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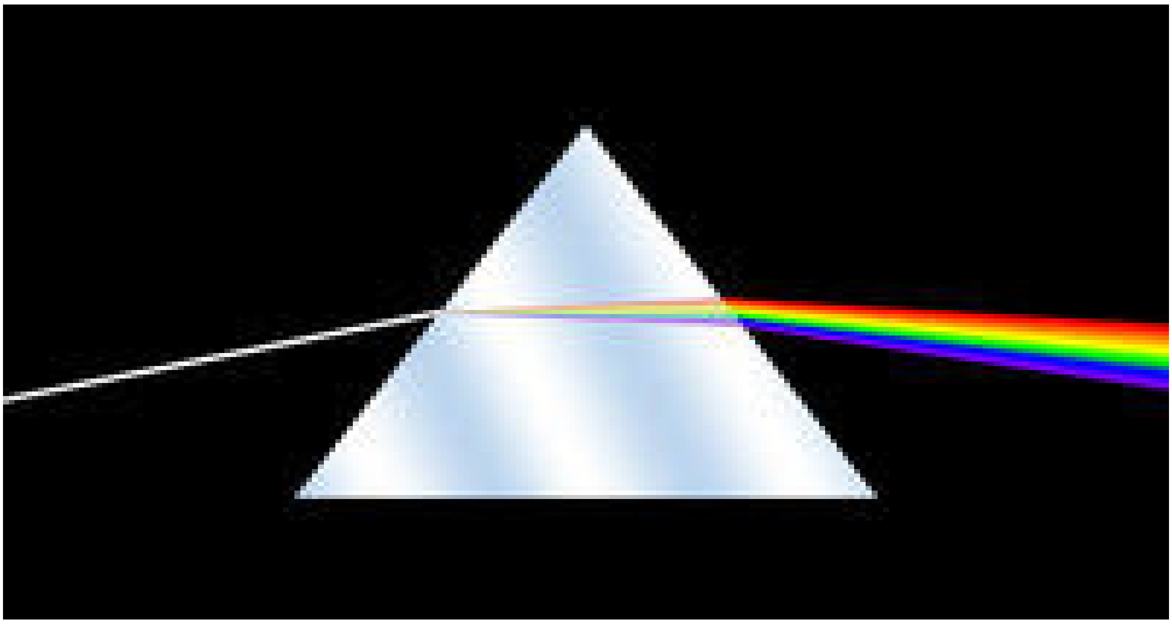
Asthenopia in Schoolchildren



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In dear memory of my mother

SUMMARY

Asthenopia is a term used to describe different symptoms associated with the use of the eyes, such as pain, blurred vision, diplopia, headaches. Asthenopia is most often reported in association with near vision. Children with asthenopia complain of such symptoms particularly when reading and writing. Asthenopia is often divided into two main categories: refractive including refractive errors and anisometropia, and muscular, comprising strabismus and convergence insufficiency. Asthenopia due to accommodative problems has in the present studies been regarded as muscular asthenopia.

In paper I the prevalence of asthenopia, refractive errors and binocular disorders was determined in a representative population of 216 Swedish schoolchildren aged 6 – 15 years. The prevalence of asthenopia was 23.1 %. The prevalence of hypermetropia and myopia changed with age, while astigmatism, convergence ability and strabismus did not. Accommodative insufficiency was more common in the older schoolchildren. Asthenopia was related to uncorrected visual acuity and refractive errors, and to accommodative insufficiency.

Paper II described the orthoptic and ophthalmological findings in a group of 120 schoolchildren with asthenopia. The effect of asthenopia treatment was also evaluated. The most frequently occurring findings related to asthenopia were refractive errors, heterophoria and accommodative insufficiency. With appropriate treatment with glasses, prism or orthoptic exercises for 3 – 6 months, 112 out of the 120 children (93%) became asymptomatic.

In paper III 49 schoolchildren with asthenopia due to accommodative insufficiency were assessed with the Visual Analogue Scale (VAS) and the grade of asthenopia was correlated with the degree of accommodative deficiency. The aim was to investigate if VAS grading of the asthenopic symptoms could be used as an instrument to indicate the level of improvement of accommodative insufficiency after treatment. A statistically significant reduction of asthenopic symptoms as graded with the VAS scale was observed, and the improvement in accommodation was also significant. However, there was no correlation between VAS values and the accommodation before and after treatment, and VAS values can only give a general impression of the level of accommodative ability in asthenopia ($p < 0.001$).

Paper IV described how accommodative insufficiency influenced reading performance. Twelve children with asthenopia due to accommodative insufficiency were examined. Reading eye movements were recorded before and after treatment of asthenopia, using the IR corneal reflection technique, Orbit Eye trace System. Large variations in reading patterns were found. Despite successful accommodative treatment ($p < 0.001$), no correlation was found to the different eye movement parameters that could suggest that reading velocity was improved.

Key words
Asthenopia, prevalence, accommodative insufficiency, convergence, binocular disorders, refractive errors, Visual Analogue Scale, eye movements and reading.

List of Papers

The thesis is based on the following papers, which will be referred to in the text by their Roman numerals:

I. Abdi S, Lennerstrand G, Pansell T, Rydberg A.
Orthoptic findings and asthenopia in a population of Swedish schoolchildren aged 6 to 16 years.
(Submitted to Strabismus).

II. Abdi S, Rydberg A.
Asthenopia in school children, Orthoptic and ophthalmological findings and treatment.
Documenta Ophthalmologica, 2005; 111:65 – 72.

III. Abdi S, Rydberg A, Pansell T, Brautaset R.
Evaluation of accommodative insufficiency with the Visual Analogue Scale (VAS).
Strabismus, 2006; 14:199 – 204.

IV. Abdi S, Brautaset R, Rydberg A, Pansell T.
The influence of accommodative insufficiency on reading.
Clinical and Experimental Optometry, 2007; 90:36 – 43.

Contents

1. Introduction

1.1. Asthenopia

Asthenopia is a term used to describe a sense of strain and weakness or ocular fatigue set up by the use of the eyes (a = not, sthenos = strengh, ops = vision) (Atencio 1996, Palmer 1993). Asthenopia is a common presenting complaint among patients with accommodative and convergence insufficiency, refractive errors and intermittent strabismus. The different symptoms described as asthenopia are shown in Fig 1.

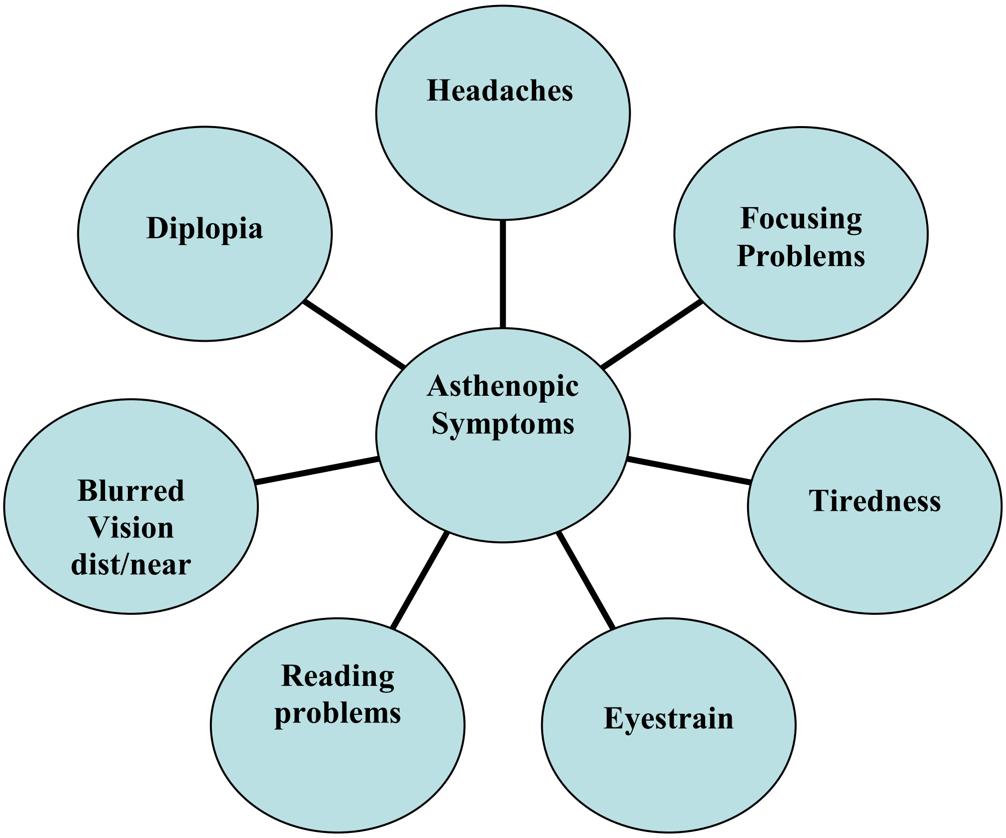

Figure 1. The main symptoms of asthenopia

Asthenopic symptoms are less frequent at distance vision than at near vision, because there is less strain on the accommodation and vergence systems. Asthenopic symptoms are becoming more common in modern society where near work at computers require sustained fixation, often for hours, at the same visual distance, which puts a strain on the system for near vision However, also in schoolchildren asthenopia can occur, and recent studies report a prevalence of

15.2% in 6 year old children (Ip et al. 2006) and 34.7% in schoolchildren 6-10 years old (Sterner et al. 2006).

