomalies during pre school screening and that the level of unnecessary referrals was much lower when orthoptists perform screening as compared to general practitioners and community nurses[7,22,25].

In the 1989 Australian Census[26] there were 277,000 pre school 3 year old children in this country, however there were no figures available on their visual status. The aim of this study therefore, was to determine the incidence of reduced VA and strabismus in pre school children in Australia. These anomalies may otherwise remain undetected until school age or later.

Referral of children with reduced VA and/or strabismus may result in earlier detection of and treatment for any ocular anomaly including amblyopia. This in turn may reduce the incidence of unnecessary visual loss.

METHODS:

The Orthoptic Association of Australia (OAA) called for volunteer orthoptists throughout Australia to test pre school children. The majority of the children in the study were attending

Long Day Care Centres, administered by the Commonwealth Department of Health, Housing and Community Services. It was considered that these centres should provide a broad socio economic cross section of the Australian three year old population as children from a broad cross section of backgrounds attend these government funded centres.

The orthoptists who participated in the study assessed a total of 3020 children aged 3. For each child the date and location (via postcode) of screening was recorded together with date of birth, gender and whether or not the child wore glasses. All recordings and test results were made on the OAA data form provided.

Prior to screening, written instruction on methods to be used to test VA and cover test (CT) were distributed to the orthoptists. The children were chosen at random by the orthoptists from their class rooms. Best corrected monocular VA was assessed at 6 meters using Sheridan Gardiner (SG) single letter books and matching cards. Acuity was assessed down to 6/3 where applicable and was recorded using the standard 6 meter notation (ie 6/4, 6/5, etc). If a child was unable to perform the test at 6 meters, 'can't do' was recorded.

The criteria selected for analysis of the results of the VA test was based on the criteria used in similar studies conducted by orthoptists in Britain[7,15,22,25]. These criteria were 'pass' (those children with VA 6/9 or better) and 'fail' (those children with VA 6/9 or worse). All VA results from the OAA study were divided into the criterion pass, fail or can't do. VA of 6/9 or worse was used to denote children who would have required further investigation.

Cover test was performed at 6 meters (CT 6m) and 1/3 meter (CT 1/3m) using an accommodative target. Any constant or intermittent strabismus was recorded. Children with these anomalies would also have required further investigation. A space was left on the data form for any comments that orthoptists thought relevant.

Statistical Methods:

For the purpose of analysis it was necessary to convert Snellen's results into simple numbers as there were drawbacks to the Snellen scale which made it difficult to easily convert to a number. The method used was recommended by Berry[27] whereby each line of the chart was allocated a number with 6/4 or better being allocated number 1, $6/4^-$ or $6/5^+$ allocated number 2, 6/5 allocated number 3 and so on. The interval between adjacent numbers on this scale represented roughly equal changes in VA.

The mean VA and standard deviation were estimated for the population sampled. Analysis of variance (ANOVA) and Chi-square tests were performed to determine the effect of independent variables (such as age and gender) on VA and/or the presence of a strabismus and, to test for any variability between the right and left eyes.

Plots of the shape, skewness and kurtosis of the sample measures suggested that most of the data were suitable for parametric analysis. There was some uncertainty whether or not the data from the sub-sample who wore glasses were suitable for parametric analysis because their data showed serious departures from normality in skewness and kurtosis. A conservative decision was made to use non parametric tests on the data. In cases where repeated measures analysis was needed it was decided to use the Friedman repeated measure non parametric ANOVA. The decision was made because bivariate scatterplots of the data showed a tendency towards heteroscedasticity. The analysis programme employed, SPSS, performed repeated measures ANOVA with its multivariate analysis of variance (MANOVA) command. Tabachnick and Fidell[28] recommend against using MANOVA unless the data are homoscedastic. Repair of the data, even if possible, would have required extensive transformations which were not deemed to be warranted in light of the likely returns.

The Bonferroni adjustment was used to produce a family-wise error rate of $p<0.05$. This means that in most cases, where a series of tests were performed, the individual error rate was $p<0.01$.

