Visual, musculoskeletal and balance symptoms in people with visual impairments

Dedication

To all my patients, collegueas family and frends through the years who all have inspired me and encouraged me to continue my research work.

Örebro Studies in Medicine 162

CHRISTINA ZETTERLUND

Visual, musculoskeletal and balance symptoms in people with visual impairments

Title: Visual, musculoskeletal and balance symptoms in people with
visual impairments.
Publisher: Örebro University (2017)
www.publications.oru.se

Print: Örebro University, Repro 04/2017

ISSN 1652-4063
ISBN 978-91-7529-192-5

Abstract

Background: Worldwide, about 300 million people have some kind of visual impairment (VI). Most people with VI are in the older age range, as visual deficits increase with age. It is not unusual that people with VI suffer both from neck pain or scapular area symptoms and reduced balance, which they consider to be symptoms of old age. However, their symptoms may not be attributable to age, but rather to poor vision.
Aims: First, to identify associations between visual, musculoskeletal and balance symptoms in people engaging in near work every day and in people with VI. Second, to design and validate a suitable instrument for gathering information about visual, musculoskeletal and balance symptoms in people with VI. Third, to explore differences in perceived symptoms between VI patients and people with normal vision in cross-sectional studies and by following a group of age-related macular degeneration (AMD) patients in a longitudinal study. Fourth, to identify the most specific predictors of higher levels of visual, musculoskeletal and balance symptoms.
Methods: A specific instrument was developed: the Visual, Musculoskeletal and Balance symptoms (VMB) questionnaire. Patients with VI were compared to an age-matched reference group with normal vision in three different studies in order to detect differences in self-reported symptoms between the groups. In addition, a follow-up was conducted in a group of AMD patients.
Results: Patients with VI reported higher levels of VMB symptoms than controls, and this increased over time. Visual deficits and the need for visual enhancement increased the risk of VMB symptoms.
Conclusion: People with VI run a potentially higher risk of VMB symptoms than age-matched controls.

Keywords: Visual impairment, musculoskeletal symptoms, balance symptoms, visual enhancing aids, age-matched controls.

Christina Zetterlund

Örebro University, SE-701 82 Örebro, Sweden
christina.zetterlund@regionorebrolan.se

List of papers

This thesis is based on the following original papers.

I. Richter HO, Zetterlund C and Lundqvist L-O. Eye-neck interactions triggered by visually deficient computer work. Work 2011; 39: 67-78.

II. Lundqvist L-O, Zetterlund C and Richter HO. Reliability and validity of the visual, musculoskeletal and balance complaints questionnaire. Optometry and Vision Science 2016; 93: 1147-1157

III. Zetterlund C, Lundqvist L-O and Richter HO. Visual, musculoskeletal and balance symptoms in individuals with visual impairment and with age-normal vision. Clinical and Experimental Optometry [submitted]

IV. Zetterlund C, Lundqvist L-O and Richter HO. The Relationship between Low Vision and Musculoskeletal Complaints. A Case Control Study Between Age-related Macular Degeneration Patients and Age-matched Controls with Normal Vision. Journal of Optometry 2009; 2: 127-133

V. Zetterlund C, Richter HO and Lundqvist L-O. Visual, musculoskeletal and balance complaints in AMD - a follow-up study. Journal of Ophthalmology vol. 2016, Article ID 2707102, 10 pages, 2016. doi:10.1155/2016/2707102

ABBREVIATIONS

AMD= Age-related macular degeneration
CFA= Confirmatory factor analysis
EVES= Electronic vision enhancement systems
ICD-10=International Statistical Classification of Diseases and Related Health Problems, 10th revision.
ICF= International Classification of Functioning, Disability and Health
MAR= Minimal angle of resolution
NAS= Near Activities Subscale
NDI= Neck Disability Index
NEI-VFQ= National Eye Institute Visual Functioning Questionnaire
OR= Odds ratio
VA= Visual acuity
VI= Visual impairment
VMB= Visual, musculoskeletal and balance

Table of Contents

Preface

When I started working at the low vision clinic in Örebro in 1998, I returned to optometry from a period serving as a secondary school teacher. In order to refresh my knowledge in optometry I enrolled in a master programme in optometry in Uppsala. It was during this programme that I first came into contact with Hans Richter, who became my supervisor for my master thesis. His research topic was visual fatigue and theories concerning how visual fatigue could influence the development of discomfort in the neck/scapular area. This inspired me to look at visual deficits, symptoms and aids in a new way.

In my profession as an optometrist in a low vision clinic I meet people with visual impairments with individual needs and demands for everyday optical solutions. Although all visual enhancement devices are aimed to facilitate visual performance, these are often also associated with some drawbacks, such as reduced field of vision or the need to maintain a specific head or neck posture, which could have a negative impact on the interaction between various bodily functions. Current scientific knowledge in this area is sparse, and the total burden of visual impairment is unclear. This thesis takes an interdisciplinary approach to interpret and elucidate the interactions between visual function, visual symptoms, visual correction and visual performance, and their impact on the musculoskeletal and balance system. The aim has been to prepare for future interventions and provide guidelines for further improvements in rehabilitation and healthier living with visual impairment.