Asthenopia is also often caused by uncorrected refractive errors (hypermetropia, myopia, astigmatism and anisometropia), and the condition is then called ***refractive asthenopia*** (Fig 2 A). Asthenopic symptoms can be caused by neuromuscular anomalies and this form is termed ***muscular asthenopia*** (heterophoria, heterotropia and convergence insufficiency) (Fig 2 B). Asthenopia due to disturbances of accommodation may be regarded as either refractive asthenopia or as muscular asthenopia (von Noorden and Campos 2002). In the present studies it is regarded as a part of muscular asthenopia (Fig 2 B).

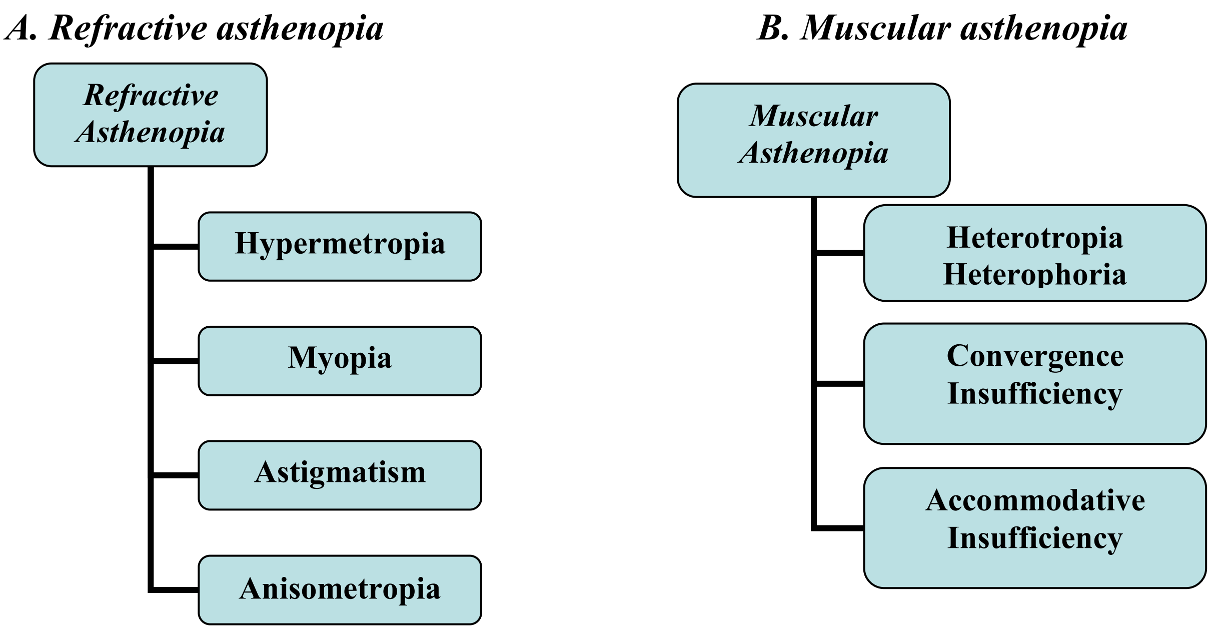

Figure 2. The major types of asthenopia and the under groups (Modified from von Noorden & Campos, 2002)

1. 2 Refractive Asthenopia

1.2.1 Hypermetropia

Hypermetropia is a condition in which distance objects are focused behind the retina when the accommodation is relaxed, i.e. the image is defocused unless the subject accommodates or wears convex lenses (Fig 3).

Hypermetropia can be categorized by the degree of the refractive error in low hypermetropia (≤ 2.00 D), moderate hypermetropia (2.25–5.00 D) and high hypermetropia (≥ 5.00 D) (Augsburger 1987).

Hypermetropia does not always require correction because young patients can accommodate to overcome part or all of their refractive error, hence achieving good near and distance vision (Khan 1999, Jones 1997).

However, in most children with asthenopia due to hypermetropia the amplitude of accommodation is low in relation to their degree of hypermetropia, i.e. these children are not able to comfortably overcome their hypermetropia. In these children correction of hypermetropia will reduce the accommodative demand resulting in stable binocular vision, and a decreased level or elimination of the asthenopic symptoms (Evans 1999).

Thus, in the case of asthenopia and reading problems the hyperopic children should be prescribed plus lenses to help the stability of the accommodative response and compensate for the given degree of hypermetropia, when the level of hypermetropia exceeds 1.00D (Petres 1961).

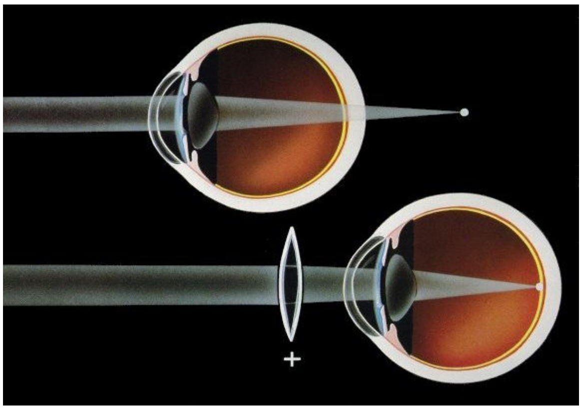

Figure 3. Hypermetropia uncorrected (above) and corrected by convex lenses (below)

1.2.2 Myopia

Myopia is a refractive condition of the eye in which the images of distant objects are focused in front of the retina when the accommodation is relaxed. However, objects located at the dioptric distance equivalent to the degree of myopia will be focused on the retina. In order for myopic subjects to see objects in a distance clearly they need to wear a concave refractive correction (Fig 4).

In addition to distance defocus uncorrected myopia can cause an increase in the size of near eso-deviation (see section 1.3.4 for explanation) or accommodative fluctuations at near (Caloroso and Rouse 1993). The abnormal accommodative response in school age children with uncorrected myopic can give rise to uncomfortable vision and eyestrain when reading and writing (von Noorden and Campos 2002).

Myopia of more than 1.00 D in preschool children should be corrected. In cases of high exophoria or intermittent exotropia, a prescription for fulltime wear of the full refractive error is recommended. In cases of esophoria at near or accommodative insufficiency, a plus lens addition for near can also be appropriate (Blume 1987).

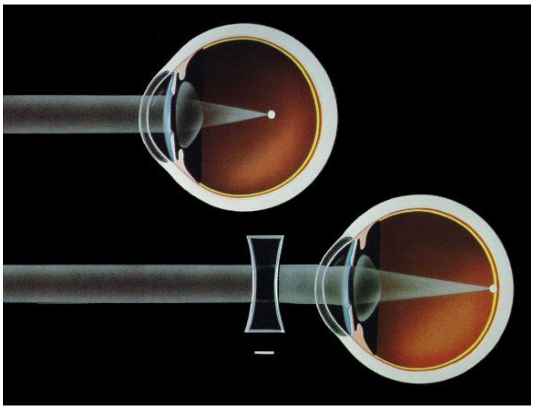

Figure 4. Myopia uncorrected (above) and corrected by concave lenses (below)

1.2.3 Astigmatism

Astigmatism is a condition of refraction in which the image of a point object is not projected as a single point but as two focal lines at different distances from the optical plane (the retina). Astigmatism can be present in combination with hypermetropia or myopia. The focal lines can be focused: 1) behind the retina (compound hypermetropic astigmatism); 2) in front of the retina (compound myopic astigmatism); 3) behind and in front of the retina (mixed astigmatism) (Fig 5); 4) or one focal line on the retina while the other is either in front or behind (simple astigmatism). In the case of astigmatism the patient needs a cylindrical correction in order to obtain a point focused image.

Generally, all astigmatic refractive errors larger than 0.25D should be corrected if asthenopic symptoms are present (Benjamin 1998). Correction of astigmatism in all patients including those with asthenopia improved the visual acuity and stabilised the input into the accommodative system, thereby eliminating or reducing the symptoms of asthenopia (Caloroso and Rouse 1993).