RESULTS

i. Population Sampled

Three thousand and twenty children aged 3 were assessed, thus there were 6040 eyes in the study. (See table 1 for the demographic breakdown). The age of the children ranged from 3:0 (years : months) to 3:12 with the mean age being 3:6.5. (3:12 included only children who were older than 3:11 but had NOT turned 4 years old at the time of testing). The children were put into 12 separate age groups for the purpose of analysis (see table 2).

Table 1
Demographic Breakdown

State	Total No. of Children Assessed	Percentage Assessed Per Orthoptist	No. of Children Assessed Per Orthoptist
ACT	177	5.9%	44
NSW	1400	46.4%	11
QLD	268	8.9%	16
SA	222	7.4%	27
VIC	926	30.7%	11
WA	27	0.9%	2
TOTAL	3020	100.0%	av = 18.5

Table 2
Age Groups

AGE - Y:M	Number	Percentage
3:0 - 3:1	308	10.2%
3:1 - 3:2	196	6.5%
3:2 - 3:3	206	6.8%
3:3 - 3:4	235	7.8%
3:4 - 3:5	265	8.8%
3:5 - 3:6	259	8.6%
3:6 - 3:7	243	8.0%
3:7 - 3:8	265	8.8%
3:8 - 3:9	294	9.7%
3:9 - 3:10	242	8.0%
3:10 - 3:11	265	8.8%
3:11 - 3:12*	242	8.0%

** Note: 3:12 includes only children who had NOT turned 4 years old at the time of testing.*

In the population tested, 51.4% were males (see table 3). There was no significant difference in the numbers of males or females in any of the 12 age groups (x^2=4.28, df=10, p=0.93). ANOVA indicated that there was no main effect of gender on RVA ($F_{1,2998}$=0.451, p=0.50) nor on LVA ($F_{1,2998}$=0.197, p=0.66).

Table 3
Gender

Gender	No of Children	Percentage
Male	1552	51.4%
Female	1468	48.6%

A total of 29 (or 0.96%) children wore glasses (see table 4).

Table 4
Number of Children with Glasses

Glasses	No. of Children	Percentage
YES	29	0.96%
NO	2991	99.04%

ii. Visual Acuity

Assessment of VA was performed monocularly and the results are summarised in table 5. It is of interest that 21 children, 38 eyes achieved VA of 6/3). There was no significant difference in the VA of the right eye (RVA) when compared to the VA in the left eye(LVA) in any age group (Friedman repeated measures non parametric ANOVA; x^2=0.6707, df=1, p-0.42). For the purpose of analysis, VA results were put into 1 of 4 categories (see table 6) 'Poor vision': 6/9 or worse was selected to denote the level of VA that would be used as a criterion for referral for further investigation. The number of children in each VA category is outlined in table 7.

Table 5
Visual Acuity; RVA and LVA

Vision	Right Eye		Left Eye	
	No.	%	No.	%
6/4 or better	146	4.8	160	5.3
6/4- or 6/5+	114	3.8	130	4.3
6/5	267	8.8	265	8.8
6/5- or 6/6+	329	10.9	329	10.9
6/6	1079	35.8	1044	34.6
6/6- or 6/9+	439	14.5	460	15.2
6/9	248	8.2	222	7.4
6/9- or 6/12+	81	2.7	86	2.8
6/12	79	2.6	68	2.3
6/12- or 6/18+	16	0.5	15	0.5
6/18	20	0.7	25	0.8
6/18- or 6/24+	4	0.1	3	0.1
6/24	1	0.0	4	0.1
6/24- or 6/36+	0	0.0	1	0.0
6/36 or worse	8	0.3	7	0.2
Can't Do	189	6.3	201	6.7

The mean VA was 6/6 to $6/6^-$ (or $6/9^+$; ie

Table 6
Categories of Visual Acuity

Category	Visual Acuity
Pass	6/6- or better
Fail	6/9 or worse
Can't do	not possible to test at 6 metres

Table 7
Visual Acuity in each Category

VA Category	Number of Children RE	LE	Overall &
Pass	2374	2388	78.8%
Fail	457	431	14.7%
Can't do	189	201	6.5%
	3020	3020	100.0%

'pass' category) in either eye. However the standard deviation was three lines of vision in either direction. As a result, the overall distribution was slightly skewed towards poor vision.

