Visual Processing in Adolescents Born Extremely Low Birth Weight and/or Extremely Preterm

WHAT'S KNOWN ON THIS SUBJECT: Data available before the 1990s in addition to small studies with clinical populations have shown that ocular growth and development differ between extremely preterm and term-born children.

WHAT THIS STUDY ADDS: Contemporary data on long-term visual outcomes indicate that adolescents born extremely low birth weight and/or extremely preterm exhibit more visual sensory and perceptual morbidity than adolescents born at term.

abstract

BACKGROUND AND OBJECTIVES: Ocular growth and development differs between preterm and term-born infants and may cause long-term negative consequences for visual function, but contemporary data on long-term visual outcomes in representative samples of the highest risk extremely low birth weight (ELBW, <1000 g birth weight) or extremely preterm (EP, <28 weeks' gestation) survivors are lacking. Our objective was to compare visual functioning between ELBW/EP and normal birth weight (NBW, >2499 g birth weight) control adolescents.

METHODS: Geographically determined cohort study of 228 consecutive ELBW/EP survivors born in the state of Victoria in 1991 and 1992, and 166 randomly selected NBW controls assessed between 14 and 20 years of age. Visual acuity, stereopsis, convergence, color perception, and visual perception were assessed and contrasted between groups.

RESULTS: ELBW/EP subjects had significantly worse visual acuity with habitual correction in both the left and right eyes, and for the best eye ($P < .001$). The ELBW/EP adolescents also exhibited poorer stereopsis, odds ratio (OR) 3.22 (95% confidence interval [CI] 1.78 to 5.84), and convergence, OR 2.76 (CI 1.32 to 5.75) than controls, and more problems with visual perception, OR 3.09 (CI 1.67 to 5.71) after habitual correction.

CONCLUSIONS: Despite advances in medical care improving the survival rate of high-risk ELBW/EP infants, visual morbidity is still relatively high compared with controls in late adolescence. Pediatrics 2013;132:e704–e712

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KEY WORDS: extremely low birth weight, extremely preterm, visual acuity, visual processing, visual perception

ABBREVIATIONS

CI—95% confidence interval
ELBW—extremely low birth weight
EP—extremely preterm
NBW—normal birth weight
OR—odds ratio
ROP—retinopathy of prematurity
TVPS-3—Test of Visual Perceptual Skills, 3rd Edition

Dr Molloy conceptualized and designed the study, performed data acquisition, drafted the initial manuscript, performed data analysis and interpretation, and approved the final manuscript as submitted; Dr Wilson-Ching was involved in the conceptualization and design of the study, performed data acquisition and interpretation of data, reviewed and revised the manuscript, and approved the final manuscript as submitted; Dr V. Anderson was involved in the conceptualization and design of the study and interpretation of data, reviewed and revised the manuscript, and approved the final manuscript as submitted; Dr Roberts was involved in the interpretation of data, reviewed and revised the manuscript, provided supervision, and approved the final manuscript as submitted; and Drs P. Anderson and Doyle were involved in the conceptualization and design of the study and interpretation of data, provided supervision, reviewed and revised the manuscript, provided administrative and technical support, and approved the final manuscript as submitted.

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Ocular growth and development differ between extremely low birth weight (ELBW, <1000 g) or extremely preterm (EP, gestational age <28 weeks) and term children and may have long-term negative consequences for visual function.1 Although past research has reported that preterm children have higher rates of a range of visual abnormalities2–6 lacking are studies examining visual function in representative samples of ELBW/EP children born since the early 1990s when important advances in medical care were introduced and survival rates of the most immature and vulnerable infants rose dramatically.

Visual sensory and perceptual skills are important for a range of functions and everyday activities, such as classroom learning, overall school performance,6–8 successful social interaction, and social cognition.10–12 Consequently, understanding the nature and frequency of visual deficits in ELBW/EP children is vital to inform adequate and appropriately targeted clinical follow-up and to increase focus on developing avenues for remediation.