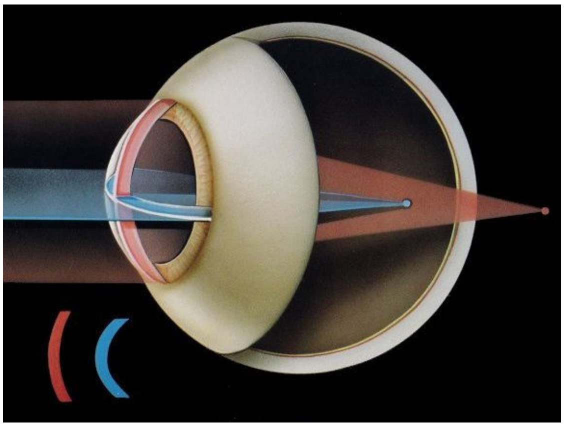

Figure 5. Mixed astigmatism with focal points in front of and behind the retina

1.2.4 Anisometropia

Anisometropia is a condition of unequal refraction in the two eyes, due to differences between the eyes in size and/or in the refractive components (Daw 1995, Rutstein and Daum 1998). Anisometropia is generally defined as a difference of spherical refraction of more than 1.00 D and astigmatism of more than 0.50 D. In the case of a large uncorrected anisometropia a central retinal suppression area can develop in the eye with more blurred vision, leading to abnormal visual development and amblyopia of this eye. When the anisometropia is corrected by glasses two problems may appear. That is a prismatic effect of the glasses, and an aniseikonia caused by differences in magnification of the two lenses, which may make binocular vision difficult or impossible (Pickwell 1989, Evans 1999). Young children below school age can adapt to these effects of anisometropic correction and may not experience impairment of binocular vision.

1.3 Muscular Asthenopia

1.3.1 Accommodation

Accommodation is the ability of the ocular lens to change the refractive power in order to keep the image of the fixated object clear on the retina. Most visual problems associated with accommodation occur because accommodation is excessive, too low, or too slow (Evans 1999, Rutstein and Daum 1998).

The normal value of the near point of accommodation in relation to age is in cm (100/(18.5D – (0.3age))) according to Hofstetter (1943), e.g. a 10 year old child is expected to have a near point of accommodation equal to (100/(18.5D – (0.3x10))) = 6.45 cm (or 15.5D).

Anomalies of accommodation are frequently classified as one of the six following conditions.

1. *Insufficiency of accommodation*– a condition in which the amplitude of accommodation is lower than expected in relation to the age of the patient (Borish 1970, Duke-Elder 1970). According to Daum (1983a,b) accommodation insufficiency is the most frequently diagnosed anomaly of near vision.

2. *Infacility of accommodation* – a deficiency of the accommodative system to react to a defocused image, i.e. the patient will have trouble adjusting their accommodative response to the appropriate stimulus. This can be diagnosed when the time taken to alter focus from one distance to another amounts to one second or more (Evans 1999, Daum 1983a).

3. *Fatigue of accommodation* – a deficiency of accommodation in which the accommodative amplitude becomes reduced with repeated measurements (Hofstetter 1943).

4. *Spasm of accommodation (accommodative excess)* – a condition caused by an overaction of the ciliary muscle or excessive flexibility of the lens. Spasm or excess occurs when the accommodative response is greater than what is required for a given stimulus. In cases of accommodative spasm the patient cannot relax the accommodation properly (Evans 1999, Griffin 2002).

5. *Paresis of accommodation*– a deficiency of accommodation which is due to an organic lesion (Rutstein and Daum 1998).

6. *Unequal Accommodation* – a condition in which the accommodative ability of the two eyes is unequal. Differences can occur in amplitude or facility and in spasm of accommodation (Rutstein and Daum 1998).

The prevalences of the different types of accommodative dysfunction syndromes are shown in Table 1 (Daum KM 1983b). In the present study the anomalies of accommodation recorded have been insufficiency, infacility and/or fatigue of accommodation.

Table 1. The prevalence of the type of accommodation dysfunction

Type	Prevalence
Insufficiency	84%
Infacility	1%
Fatigue	12%
Spasm	3%
Total	100%

1.3.2 Convergence

Vergence eye movements (the term common for either convergence or divergence) are prerequisite of normal binocular vision. Vergence eye movements minimize retinal disparity and place the two retinal images of a single object on corresponding retinal points (Brautaset 2004). In the description of vergence movements, the term convergence (i.e. a disjunctive inward movement of the eyes) is sometimes used synonymously with vergence.

The term "initial convergence" is used to describe the movement of the eyes from the physiological position of rest to the position of single binocular fixation of a distance object.

The near point of convergence (or the amplitude of convergence) is the nearest point where the lines of sight intersect when the eyes converge to the maximum with preserved binocular single vision. This point is normally about 6 to 10 cm in front of the eyes and it is independent of the age of the patient.

The most common vergence eye movement disorder is convergence insufficiency (Evans 1999), which is an inability to maintain convergence to meet the visual near point demand, and symptoms of asthenopia may arise (Grisham 1988). Convergence insufficiency can be regarded as an exophoria related binocular problem, i.e. the exophoria puts a large demand on the vergence system causing it to fatigue, or as muscular deficiency, i.e. the muscular system is not capable to meet the vergence demand. Regardless of its origin, exophoric or muscular, convergence insufficiency most commonly shows the clinical signs of a high exophoria or intermittent exotropia at near vision (Michaels 1980).

1.3.3 Near vision complex

The near vision complex is the coupling of accommodation, convergence and constriction of pupil (miosis). In fixation at near the accommodative process produces a clear image on the retina, the relative position of the visual axes is changed by the convergence system, and the size of the pupil is reduced by constriction of the pupillary sphincter muscle.

Different parts of the nervous system are involved in the near response: The cerebral cortex generates the signals of the three components of near response, the pretectum and tectum of the midbrain controls, integrates, and synthesizes the impulses, and the oculomotor nuclear complex, including the Edinger-Westphal nucleus, acts as the final common pathway, and transmits the impulses to the effector organs; ciliary body, medial rectus, and iris sphincter (Miller and Newman 1999, von Noorden and Campos 2002).

It is known that the final common pathways along the oculomotor nerve to the effector organs runs separately since the three components may be abolished selectively by appropriate lesions of the oculomotor nerve or the ciliary ganglion.

Asthenopia is commonly reported in association with improper balance of the near vision complex.

1.3.4 Heterotropia/ Heterophoria

Heterotropia is a condition in which the visual axes of the two eyes are not directed towards the same fixation point when the subject actively fixates an object. The direction of the heterotropia is described as the direction of the deviating eye in relation to the fixating eye and can be inward (esotropia), outward (exotropia), vertical (hyper- or hypotropia), or the eye has rotated around the visual axis (cyclotropia). Heterophoria is a condition in which the visual axes of the two eyes are not directed towards the same fixation point when the subject is prevented from being able to fuse the images of the two eyes, i.e. when the eyes are dissociated. The direction of the phoria is described in relation to the relative position of the dissociated eye and can be inward (esophoria), outward (exophoria), vertical (hyper- or hypophoria), or the eye has rotated around the visual axis (cyclophoria). When a heterophoric patient has adequate stimulus to maintain fusion the deviation can only be detected by dissociating the eyes, which is why the term latent strabismus is sometimes used to describe the condition. Fusional eye movements (also called motor fusion) represent the ability of the eyes to perform vergence eye movements until the object of regard falls on corresponding retinal areas normally the two foveas (Evans 1999). When the fusional reserves are large enough to comfortably overcome the angle of the heterophoria the phoria said to be compensated, and does not give rise to any symptoms. A decompensated phoria is, on the other hand, defined as a phoria that gives rise to symptoms, i.e. asthenopia and/or diplopia, and decompensated heterophoria is a very common cause of asthenopia.

Heterophoria and heterotropia have two major forms: comitant or incomitant. A comitant deviation is a condition of heterotropia or heterophoria in which the angle of deviation remains the same with either eye fixating and in all the directions of gaze. An incomitant deviation is a condition where the angle of deviation in a heterotropia or heterophoria differs according to which eye is fixating or in which direction of gaze the fixating eye is looking. Comitant deviations are usually conditions appearing congenitally or from an early age, while incomitant deviations are more commonly acquired, e.g. in paralytic strabismus (Burian and Spivey 1964, Rutstein and Daum 1998, von Noorden and Campos 2002).

1.4 Measurement of asthenopic symptoms (Questionnaires for asthenopia)

A major difficulty in quantifying the type and severity of symptoms in asthenopic patients is the lack of standardized instruments for asthenopia assessment that are easy to use, also in schoolchildren. A scale for estimating asthenopic symptoms due to convergence insufficiency and other binocular vision disorder was presented by Cooper et al. (1983) and involved a questionnaire with 8 questions for which most questions had five alternatives. Borsting et al. (1999) have also designed a questionnaire to evaluate asthenopic symptoms, and the Convergence Insufficiency and Reading Study group (CIRS), (for reference see Borsting et al. 2003) has developed a classification scheme based on measurements the asthenopic problems in relation to accommodative insufficiency and convergence insufficiency. However, these questionnaires and other classification schemes like the COVD-QOL (the College of Optometrist in Vision Development Quality of Life Checklist) are quite complicated and time consuming for both the patient and the examiner, and are difficult to use in children, especially since they try to address several issues within the same question (Borsting et al. 1999).