A Kruskal-Wallis 1 way non parametric ANOVA suggested that VA tended to improve with age (RE: x^2=106.4623 corrected for ties, $p<0.0001$; LE: x^2=112,5338 corrected for ties, $p<0.0001$). ANOVA indicated that both RVA ($F_{10,3009}$=8:94, $p<0.0001$) and LVA ($F_{10,3009}$=10.01, $p<0.0001$) were affected by the age category. Using age category and VA in non parametric correlations there was a tendency for VA to be better with increased age (RVA r=-0.18 and LVA r=-0.19).

Table 8
Children who 'can't' do Vision

Can't do VA	No. of Children	No. of Eyes	%of Eyes
Both eyes	188	376	6.23%
Can't do RVA	1	1	0.02%
Can't do LVA	13	13	0.22%
Total	202	390	6.47%

Of the 3020 children 390 were in the category of 'can't do' VA at 6 meters ('can't do' either eye = 188; RVA = 1; LVA = 13. The small numbers in some cells precluded statistical analysis; see table 8). These numbers represented 6.5% of the population tested. Cross tabulation of age group with ability to do VA revealed that if VA could not be assessed the child was most likely to be a young 3 year old (x^2=41.12055, df-10, $p<0.001$).

Criteria for referral:

a)Fail VA: In the whole population of 6040 eyes there were 14.7%, (771 eyes in 444 children) with VA 6/9 or worse hence were categorised as fail VA. There were a total of 10.8%, (327 children in 654 eyes) with 6/9 or worse in both eyes. Another 3.9%, (117 children in 117 eyes) had 6/9 or worse in only on eye (see table 9).

Table 9
Children with 'poor' vision

Poor VA	No. of Children	No. of Eyes	%of Children
Both eyes	327	654	10.8%
One eye	117	117	3.9%
Total	444	771	14.7%

Of the total of 444 children with 6/9 or worse in one or both eyes only 12 children (2.7%) wore glasses at the time of testing. (Seven had 6/9 or worse in both eyes and five had 6/9 or worse in one eye).

(The American Academy of Paediatrics standard for referral in visual screening is 6/12 or worse in either eye in children under the age of 5 years. Only 4.1% of the children in the OAA study would have met the criteria for referral VA screening in the USA; see table 10).

Table 10
USA screening standards

Visual Acuity	Number of Children RE	LE	% of Children
6/9+ or better	2703	2696	89.4%
6/12 or worse	128	123	4.1%
Can't do	189	201	6.5%
Total	3020	3020	100.0%

Table 11a
More than 1 line difference in VA;
All Children

Visual Acuity	No. of Children	% of Study
Poorer RVA	209	6.9%
Poorer LVA	240	8.0%

(Poorer RVA = RVA more than 1 line worse than LVA.
Poorer LVA = RVA more than 1 line worse than LVA).

b)Difference of more than one line: In this study there were 449 children (14.9%) who had a difference in VA of more than one line between the two eyes (see table 11a). If there

Table 11b
Difference between RVA and LVA;
Children without glasses versus children with glasses

Visual Acuity	Number of Children Without Glasses	With Glasses	Total
Equal	1722	9	1735
1 line diff	630	8	638
> 1 line diff	439	10	449

was no greater chance of poorer VA occurring in the right eye (poorer RVA) than the left eye (poorer LVA) the expected frequency for poorer RVA and poorer LVA would be 224.5. Analysis revealed poorer RVA in 209 cases and poorer LVA in 240 cases. Statistical analysis revealed that VA was no more likely to be poorer RVA than the poorer LVA (x^2=2.4, df-1, $p<0.05$).

Only 10 of the 449 children with more than 1 line difference in VA between the two eyes wore glasses at the time of testing (see table 11b). Statistical analysis revealed that children wearing glasses were more likely to have more than one line difference between the two eyes than children who did not wear glasses (x^2=11.71091, df=2, p=0.003). A difference of more than one line in VA between the two eyes was also statistically more likely to occur in children who had squints (x^2=44.15842, df=4, $p<0.0001$).