Infants born ELBW/EP are susceptible to retinopathy of prematurity (ROP), and ~5% to 10% exhibit severe brain pathology, particularly with the periventricular white matter.13–15 These perinatal insults have been identified as risk factors for poor visual outcome.2–6,16–20

The aim of this study was to compare visual functioning between ELBW/EP and normal birth weight (NBW, >2499 g birth weight) control adolescents. It was hypothesized that ELBW/EP adolescents would have higher rates of visual abnormalities in all areas assessed compared with controls.

**METHODS**

**Participants**

The subjects were derived from a geographic cohort study of all 298 surviving ELBW or EP children born between January 1991 and December 1992, inclusive, in the state of Victoria, Australia. The control cohort, enrolled at birth, comprised 262 randomly selected NBW infants. These cohorts have had extensive evaluations at 2,21,22 5,23 and 824 years of age; none of these assessments included formal assessments of visual functioning, apart from visual acuity.

Written informed consent was obtained from parents of adolescents, and from the participants themselves, if they were able to provide consent. The study was approved by the Human Research Ethics Committees of the participating hospitals.

**Outcome Measures**

Participants were assessed between 14 and 20 years of age by a trained examiner who was blind to group membership. Visual functions were measured with habitual correction (eg, glasses). Parents were asked to report on diagnosed visual problems, but precise refractive error data were unavailable.

**Sensory**

(a) Visual Acuity: The 3m Early Treatment Diabetic Retinopathy Study (ETDRS) logMAR chart test25 was used to assess visual acuity; scoring was per letter. The ETDRS logMAR chart is sensitive to the most common sources of visual impairment, such as refractive error; cataract, macular disease, and amblyopia.26 Visual acuity was measured monocularly (ie, left and right eyes were assessed separately). As is commonly used, logMAR equivalent scores <0.20 (Snellen equivalent 6/9) were considered normal6,9,16,27 and participants with logMAR ≥0.2 were determined to be clinically impaired.

(b) Stereopsis (binocular depth perception): Stereopsis was assessed with the Randot Stereotest.28 The test plates viewed through polarized spectacles can identify retinal disparities ranging between 20 and 500 seconds of arc; resolution ≤70 seconds of arc was considered normal.29

(c) Convergence: Convergence was assessed with the Prentice card, and a “dissociating prism” was used to create vertical double vision (of a ruler, split into 2 halves with numbers and an arrow over the zero or midpoint point). Adolescents were asked to name the number to which the arrow appeared to point. Abnormal convergence was defined as a near point of convergence >7 cm.30

(d) Color Perception: The Ishihara Color Perception Test was used to assess color vision; it is good for detecting red-green color vision deficiency with high sensitivity and specificity, and it can perform acceptably even with poor illumination.31 The incidence of red-green color blindness in Australia is ~5% to 8% of males and 0.4% of females.31–34 Three or more errors out of 14 plates were considered abnormal.

**Visual Perception:**

Five subtests from the Test of Visual Perceptual Skills, Third Edition (TVPS-3) were administered.35,36

1. Visual discrimination: Assessed ability to distinguish 1 object from another.

2. Visual-spatial relationships: Assessed ability to identify 1 item that was different from remaining items in terms of direction/orientation.

3. Form constancy: Participants selected the item that included the same shape as the reference item; size and/or spatial orientation varies.

4. Visual figure-ground: Participants selected the item in which the reference item was imbedded within another object.
5. Visual closure: Participants selected the item that would match the reference item if all lines on the picture were connected. Each scale is age standardized with a normative mean of 10 (SD 3), with higher scores indicative of better performance; the upper age band of 18 years, 11 months was used for all subjects aged >19 years.
The raw scores of these 5 subtests were summed to form an overall visual perceptual score. To classify visual perceptual impairment we used a cut-off equivalent to the 10th percentile of the control group, therefore scores ≤28 were considered clinically impaired.