1.4.1 Scales for assessing disease symptoms

There are numerous scales available for assessing disease symptoms in children, for example pain (Jaywant and Pai 2003). Several Pain Face Scales (PFS) exist and were developed primarily for use with young children, but are also used with adults who have difficulty using the numbers on the visual analogue scale. Kuttner and LePage (1989) and Bieri et al. (1990) constructed two face scales, which can be used for children from 4 or 5 years of age. Children indicate their pain by pointing to the face expression best representing their pain intensity (Fig 6).

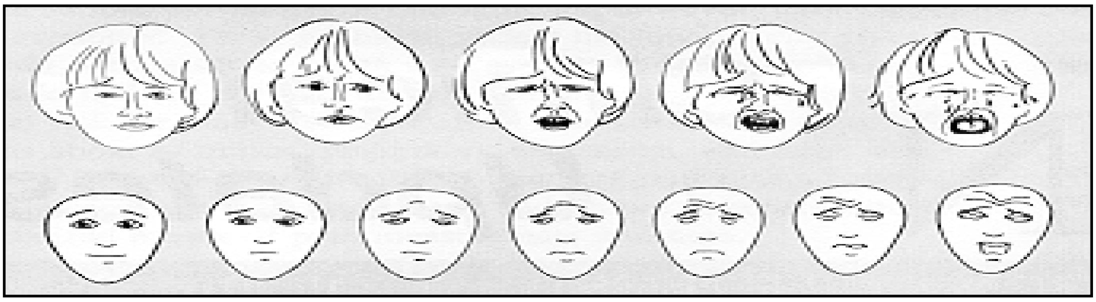

Figure 6. Two different Faces scales

Word graphic rating scales are descriptive pain scales, which can be used for 6 or 7 years old children (Fig 7). Children are asked indicate how much pain they have on a line with five verbal anchors. These scales can also be used to measure, monitor and evaluate the effect of treatment. They have gained popularity since they easily communicate the level of complaints or symptoms, and give the clinicians a way of tracking the perception of disease symptoms of individual patients, just as one would keep track of other vital signs, like temperature, blood pressure, respiration etc.

Figure 7. Word graphic rating scale.

1.4.2 The Visual Analogue Scale (VAS)

The Visual Analogue Scale (VAS) has been used for a long time to assess subjectively the perception of symptoms. It is easy to administer and it provides reproducible results (Todd 1996). It has been found a useful and reliable method for children as young as six year of age (Tesler et al. 1991, Tiplady et al. 1998; Pointer 2003). The VAS has also been found sensitive to treatment effects and the data derived can be analysed statistically (Philip 1990; Dexter and Chestnut 1995).

There are two main variants of the Visual Analogue Scale (VAS). The original VAS is a horizontal (or sometimes vertical) 10 (cm) line with word anchors at the extremes, such as “no pain” on one end and “the worst pain possible” on the other end (Fig 8). The patient is asked to make a mark along the line to represent pain intensity.

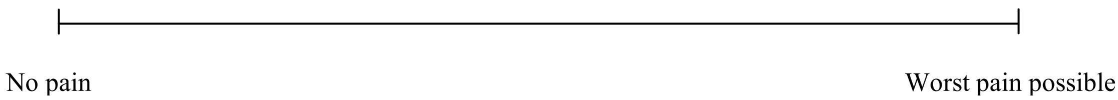

Figure 8. Illustration of a Visual Analogue Scale with anchors only at the ends.

Another variant of the VAS (also called the Numerical Pain Scale – NPS) allows the patient to rate pain intensity on a numbered scale, such as 0 to 10 (Fig 9).

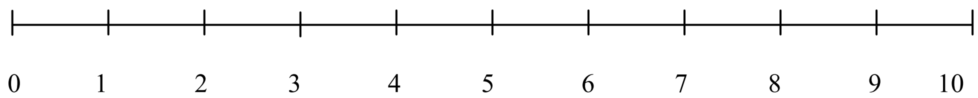

Figure 9. The Visual Analogue Scale (VAS) with a numbered scale.

In studies comparing different variants of the VAS, pain ratings of 2.5 or lower have been found to indicate a tolerable level of pain (i.e. normality) and ratings above 4 should be regarded as agitation (i.e. true symptoms of pain) (Jaywant and Pai 2003).

1.5 Eye movements

Since only the central part of the visual field (i.e. the fovea) can distinguish small objects such as letters in a textbook, the eyes have to scan to picture the whole visual scene. We shift gaze with fast eye movements (i.e. *saccades*) to align the visual axis on the object of interest and thereby placing the image of the object onto the retinal fovea while *fixation* eye movements maintain gaze on a stationary target. Examination and assessing of eye movement is an important part of diagnosis and treatment of patients in many areas of clinical practise in ophthalmology and neurology.

1.5.1 Eye movement in reading

In order to read a text in a book the eyes have to scan the text lines by forward-directed saccades and fixations. When shifting from one text line to the following the eyes make a return-sweep (saccade) placing the eyes in the beginning of the new text line (see Fig 10). The actual decoding of the text is made during the fixation when the eyes are stationary on the word(s) of interest. When the decoding is done an internal trigger brings the eyes forward with a saccade to the following word(s) to the right. If the reader becomes distracted or if the text is difficult to understand the reading pattern is often disrupted by so called regressions, i.e. making backwards saccades and re-reading of the text just fixated.

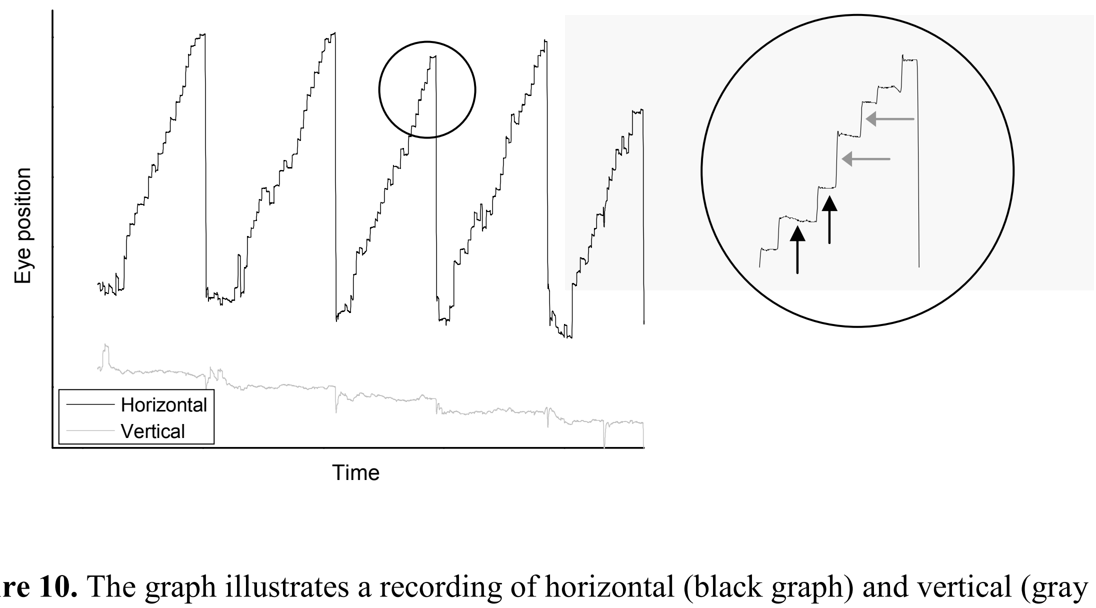

Figure 10. The graph illustrates a recording of horizontal (black graph) and vertical (gray graph) reading eye movements. The magnified part of the recording (big circle) clearly shows the forward directed saccades (marked with the gray horizontal arrows) as well as the stable fixations (marked with the black vertical arrows).

1.5.2 Recording eye movements

There are several recording systems in use to monitor the shift of eye positions. In this study (paper IV) we used an infrared reflection system (Orbit XY-1000, IOTA AB, Sweden) to record eye movements during reading. In the Orbit XY-1000 system, infrared light is transmitted from illuminators and reflected against the eyes (Fig 11a,b). Photo detectors sample the reflected light and the received signal generates an eye position signal. The fluctuation of the reflected light, which is induced by changes in the position of the ocular surface during the eye movement, is interpreted as eye movements. In modern devices the signals, which basically are photocurrent subtractions, are conducted into the soundcard of a computer and finally presented by a software program as eye movements (Ober 1994).