INTRODUCTION

Visual impairment (VI) is a leading cause of disability worldwide (Stevens, White et al. 2013). The number of people suffering from VI was estimated in 2012 to be 285 million, of whom 39 million are blind (WHO 1995, Resnikoff, Pascolini et al. 2004, Stevens, White et al. 2013). The terms "VI" and "low vision" are often used interchangeably, referring to similar borderline functionality according to World Health Organization (WHO), International Classification of health and disease (ICD-10), and low vision specialists (Dagnelie 2013).

Classification of visual impairments and low vision

The classification of VI that is accepted worldwide consists of five categories, based on *visual acuity* measures and *visual field* deficits, and refers to mild visual impairments, moderate visual impairments and three levels of blindness (WHO 1999, Resnikoff, Pascolini et al. 2004, Rosenberg and Sperazza 2008) (Table 1).

Visual acuity (VA)

VA is a concept based on an estimate of spatial resolving capacity described in terms of minimal angle of resolution (MAR) at maximum contrast. In testing methods, this refers to the identification of black letters on a white surface. MAR is the angle representing the minimal distance between two objects in view at 6 m that can be distinguished as separate objects. This angle is measured in minutes of arc, where approximately 1 minute of arc (1/60 of a degree) is considered to be the normal angle in most human emmetropic eyes, according to the receptor theory (Rabbetts 2007), see Figure 1.

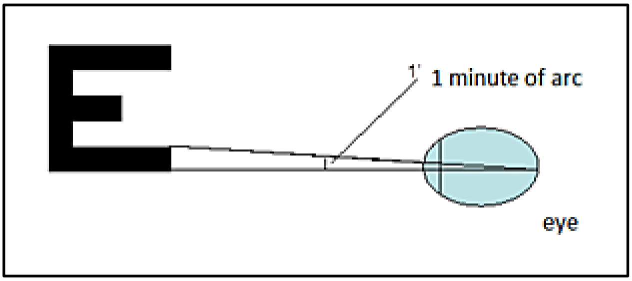

Figure 1: Minimal angle of resolution. *Illustration: C. Zetterlund*

Table 1. Categorization of visual impairment

Category	Classification	Acuity under	Acuity equal to or over
	Mild visual loss		6/18 [a] ; 20/60[b] (0.3)[c] 0.5 logMAR[d]
1	Moderate visual impairment	6/18[a] ; 20/60[b] (0.3)[c] 0.5 logMAR[d]	6/60[a] ; 20/200[b] (0.1)[c] 1.0 logMAR[d]
2	Severe visual impairment	6/60[a] ; 20/200[b] (0.1)[c] 1.0 logMAR[d]	3/60[a] ; 20/400[b] (0.05)[c] 1.3 logMAR[d]
3	Legal blindness	3/60[a] ; 20/400[b] (0.05)[c] 1.3 logMAR[d]	1/60[a]; 20/1000[b] (0.02)[c] 1.5 logMAR[d]
4	Blindness	1/60[a] 20/1000[b] (0.02)[c] 1.5 logMAR[d]	light perception
5	Total blindness	No light perception	

The values refer to best-corrected visual acuity, based on the minimal angle of resolution (MAR) but different scales are used in different parts of the world.

[a], MAR required distance (metres)
[b], MAR required distance (feet)
[c] 1/MAR (decimal units)
[d] logMAR (logarithmic scale)

Visual Field

The human visual field derives from visual inputs from two frontally situated eyes. Each eye has a visual field limited by the margins of the orbits and the nose, where the nasal field is not as wide as the temporal one, 60 and 100 degrees, respectively (Figure 2).

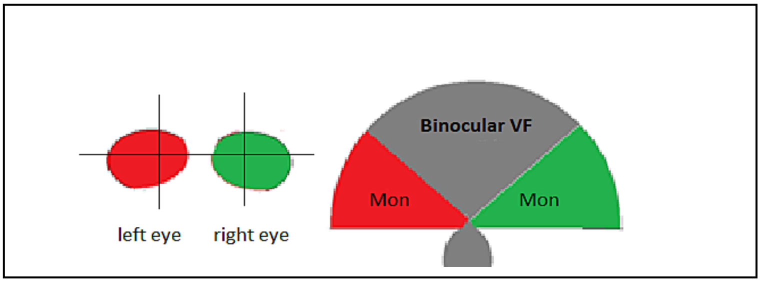

Figure 2. Left side: The visual field from each eye. Right side: The combined total visual field. (Mon = monocular.) Illustration: C. Zetterlund

The fields from the left and right eye overlap one another, producing a binocular field of about 120 degrees of the total visual field of approximately 180 degrees in adults.