General Intellectual Function
The Wechsler Abbreviated Scale of Intelligence assessed general intellectual function.

Statistical Analysis
Between-group differences (ELBW/EP versus control) for dichotomous outcome data were analyzed by χ² analysis and for continuous data by t tests, or Mann-Whitney U test for skewed data. Rates of impairment across the sensory and visual perceptual measures were compared between groups. Two dichotomous variables were created to depict the number of adolescents with 1 or more visual impairments and for those with 2 or more impairments across multiple areas. In ELBW/EP adolescents the effects of severe ROP (stage 3 or higher) and severe brain injury on cranial ultrasound (cystic periventricular leukomalacia and/or grade 3 or 4 intraventricular hemorrhage) on the likelihood that ELBW/EP adolescents would have impaired visual acuity, stereopsis, convergence, or color vision were assessed by logistic regression.

RESULTS
Two hundred and twenty-eight (76.5%) ELBW/EP and 166 (63.4%) control adolescents participated. The mean age at follow-up for the ELBW/EP group was 17.0 years (SD, 1.5; range, 14.5–20.0 years) and 17.4 years (SD, 1.6; range, 14.4–20.2) for the control group. Figure 1 details the reasons for non-participation.

There were no significant differences between ELBW/EP participants and nonparticipants in perinatal variables except that nonparticipating ELBW/EP adolescents had higher rates of cystic periventricular leukomalacia (Table 1). When assessed at 8 years, nonparticipants were more likely to be legally blind or deaf. There were no differences between control participants and nonparticipants, except there were more female participants (56.6% vs 44.3%).

Sensory Outcomes
Five individuals from both groups did not complete the visual assessment owing to unavailability of equipment. Of the 223 ELBW/EP adolescents who attempted the visual assessment, 12 (5.4%) were too visually impaired to complete the test of visual acuity, whereas 2 were too impaired due to cerebral palsy, and 1 due to autism. A similar proportion of control adolescents were too visually impaired to complete the test of visually acuity, 8 (5%), whereas 2 had neurosensory disability and were unable to understand the task. Vision was subsequently classified as impaired and scores were not imputed for group comparisons. More ELBW/EP adolescents wore corrective eyewear than controls, but this did not reach statistical significance (31.7% vs 23.6%). Other ophthalmologic details, as reported by the participant’s parent, were for the ELBW/EP group: any refractive error 14 (6.3%), strabismus 2 (1%), and astigmatism 2 (1%); and for the NBW group: any refractive error 8 (5%) and astigmatism 1 (0.6%).

The ELBW/EP group had a worse (higher) median acuity and a greater spread of values for logMAR visual acuities of left, right, and score in the better eye after habitual correction (Fig 2). Of note, the median acuities of the ELBW/EP group were within the normal range in each condition. Statistically significant differences were found between ELBW/EP adolescents and controls with habitual correction for either eye (left eye, z = −4.07, P <
TABLE 1 Demographic Characteristics of ELBW/EP Adolescents Who Participated Versus Nonparticipants and the Term-Born Group