Statistical analysis revealed that age (x^2=15.60211, df=20, p=0.74) and gender (x^2=0.78033, df=2, p=0.68) had no effect on this outcome.

As mentioned previously 29 (or 0.96%) of the population sampled wore glasses (13 males and 16 females). These children were statistically analysed separately. A Kruskal-Wallis 1 way non parametric ANOVA suggested there was no effect of gender on VA in this sub group; (RE; x^2=1.97 corrected for ties, p=0.16, LE x^2=1.89 corrected for ties, p=0.17). There was no significant difference between RVA and LVA in the children who wore glasses (Friedman repeated measures non parametric ANOVA; x^2=1.2414, df=1, p=0.27).

When looking at the breakdown of VA into the 3 categories it is apparent that there were fewer children wearing glasses in the 'pass' VA category (see percentages in table 12 compared to table 7). Despite this observation statistical analysis revealed that only RVA was significantly worse in children who wear glasses (Kruskal-Wallis 1-way ANOVA, x^2=5.638 corrected for ties, p=0.02). The same statistical analysis of LVA in children who wore glasses compared to those who do not revealed no significant difference (Kruskal-Wallis; x^2=3.25 corrected for ties, p=0.07).

Table 12
Children who wear glasses

Visual Acuity Category	Number of Children RE	LE	Overall %
Pass	17	18	60.4%
Fail	10	9	32.7%
Can't do	2	2	6.9%
	29	29	100.0%

iii. Strabismus

A total of 76 children (2.52%) had strabismus.

Table 13
Children with squint
Type of Squint* (n=76)

ESO 1/3m	ESO 6m	No.	EXO 1/3m	EXO 6m	No.
Et	ET	17	XT	XT	3
IET	IET	5	IXT	IXT	6
IET	NAD	10	IXT	NAD	26
			NAD	IXT	9

**ET = constant esotropia, XT = constant exotropia, IET = intermittent esotropia, IXT = intermittent exotropia, NAD = no tropia*

Of the 76 children there were 20 with constant strabismus and 56 with intermittent strabismus (see table 13).

The VA of the children with strabismus was fairly evenly divided between the categories 'pass' (n=37) and 'fail' (n=36) with 3 children with strabismus unable to do VA at 6 meters,

Table 14
VA of children with squint

VA	No. of Children	No. with Glasses
Pass	37	4
1 poor eye	15	3
2 poor eyes	21	2
Can't do	3	0
Total	76	9

(see table 14). This finding is in keeping with the larger proportion of intermittent strabismus. Statistical analysis revealed that VA tended to be worse in children with strabismus compared to children who did not have strabismus (Kruskal-Wallis 1-way ANOVA; CT 1/3m, RVA; x^2=33.0146 corrected for ties, p<0.0001: LVA x^2=19.3007 corrected for ties, p<0.0001; CT 6m, RVA; $x^2$28,3836 corrected for ties, p<0.0001: LVA; x^2=22.6118 corrected for ties, p<0.0001).

Nine of the children with strabismus wore glasses at the time of screening. Numbers of children wearing glasses were too small to do a meaningful statistical analysis.

ANOVA revealed that neither age nor gender had an effect on the chance of finding strabismus (constant or intermittent) when testing at near. A Bonferroni adjustment was used to ensure a family-wise error rate of p<0.05. With the significance level for individual comparisons set at 0.0125 there were no significant main effects of gender ($F_{1,2998}$=0.046, p=0.83) or age ($F_{10,2998}$, p=0.02) and there were no intersections ($F_{10,2998}$=0.687, p=0.74). (Although the main effect for age was not significant it was close to significance. With a very large sample size small sized effects can approach or achieve significance but will not be of clinical use. The fact that this result did not achieve significance means that it is probably a very small effect in the population and therefore not of clinical significance to orthoptists). Similarly for distance cover test there were no main effects of gender ($F_{1,2998}$=0.014, p=0.90) or age ($F_{10,2998}$,p=0.61) and there was no interaction of gender with age on strabismus.

