Accommodative Dysfunction in Children with Cerebral Palsy: A Population-Based Study

Julie F. McClelland,1,2 Jackie Parkes,5 Nan Hill,4 A. Jonathan Jackson,1,2,5 and Kathryn J. Saunders1,2

PURPOSE. To determine the prevalence, nature, and degree of accommodative dysfunction among children with different types and severities of cerebral palsy (CP) in Northern Ireland.

METHODS. Ninety subjects with CP (aged 4–15 years) were recruited through the Northern Ireland CP Register (NICPR). Modified Nott dynamic retinoscopy was used to measure lag and lead of accommodation at three test distances: 25 cm (4 D), 16.7 cm (6 D), and 10 cm (10 D) with the distance correction in place. Accommodative function was also assessed in an age-matched control group (n = 125) for comparison. Each subject’s neurologic status was derived from the NICPR.

RESULTS. Children with CP demonstrate significantly reduced accommodative responses compared with their neurologically normal peers. Of the subjects with CP, 57.6% demonstrated an accommodative lag outside normal limits at one or more distances. Reduced accommodative responses were significantly associated with more severe motor and intellectual impairments (ANOVA P = 0.001, P < 0.01, respectively).

CONCLUSIONS. Brain injury such as that present in CP has a significant impact on accommodative function. These findings have implications for the optometric care of children with CP and inform our understanding of the impact of early brain injury on visual development. (Invest Ophthalmol Vis Sci. 2006;47:1824–1830) DOI:10.1167/iovs.05-0825

Cerebral Palsy (CP) is a group of disorders of movement and posture that occur as a result of damage to the brain or inadequate development of the brain.1 It is well documented that CP has a significant impact on various aspects of visual function, including refractive status, visual acuity, and ocular posture (McClelland et al. IOVS 2004;45:ARVO E-Abstract 2735; McClelland et al. IOVS 2005;46:ARVO E-Abstract 1935).2,3

The condition may be classified into three main subtypes, each primarily affecting different areas of the developing brain.2,3 Spastic CP affects approximately 75% to 94% of people with CP and results in tightness and stiffness of muscles.9–12 This subtype is primarily caused by diffuse damage to the cerebral cortex and specifically to the periventricular white matter.2,13,14 Dyskinetic CP affects 3% to 5% of people with CP, causing uncontrolled, slow, writhing movements affecting hands, feet, legs, face, and tongue and may be attributed to damage to the basal ganglia.2,8,10–13 The least common form is ataxic CP in which the person affected has balance and coordination problems. This type accounts for approximately 1% to 4% of the CP population and reflects damage to the cerebellum.2,9,12,14

There is evidence in the literature that accommodative function is impaired in those with CP.15,16 In 1984, Duckman15 reported reduced accommodative facility in a group of children with CP (aged 5–14 years) attending a special-needs school. In this particular study, the use of subjective methods of assessing accommodative facility limited inclusion to those children able to understand the test and express a response to the stimulus provided.

Leat16 used an objective technique, a modification of Nott dynamic retinoscopy, to examine accommodative function in a group of 43 people with CP, recruited from a variety of sources. The type and severity of CP was defined by observation, questioning parents, and/or consulting school records. Leat demonstrated reduced accommodative responses in 43% of subjects with CP. Nott dynamic retinoscopy has also been used to demonstrate reduced accommodation in Down syndrome and provides rapid, reliable, and valid measures of accommodative responses in children with and without intellectual impairment.17–20

Duckman15 and Leat16 indicate that deficits in accommodation are common among children with CP. However, due to the subjective nature of Duckman’s technique for assessing accommodation and the methods by which subjects were recruited in both Duckman and Leat’s studies, it is not clear how common deficits of accommodative function are across the CP population. It is also currently not known how CP subtypes and the severity of associated impairments affect ocular accommodation. A clearer understanding of these relationships may inform our understanding of the mechanisms involved in the development of accommodation and the impact of different types of brain injury on its function.