A) B)

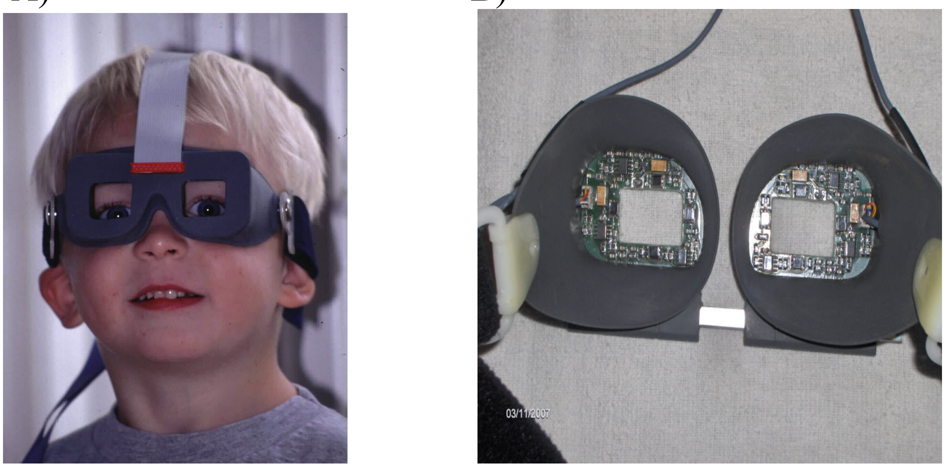

Figure 11 A, B. The recording goggles of the infrared reflection technique.

1.6 Treatment of Asthenopia

Treatment of asthenopic symptoms is depended on the underlying cause. In the case of refractive asthenopia any significant refractive errors should be corrected. Treatment of muscular asthenopia could be orthopic or combination of orthoptic treatment and glasses (Table 2).

Table 2. Diagnostic tests and treatment modalities in asthenopia

Diagnosis and Treatment		
Causes of asthenopia	Investigation	Treatment
Hypermetropia	Refraction/Cycloplegia	Refractive correction
Myopia	Refraction/Cycloplegia	Refractive correction
Astigmatism	Refraction/Cycloplegia	Refractive correction
Anisometropia	Refraction/Cycloplegia	Refractive correction
Reduced accommodation	Near point of accommodation	Plus glasses
Convergence Insufficiency	Near point of convergence/Degree of deviation/Prism cover test	Convergence exercises/ Prism/Surgery
Heterophoria	Degree of deviation/Prism cover test	Prism glasses/Surgery
Heterotropia	Degree of deviation/Prism cover test	Surgery/Prism glasses

Subjects with reduced accommodation can be treated with reading addition or by orthoptic exercises. When prescribing reading addition and/or orthoptic exercises to these patients the aim is to produce a clear and focused image on the fovea. The visual sensory system will "learn to recognise" a clear image, which then will reinforce the normal accommodative response to a defocused image. An example of a commonly used exercise is the "flip lens" or "spherical flipper" with for example a +2.00D lenses on one side and a –2.00D lenses on the other side. The task of the patient during treatment is to alternately view an object (normally placed at 40 cm) through the plus- and minus side of the flipper, and to obtain a clear image before flipping to the other side (Rutstein and Daum 1998).

In subjects with convergence insufficiency the two most common modalities of treatment is prescribing prisms and orthoptic exercises. The power of the prescribed prism is based on the measurement of the deviation at distance and near. The aim of the prism prescription is to reduce the deviation. For near vision, prisms are given which will reduce the deviation to such a degree that comfortable near vision can be gained. In some subjects the deviation will enlarge itself and the prism will have to be increased in power before a stable deviation is achieved. In subjects where the deviation becomes too large surgery should be considered. An alternative to surgery in subjects with deviations of less than 15 prism dioptres is treatment with Botulinum toxin type A

(Lennerstrand et al. 1998). However, this treatment may not be appropriate for children.

Convergence insufficiency has also been found amenable to orthoptic exercises by several researchers (Brautaset 2006). The most commonly prescribed treatments are home-based exercises such as “pencil push-up”, flipper spherical lenses and flipper prisms (a prism flipper is similar to a spherical flipper but made of prismatic lenses, base-in on one side and base-out on the other) (Scheiman et al. 2002).

2. Aims of the Present studies

I) The aim of Paper I was to determine the prevalence of refractive errors and binocular disorders in relation to asthenopia in a representative population of Swedish schoolchildren.

II) The aim of Paper II was to describe the orthoptic and ophthalmological findings in schoolchildren with asthenopia, to correlate the findings with asthenopic symptoms and to evaluate the effect of treatment.

III) The aim of Paper III was to evaluate whether asthenopic symptoms in schoolchildren diagnosed with accommodative insufficiency (AI) graded with Visual Analogue Scale (VAS) could be correlated with the degree of accommodative deficiency in these children, and to investigate if VAS grading of the asthenopic symptoms could be used as an instrument to indicate the level of improvement of AI.

IV) The aim of Paper IV was to determine how accommodative insufficiency influences reading performance.

3. Material and Methods

3.1 Paper I

Schoolchildren in 8 junior level schools were invited to participate. The study group consisted of a total of 216 schoolchildren in the age range of 6 – 16 years, 111 girls and 105 boys. The schoolchildren were attending 4 different classes at grade 1 (age 6 – 7 years), 5 classes at grade 4 (10 – 12 years) and 3 classes at grade 8 (14 – 16 years). All students were examined at the clinics of the school nurses. Sixteen of the schoolchildren were already wearing glasses for refractive errors. The information of the eye conditions of these students were collected from the files at the eye departments and from the optometrists where they had been examined.

A general medical history was taken. Questions regarding the asthenopic symptom were asked. Visual acuity was tested for distance (5 m) and near (40 cm) with the KM acuity test (Moutakis et al. 2004) uncorrected and with best subjective refraction without cycloplegia.

A complete refraction in cycloplegia using an autorefractometer was done in all students. Students who refused to have cycloplegic drops instilled, 8 in total, were refracted without cycloplegia. For cycloplegia a mixture of cyclopentolate 0.75% and phenylephrine 2.5% was used. Hyperopia was defined as ≥ +0.50 D spherical equivalent, myopia as ≤ – 0.5 spherical equivalent and astigmatism as ≤ – 0.5 cylindrical refractive errors. Binocular vision was assessed with the Lang II stereo test and with the Bagolini striated glass test for distance and near. Strabismus was determined with the cover test for distance and near with the best correction. Prism cover test was used to assess the angle of strabismus. Exophoria was defined as ≥ 4 prism diopters at distance and ≥ 6 prism diopters at near. Esophoria was defined as ≥ 2 prism diopters at distance and ≥4 prism diopters at near**.** The near point of convergence was measured with the RAF (Royal Air Force) rule. The normal range was set at 6 – 9 cm. A near point 10-14 cm was denoted as mild convergence insufficiency, 15 – 19 cm as moderate insufficiency and 20 cm or more as marked convergence insufficiency. The near point of accommodation was also measured with the RAF- rule. Normal accommodation was at 6 – 9 cm, mild accommodation deficit was defined as a near point at 10 – 15 cm, moderate deficit at 16 – 20 cm, and marked deficit more than 20 cm.

3.2 Paper II

One hundred and twenty students between 6 and 16 years old were included in the study. They comprised a different population of children from the students of paper I. They all complained of asthenopia and eye problems interfering with their schoolwork. The students were referred by the school nurse for an ophthalmological and orthoptic investigation. The visit to the nurse was initiated by the teachers, parents or students themselves.

Based on the asthenopic symptoms, the population of patients was divided into 3 different groups: A) blurred vision, tiredness, sore eyes, focusing problems and intermittent diplopia; B) those with headaches; C) a combination of symptoms as in A and B.
The investigation of the refraction and binocular vision was done as described in section 3.1. An examination of fundi and media was also done in all students.

3.3 Paper III

One hundred and thirty schoolchildren, aged between 7 and 16 years were referred by school nurses for an ophthalmological and orthoptic investigation due to asthenopic symptoms. These children were the same population as in Paper II. Forty-nine of the children were diagnosed with accommodative insufficiency (AI).
In all children a complete orthopic investigation was done as described in section 3.1. An examination of fundi and media was also done in all students.
To be included in the study as an AI subject several criteria had to be fulfilled: 1) symptoms revealing uncomfortable vision, blurring and headache; 2) refractive error <1.00 D of hypermetropia and <0.50 D of myopia, and/or astigmatism <0.50 D measured in cycloplegia; 3) distance heterophoria between 2Δ of exophoria and 2Δ of esophoria, and near heterophoria between 6Δ of exophoria and 4Δ of esophoria; 4) near point of convergence of 10 cm or better on the RAF (Royal Air Force) rule; 5) compensating fusional reserves at least twice the near phoria; 6) near point of accommodation worse than (100/(15D – (0.4 age))) on the RAF-rule; 7) distance Snellen visual acuity of 0.8 or better both monocularly and binocularly; 8) no ocular pathology; 9) no history of ophthalmological treatment; 10) no intake of drugs with known effect on visual acuity and/or binocular function and accommodation. The near point of accommodation was tested three times in the right eye, left eye and binocularly using the RAF-rule both before and after a 12-week treatment period.