DISCUSSION

Children who were found to have reduced VA as indicated by their failure to meet the'pass' criteria for VA when tested in a classroom situation, together with those who were found to have strabismus, may be considered to be 'at risk' of having or developing amblyopia. Such risk can only be ruled out by having the child referred for a full ocular examination in a clinical setting, hence the 'at risk' children's parents must be made aware that such an examination is necessary. Without some routine method of pre school screening in Australia, these 'at risk' three year olds may not be identified.

The major findings in this study were the incidence of reduced VA detected during screening; (14.7%), the number of children with more than one line difference in VA between the two eyes; (14.9%) and the incidence of strabismus detected during screening; (2.5%). The other finding of interest was that 6.5% of the children could not do the SG singles VA test at 6 meters.

The incidence of reduced VA in the OAA study was very high when compared to a study by Beardsell[22] in which 2475 three and a half year old children were assessed by orthoptists using SG singles at 6 meters and cover test and the same referral criteria. Beardsell's incidence of reduced VA (and thus referral) was 4.12%. (Their assessment included stereopsis, ocular movements and 20 dioptre prism test). On the other hand, Feldman et al[4] conducted a study using the illiterate E test and the same referral criteria as the OAA, and their incidence of reduced VA was 12.5%.

In another study, where orthoptists tested SG linear VA at 6 meters and VA 6/12 or worse and/or squint was used as referral criteria, Ingram et al[5] reported a referral rate of 8%. This represented a higher incidence of reduced VA and/or strabismus than the OAA study. Using 6/12 or worse as the referral criterion only 4.1% of the OAA study subjects would have been referred for reduced VA and 2.5% for strabismus. This finding may be partially explained by the use of single letter optotypes to test VA in the OAA study. Ingram used linear optotypes. Single letter optotypes are generally considered to over estimate visual acuity[23]. Ingram et al found that 5.3% of their study could not do the SG linear chart at 6 meters in a screening situation. This finding was slightly lower than the finding of 6.5% in the OAA study.

Results demonstrated that, of the children who could not do VA in one eye only, there

was one child who could not do RVA while 13 children could not do LVA. From this finding it is tempting to assume that RVA may have been tested first in many cases and thus to speculate that the larger number of 'can't do' LVA suggests that the children became bored or lost concentration following RVA testing.

The finding in the OAA study of 2.52% of children with strabismus was lower than a study by Bruce et al[8]. In Bruce's study orthoptists found 4.2% of the 2:6 to 3 year old children tested had strabismus. In another study by Edwards[7] et al, orthoptists found an incidence of 1.4% of 3:6 to 4 year old children with strabismus.

There were numerous studies in the literature which reported on the incidence of reduced vision and/or squint in children following screening[1-3,6,9,15,21,25,29] however, it is difficult to compare the OAA study to these as the referral criteria and/or the ages of the children differed too greatly from those in the OAA study.

CONCLUSIONS:

We know that there are over 277,000[26] pre school 3 year old children in this country. The results of the OAA study have demonstrated that there is a high level of reduced VA when testing vision with single letters in a classroom situation. The children found to have reduced VA and/or strabismus in such situations should be referred for clinical examination. Without regulated pre school assessment many 'at risk' three year old children may remain undetected until school age or later.

With the scientific and medical knowledge we have today it is unacceptable that reduced VA should remain undetected in any Australian child until such time as the child is routinely screened at school. By then, valuable time for the treatment of amblyopia has been lost.

In a commentary on the incidence of amblyopia and its detection rate Sir Stewart Duke Elder[30] quoted Franceschetti; and stated

That this enormous number of people suffer from a serious visual defect is a grave economic and social matter, and that it should be tolerated with complacency is a depressing reflection of the neglect shown by modern civilisation towards its human material.

It is up to the OAA to ensure that our findings are brought to the attention of the public so that 'at risk' children can be fully examined and amblyopia in this country is no longer tolerated with complacency.

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