The total visual field decreases successively with age. Rosenbloom reports that a person at 60 years has only 52% of what is expected in a 20-year-old (Rosenbloom 2007). A person with a total visual field of 5–10 degrees is visually very limited and considered "legally blind," even in combination with a VA of 1.0 MAR (Resnikoff, Pascolini et al. 2004)(ICD-10).

Prerequisites for accurate vision

In order to obtain the best possible visual image, the visual system relies on visual cues. Both *disparity* and *blur* constitute important stimuli that trigger convergent or divergent eye movements and at the same time lens accommodation (Leigh 1983, Borsting, Chase et al. 2007, Chase, Tosha et al. 2009). A fully focused image necessitates a steady projected image on the foveal region of the retina, where the photoreceptor density is the greatest. In addition, both eyes must be perfectly synchronized when fixating the object in view (Leigh 1983). Retinal correspondence during fixation is described by Hering's and Sherrington's laws of equal and reciprocal innervation dating from 1868, based on Sherrington and Listing

(Westheimer 2014). This means that any change in eye position, will normally also trigger and involve synergistic innervation of the external muscle mechanisms of the other eye (Krimsky 1967).

The object in view in each eye, must be focused and fixated by gaze direction so that the object is imaged on *corresponding retinal points* in each eye, allowing only a very limited retinal displacement defined in space as *Panum's fusional area* (Leigh 1983, Donahue 2005). If the visual image is presented beyond this area, it may appear as two images and/or be blurry. A continuous mismatch between the left and right eye constitutes a risk of symptomatic headaches or dizziness caused by the effort to produce a single image of the object in view (Gordon, Chronicle et al. 2001). In younger individuals this mismatch may lead to suppression of the least accurate image, which could further lead to amblyopia (Leigh 1983, Donahue 2005).

Other visual cues

Colour vision, contrast sensitivity, light and dark adaptation do not contribute to the classification of VI according to ICD-10. Measurements of these properties are often performed initially at the first visit to the low vision clinic, or performed at the eye clinic at the hospital before entering the low vision clinic. These measurements are time-consuming, difficult to administer in low-vision settings and sometimes tiresome for the patient, although they are still highly informative because of the impact they have on the patient's ability to see comfortably. Most often these measurements are not included in the ordinary visual examination when following a low-vision patient's progress, as the results rarely present any obvious solutions. However, these tests may be helpful when verifying an existing problem.

The near triad

Accommodation, the mechanism for adjusting the lens focus, is tightly coupled with *convergence* and *pupillary constriction* and is triggered by disparity and defocus. (Schor and Kotulak 1986, Schor and Tsuetaki 1987, Ciuffreda, Rosenfield et al. 1997, Franzén, Richter et al. 2000, Richter, Costello et al. 2004). These three synergistic functions are referred to as the *near triad.*

For a young person, in order to obtain a clear, retinal image of a near object in view, the crystalline lens must change its shape and the extra-ocular muscles must produce convergent gaze alignments. The accommodation/vergence system is best understood as a closed loop negative feedback system, with visual cues from both eyes, that strives to maximize retinal contrast and luminance by minimizing retinal blur (Franzén, Richter et al. 2000).

The mechanism is conducted with simultaneous activation of the muscles performing accommodation (incorporation the ciliary muscle) and the muscle performing pupil constriction (the iris sphincter muscle). Both are smooth muscles with autonomous innervation from the parasympathetic and sympathetic nervous system. (Leigh 1983, Gilmartin 1986).

Presbyopia

Presbyopia is the gradual reduction in accommodative capacity caused by the physiological continuous growth of the crystalline lens.

This decline is associated with normal aging; the reduced amplitude affects visual acuity for near work from approximately 45 years of age (Ciuffreda, Rosenfield et al. 1997, Duane 1922). Duane presented studies where he calculated a curve showing the loss of accommodative response in relation to age. His calculations, still current and in use today, indicate accommodative decline from the age of 8 up to 50 years, of 0.3 dioptres (D) per year. His results have subsequently been confirmed by others (Charman 2008). The normal consequence of presbyopia is the more frequent use of reading glasses or the prescription of glasses that allow near vision.

Prevalent aetiologies for visual impairments

VI can arise from many conditions and diagnoses (Rosenbloom 2007, Rosenberg and Sperazza 2008). Some have congenital or hereditary origins, some are caused by trauma or accidents, and others are related to diseases and decline with age (Werner, Peterzell et al. 1990, Resnikoff, Pascolini et al. 2004, Rosenberg and Sperazza 2008, Dagnelie 2013). There is also a higher prevalence of VI in women than in men (Stevens, White et al. 2013).

The majority (65%) of all people with VI are 50 years or older (WHO 1999, Stevens, White et al. 2013). This age distribution depends on common degenerative aging processes in the eye tissues (Taylor, Pezzullo et al. 2007, Dagnelie 2013, Voleti and Hubschman 2013). Recent predictions also indicate further increases in life expectancy and thereby an expanding older population (Christensen, Doblhammer et al. 2009). As a consequence, an increase in age-related VIs can be expected (Dagnelie 2013, Wong, Su et al. 2014).