Children for the present population-based study were recruited from the Northern Ireland Cerebral Palsy Register (NICPR). This register was established to provide a systematic approach to monitoring and surveillance of CP in a geographically defined population.12 Each child on the register receives a confirmed diagnosis of CP after an assessment by a pediatrician, at 5 years of age. The assessment includes a record of the type and severity of motor impairment and the presence and severity of associated impairments (e.g., vision, hearing, intellectual, communication, and the presence of seizures).

The NICPR has adopted the case definition and classification scheme described by the Surveillance of Cerebral Palsy in Europe project.21 Leg function is used as a measure of the severity of motor impairment, where very mild is defined as no functional consequences, mild as functional but not fluent,
moderate as obviously abnormal restricting mobility, and severe as no independent walking. Intellectual impairment is considered present where the intelligence quotient (IQ) is less than 70, moderate intellectual impairment as an IQ between 70 and 50, and severe intellectual impairment as an IQ less than 50.

In the present population-based study, we sought to examine accommodative function in a representative group of children with different types of CP and a range of severities of intellectual and motor impairments.

METHODS

Recruitment of Subjects

Subject selection was not restricted on the basis of visual status, subtype of CP, severity of CP or level of intellectual impairment. School-aged children were chosen as it is accepted that, in neurologically normal children, by 4 years of age, visual maturation is largely complete and that accommodation has reached adult levels.

Subjects for the present study were recruited via direct invitation from their pediatricians, which was sent out with information describing the study and a consent form to all the children under the pediatrician's care who fulfilled the study criteria. Five consultant pediatricians from different regions of Northern Ireland participated in the recruitment. All children for whom consent was received were tested on school premises during school hours. Permission for testing was obtained from principals of 34 mainstream schools and 34 special-needs schools.

Recruitment and experimental protocols were conducted in compliance with the Declaration of Helsinki and approved by local ethics committees.

After visual function data collection, the subjects' details were cross-referenced with the NICPR. Confirmation of diagnosis of CP and the type and severity of motor and intellectual impairments were obtained from the NICPR. After this information had been obtained, subject names were anonymized and strict confidentiality was maintained throughout.

Subjects

The study's inclusion criteria were that the child must be of school age (4–18 years of age), be included on the NICPR, and have a CP subtype diagnosis. Three children were excluded because they had unclassified forms of CP.

A group of 90 children with CP, aged 4 to 18 years (mean age, 10.96 ± 3.49 SD) were recruited for the present study (56 male, 34 female). Eighty-four subjects had the spastic subtype of CP, four the dyskinetic, and two the ataxic (Table 1). Motor impairments varied from very mild ($n = 7$) to severe ($n = 30$; Table 2). Intellectual impairments varied from no ($n = 44$) to severe ($n = 23$) learning difficulties (Table 3). The cohort was representative of a general CP population in subtype, motor impairment, and intellectual impairment. Thirty-three children attended mainstream schools and the remaining 57 attended schools for children with special educational needs.

Control data for comparison of accommodative responses were available from 125 neurologically and visually normal school-aged children (aged 4–15 years) tested under identical protocols by the first author (JM). The normative data obtained from this group have been published.

Accommodative function was tested with the full-distance correction in place using trial frames and lenses. Objective measurements of refractive error were available for this group (McClelland et al. IOVS 2004;45:ARVO E Abstract 2735). Either distance static retinoscopy ($n = 54$ [60%]) or cycloplegic retinoscopy ($n = 36$ [40%]) using 1 drop of 1% cyclopentolate hydrochloride in each eye, had been performed 2 to 4 weeks before the present study. Distance static retinoscopy was performed on those subjects with good communication abilities and either no intellectual impairment or a mild intellectual impairment. The mean spherical refractive error (MSE, sphere + cylinder/2) ranged from −7.50 D to +6.25 D (mean MSE, +0.97 ± 2.27 D [SD] in the right eye and +0.83 D ± 2.27 in the left eye). If new spectacle needs were needed, subjects were given at least 2 weeks to adapt to the refractive correction before accommodation was assessed. Visual acuity data were also available, to ensure that the target used to assess accommodative function contained suitable spatial frequencies (McClelland et al. IOVS 2005;46:ARVO E Abstract 1935). Visual acuity, as measured with the Cardiff Acuity Test, ranged from 0.00 to 1.00 logMAR (mean, 0.11 ± 0.17 logMAR).