<table>
<thead>
<tr>
<th>Neonatal characteristics</th>
<th>ELBW/EP Participants (n = 228)</th>
<th>Nonparticipants (n = 70)</th>
<th>Controls (n = 166)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male: n (%)</td>
<td>99 (43.4)</td>
<td>39 (55.7)</td>
<td>67 (40.4)</td>
</tr>
<tr>
<td>Gestational age at birth, wk, mean (SD)</td>
<td>26.6 (2.0)</td>
<td>27.0 (1.7)</td>
<td>30.2 (1.4)</td>
</tr>
<tr>
<td>Birth weight, g, mean (SD)</td>
<td>884 (161)</td>
<td>898 (161)</td>
<td>3401 (453)</td>
</tr>
<tr>
<td>Multiple birth, n (%)</td>
<td>75 (32.9)</td>
<td>18 (22.9)</td>
<td>2 (1.2)</td>
</tr>
<tr>
<td>Grade III or IV IVH, n (%)</td>
<td>16 (7.0)</td>
<td>2 (2.9)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Cystic PVL, n (%)</td>
<td>9 (3.9)</td>
<td>9 (12.9)*</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Antenatal corticosteroids, n (%)</td>
<td>162 (71.1)</td>
<td>55 (78.6)</td>
<td>2 (1.2)</td>
</tr>
<tr>
<td>Postnatal corticosteroids, n (%)</td>
<td>73 (32.0)</td>
<td>25 (35.7)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Bronchopulmonary dysplasia, n (%)</td>
<td>81 (35.5)</td>
<td>30 (42.9)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Patent ductus arteriosus, n (%)</td>
<td>106 (46.5)</td>
<td>28 (40.0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Surgery, n (%)</td>
<td>58 (25.4)</td>
<td>19 (27.1)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>ROP stage = 3 either eye, n (%)</td>
<td>28 (12.5)</td>
<td>8 (11.4)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Neurosensory disability at 8 years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cerebral palsy, n (%)</td>
<td>21 (9.4)</td>
<td>8 (15.7)</td>
<td>0 (0)*</td>
</tr>
<tr>
<td>Blind *</td>
<td>0 (0)</td>
<td>3 (4.9)*</td>
<td>0 (0)*</td>
</tr>
<tr>
<td>Deaf†</td>
<td>0 (0)</td>
<td>2 (3.5)*</td>
<td>0 (0)</td>
</tr>
<tr>
<td>IQ &lt; 70†</td>
<td>13 (6)</td>
<td>1 (3.5)</td>
<td>2 (1.2)*</td>
</tr>
<tr>
<td>Social risk</td>
<td>Higher Social Risk*, n (%)</td>
<td>112/221 (50.7)</td>
<td>28/48 (58.3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>53/161 (32.9)*</td>
<td></td>
</tr>
</tbody>
</table>

IVH, intraventricular hemorrhage; PVL, periventricular leukomalacia; ROP, retinopathy of prematurity.

* Visual acuity worse than 6/60 in the better eye.
† Required hearing aids or worse.
‡ High social risk determined by maternal education when the child was 8 years of age.
* P < .05 versus nonparticipants.
† P < .05 versus term.

.001; right eye, $z = -5.62, P < .001$, and for the best score overall (better eye, $z = -4.93, P < .001$). The best eye logMAR score with habitual correction was used for subsequent analyses determining impairment.\(^{30}\)

The ELBW/EP group had higher rates of sensory visual impairment than controls, but the group differences only reached significance for stereopsis and convergence (Table 2). There were more ELBW/EP adolescents who demonstrated difficulties in 1 or more areas compared with the control group (Table 2).

More ELBW/EP adolescents who had a previous diagnosis of severe ROP were likely to have impaired visual acuity (42.9% vs 17.1%) and stereopsis (53.6% vs 22.4%). They were also more likely to have any visual impairment (67.9% vs 39.3%) or multiple impairments (35.7% vs 14.8%). These statistical conclusions remained after adding severe white matter injury as a predictor of visual sensory outcomes. Only severe ROP was independently related to impaired visual acuity (odds ratio [OR] 3.65; 95% confidence interval [CI] 1.57 to 8.49), with the overall model explaining 7.4% of variance. Both severe ROP (OR 4.12, 95% CI 1.79 to 9.44) and severe white matter injury (OR 3.71, 95% CI 1.45 to 9.51) were independently related to impaired stereopsis, with the overall model explaining 11.4% of variance. The models for convergence and color vision were not significant.