The most common aetiologies for VI are cataract, age-related macular degeneration (AMD), glaucoma and diabetic retinopathy. Furthermore, uncorrected refractive error, which was not originally included in the classification of VI, constitutes the most common reason for decreased VA worldwide (Wong, Su et al. 2014, Varma, Vajaranant et al. 2016).

Worldwide, cataract is the most prevalent condition (50%) leading to VI, or even to blindness in non-industrialized countries, where eye surgery is rarely available. Nearly all individuals over the age of 80 will naturally have some degree of cataract and, of these, 50% in industrialized countries will already have had an eye surgery (Rosenberg and Sperazza 2008).

The various aetiologies for VI are not equally distributed around the world. In Europe and most industrialized countries with a predominance of white people, AMD is the most common diagnosis leading to VI, although it is less common in other racial groups and increasing with age(Berger 1999, Jager, Mieler et al. 2008). From a sparse prevalence of 2% at the age of 50, it increases dramatically to 30% at the age of 80 (Ehrlich, Harris et al. 2008, Jager, Mieler et al. 2008, Christoforidis, Tecce et al. 2011, Dagnelie 2013).

Glaucoma accounts for approximately 12% of all VI (Resnikoff, Pascolini et al. 2004, Rosenberg and Sperazza 2008, Lin and Yang 2009), often developing in middle age with gradually worsening visual field deficits. One person in ten will develop open-angle glaucoma but half of them will never be aware of this, as it might not reach a severe level (Rosenberg and Sperazza 2008, Lin and Yang 2009).

Diabetic retinopathy represents 5% of all VI; it develops and increases as the diabetes progresses, and early detection and treatment can prevent up to 98% of visual loss associated with this condition.

Refractive disorders (normal variation in refraction that can be corrected with glasses or contact lenses) are however the most common worldwide disorder: 4.2 billion people need some kind of correction, and about 2.5 billion people lack such aids today. WHO highlight the urgency of properly trained eye care practitioners to identify refractive disorders and provide refractive aids (Willis, Vitale et al. 2013).

Visual rehabilitation

The first low vision clinic was established in New York in 1953 by the ophthalmologist Gerald Fonda and Natalie Baragga, a specialized educator. Their principal goal was to reduce the impact of VI and minimize disability through prescription of assistive devices combined with training in their use (Jose 1985, Jackson 2007, Rosenberg and Sperazza 2008, Dagnelie 2013). From the beginning, optometrists and specialized educators worked in teams, taking care of most of the patient's visual needs. Low vision clinics have since then gradually improved by integrating new professionals and new methods according to their patients' requirements.

At present, most patients at low vision clinics have been referred there by an expert ophthalmologist after a thorough eye examination. Some patients may still be under treatment or scheduled for new appointments in connection with the progress of their eye condition. Most low vision clinic patients are elderly, with neural decline, atrophy or opacities in the visual pathway, and co-morbidity with other age-related conditions (Dagnelie 2013). Many new specialized methods and techniques have radically improved the prospects for markedly enhanced sight in many patients, with immense impact on quality of life, but this may be dependent on the use of special visual enhancement aids (Jose 1985, Hemmel 2002).

Reading performance

Reading is an important goal for many low vision patients. During reading, the eyes track the words in conjunctive saccades with a small disparity tolerance of 5–15% between the images produced from each eye under convergent gaze angles. If exaggerated, this may cause visual discomfort and could contribute or worsen any existing dyslexia (Bucci, Vernet et al. 2009)

In people with VI, a common goal is to be able to read newspapers, books, mail and other printed text in common font sizes. In the printing industry, the size of the typeface is specified in points, where the most common print size used in printed text and advertisements consists of a typeface of 8 points. The unit refers to the body height of the letter (x-height), where one point refers to 1/72 of an inch. Another inconvenience for low vision patients is that newspapers also use weak print on greyish paper with low contrast.

Reading speed is an important outcome measure, where low vision guidelines advocate a reading speed of approximately 80 words per minute (Latham and Tabrett 2012). Research on the effect of print size on reading speed has led to the use of two important estimates: *the critical print size* (the smallest print size that can support reading at a near-maximum reading speed) and *reading acuity* (the smallest print size that can be read). There is a relationship between critical print size and reading acuity, which should be taken into consideration: *the optimum acuity reserve*. In practical settings this often relates to a near visual acuity better than 0.1 in decimal units, or logMAR 0.85, where adding the required magnification (most often 2:1) could bridge the gap between current acuity and goal print size (Table 2).