Testing took place on school premises during school hours in a darkened, quiet, school medical room. Uniform testing conditions were maintained when possible. Participants were accompanied in most cases by a classroom assistant familiar with, and to, the child.

Assessment of Accommodative Function

Nott dynamic retinoscopy was used to assess accommodative function at demand of 4, 6, and 10 D. This technique has been shown to provide valid and repeatable measures of accommodative responses.

The dynamic retinoscopy target consisted of an internally illuminated, translucent, white Persex cube measuring $4 \times 4 \times 4$ cm mounted on a meter rule (Fig. 1). A high-contrast picture containing a range of spatial frequencies was drawn on each face of the cube. The subject was encouraged to view, and keep clear, the most appropriately detailed target for their level of visual acuity, and measurements were obtained when the examiner was confident that the subject was fixating the target. Three different target distances (25 cm [4 D], 16.7 cm [6 D], and 10 cm [10 D] from the front surface of the eye) were used to provide a range of accommodative demands. The order of target presentation was random. It has been shown that the order of target presentation does not significantly influence the results achieved by this technique. All subjects wore their full-distance refractive correction, with a back vertex distance of 10 mm, either in a trial frame or with spectacles. The examiner placed the retinoscope alongside the target and used the known refractive error, observed the

<table>
<thead>
<tr>
<th>Subjects</th>
<th>CP Subtype</th>
<th>$n$, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate</td>
<td>Spastic</td>
<td>4 (4.4)</td>
</tr>
<tr>
<td>Severe</td>
<td>Dyskinetic</td>
<td>2 (2.2)</td>
</tr>
</tbody>
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Table 1. Number of Subjects with Each CP Subtype

<table>
<thead>
<tr>
<th>Subjects, $n$, %</th>
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</thead>
<tbody>
<tr>
<td>Very mild</td>
</tr>
<tr>
<td>Mild</td>
</tr>
<tr>
<td>Moderate</td>
</tr>
<tr>
<td>Severe</td>
</tr>
<tr>
<td>Unclassified</td>
</tr>
</tbody>
</table>

Table 2. Number of Subjects with Each Level of Motor Ability

<table>
<thead>
<tr>
<th>Subjects, $n$, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
</tr>
<tr>
<td>Moderate learning difficulties</td>
</tr>
<tr>
<td>Severe learning difficulties</td>
</tr>
<tr>
<td>Unclassified</td>
</tr>
</tbody>
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Table 3. Number of Subjects with Each Level of Intellectual Ability

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meridian that was previously recorded as the least hypermetropic meridian of the least hypermetropic eye. This is the standard practice used when performing Nott dynamic retinoscopy to ensure that if accommodation is assessed when subjects are uncorrected or not fully corrected for distance, the meridian that will most readily focus the target is examined. The authors are aware that in subjects with fully corrected vision, as in the present study, all meridians should be focused in the same plane. However, the method was maintained for consistency. If a neutral reflex was observed, the subject was judged to be accurately focusing on the target. If an “against” reflex was observed, it was deemed to indicate a lead of accommodation, and the retinoscope was moved closer to the subject until a neutral reflex was observed and this position was noted. An initial “with” movement indicated a lag of accommodation. In this case, the retinoscope was moved farther away from the patient until neutrality was obtained. The target remained stationary. The subject’s accommodative response was determined from the point on the rule at which neutrality was achieved and compared to the target distance to calculate the accommodative response for each distance.19,20

As in previous studies using this technique to assess accommodative function in children with neurologic impairment, lens effectivity was not formally taken into consideration when recording accommodative response.16,17

RESULTS

Success Rates

Of the 90 subjects included in the study, accommodative responses were successfully recorded at three different accommodative demands (4 D [25 cm], 6 D [16.7 cm], and 10 D [10 cm]) in 85 (94.4%). Those who were unable to complete or comply with testing were generally uncooperative, had extremely poor fixation, or had grossly abnormal eye movements.

