Ophthal. Physiol. Opt. 2006 **26:** 148–155

Accommodation and the relationship to subjective symptoms with near work for young school children

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Abstract

The aim of this work was to study the relation between subjective symptoms at near and ocular accommodation in terms of the amplitude of accommodation and the relative accommodation. A secondary aim was to discuss the diagnosis of accommodative insufficiency. The chosen cohort was examined on two occasions with 1.8 years in between. The first examination included 72 children, 43 boys (mean age 8.1 years, ranging from 5.8 to 9.8) and 29 girls (mean age 8.3 years, ranging from 6.2 to 10.0). The second examination included 59 of these children, 34 boys (mean age 9.9 years, ranging from 7.8 to 11.7) and 25 girls (mean age 10.1 ranging from 8.0 to 11.8). Subjective symptoms at near work (headache, asthenopia, floating text, facility problems) were recorded and the amplitude and the relative accommodation, both positive and negative, were measured. The result from the questionnaire showed that at the first examination more than one-third of the children (34.7%) reported at least one subjective symptom when doing near work and 42.4% at the second examination. No symptoms were found among children younger than 7.5 years, but for children between 7.5 and 10 years old at the first examination, the prevalence of at least one symptom was 47.2%. At the second examination, symptoms were reported also for the youngest children, i.e. from the age of 8 years. The discrimination ability for the amplitude of accommodation, both monocular and binocular, was significant. In the first examination the difference between the mean for the two groups (i.e. with and without at least one symptom) was around 2.00 D monocular and 3.00 D binocular. Corresponding figures from the second examination was a difference between the mean for the two groups of around 3.50 D monocular and nearly 4.00 D binocular. We suggest that accommodation measurements should be performed more routinely and regularly, maybe as screening, especially in children over 8 years of age.

Keywords: accommodative insufficiency, amplitude of accommodation, asthenopia, children, headache, reference values, relative accommodation, subjective symptoms

Introduction

The accommodation of the eye is the process by which the dioptric power of the eye is changed in order to obtain clear retinal images. The accommodative system in young people is usually quite flexible and resistant to fatigue. The ability to accommodate slowly deteriorates with age and insufficient accommodative ability becomes a manifest problem (i.e. presbyopia), which requires optical aid (Duane, 1912; Koretz and Handelman, 1988), at approximately the fifth decade of life.

Duane's data have been the basis of an age–amplitude formula to predict the amplitude of accommodation (AA) vs age (Hofstetter, 1950) and this age–amplitude formula is still used today. However, to predict the amplitude of accommodation at a younger age by using

Received: 29 April 2004
Revised form: 12 October 2004, 6 July 2005
Accepted: 11 September 2005

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Duane's curve has been shown to give overoptimistic predictions of accommodative function (Sterner *et al.*, 2004). Consequently, accommodative function is often mistakenly assumed to be adequate at these ages and is, therefore, often not measured. Accommodative insufficiency (AI) in young and middle-aged adults, although long known, has received little attention (Duke-Elder and Abrams, 1970).

There are several signs and symptoms of accommodative disorders (Daum, 1983; Weisz, 1983; Scheiman *et al.*, 1996). Symptoms include the inability to focus on near objects or to sustain clear vision for a reasonable period of time. A study on nine children aged 9–16 years with low accommodative amplitude in both eyes (Matsuo and Ohtsuki, 1992) showed that the subjects had severe complaints of asthenopia, diplopia and difficulty in reading. Wick and Hall (1987) presented a study on the relation among accommodative facility, lag and amplitude in elementary school children, which showed considerable deficits in all three parameters. Recently Borsting *et al.* (2003) studied the association between symptoms and monocular amplitude of accommodation (right eye only), and concluded that AI is a common condition in young school children and that AI is related to subjective symptoms. Hence a clinical recognition of AI is important to prevent unnecessary frustration in young individuals (Chrousos *et al.*, 1988). Any deficit in the accommodative function among school children might create near-work-related problems. Because the focusing system of the eyes contributes to the learning process (Flax, 1970; Sucher and Stewart, 1993) any accommodative deficiency can make it unnecessarily difficult for the child to read and develop in school. Such a subgroup of children with lower than expected accommodative function might benefit from treatment and/or optical aid for near work problems (Cooper *et al.*, 1987; Sterner *et al.*, 1999; Ciuffreda, 2002).