3.3.1 Specific method

In paper III the degree of asthenopic symptoms was also tested before and after treatment using a Visual Analogue Scale (VAS). The VAS used was a numerical scale from 0 to 10. The degree of asthenopia was graded by the children themselves on the VAS (Fig 9), and the children were instructed not to tick the line in-between numbers. The question asked with the VAS was: “If 0 equals no problems when doing near work and 10 equals the worst degree of problems, what number would you grade your problems at near work to be now?"

3.4 Paper IV

Reading performance before and after a period of treatment was measured in 12 schoolchildren (8 – 16 years of age) diagnosed with asthenopic symptoms due to AI. To be included, all subjects were thoroughly investigated to ensure that AI was the only underlying cause for the asthenopic symptoms and that the controls did not have any binocular anomalies. Three children without asthenopia and AI were used as controls. An orthoptic investigation was done in all participants as described in section 3.1. An examination of fundi and media was also done in all students. To be included in the study as an AI subject, several criteria had to be fulfilled (see section 3.3).

3.4.1 Specific method

Reading eye movements were recorded before and after treatment of accommodative insufficiency. The equipment consists of an infrared device mounted in goggles worn by the test subject (Fig 10). Horizontal and vertical eye movements (250 Hz) were recorded when the subjects read a text on the monitor (distance 50 cm). The recorded data was analyzed off-line calculating the average number of saccades, the times spent per text row and the duration spent per fixation in seconds. The outcome was statistically analyzed.

3.5 Statistical methods

3.5.1 Paper I

The data was initially analysed in a correlation matrix on all variables. The correlation scatter plots were inspected and the t-test (p=0.05) showed which variables correlated significantly. The effect of age groups (i.e. grade) on asthenopia was analyzed by the logistic regression model and the odds ratio (OR) with confidence intervals (95%) was calculated as a function of the probability of reporting asthenopia from the eye conditions in each grade. The data was converted into dummy variables and grade 1 was set as base line the continuous variables were dichotomized and the OR and confidence intervals were calculated for each eye condition.

3.5.2 Paper II

For the quantitative data the General Linear Model was used to perform a multivariate analysis of variance between symptom groups. The relationships between the measured parameters were analysed by means of the Pearson correlation coefficient. The Kruskall-Wallis non-parametric test was used to compare quantitative data when the normality assumption cannot be kept. The Spearman correlation coefficient was used to analyse the association between ordinal variables. The categorical data were analysed by means of the chi-square statistics for crosstabs.

3.5 .3 Paper III

For statistical analysis of the effect of treatment on the accommodative amplitude and VAS grading before and after treatment, the Friedman non-parametric repeated measures ANOVA test with Dunn's multiple comparison post-hoc test was used (InStat, GraphPad Software Inc., USA). The analyses of the correlation between accommodative deficiency and the VAS grading before and after treatment were done using linear regression analysis (InStat, GraphPad Software Inc, USA.

3.5.4 Paper IV

The reading data were corrected for the difference in text length and the reading velocity was calculated. The change in near point of accommodation was correlated with the change in reading velocity and analysed by a regression analysis ⟨$\alpha = 0.05$).

3.6 Treatment

3.6.1 Paper I and paper II

The students with eye symptoms when reading and writing were examined with the assumption that the abnormal findings in testing of refraction and binocular vision could be the cause of the asthenopic symptoms and they were treated accordingly.

Students with normal results were referred to a paediatrician. Children with suspected eye pathology were referred to a paediatric ophthalmologist for further investigation.

The students with asthenopia due to latent strabismus were given prism glasses. Children with refractive errors alone were prescribed glasses for near and distance. Children with combined refractive error and heterophoria were prescribed glasses with spherical lenses and prisms. Students with heterotropia were sometimes referred for strabismus surgery. Children with reduced accommodation in relation to their age were given appropriate reading glasses for near (+0.75, +1.00). Students with convergence insufficiency and accommodative insufficiency were treated with convergence exercises and glasses for close work.

3.6.2 Paper III and Paper IV

The students diagnosed with accommodative insufficiency, were given reading glasses (+1.0 D) for a 12-week treatment period (Paper III) and an 8 week treatment period (Paper IV).

4. Results

4.1 Paper I

Asthenopic symptoms were reported by 21.7% of the students in grade 1, 21.9% in grade 4, and 26.7% in grade 8, i.e. 50 students in total (23.1%).

Uncorrected visual acuity was normal in 83% at distance and 75 % in near visual acuity.

Corrected visual acuity was normal in both eyes for near and distance in all schoolchildren except two who had strabismic amblyopia of one eye.

Hyperopia of a low degree (+0.5 – + 1.0) was seen in 62% of the schoolchildren in grade 1, in 77.1% of the schoolchildren in grade 4 and in 75% of the schoolchildren in grade 8. Hyperopia of moderate degree (+ 1.25 – + 3.0) was relatively more common in grade 1 (22.5 %) than in grade 4 (5.7%) and grade 8 (3.3%). No hyperopia over 3 D was found.

Myopia at all levels was seen more frequently in schoolchildren of grade 8 (11.7%) than in grade 1 (5.8%), with the rate in grade 4 being 4.2%. Moderate myopia (–1.50 – –3.0) was not at all seen in schoolchildren of grade 1, but in 2.1 % of the schoolchildren in grade 4 and in 4.2 % in grade 8.

Astigmatism was noted in 25 schoolchildren or 11.6% of the total population. In grade 1, astigmatism was seen in 6 (10%), in grade 4 in 11 (11.5%), and in grade 8 in 8 (13.3%). The astigmatism was never higher than 1.25 diopters.

Anisometropia was uncommon and found in only 0.9% (2 students) of the total population. It was an anisohyperopia in both cases.

Binocular vision tests showed that 4 students had defective stereopsis (1.8 %) and 2 students (0.9%) had abnormal results with the Bagolini test for distance and near.

Strabismus testing showed that 93.1% of all students had an orthophoria at distance and in 50 % at near. Exophoria ≥ 4Δ at distance was observed in 4.2% of the total population and exophoria ≥ 6Δ at near in 8.8%. Esophoria ≥ 2Δ at distance and ≥ 4Δ at near was seen in 1.4%. Heterotropia was observed in 1.4% of the population, exotropia in 1 student and esotropia in 2 students.

Convergence insufficiency was seen in 6% of the schoolchildren, mostly of the mild form and in only one child the near point was moderately impaired. Convergence insufficiency was related to latent strabismus measured at distance and near fixation (p<0.001), and increased with increasing angle of strabismus. There was a clear relation to age in the relation to convergence insufficiency (p<0.001).

Accommodation insufficiency was seen in 11.1%. It was mostly mild or moderate, and a marked deficiency was seen only in two schoolchildren (0.9%), both in grade 4. Accommodation was reduced more often in schoolchildren of grade 8 (18.3%) than in schoolchildren of grade 1 (10%) and grade 4 (7.3%). Accommodative insufficiency was related to convergence insufficiency (p <= 0.001).

Aspects on asthenopia

Only two of the schoolchildren with normal examination showed asthenopia.

With regard to *age of the children*, no significant effect of age could be found between Grade 1 and Grade 4 (OR=1,05 [0,47;2,35]), between Grade 1 and Grade 8 (OR=1,71 [0,74;3, 97]) or between Grade 4 and Grade 8 (OR=1,63 [0,77;3, 41]).

With regard to *refractive errors* it was seen that schoolchildren with myopia (OR=3,37) and astigmatism (OR=1,25) reported asthenopia more often than schoolchildren with hypermetropia (OR=0,74). Many schoolchildren with *reduced accommodation* (OR=1,43) and low *uncorrected visual acuity* (OR=3,0) reported asthenopia, but few with *convergence insufficiency* did so (OR=0,49).

4.2 Paper II

Of the 120 schoolchildren with asthenopia, 64 were classified as group A, 17 as Group B and 39 as Group C.

Eleven students had a normal orthoptic and ophthalmological examination in spite of symptoms indicating asthenopia. Suspected eye pathology was found in 3 students.

Uncorrected visual acuity at distance. In the right eye 95 students had a visual acuity of 0.8 – 1.0, 14 students 0.3–0.65 and 11 students had a visual acuity < 0.3. In the left eye 94 students had a visual acuity of 0.8 – 1.0, 17 students 0.3 – 0.65 and 9 students had a visual acuity < 0.3.