**Visual Perception**

On tests of visual perception, the ELBW/EP adolescents performed worse compared with the controls on each of the TVPS-3 subtests, with most differences exceeding 0.5 SD (Table 3). Consistent with these findings, the total visual perceptual score was significantly lower for the ELBW/EP cohort compared with the control group. Adolescents in the ELBW/EP cohort demonstrated significantly more clinical impairments in visual perception. Excluding adolescents with impaired visual acuity ($n = 72$) or adolescents with an IQ $<70$ ($n = 14$) did not change any statistical conclusions concerning visual perceptual outcomes.

**DISCUSSION**

This study demonstrates that, relative to controls, adolescents born ELBW/EP exhibit poorer outcomes in both sensory and visual perception measures. Of particular concern, ELBW/EP adolescents were approximately 4 times more likely to demonstrate impairment in multiple areas. Clinically, it is notable that ELBW/EP adolescents were more likely to exhibit difficulties across a range of visual perceptual tasks, even after excluding those with sensory or intellectual impairment. As expected, those ELBW/EP adolescents with a previous diagnosis of severe ROP had more impairment across most visual sensory domains; however, ROP only explained a small proportion of the variance.

Preterm birth may have major consequences to the development of the visual pathway. Both ocular and brain pathology, ranging from local to diffuse, has been implicated in visual deficits in preterm children. Importantly, significant research gaps include limited understanding of the proportion of visual difficulties in adolescence and adulthood, in geographic samples, and after the introduction of important obstetric and neonatal interventions such as antenatal corticosteroids and surfactant therapy. Consistent with previous research, which has indicated that 50% to 65% of preterm children exhibit at least 1 visual difficulty,\(^{6,19,40}\) the current study found that almost 32% of ELBW/EP adolescents wore...
corrective eyewear, 43% were impaired in either visual acuity, stereopsis, convergence, or color vision, and ~17% were impaired in 2 or more of these outcomes.

In terms of specific sensory measures, the median visual acuity score of the best eye for the ELBW/EP group was within normal limits; however, it was significantly worse than the median of the control cohort. Although it is commonly reported that preterm children have poorer visual outcomes in specific measures and higher rates of impairment compared with term controls, previous studies have typically reported on selected samples with a focus on participants with severe white matter lesions and/or a previous diagnosis of ROP.2,16–20 In a cohort study by Evensen et al41 of 14-year-olds free of cerebral palsy who were born <1500 g in the 1980s, rates of impaired visual acuity (8%) and stereopsis (8%) were lower, but rates of convergence problems (24%) were higher than the current study.

Amblyopia and refractive errors can cause the blurring of unilateral images and may therefore affect binocular vision, resulting in the loss of stereovision.1,42 To develop normal stereopsis the neural development of binocular cortical cells requires clear retinal imaging during critical periods of visual development, which, according to Banks et al (1975),43 is between 3 and 6 months, and between 12 and 20 months. Refractive errors, strabismus, and amblyopia are often reported in preterm children9,20,44,45 whose eyes may be susceptible to damage owing to necessary medical care and/or early visual experiences during critical periods of development, which may help explain why there is a higher incidence of reduced depth perception, even in adolescence. Convergence and reduced or absent stereopsis have important implications for functional vision, such

![Visual acuity - log score left eye](image1)

![Visual acuity - log score right eye](image2)

![Visual acuity - log score best score](image3)

**FIGURE 2**
Distribution of visual acuity scores for left, right, and best eye with habitual correction. Boxplots show the median, interquartile range (IQR, 25th and 75th percentiles; the margins of the box), outliers (up to 1.5 times the IQR), and extremes (>1.5 times the IQR).