The mean accommodative response to each accommodative demand for subjects within the CP group and the control group are illustrated in Figure 2. A one-way analysis of variance showed that the mean accommodative response was significantly greater in the control group than in the CP group at each distance tested ($P < 0.01$ at 4, 6, and 10 D).

Normal ranges for accommodative responses at the three accommodative demands were obtained from McClelland and Saunders (Table 4).20 These data were applied to children with CP to determine whether the accommodative responses obtained were within normal limits. Table 5 details the number of subjects with reduced accommodation in the CP group.
TABLE 4. Mean Accommodative Response and 95% Confidence Limits for Control Group

<table>
<thead>
<tr>
<th>Age 4–15 Years (Control Group)</th>
<th>4-D Demand</th>
<th>6-D Demand</th>
<th>10-D Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Range (D) (mean response ± 2SD)</td>
<td>2.94–4.46</td>
<td>4.12–6.40</td>
<td>5.02–10.00</td>
</tr>
<tr>
<td>Mean response (D) (±SD)</td>
<td>3.70 ± 0.39</td>
<td>5.26 ± 0.58</td>
<td>7.51 ± 1.27</td>
</tr>
<tr>
<td>Mean lag (D) (±SD)</td>
<td>0.30 ± 0.39</td>
<td>0.74 ± 0.58</td>
<td>2.49 ± 1.27</td>
</tr>
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Accommodative Function and Age

A one-way analysis of variance (ANOVA) showed no significant association between the subject’s age group and the size of the accommodative lag or lead at each distance for the CP group ($P > 0.05$).

Data obtained from the NICPR allowed comparisons to be made between measures of accommodative function and CP subtype, communication, motor, and intellectual ability.

Accommodation and Clinical Characteristics

One-way ANOVAs showed significant relationships between the size of the accommodative response and the severity of the subject’s motor impairment, intellectual impairment and communication ability at each accommodative demand. Those children with more severe motor impairments, more severe intellectual impairments, and/or communication difficulties had lower accommodative responses at each distance tested (ANOVA; $P < 0.05$; Figs. 3, 4).

Although there is a statistically significant relationship between severe physical and intellectual impairment and reduced accommodative function, 17.9% of children attending mainstream schools (with minimal or no intellectual impairment and very mild or mild physical impairment) had accommodative responses outside the normal range for their age, with accommodation reduced at one or more distances.

Accommodative Function and CP Subtype

A one-way ANOVA was applied to the data to assess the relationship between CP subtype and accommodative response. Despite the small number of subjects in two of the subtypes the results showed a significant association between CP type and level of accommodative response. Those subjects with dyskinetic or ataxic CP had significantly reduced accommodative responses compared with the group of subjects with spastic CP at each accommodative demand ($P = 0.015$ at 4 D, $P = 0.002$ at 6 D, and $P = 0.003$ at 10 D).

Accommodation and Medication

A significant proportion of children in the study were receiving antiepileptic medication (e.g., carbamazepine). Ocular side effects have been reported with anti-epileptic medication.24,25 Results from a subset of 20 subjects with CP were analyzed to assess whether the quality of accommodative responses may be reduced with anti-epileptic medication. $\chi^2$ analysis showed no significant association ($P = 0.157$) between the presence of reduced accommodative responses (as classified by Table 5) and antiepileptic medication.

DISCUSSION

Using an objective technique, we showed a high incidence of reduced accommodative responses in a population-based sample of children with CP in comparison with a group of neurologically and visually normal subjects. These data support and enhance previous studies of vision in CP2,15,16 with a population-based subject group representative of the whole CP population in CP subtype, motor ability, and intellectual ability.12 Quantitative measures of accommodative function were obtained with Nott dynamic retinoscopy from 94.4% of subjects. The use of an objective technique enabled accommodative responses to be obtained from a large proportion of subjects, including those with severe impairments. It was not possible to use Nott dynamic retinoscopy on five subjects with extremely poor fixation and grossly abnormal eye movements and who were uncooperative with the technique. These subjects all had severe motor and visual impairments.