Since extrapolation of Duane's data is inappropriate at these ages, Hofstetter's prediction formulas cannot be used. Due to the inhibitory effects of different symptoms on reading skill and development in school, it is essential to develop guidelines on how accommodation should be measured, interpreted and diagnosed. In describing various diagnostic criteria, Morgan (1944) states that AI occurs when the amplitude of accommodation is reduced by more than 2.00 D below Duane's expected values for age. The diagnostic criteria, however, are not universally agreed: Cacho *et al.* (2002) listed nine different studies, all with different criteria for diagnosing AI.

The occurrence of accommodative-dysfunction-related subjective symptoms at near among otherwise healthy young school children needs further investigation. It cannot be assumed that accommodation is sufficient in all children, even at younger ages, as Duane's predicted values have been shown to fail (Sterner *et al.*, 2004). The aim of this study was to examine the relation between subjective symptoms at near and the accommodative function in terms of the maximum amplitude and of the relative accommodation. A secondary aim was to determine appropriate reference values to support the diagnosis of AI.

Patients and methods

Children from a randomly chosen junior level school in Göteborg and its suburbs were invited to participate. The examinations took place at school, and informed consent was obtained from the parents. All of the children were examined during school hours, but no record was made whether they were measured before or after any tiring schoolwork demand. The Committee for Ethics at the Sahlgrenska Academy, Göteborg University, Sweden, approved the study.

A total of 136 children in the age range 6–10 years were invited: of these, 31 did not answer the invitation and 28 declined participation. The chosen cohort was examined on two occasions with 1.8 years in between. Seventy-seven children were enrolled and all, except for one boy who did not attend, were examined at the first occasion. Four children (two girls and two boys) were excluded due to astigmatism ≥ -0.75 D after examination. Children with amblyopia, strabismus or anisometropia would have been excluded, but none were found among the participating children. Thus the first examination included 72 children, 43 boys (mean age 8.1 years, ranging from 5.8 to 9.8) and 29 girls (mean age 8.3 years, ranging from 6.2 to 10.0).

The second examination included 59 of these children, 34 boys (mean age 9.9 years, ranging from 7.8 to 11.7) and 25 girls (mean age 10.1 years, ranging from 8.0 to 11.8). A more detailed demographical presentation is given in Sterner *et al.* (2004). To avoid bias, the interviews were highly structured and standardized. Furthermore, interviews regarding subjective symptoms were blinded since these were conducted before the objective technical measurements. The technical measurements followed standardized procedures and were repeated three times.

Questionnaire

The first examination started with an oral questionnaire to investigate if the child had any subjective symptoms when reading. Each question was fully explained to ensure understanding. The different symptoms and the related questions were:

(1) Headache: 'Do you get a headache when you read or study?'

(2) Asthenopia: 'Do you feel tiredness or itching in the eyes when you read or study?'
(3) Floating text: 'Do you see the words appear to float on the page, swim, jump, or wiggle when you read or study?'
(4) Facility problems: 'Do you have difficulties in quickly changing focus from the board, to your text book, and back to the board again?'

The answers were recorded as either yes or no. 'Have had the symptom once' was not enough to render a positive answer, at least 'have had the symptom occasionally' was required. At the second examination the same questions were used, but before questioning started the child was asked to describe and define the symptoms in their own words. This was done to ensure that the child actually understood the subsequent questions which included these symptoms.

Clinical tests

A non-cycloplegic static retinoscopic refraction was performed, followed by subjective refraction for distance correction (using maximum plus and minimum minus endpoint) and visual acuity (VA). Visual acuity was determined at a test distance of 5 m, with a natural pupil using best distance correction. An officially approved acuity chart, the Monoyer–Granström, illuminated with approximately 700 cd m^{-2}, was used to determine decimal VA (the Monoyer–Granström is an acuity chart with Monoyer-built optotypes in arithmetical spacing). A Jæger chart for near distance was used to determine VA at near. Those children who were not able to read properly were nevertheless able to identify the different letters on the chart. The amplitude of accommodation was measured with Donders push-up method.