The guidelines for estimating reading performance are not based solely on VA but also on contrast sensitivity, which has been shown to have an impact on reading performance (Johansson, Pansell et al. 2014) . There is a normal decrease in contrast sensitivity in the aging eye due to loss of neurons and increased opacity in the eye tissue (Werner, Peterzell et al. 1990). This often results in demands for increased visual stimuli. (Buckley, Heasley et al. 2005, Rosenbloom 2007)

There is often, especially in older people, a conflict between the need for magnification and the acquired reading distance, where very many prefer a longer reading distance at the cost of acuity reserve in the prescribed magnification.

Table 2. Guidelines for estimating reading performance

Near visual acuity at a fixed distance	**Likely to achieve 8 points**	**Likely to achieve reading speed of 80 wpm**
Better than logMAR 0.85 (Decimal > 0.15)	Yes	Yes
LogMAR 0.85–1.0 (Decimal = 0.1–0.15)	Only if contrast sensitivity > 1.05 log CS	Yes
Worse than logMAR 1.0 (Decimal < 0.1)	Only if contrast sensitivity > 1.05 log CS	No

CS = Contrast Sensitivity, wpm = words per minute.

Impact from visual field deficits on visual performance

With reduced visual field there is an increased risk of miscalculations or misjudgements as the visual feedback to sensorimotor functions is reduced (Harwood 2001, Salonen and Kivela 2012). Blind spots in the central visual field are referred to as *scotomas*. Scotomas affect overall performance on detailed near work, where different strategies could be considered for better performance. For example, in combination with low vision, reading performance can be improved by the use of magnification in the form of handheld magnifiers or electronic vision enhancement systems (EVES), also previously known as closed-circuit television (CCTV) because they involve video cameras and real-time display of images on screens (Lovie-Kitchin 2011, Latham and Tabrett 2012). A newly introduced enhancement device is the electronic reading iPad.

When reading with electronic or optical visual aids, the *window size* (the field in view when using the device) must overlap at least 20 characters to support optimum reading speed. With a window size overlapping 10 characters, the estimated result is 85% of maximum reading speed (Lovie-Kitchin 2011).

Evaluating enlargement needs

The concept *magnification* refers to the dioptric power or level of magnification specified on the device by the manufacturer, while the concept *enlargement* refers to the patient's relative and real actual required increase in resolution capacity (Johnston 2003). Adapting to a shorter distance, known as *distance enlargement*, is the easiest way to enlarge the image. *Relative size enlargement* refers to increasing an image while the viewing distance remains the same. This can be achieved by EVES, which project an electronically enlarged image on a screen. *Angular enlargement* refers to the image enlargement obtained through an optical system, compared to when viewed directly (Johnston 2003, Macnaughton 2005). It is difficult to assess the exact value of angular enlargement in any new prescribed visual enhancement, as the enlargement compares the former distance and viewing angle with the new distance and viewing angle (Johnston 2003, Jackson 2007).

Many patients wear bifocals or progressive eyeglasses, where the additional reading power can be increased, both to compensate for presbyopia and to provide enhanced enlargement.

An increase of 3 dioptres on an ordinary prescription (+3.0 D) used at 33 cm results in approximately 6 D/3, which refers to a relative enlargement of 2x, where the reading distance must be adjusted to approximately half the distance. This solution provides higher resolution but has some drawbacks, as it gives a shorter depth of view and shorter viewing distance, as well as a more limited window size, which together induce a more static posture (Krueger, Conrady et al. 1989, Kreczy, Kofler et al. 1999). Almost all older adults have difficulties adapting to the use of *hyperocular glasses* (high head-mounted magnification). Instead, the preferred solution is often a modest additive magnification.

The additional magnification is proposed to be estimated by the reciprocal of the distance acuity calculated by Kesterbaum's rule (Lovie-Kitchin 2011, Latham and Tabrett 2012)

Example: Distance VA = 0.25
Kesterbaum's rule: 1/ 0.25 = 4
Result: addition required = 4.0 D

The achieved visual resolution does not determine the possibility to read fluently with comfort. This is often the main reason why many patients prefer use of handheld magnifiers compared to a higher additional reading power, in order to achieve what they feel to be a more normal reading distance, where the handheld magnifier is held between the text and the eyes, producing almost their normal reading distance (Figure 3).

<

Figure 3. The use of high-resolution magnifying eyeglasses (left) compared to lower levels of magnification combined with a handheld aid (right).
Photo: C. Zetterlund

VISUAL SYMPTOMS

Nearly all visual deficits are accompanied by visual symptoms, most often a consequence of refractive errors and deficiencies related to accommodation and convergence. They often occur in connection with intensive visual work (Zhang, Zhang et al. 2013). These symptoms are subjective sensations of strain or uncomfortable viewing conditions, fatigue, light sensitivity or glare, unsatisfactory imaging such as blur, shadows and double vision, dryness, burning, itching, soreness or tearing (Garcia-Munoz, Carbonell-Bonete et al. 2014). Any symptom can occur separately or combined or associated with headaches (Gordon, Chronicle et al. 2001, Sheedy 2003).