Uncorrected visual acuity at near. One hundred and sixteen students had a visual acuity of 0.65–1.0 and 4 students had a visual acuity < 0.65 at right and left eye.

Hypermetropia between 1.50 and 3.75 D was found in 22 students. Thirteen students had hypermetropia combined with astigmatism and 9 students had only hypermetropia. The astigmatism was between 0.50 and 1.75 D.

Myopia was found in 17 students. Sixteen of these students were prescribed adequate glasses. Nine students had myopia combined with astigmatism. The astigmatism was between 0.50 and 1.0 D and 7 students had only myopia between 0.50 and 2.75 D.

Astigmatism alone between 0.75 and 1.0 D showed in 3 students.

Strabismus was manifest in 3 students with an angle between 25 and 35 prism dioptres. One student had an esotropia and 2 students had exotropia. Latent strabismus more than 10 prism dioptres for near was shown in 9 students. Two of them had a left hyperphoria between 4 to 8 prism dioptres. A comparison between the age and prism cover test for distance showed that the angle of the phoria increased with age.

Binocular single vision was normal in 113 students and 7 students showed an abnormal stereopsis. The abnormality was due to strabismus, anisometropia and high value of hypermetropia and accommodative insufficiency.

Ocular motility was normal in 116 students. Four students showed an over action of the inferior oblique muscle, but no signs of paralytic strabismus.

Accommodative insufficiency was diagnosed in forty-nine students. The total number of students with reduced near point of accommodation (10 – 25 cm) in relation to their age was 74. It was further shown that the students with reduced near point of accommodation had reduced near point of convergence.

Convergence near point of 5 – 9 cm was found in 98 students. Abnormal convergence ability, i.e. a convergence near point ≥ 10 cm, was separated into three groups Thirteen students had a mild defect between 10 – 14 cm, 4 students had a moderate defect between 15–19 cm and 5 students had a marked defect between 20 and 25 cm.

A correlation was seen between prism cover test for near and for distance, and the near point of convergence, indicating that the students with reduced convergence also had a larger angle of strabismus.

Anisometropia was seen in six students. The largest value of anisometropia was 5.50 dioptres.

Amblyopia with a visual acuity less than 0.5 in the amblyopic eye was found in 4 students.

Aspects on asthenopia

There was no statistically significant difference between the different asthenopic symptom groups and the values of *near point of accommodation, prism cover test for near, and near point of convergence* except for astigmatism which was more related to eye problems than headache.

Among the *refractive parameters*, the spherical equivalent was related to asthenopic symptoms group B (headache). A significant correlation was found between age and refractive errors.

Effect of treatment

Treatment was done as described in section 3.6.

At the follow up 3 – 6 months after treatment had started an orthoptic assessment was performed.

The majority of the students in group A, group B and group C were symptom free (93%) and the rest described reduced symptoms (7%).

Also the schoolchildren with reduced near point of accommodation or convergence, or a combination of both, showed improved in these function and most of them were free from asthenopia.

All children that were prescribed glasses for refractive errors became symptom free or reported reduced symptoms.

All children with strabismus became symptom free after using prism glasses (in latent strabismus) or after surgery (in manifest strabismus).

4.3 Paper III

Forty-nine children of the 130 referred for asthenopia had reduced accommodation in relation to their age before treatment. The pre- and post-treatment measurements of accommodative amplitude showed that 84% of the children with AI obtained normal accommodative amplitude in relation to their age (i.e. between 6 and 9 cm), but that 16% still presented with slight accommodative insufficiency (i.e. a near point between 10 and 15 cm). All the children with accommodative insufficiency remaining after treatment were in the lower age range of 6 – 11 years. The measurements of asthenopia before treatment with the VAS scale showed that all of the children indicated a symptom level of asthenopia between 6 and 10 VAS scale units (Fig 12), which indicates a prominent degree of asthenopia. After 12-weeks of treatment VAS measurements showed that 90% of the children were non-symptomatic, at a VAS level between 0 and 2 units.

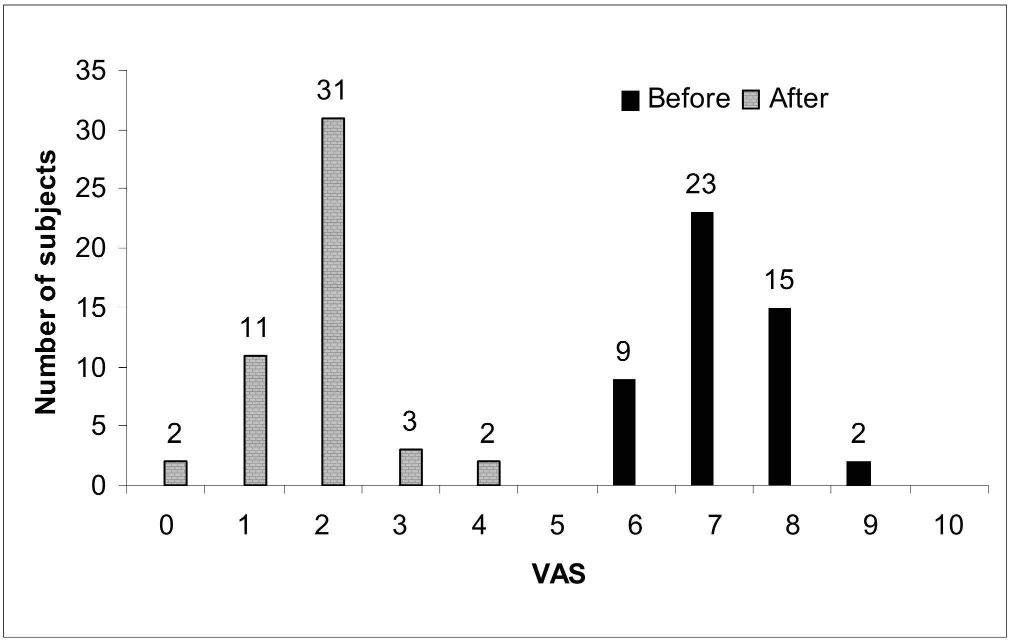

Figure 12. VAS grading before and after treatment

This reduction in the degree of asthenopic symptoms after treatment was statistically significant. Despite the statistically significant correlation between accommodation and the VAS before treatment and between the improvements/difference in accommodation and VAS before and after treatment, accommodation can only account for about 13% of the improvement in the VAS grading. Furthermore no statistical correlation could be found between accommodation and VAS-score after treatment, possibly due to the limited range of post-treatment data.

4.4 Paper IV

Twelve schoolchildren suffering from asthenopia and accommodative insufficiency were treated using near addition (+1.0D) during near work over an eight-week period. Three subjects without asthenopia and accommodative insufficiency were used as controls and they did not receive any treatment. No significant change of the near point of accommodation was observed in the three control subjects between the first and second time of testing after 8 weeks without treatment (dep +1.0D readingt–test; p=0.42).

In the schoolchildren with asthenopia a significant improvement in the near point of accommodation was obtained in all subjects (dep t–test; $p < 0.001$).

Before and after treatment the subjects with accommodative insufficiency were asked to read a text while the eye movements were recorded. Seven subjects showed improved speed of reading while five subjects showed a decreased reading velocity. A regression analysis could not reveal any significant correlation between speed of reading and improved accommodation.

Examples of how the accommodative treatment could influence reading eye movements are given for three individual subjects in Paper IV.

5. Discussion

5.1 Paper I

Many schoolchildren experience eyestrain or asthenopia during schoolwork, mainly for near work in reading and writing. Asthenopia may manifest itself as headache, sore and red eyes, blurred vision and difficulties in keeping focus on the text, and even diplopia (Abdi and Rydberg 2005). We have recorded asthenopia in a population of Swedish school schoolchildren in different age groups and compared these symptoms with the orthoptic findings in the same group of schoolchildren.

The prevalence of asthenopia in our population of schoolchildren was lower than what has been reported by Sterner et al. (2006) in the age group 6 – 10 years, which may be due to differences in the type of questions about eye problems presented to the children of the different groups.

We found that the schoolchildren with normal orthoptic examination very seldom reported asthenopia. However, many schoolchildren in our study with reduced accommodation reported asthenopia, but few with convergence insufficiency.

The corrected visual acuity was normal in all schoolchildren except in two with monocular amblyopia due to strabismus. This implies that the amblyopia rate in this population was 0.9%, which agrees with the findings of another population study by Kvarnström et al (1998). It also shows that the system in screening for visual deficits used in Sweden has worked quite well for the population of children that we have studied.