Relative accommodation

The relative accommodation was measured as described by Goss and Zhai (1994) and Hung and Ciuffreda (1994). The accommodative stimulus was binocularly decreased (with positive lenses) in +0.25 D steps over the distance correction, with the vergence stimulus (at 40 cm) held constant, until the first slight sustained blur was subjectively noted by the patient. The decreased amount of accommodative stimulus at this point was referred to as the negative relative accommodation (NRA) value. Starting with the distance correction again, the accommodative stimulus was now increased binocularly (with negative lenses) in −0.25 D steps until the first slight sustained blur was again noticed, the increased amount of accommodative stimulus at this point was referred to as the positive relative accommodation (PRA).

Accommodative amplitude

The amplitude of accommodation was measured using the Donder's push-up method with the R.A.F. Near Point Rule, a rod with a movable target, and metric as well as dioptric markings. The child wore distance correction placed in a trial frame, and the examiner placed one end of the ruler on the child's forehead. The child was required to read a line of letters that corresponded in size to 1.0 VA at distance. The target was slowly moved towards the child along the ruler until the child reported blurring. The distance from this point to the spectacle plane was then recorded in dioptres. Measurements were made monocularly as well as binocularly. All measurements were repeated three times and the average result was recorded. When the dioptric result showed 20.00 D, i.e. the highest value measurable on the R.A.F. rule, a suitable concave lens (−3.00 or −6.00 D) was added to the correction and a corresponding correction made in the findings.

Statistics

Receiver operating characteristic (ROC) was used to analyse the discrimination ability of the different variables (Hanley and McNeil, 1982). The area under the curve is presented. Possible reference values were studied in an exploratory manner by using descriptive statistics, graphs and ROC-tables specifying the positive and negative predictive values. The primary variable with regard to subjective symptoms is the summarized 'at least one symptom' vs 'no symptoms'.

Results

Symptoms at first and second investigation

The result from the questionnaire and the distribution of subjective symptoms is presented in *Table 1*. Headache and asthenopia are the two most frequent symptoms followed by floating text and finally facility problems. The prevalence of at least one symptom was higher at the second examination, i.e. 42.4% compared to 34.7%. At

Table 1. The proportion of yes answers (prevalence) regarding subjective symptoms at first examination ($n = 72$) and at second examination ($n = 59$)

	Prevalence (%)	
Symptom	**First examination**	**Second examination**
Headache	20.8	28.8
Asthenopia	26.4	23.7
Floating text	11.1	18.6
Facility problems	4.2	5.1
At least one symptom	34.7	42.4

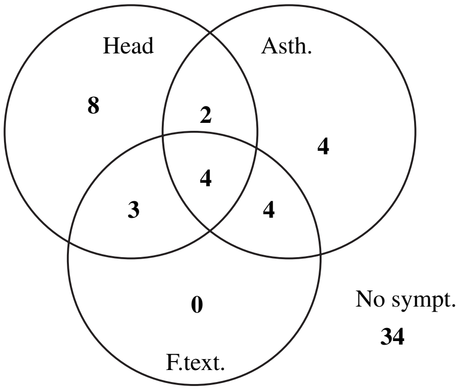

Figure 1. Illustration of the relationship between the different symptoms at second examination.

the first examination there were no symptoms reported before the age of 7.5 years (26% of the children were younger than 7.5 years at first investigation). At the second examination symptoms were also reported by the youngest children, i.e. from the age of 8 years. We found no relationship between symptoms and gender.

In *Figure 1* the relationship between the different symptoms at second examination is illustrated. Floating text problem does not occur as a single unique symptom, and among the 14 children with asthenopia, 10 of them also had at least one other symptom. Finally, among the 17 children with headache nine of them also reported other symptom(s). Thus, it is more likely that a symptom is accompanied by another symptom instead of being just a unique symptom.