**TABLE 2** Sensory Outcomes: Visual Impairments in ELBW/EP and Control Groups

<table>
<thead>
<tr>
<th>Visual Impairment</th>
<th>ELBW/EP (n = 223)</th>
<th>Controls (n = 161)</th>
<th>Odds Ratio</th>
<th>95% CI</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual acuity &gt;0.2 c</td>
<td>45 (20.3)</td>
<td>27 (15.8)</td>
<td>1.26</td>
<td>0.74 to 2.14</td>
<td>0.46</td>
</tr>
<tr>
<td>Stereopsis c</td>
<td>59 (26.2)</td>
<td>16 (9.9)</td>
<td>3.22</td>
<td>1.78 to 5.84</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Convergence c</td>
<td>35 (15.7)</td>
<td>10 (6.3)</td>
<td>2.76</td>
<td>1.32 to 5.75</td>
<td>0.009</td>
</tr>
<tr>
<td>Color vision</td>
<td>7 (3.1)</td>
<td>1 (0.6)</td>
<td>5.15</td>
<td>0.63 to 42.30</td>
<td>0.18</td>
</tr>
<tr>
<td>Visual impairment ≥1</td>
<td>96 (42.7)</td>
<td>47 (29.2)</td>
<td>1.81</td>
<td>1.17 to 2.78</td>
<td>0.009</td>
</tr>
<tr>
<td>Visual impairment ≥2</td>
<td>39 (17.3)</td>
<td>8 (5.0)</td>
<td>4.01</td>
<td>1.82 to 8.84</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

c. habitual correction.
as activities requiring motion perception, and many visual motor activities including reaching, manipulation of objects, and the ability to guide one’s body or a vehicle in the environment. Motor coordination and visual motor integration impairments are reported in high numbers in preterm children, thus the findings that almost 16% of ELBW/EP adolescents were impaired in the convergence task and 26% impaired in stereopsis are clinically important. Consequently, the early identification of visual dysfunction that can lead to secondary issues with stereoaucuity should be considered an important part of screening in preterm children.

ELBW/EP adolescents with a previous diagnosis of severe ROP were ~4 times more likely to have impaired visual acuity and stereopsis. Severe white matter injury on the other hand, only significantly predicted impairment in stereopsis. Not surprisingly, however, each model only explained a small proportion of the variance, suggesting these variables do not fully account for the visual deficits demonstrated in preterm survivors. Others have reported that children with severe ROP have an increased incidence of strabismus, amblyopia, and refractive errors, in particular myopia, compared with other preterm infants and term controls. Although severe white matter damage has been identified as a risk factor for a number of visual deficits, it only predicted poor stereopsis, which is consistent with research highlighting the importance of the cortical visual pathways for the development of binocular stereopsis.

Interpreting reported data to guide clinical management and assessment of visual function in preterm children is hampered by variability in methods and findings, as discussed previously. Furthermore, there is a paucity of research that has thoroughly examined visual perceptual outcomes in high-risk ELBW/EP children beyond school age, although difficulties have been noted in judgment of line orientation, perceptual matching, and biological motion processing. The current study was a unique opportunity to report on a contemporary and representative cohort on long-term visual outcomes in preterm adolescents. As expected, ELBW/EP adolescents performed significantly more poorly across the range of visual perceptual tasks, suggesting global, rather than specific, perceptual difficulties persist into adolescence. Of clinical relevance is that this ELBW/EP adolescent group had higher rates of impairment even after excluding adolescents with low IQ and sensory impairment. That difficulties with visual perception are common even in ELBW/EP adolescents with normal sensory functioning suggests impaired perception can result from problems with higher order processing.

This study has a number of strengths, including a large geographic sample and prospective design with contemporaneously recruited controls. Moreover, it reports data from the oldest survivors born in the 1980s. In addition, we were able to explore outcomes from a variable-centered approach by comparing group means on the domain or task of interest as well as by a person-centered approach by investigating patterns of functional deficits across different aspects of visual processing. Although cut-off scores are a convenient way of defining dysfunction, the choice of where to draw this line is arbitrary. Some studies use a more liberal cut-off, such as the 15th percentile, whereas others use a more conservative cut-off of the fifth centile. According to Fay et al, the choice of the 10th percentile overcomes the problem of defining too many as impaired, including the control group. Importantly, although there is no consensus as to what constitutes a functional or clinically important impairment, scores that fall below the 10th percentile (ie, ≤ −1.3 SD) are often considered to fulfill this general criterion. We also acknowledge the limitations of this study. As noted, retention rates were 76% and 63% for the ELBW/EP and control groups, respectively, although the only difference between the participating and non-participating ELBW/EP adolescents was the higher rate of periventricular leukomalacia in nonparticipants.