It has been proposed that symptoms concerning the inside of the eyes are caused by internal factors (such as effects from continuous accommodation or convergence) and symptoms concerning the outside of the eyes are caused by external factors (such as poor illumination, glare and small font size) (Sheedy 2003).

Blur

A very common visual symptom refers to blur, or difficulty finding a clear representative image. This is mostly due to refractive disorders, where the refraction in the eye does not allow a clear image on the retina (Gordon, Chronicle et al. 2001, Chase, Tosha et al. 2009, Borsting, Tosha et al. 2010, Drew, Borsting et al. 2012); alternatively, it may be the result of differences between the images produced by the right and left eye (anisometropia), or neural deficiencies. An anisometropia exceeding 4–5 dioptres and astigmatism more than 1.5 dioptres between the left and right eye are two risk factors for refractive amblyopia during the development of the visual pathways (Hamm, Black et al. 2014).

Symptoms from excessed or insufficient lighting

The human visual system is built on light perception in photoreceptors on the retina. The number of stimuli required to trigger a neural action potential may vary according to age and individual differences, where young people may be able to respond to very low thresholds. When the visual system is weakened, by disease or by natural decline with age, there is not only a need for visual enhancement aids but also a need for adequate illumination in order to increase the visual stimuli. The number of neurons in the human visual system is decreased by 25% from the age of 20 to the age of 80 years (Werner, Peterzell et al. 1990), resulting in a need for increased illumination already being evident at the age of 30 years. Most of the incident light on the cornea is lost en route to the retina due to absorption, scatter and reflection in the ocular media. At the age of 70, the crystalline lens transmits 22 times less light than that of a one-month-old baby (Werner, Peterzell et al. 1990, Rosenbloom 2007). Primarily this is due to normal aging and the development of cataract.

Low illumination or insufficient light often limits and diminishes visual performance, even with normal or perfect vision. Indoor workers over 50 years require twice as much light level than young adults. In reading situations a minimum illumination level of 480 lux is recommended(Rabbetts 2007).

Reflections flicker and glare from excessive amounts of light on a bright surface are profound stressors for the visual system, reducing contrast and affecting visual performance (Wilkins 2004, Borsting, Chase et al. 2007, Glimne, Brautaset et al. 2015). Glare and flicker affects visual imaging with symptoms of dizziness, fatigue and headaches, and is also associated with increased risk of migraine (Gordon, Chronicle et al. 2001, Harle and Evans 2004, Brewer, Van Eerd et al. 2006, Borsting, Chase et al. 2007, Hendricks, J et al. 2007, Akinci, Guven et al. 2008, Glimne, Brautaset et al. 2015) To avoid glare, the object in view, as well as the surroundings, should be illuminated at a similar level to facilitate adaptation (Nyhlen 2012).

Glare is also often associated with aging in the eye tissue, due to opacities in the optical system (Werner, Peterzell et al. 1990, Rosenbloom 2007).

Symptoms from insufficient visual imaging

Eyelid squinting often occurs among people who suffer from excessive amounts of light or glare but could also often occur as a result from uncorrected refractive errors. Squinting gives them a reduced aperture for incident light (pinhole effect) which often results in a better visual representation.

During squinting, the annular muscle surrounding the eye (the orbicularis oculi muscle) is constricted. When this contraction is continuously ongoing for longer periods, this affect the eyelids, the surface of the cornea and the tear film, often also associated with headaches and symptoms in the neck and scapular area (Thorud, Helland et al. 2012, Gold, Hallman et al. 2016).

Asthenopia

Asthenopia refers to weakness or fatigue of the eyes, usually accompanied by headache and dimming of vision, without any prominent visual or refractive error. It is a common phenomenon in people with high near-vision demands, such as office workers, and is in these settings referred to as *computer vision syndrome* (Neugebauer, Fricke et al. 1992, Blehm 2005, Anshel 2007, Gowrisankaran and Sheedy 2015). All these symptoms are warning signals, indicating that something is seriously wrong and we need to find out the root cause. This has led to an increased awareness of the importance of adequate individual optical correction adjusted for the specific environment, with EU-level guidelines and workplace regulations being introduced.

Existing solutions for minimizing visual symptoms

Refractive aids

Refractive errors need to be corrected, most often with eyeglasses. Wearing refractive aids (optical lenses) in frames, especially eyeglasses with bigger frames or high optical power, is nearly always associated with disturbing optical aberrations. However, these aberrations can be limited or minimized when viewing through the very centre of the lens or focal pathway, so that the viewer's eye becomes a part of the total optical system.

Corrections in frames produce either an enlarged or a decreased image when positioned at a distance from the eye. A difference in the retinal image between the left and right eye can result in visual discomfort and even inability to assimilate these images into one single image; it can also restrict the ability to vary head posture (Aaras, Horgen et al. 2005, Naz and Yildirim 2010).