Relation between symptoms and accommodative function

The amplitude of accommodation is presented descriptively in *Table 2*. Clinically relevant differences are seen between children with vs without symptoms at both examinations. In the first examination the difference between the mean for the two groups was around 2.00 D monocular and 3.00 D binocular. Corresponding figures from the second examination was a difference between the mean for the two groups of around 3.50 D monocular and nearly 4.00 D binocular. Generally, the amplitude of accommodation was lower at the second examination.

The relationship between the change in symptom status between the two examinations and the change in accommodative amplitude is presented in *Table 3*. Most of the children (68%) had the same symptom status at both examinations, i.e. either with symptoms at both examinations or free from symptoms at both examinations. Within this subgroup the mean change was around 0.85 D monocular and 0.23 D binocular, which corresponds to a change of 0.47 and 0.13 D per year, respectively. In the subgroup with symptoms at first examination but symptom free at second, the mean change was at maximum 0.30 D which equates to less than 0.20 D change per year. Neither the changes in either of these two subgroups nor the difference between the two groups were significant. However, in the group of children who had symptoms only at the second examination there was a significant change in accommodation amplitude of 3.40 D (right eye), 3.30 D (left eye) and 3.80 D (binocular).

Table 2. Descriptive statistics; monocular and binocular amplitude of accommodation at first and second examinations, by presence of at least one symptom

	At least one symptom?					
	First examination			**Second examination**		
Accommodative amplitude	**No (n = 47)**	**Yes (n = 25)**	**All (n = 72)**	**No (n = 34)**	**Yes (n = 25)**	**All (n = 59)**
Right eye						
Mean	13.1	11.1	12.4	12.4	8.8	10.9
Median	12.7	11.3	12.0	11.7	8.0	10.7
S.D.	3.7	3.4	3.6	3.0	3.5	3.7
LQ	11.0	9.0	9.7	10.0	5.7	8.3
UQ	15.0	13.8	15.0	14.4	12.0	13.3
Left eye						
Mean	13.21	11.20	12.51	12.4	9.0	11.0
Median	13.33	11.00	12.67	12.0	8.0	11.0
S.D.	3.53	3.71	3.69	3.1	3.7	3.7
LQ	11.00	8.84	10.08	9.9	6.0	8.0
UQ	15.00	14.16	15.00	14.4	12.0	14.0
Binocular						
Mean	16.32	13.19	15.24	15.8	11.9	14.1
Median	16.00	13.33	15.00	15.0	13.3	15.0
S.D.	2.96	4.44	3.82	2.9	4.5	4.1
LQ	15.00	10.00	13.00	14.0	7.8	12.3
UQ	19.00	16.34	18.00	17.8	15.0	17.0

S.D., standard deviation; UQ, upper quartile; LQ, lower quartile.

Table 3. Change in amplitude of accommodation (first–second examination), by change in symptom status

Amplitude of accomodation	Symptoms only at second exam (n = 13)	Same status (n = 40)	Symptoms only at first exam (n = 6)	Total
Right eye				
Mean	3.4†‡	0.8	0.2	1.3
S.D.	3.4	3.4	1.5	3.4
Left eye				
Mean	3.3†‡	0.9	0.3	1.3
S.D.	3.0	3.0	1.8	3.1
Binocular				
Mean	3.8†‡	0.2	0.3	1.0
S.D.	2.9	2.8	1.4	3.1

†Change between examinations significant ($p < 0.05$).
‡Significantly different from change in the other two groups ($p < 0.05$).

The amplitude of accommodation and symptom status for each individual child, at second examination, is shown in *Figure 2a–c*. The graphs illustrate the relationship between low amplitude and subjective symptoms, e.g. most of the children below the lower quartile have symptoms while the majority of those above the upper quartile are free from symptoms. The discrimination ability of each variable was more formally tested with ROC analysis and the results are presented in *Table 4*. The results at the two examinations are consistent. The amplitude of accommodation and NRA showed a significant relationship to 'at least one symptom' and to individual symptoms as well. Generally, refraction and PRA did not show any discriminating potential.