### Table 3 Visual Perceptual Outcomes From the TVPS-3 for the ELBW/EP and Control Groups

<table>
<thead>
<tr>
<th>TVPS-3 Scales</th>
<th>ELBW/EP (n = 223)</th>
<th>Controls (n = 160)</th>
<th>Mean Difference (95% CI)</th>
<th>Mean Difference (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual discrimination (SS)</td>
<td>7.16 (5.80)</td>
<td>8.82 (3.89)</td>
<td>1.66 (−2.45 to −0.88)*</td>
<td>1.29 (−2.13 to −0.46)*</td>
</tr>
<tr>
<td>Spatial relations (SS)</td>
<td>8.62 (3.62)</td>
<td>10.03 (2.95)</td>
<td>1.41 (−2.04 to −0.78)*</td>
<td>−0.97 (−2.62 to −0.52)†</td>
</tr>
<tr>
<td>Form constancy (SS)</td>
<td>7.12 (4.52)</td>
<td>9.14 (4.82)</td>
<td>−2.02 (−2.95 to −1.08)*</td>
<td>−1.49 (−2.48 to −0.50)†</td>
</tr>
<tr>
<td>Figure ground (SS)</td>
<td>8.92 (5.11)</td>
<td>11.57 (4.71)</td>
<td>−2.64 (−3.65 to −1.64)*</td>
<td>−1.97 (−3.05 to −0.89)*</td>
</tr>
<tr>
<td>Visual closure (SS)</td>
<td>9.29 (3.90)</td>
<td>11.09 (3.38)</td>
<td>−1.79 (−2.55 to −1.04)*</td>
<td>−1.43 (−2.23 to −0.64)*</td>
</tr>
<tr>
<td>Total score</td>
<td>41.04 (17.22)</td>
<td>50.59 (15.73)</td>
<td>−9.54 (−12.93 to −6.16)*</td>
<td>−7.08 (−10.48 to −3.68)*</td>
</tr>
<tr>
<td>Visual perceptual impairment, n (%)</td>
<td>54 (24.2)</td>
<td>15 (9.4)</td>
<td>OR: 3.09 (1.67 to 5.71)*</td>
<td>OR: 2.16 (1.06 to 4.41)†</td>
</tr>
</tbody>
</table>

Data are mean (SD) unless otherwise indicated. SS, scaled score.

* After excluding participants with impaired visual acuity (logMAR ≥0.20) and IQ ≤70.

† P < .001.

‡ P < .05.
CONCLUSIONS

Despite advances in medical care improving the survival rate of high-risk ELBW/EP infants, visual morbidity is still relatively high compared with controls in late adolescence. Notwithstanding the fact that visual acuity in most ELBW/EP adolescents is within the normal range, the current study results demonstrate support for the persistence of visual perceptual problems in ELBW/EP adolescents, which may lay the foundation to examine more complex relationships between visual perception and other visual-based cognitive and functional outcomes. In Australia, it is not routine to screen for visual perceptual difficulties, neither are there intervention strategies with proven efficacy to deal specifically with these problems. Given the potential importance of visual perceptual skills to more complex tasks and academic achievement, these results have important clinical relevance. Additionally, it may be important to focus future research toward identifying those ELBW/EP infants most at risk, as well as developing clinical screening instruments and appropriate intervention programs to foster achievement within this domain.

VICTORIAN INFANT STUDY GROUP

This work is published on behalf of members of the Victorian Infant Study Group, who were involved in data collection at the various study sites.

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