The human eye is controlled by six extraocular muscles that either pull or roll the eye, with combined actions from rotation of the eye at gaze angles in the periphery of the visual field; this rotation can at certain gaze angles result in misalignment between the refractive prescription positioned in the frames in front of the eyes and the ideal prescription at this angle. Effects from difference in alignments are more profound when the correction includes, for example, near addition, astigmatic cylinder correction and prisms (Rosenfield, Hue et al. 2012) , which can induce visual discomfort and vertigo.

If the difference in retinal image size between the left and the right eye is excessive, this can result in suppression of the least appropriate image which in growing children may induce amblyopia (Wu and Hunter 2006).

Figure 4. Strong visual correction with eyeglasses. Photo: C. Zetterlund

To minimize differences in retinal image size, the correction lens should be positioned at a distance of no more than 10–14mm from the eye, or as close as possible to the anterior optical breakpoint of the eye, according to *Knapp's Law* (Rabbetts 2007).

There are several ways to handle refractive errors. The contact lens is a recent invention in comparison to eyeglasses. The materials in both glasses and contact lenses have successively been developed to better suit their purpose. Today there is a wealth of available lenses to correct the most common refractive errors; however, there is still a severely limited collection to choose from when correcting more complex refractive errors. Contact lenses have several advantages over correction with eyeglasses, as they can correct nearly any type of refractive error, even extreme anisometropia between the left and right eye, without inducing any problems of different-sized retinal images.

Many patients, especially older people, find contact lenses a little unnerving to handle. Indeed, these visual aids can be difficult to handle if the person suffers from hand tremor, because fine motor skill and routines for hygiene are crucial when handling contact lenses.

Visual ergonomic guidelines

In order to limit or inhibit unnecessary symptoms, the Visual Ergonomics Technical Committee at the International Ergonomics Association (IEA) has formulated a definition of visual ergonomics, including the topics it encompasses:

> Visual ergonomics is the multidisciplinary science concerned with understanding human visual processes and the interactions between humans and other elements of a system. Visual ergonomics applies theories, knowledge and methods to the design and assessment of systems, optimizing human well-being and overall system performance. Relevant topics include, among others: the **visual environment**, such as **lighting**; **visually demanding work** and other tasks; **visual function and performance**; **visual comfort** and safety; **optical corrections** and other **assistive tools.** (**Long 2014** p287).

NECK PAIN AND SCAPULAR AREA SYMPTOMS ASSOCIATED WITH VISUAL DEFICITS

Is there an association between visually demanding near work and neck pain or scapular area symptoms? The prevalence of these symptoms is between 10–21% (Fejer, Kyvik et al. 2006, Hoy, Protani et al. 2010) and seems to be more common in people with sedentary work involving prolonged computer use (Knave B.G. 1985, Falla 2004, Blehm 2005, Ustinaviciene and Januskevicius 2006, Hayes 2007, Wiholm 2007). There is also a higher prevalence for women than for men (Wijnhoven, de Vet et al. 2006). Those affected report periods of symptoms with frequent relapses that often become chronic problems (Hoy, Protani et al. 2010).

Beside these observations, a national survey in Sweden noted that neck pain was twice as common among people with near-vision problems (i.e. problems reading normal print size), compared to people with normal sight (Boström 2006).

The aetiology of combined visual and neck/scapular area discomfort is not fully understood. Clinical and applied research normally handles these two symptom categories in isolation and in separate disciplines. Eye–neck/scapular area symptoms may generate from many different exposure factors ranging from internal physical and psychosocial factors to external exposures or a combination of these(Wiholm 2007). People with VI may be more exposed to all these factors as they by definition are exposed from internal factors (visual deficits) and external factors (need for vision enhancing aids) and fear of continuous visual decline, stressors from the knowledge of their visual weakness that constitute excessive concentration in order to not make severe visual misjudgements.

Use of visual enhancement aids

The frequent use of high optical magnification in near work is strongly associated with the development of neck and scapular area symptoms (Krueger, Conrady et al. 1989, Kreczy, Kofler et al. 1999). Very many low-vision patients need magnifying aids in order to read commonly used print sizes or to carry out precision near work (Bowers, Cheong et al. 2007). During near work sessions, many describe discomfort from static posture, eye fatigue and headaches to such an extent that they must stop the ongoing activity.

The extended Heuer model

In an attempt to ease the effects of accommodation, accommodative convergence and squinting to achieve the pinhole effect, a head-over-trunk posture with the head tilted backwards may offer a gaze angle through an elevated eyelid that thereby constitutes a substitute for squinting by minimizing the aperture on incident light.

Other occasions when this posture occurs is referred to as the extended Heuer model (Mon-Williams, Burgess-Limerick et al. 1999). The model builds on mechanisms in the oculomotor system that ensure a clear and single image using the accommodation and vergence eye movements described earlier.

The common understanding is that a change in fixation from a distant object to a closer one is derived from the initially defocused retinal image. This blur is due to vergence error in angular fixation or disparity between retinal images from the right and left eyes. This error is corrected by shared near-triad actions: *accommodation* (to bring the object into focus) and change of *vergence* angles (to diminish image disparity), where fixation is accomplished on corresponding retinal areas in each eye.