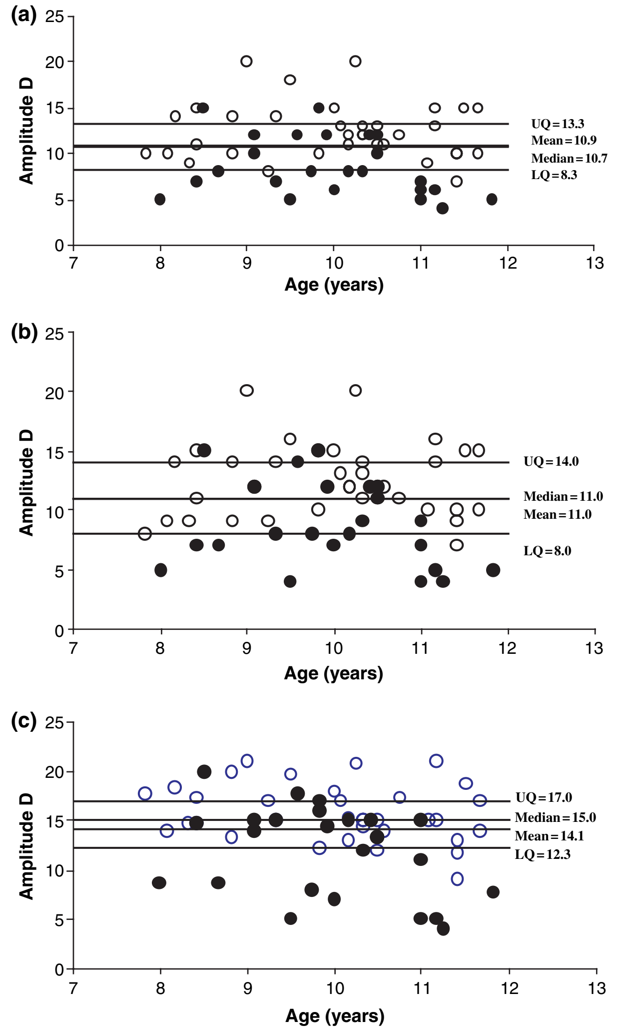

Figure 2. The amplitude of accommodation, right eye (a), left eye (b) and binocular (c) by age for subjects without symptoms (open symbols) and with at least one subjective symptom (filled symbols). The reference lines are mean, median, upper quartile (UQ) and lower quartile (LQ) based on all subjects.

Amplitude of accommodation and possible diagnostic criteria

The two examinations showed consistent results but since not all of the youngest children in the first examination were frequent readers and they did not have that much intensive near work we found the age span to be more appropriate at second examinations. Therefore, we chose to analyse diagnostic criteria based only on this examination. However, the result is similar if the data from the first examination are included. A ROC-table showing the positive and negative predictive values is important to suggest an underlying explanation for subjective symptoms. Sensitivity and risk of false-positives are of limited interest. In this situation, the positive and negative predictive values represent the likelihood that a child with an amplitude of accommodation below the reference value has subjective symptoms (PPV) and the likelihood that a child above the reference value is symptom free. Since the graphs discussed above indicated that the majority of children below the lower quartile had symptoms, we calculated diagnostic precision for the integer closest to the lower quartile and ±1.00 D. If the lower quartile for monocular amplitude (rounded to 8.00 D) is used we can see that around 90% of all children below the lower quartile suffer from subjective symptoms (*Table 5*), while around 75% of the children above the lower quartile (8.00 D) are symptom free. For binocular amplitudes we can find nearly the same PPV if we use the lower quartile minus 1 D, i.e. 11.0 D as reference value. The proportion of symptom-free children above this reference is nearly 70% instead of 75% as for the monocular reference values. In summary, if we use 8.0 D monocular and 11.0 D binocular we will find that around 90% of the children below these reference values suffer from subjective symptoms; this is more than twice as much as the general prevalence (42.4%) of these symptoms.