The results of the present study clearly demonstrate that CP has a negative impact on ocular accommodation. Compared with neurologically normal, age-matched control subjects, children with cerebral palsy have significantly reduced accommodative responses to near targets. More than half the children with CP failed to accommodate normally. This was most marked at the highest accommodative demand, where lags were largest for all subjects, including the control group. It is not surprising that accommodative lag was greatest under conditions of highest accommodative stress, as neurologically normal subjects of all ages also show the greatest accommodative lag at higher demands.18,20 Woodhouse et al.17 used Nott dynamic retinoscopy to evaluate amplitude of accommodation in developmentally normal children and those with Down syndrome. Data from the present study (Figs. 3, 4) suggest that children with severe intellectual and physical impairments have a virtually flat response to the greater accommodative demands. This suggests that the Nott technique reveals their accommodative amplitude and that it is vastly reduced from that normally expected from school-aged children.26

The present study showed that children with more severe motor impairments were at a greater risk of having accommodative deficits. This is consistent with the findings of Leat16 who noted an association between the level of physical ability and accommodative function. In contrast to Leat’s study, the present data demonstrate a significant relationship between reduced accommodation and more severe intellectual impairment and reduced communication ability.10 Leat graded the subject’s cognitive and communicative ability by questioning parents and examining school records. In the present study information on communication and intellectual impairment was available from the NICPR where standardized protocols
were used to source data from pediatricians, educational psychologists, and parents.

From the data available in the present study, it is not possible to determine the etiology of the accommodative dysfunction found in CP. CP is a disorder of motor function, and, in cases with more severe motor impairment, the likelihood that the ocular muscles are involved is increased, and hence accommodative function is reduced. However, children with CP are also at a greater risk of reduced visual acuity, disorders of ocular posture, and significant refractive errors (McClelland et al. IOVS 2004;45:ARVO E-Abstract 2735; McClelland et al. IOVS 2005;46:ARVO E-Abstract 1935). These findings suggest that the accommodative dysfunction in CP may not be linked solely to motor function. Accommodation in the normal visual system is a complex response to a combination of visual, mechanical, and psychological stimuli, and implying a solely motor origin for the accommodative impairment demonstrated in CP is likely to be an oversimplification.

The development of accurate accommodation in infancy is linked to several visual functions including visual acuity, disparity detection, and convergence ability. It is also likely to be influenced by refractive status. Previous work on the present cohort demonstrates that the reduced accommodation found in CP is significantly associated with poor visual acuity, high refractive errors, and the presence of strabismus (McClelland et al. IOVS 2004;45:ARVO E-Abstract 2735; McClelland et
wearing bifocals. Children with visual impairments, including accommodative dysfunction are at a disadvantage to their visually normal peers, especially in the school environment.\textsuperscript{34,35} Many visual tasks including school work, using computers, and the use of communication boards may be affected by poor accommodation that results in impaired near vision. This is also likely have a significant impact on their general and intellectual development.

It might have been anticipated that subjects with more severe motor or intellectual impairments, who are traditionally harder to test, would have been most disadvantaged in the current system. However, the present study suggests that even those who can respond well to standard optometric testing protocols are not receiving optimal care. A significant proportion of those with uncorrected accommodative deficits were receiving mainstream education. Assessment of accommodative function with Nott dynamic retinoscopy is rapid and simple and requires inexpensive and low-tech equipment. Its objective nature makes it suitable for all but the most severely impaired. We suggest that optometric care available for children with CP in Northern Ireland be revised in light of the present study’s findings.

Failure to identify accommodative dysfunction will inevitably lead to visual disadvantage. Remedy, in the form of spectacle correction or enlargement of educational material is straightforward and effective (Saunders et al.\textsuperscript{2004;45:ARVO E-Abstract 1394}). Thorough visual assessment of all children with CP including an objective assessment of accommodative function is not performed routinely in the UK. We advocate that this form part of the standard clinical protocol.

Acknowledgments

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References