We found that the prevalence of hyperopia was higher in schoolchildren 6 – 7 years old than in children 14 – 16 years, which is in agreement with other studies (Laatikainen and Erkkilä 1980, Ohlsson et al 2001). Low grade myopia (1.5 – 3 D) was rare at 6 – 7 years of age but more common at 10 – 12 years of age and at age 14 – 16 years. This is also in accordance with the findings of Laatikainen and Erkkilä (1980) in a Finnish population of schoolchildren in the same age range, but lower than the prevalence reported for 15 year old Swedish children by Villarreal et al (2000).

Our prevalence value of astigmatism did not deviate very much from the finding in studies by Ohlsson et al (2001) and Larsson et al (2003), except that in our study astigmatism higher than 1.25 D was not observed.

Anisometropia was seen in 0.9% of the children in this study, and this is at the same level as reported by Larsson et al (2003).

Latent strabismus was common in children, particularly latent divergent strabismus (exophoria) at near fixation, but the prevalence will vary with type of examination and definitions.

Convergence insufficiency has been reported to be a common binocular disorder and in school schoolchildren (Rouse et al 1987) but in our population only 6% of showed reduced convergence and it was mostly of a mild form. Few children with convergence insufficiency reported asthenopic symptoms. However, there was a clear relation between convergence insufficiency, and latent strabismus or accommodative insufficiency.

There are very few studies on the prevalence of accommodative insufficiency in school schoolchildren. Marran et al. (2006) reported a prevalence of 4.7% in schoolchildren of grade 4 – 6 with a mean age of 11.5 years, which is about the same (7.3%) that we found in grade 4 and the same age group, but lower than the 18.3% we found for schoolchildren in grade 8 (14 – 16 years).

5.2 Paper II

In a population of schoolchildren with asthenopia referred for orthoptic and ophthalmological examination, there was no clear relation between symptoms of asthenopia, separated in the groups with eye problems (group A), headache (group B) or a combination (group C), and the ophthalmological and orthoptic parameters such as accommodative insufficiency, convergence insufficiency, latent strabismus and refractive errors. An exception was astigmatism which was more related to eye problems than headache. Therefore one cannot determine the cause of asthenopia from the symptoms of the patients, but all factors of asthenopia, whether refractive or muscular, would seem to give rise to any type of symptoms.

Due to the extent of the subjective symptoms all the students were given appropriate treatment based on the findings of refractive and/or muscular causes of their asthenopia. Full correction of myopia stimulated the accommodative and convergence system to overcome asthenopic problems (von Noorden and Campos 2002), and myopic students became symptom free.

The students with significant refractive errors and an angle of heterophoria of 5 – 12 prism diopters became symptom free just by correction of the refractive error. Schoolchildren with refractive errors and larger heterophoria could be helped with correction for refractive errors and appropriate prisms. Asthenopic symptoms associated with hypermetropia disappear in most cases with refractive correction (von Noorden and Campos 2002; Cooper and Duckman 1978). Students with convergence insufficiency could be symptom free after refractive correction and convergence exercises, as also reported by Cooper and Duckman (1978).

The use of weak plus lenses for near (+0.75 and +1.0) in students with moderate and marked reduced accommodation had alleviated most of the symptoms and relaxed the accommodation when retested 3 – 6 months after the study had started. In a total of 93% (112/120) of all the schoolchildren no asthenopia was reported at 3 – 6 months after treatment had started, and 7% had reduced symptoms. Daum reported that most patients (90%) obtained some relief with treatment of asthenopic problems related to accommodative insufficiency by reading glasses (Daum 1983 a,c).

5.3 Paper III

The study showed that there is a statistically significant improvement in the near point of accommodation in schoolchildren with accommodative insufficiency (AI) after 12–weeks of wearing reading addition. This result is in agreement with previously published data (Daum 1983a; Mazow et al. 1989; Rutstein and Daum 1998). The inclusion criteria for the group with AI were strict and there should be very small possibilities of confounding factors, such as refractive or other muscular factors than poor accommodation, to cause the asthenopia in these children. The present study is the first one to use the Visual Analogue Scale (VAS) in the assessment of the severity of asthenopic symptoms. The VAS has been found easy to use even in young children and to provide reproducible results (Todd 1996). In this study all children were able to grade their VAS level of asthenopic symptoms without difficulty both before and after treatment. There seemed to be no correlation between the VAS grading and the near point of accommodation neither before nor after treatment. It is concluded that the VAS provided as an instrument to assess and document the level of asthenopic symptoms, and also to indicate the relief of symptoms. However, the VAS could not be used to estimate the degree of accommodative deficiency nor could it indicate the level of improvement of accommodation during the course of treatment. We feel that the VAS can be useful also as a screening measure to assist the clinician in identifying asthenopic problems especially in patients who are unable to complete more complicated questionnaires (Millis et al. 2001).

5.4 Paper IV

Accommodative insufficiency is an important factor in asthenopic symptoms in schoolchildren as shown in Paper II and III Many subjects complained of blurred and unsteady text during reading. Despite the clear relationship between accommodative insufficiency and asthenopia in reading, no study has in detail investigated reading eye movements before and after treatment of accommodative insufficiency.

The study showed that all subjects had close to normal accommodative range with respect to age after treatment. The change in the near point of convergence found after treatment was most certainly an effect of the increase in accommodative range. However, the statistical analysis did not show any significant relation between improved accommodation and reading velocity.

In order to find out more about possible factors for reading difficulties we examined more closely three subjects with successful accommodative treatment where the changes in reading velocity seemed to differ depending on the underlying reading problem.

In one subject, it appears that blinking had a negative influence on reading, while in another subject, the poor reading comprehension seems to be related more to concentration and understanding. It is not clear if the reading problems were related only to the blurred or defocused image due to accommodation insufficiency, which reduced the visual acuity and made the text decoding more difficult, or if other mechanisms were interfering with the control of near vision during reading. A completed investigation of dyslexia was not performed in these children.

For future studies one should take into consideration to measure the accommodative response by dynamic retinoscopy, as well as using the near point of accommodation measured by the RAF-rule. This would tell us whether the target was focused or not during reading and maybe explain the diverse response found in reading velocity to accommodative treatment. In addition one should apply a robust reading comprehension test on the subjects and use poor performance in the test as an inclusion criterion for further analysis. Further, one should record reading eye movements over a longer period and try to monitor the change from a symptomatic to an asymptomatic stage in reading. This might reveal the objective changes in the eye movements over time, which would provide a basis for a more robust analysis of the effects on reading velocity and a better understanding of how accommodative insufficiency could influence reading.

6. General Conclusions and Implications of the study

The study has addressed some general questions with regard to asthenopia in schoolchildren:

How common are asthenopic symptoms among Swedish schoolchildren? How are asthenopic symptoms related to visual and binocular abnormalities, and can theses deviations be detected in tests done by the school nurses and teachers? What examinations have to be done by ophthalmologists and orthoptists in order to identify causes of asthenopia and institute treatment? How can we treat children with asthenopia and how efficient is the treatment? Are there tests for assessing asthenopia that can be used in the follow-up of treatment? How common is accommodative insufficiency in children with asthenopia? Does treatment of the insufficiency affect the level of asthenopia? Does such treatment affect the reading ability of the children, assessed by reading eye movements?

The study gave information in several of these areas.

The prevalence study showed that the occurrence of asthenopia was 23.1% among the schoolchildren in a Swedish population. Asthenopia was related to reduced uncorrected visual acuity, to refractive errors of different kinds, and to accommodative insufficiency. Examination at the schools by the school nurses of visual acuity at near, and the accommodation ability would give additional information for referral of children with asthenopia to the ophthalmologist and orthoptist. However, we do recommend that all schoolchildren with asthenopic symptoms should have a proper orthoptic assessment including visual acuity, refraction, near point of convergence, near point of accommodation and assessment of the binocular functions in order to design proper treatment for the individual child.

Treatment consisted of correction of refractive errors with glasses, reading glasses to children with accommodation insufficiency and prism glasses to children with latent strabismus. As a result the majority of children with asthenopia became symptom free, and in the others symptoms were markedly reduced.

Accommodative insufficiency is common in children with asthenopic symptoms and special studies were performed to assess effects of treatment on asthenopic symptoms and reading ability. The Visual Analogue Scale (VAS) developed for assessment of symptoms of pain in children, was found to be a useful instrument also to quantify asthenopic symptoms. VAS values could be assessed before and after treatment of accommodative insufficiency and a reduction of VAS values was found to correspond with improved accommodation. VAS could be recommended for use in the clinic to evaluate treatment in children with asthenopia and indicate the rate of relief of symptoms. Reading ability was assessed with measurements of reading eye movements and the influence on reading of treatment of asthenopia due to accommodation insufficiency was evaluated. Even if asthenopic symptoms were reduced and the accommodation ability improved, no correlation could be seen with speed of reading as monitored with reading eye movements. This would indicate that reading disability is often not related to reduce accommodation, and it would also support the well documented observations that visual and binocular disturbances are involved to a very limited degree in disabilities of reading and writing.

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