Table 4. Receiver operating characteristic analyses (area under the curve) for each examination by symptom

	Symptom							
	Headache		Asthenopia		Floating text		At least one symptom	
Examination	First	Second	First	Second	First	Second	First	Second
n	72	59	72	59	72	59	72	59
Prevalence (%)	21	29	26	24	11	19	35	42
Refraction (R)	0.57	0.60	0.51	0.68*	0.61	0.59	0.58	0.59
Refraction (L)	0.56	0.60	0.53	0.68*	0.61	0.59	0.62	0.59
Accommodative amplitude (R)	0.63	0.69*	0.65*	0.73*	0.61	0.86*	0.68*	0.77*
Accommodative amplitude (L)	0.61	0.67*	0.67*	0.74*	0.60	0.84*	0.67*	0.75*
Accommodative amplitude (B)	0.69*	0.62	0.74*	0.81*	0.64	0.83*	0.71*	0.73*
NRA	0.68*	0.62	0.64	0.77*	0.62	0.69	0.69*	0.70*
PRA	0.55	0.70*	0.63	0.55	0.53	0.66	0.55	0.62

R, right eye; L, left eye; B; binocular; NRA, negative relative accommodation; PRA, positive relative accommodation.
**p*-value <0.05.

Table 5. Receiver operating characteristics (ROC) table and positive and negative predictive values, for the amplitude of accommodation (AA), monocular (R = right, L = left) and binocular (B)

	Reference value	Proportion of children with AA less than or equal to reference value (%)	Sensitivity	False-pos.	Positive predictive value	Negative predictive value
AA (R)	7.0	20	0.44	0.03	0.92	0.70
	8.0	29	0.60	0.06	0.88	0.76
	9.0	32	0.60	0.11	0.79	0.75
AA (L)	7.0	19	0.40	0.03	0.91	0.69
	8.0	25	0.52	0.06	0.87	0.73
	9.0	37	0.60	0.21	0.68	0.73
AA (B)	11.0	19	0.40	0.03	0.91	0.69
	12.0	24	0.44	0.09	0.79	0.69
	13.0	29	0.44	0.18	0.65	0.67

Discussion

The aims of the present study were to evaluate possible relations between near-work problems and accommodative dysfunction. A questionnaire for identifying subjective symptoms related to accommodation was used in the study. The questionnaire contained four different questions related to four different symptoms that, according to previous studies (Daum, 1983; Hoffman and Rouse, 1980; Hennessey *et al*., 1984), are the subjective symptoms most frequently related to an accommodative dysfunction.

The first examination clearly indicated a relationship between accommodation and subjective symptoms. However, there were no symptoms reported among children below the age of 7.5 years. This may be due to the fact that below this age, there is not that much intensive near work and they are not yet frequent readers. It is also possible that, even if it was not apparent during the interviews, the youngest children did not understand the different symptoms completely. Another possible explanation is bias in answers, for instance, children may tend to give the 'correct' reply just to please the interviewer. Thus, the second examination was performed primarily to confirm the relationship between accommodation and symptoms. It also allowed us to study changes in accommodation and symptom status. To improve the reliability of the interview and guarantee that the children really understood the questions, the second examination started with letting the children describe the symptoms. We found that they did not have any problems with this and we believe that the questions were well understood and that the answers were reliable.

The most frequent symptoms were asthenopia and headache. In a previous study (Sterner *et al*., 1999) these symptoms were also present in children having an impaired accommodative facility. The children in the previous study (Sterner *et al*., 1999) had relief from their symptoms after facility training. Treatment of accommodative dysfunction has been described in several studies (Hoffman, 1982; Daum, 1983; Weisz, 1983; Bobier and Sivak, 1983; Cooper *et al*., 1987; Russell and Wick, 1993; Sterner *et al*., 1999; Ciuffreda, 2002). This treatment is an effective therapy for slow accommodative responses and may eliminate both the poor objective values and the subjective symptoms of the patients.

There was a significant relationship between different accommodative parameters and subjective symptoms at both examinations in the present study. However, since we found that the age span was more suitable at the second examination, our diagnostic analyses are based on that data. The ROC-analyses illustrate that the amplitude of accommodation has potential discrimination ability. In many situations a statistical approach is used and reference values are often constructed as the mean ± 2 S.D. This is the case for amplitude of accommodation references for adults using Hofstetter's curve. Assuming a normal distribution such an approach leads to 95% of all individuals falling within the limits and 5% outside. However, since we have found a relationship between the amplitude and subjective symptoms, we believe it is reasonable to use reference values which take account of this information. The choice is somewhat arbitrary and we hope it will be investigated by others, but we believe that either the value 8.00 D monocular or 11.00 D binocular, which approximately correspond to the lower quartile monocular, and lower quartile minus 1.00 D binocular amplitude, are values which could be used as reference values since they clearly imply a high risk of symptoms (around 90%) for children with results below these limits. Using these values is a more liberal choice than using 2 S.D. from the mean, i.e. the prevalence is around 25% instead of 2.5%. However, since false-positives are practically harmless in this situation, we find it reasonable to use limits which include 25% of all children, due to the fact that around 90% of them present symptoms.

As pointed out earlier, accommodative amplitude is not used for diagnosing symptoms in this case – *Table 5* only presents information about the frequency of symptoms related to different levels of accommodation amplitude. We think that a discussion about the definition of the diagnosis AI is also necessary. If either 8.00 D monocular or 11.00 D binocular, respectively, are used as diagnostic criteria, it would mean that around 25% of all children have AI. It may therefore be more reasonable to have a joint diagnosis, demanding an amplitude of accommodation below either 8.00 D (monocular) or 11.00 D (binocular) together with the presence of symptoms.

It should be remembered that in a single study like this, reference values are based on and adjusted to the observed values. The diagnostic precision may therefore be overestimated and the reference values may have to be adjusted in the future. It is also recommended to establish confidence intervals for estimates of diagnostic accuracy (Bossuyt *et al.*, 2003).

Since subjective symptoms are common among school children and since we identified the lower quartile as a reference, the proportion of children who would benefit from an eye examination is high, which makes routine screening an option. We would recommend screening, even though it is difficult to implement. At least we should inform schools and care givers about this possible relationship. We believe that an eye examination should be offered at least to those with symptoms during near work. It is reasonable to be alert to these symptoms from around the age of 8 years. As we also found significant changes for some children between the two investigations, we recommend being observant over the years. Even if an initial examination of the accommodation shows high amplitude, it may be decreased more than expected over a period of time, as was the case for some individuals in this study.

We do not know why the result between the two examinations for some of the children changed so much over this period of 1.8 years. However, the result from this study further supports the need for better knowledge of how the accommodative system functions at younger ages.

This study was based on a population which could be described as an invited population. Perhaps children with symptoms were more willing to take part in the study implying that the prevalence is higher than it would be if a true screening was applied. The result from this study does, however, throw light upon how a comprehensive eye screening programme including the accommodative function could be of use, which is in concordance with the conclusion of Borsting *et al.* (2003). Such screening might be suitable for children older than 8 years. We suggest the use of *Table 5* as a reference table. It is important to bear in mind that the positive predictive value increases/decreases with increased/decreased prevalence. Thus, if the table were used for patients visiting the clinic due to suspected eye problems the prevalence would probably be higher than in this study and the positive predictive values higher. This table is based on a limited number of subjects and levels must be confirmed in forthcoming studies. Nevertheless, we think that this table could be useful in clinical practice. We also believe that it is important to increase awareness of the relationship between accommodation insufficiency and subjective symptoms.

Acknowledgements

This work was supported by grants from the 'De Blindas Vänner' Association, the Sigvard & Marianne Bernadotte's Research Foundation for Children's Eye Care, the Solstickan Foundation, the Swedish Optometric Association, and the Sunnerdahl's Disability Foundation.

The authors are grateful to the staff at the Krokslätt school and the children participating in this study.

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