Mon-Williams and colleagues have demonstrated that, when adapting to an elevated gaze angle, the inferior oblique muscles are constricted, which also creates a horizontal divergent pull on the eye. However, lowering the gaze constricts both superior oblique muscles, which results in a rotation of the eyes in a relatively convergent position; this allows a reduced effort to achieve accommodative convergence, as this eye position is favourable for near visual calibration (Heuer, Bruwer et al. 1991, Mon-Williams, Burgess-Limerick et al. 1999). Hering presented this theory in 1868 with a simple demonstration that could easily be performed and tested by anyone with binocular vision:

> When viewing a near object, for example a tip of a pen, fixated at the closest possible distance to the eyes without double images. Then the pen tip is lifted to a higher position, but at the same distance from the eyes, where gaze needs to be elevated, which will induce either double or blurred images of the pen.
>
> (From Hering: 1868/1977 The Theory of Binocular Vision English translation by Bridgeman B, Eds. Bridgeman B. and Stark L. New York: Plenum Press1977)

Mon-Williams et al. confirmed further that lowering the gaze to approximately 27 degrees below the eye–ear line was beneficial for visual comfort when viewing proximate targets. He also concluded that observers in general vary their gaze angle to view any visual target by altering the posture of the head. Flexing the neck backward will allow a lower vertical gaze angle and result in less effort on convergence and accommodation (Mon-Williams, Burgess-Limerick et al. 1999)

If this posture becomes a habit, it constitutes a head-over-trunk misalignment, with increased cervical lordosis (the concave curvature of the spinal column at the neck) and rounded shoulders, often associated with shortening of the cervical extensors and weakness in the deep cervical flexor muscles (Naz and Yildirim 2010). Naz and Yildirim described how to measure these misalignments, referring to *gaze angle, head angle* and *neck angle*, where the *gaze angle* is the angle between the horizontal line and the ear- eye line, the *head angle* is the angle between the ear–eye line and the ear- C7 line (cervical vertebra 7) and the *neck angle* is the angle between the line connecting ear-C7 and the line connecting C7- L4 (lumbar vertebra 4). They noticed a significant difference in neck and head angles between those who wore eyeglasses and those who did not (Naz and Yildirim 2010), Figure 5

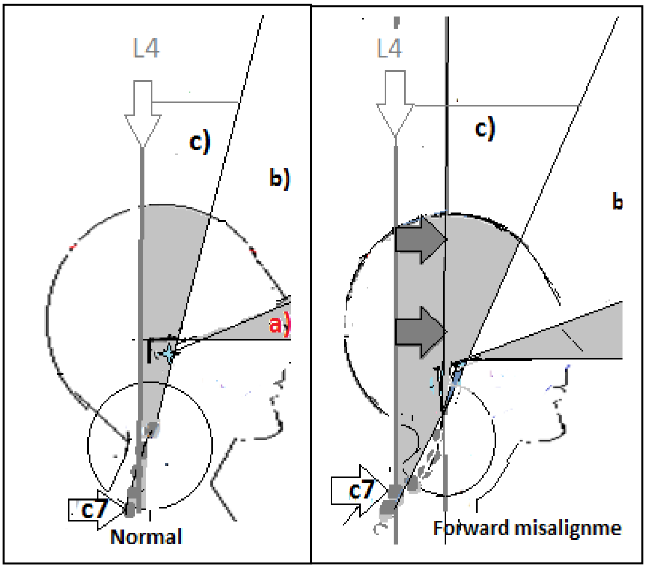

Figure 5. Left: Normal head posture. Right: Forward head-over-trunk misalignment. ***a)*** *gaze angle ,* ***b)*** *head angle,* ***c)*** *neck angle. The arrow show line connecting L4 (Lumbal vertebra 4) through C7 (Cervical vertebrae7).* Illustration C. *Zetterlund*

This specific posture has also been observed in combination with neck and scapular area symptoms among employees who spend a lot of time in front of computer terminals. This is especially common in older employees, whose physiological condition has started to restrict their options for comfortable near viewing. Intervention studies have reported recovery from pain when better refractive solutions have been provided combined with a better head posture and viewing angle (Aaras, Horgen et al. 1998, Aaras, Horgen et al. 2001, Aaras, Horgen et al. 2005, Anshel 2007).

The gaze control model

In the late 1980s, when work with visual display units became more common, computer vision syndrome became an accepted concept, several researchers investigated the association between neck muscles, head posture and lens accommodation in different test situations or at different workplaces (Lie and Watten 1987, Lie and Watten 1994).

Richter and colleagues further elucidated interactions between lens accommodation and an eye-head-neck-scapular motor program responsible for posturing gaze. In the earlier studies, they noticed increased EMG in the upper trapezius muscle during visually fatiguing near tasks in demanding viewing conditions (Richter 2007, Richter, Banziger et al. 2010, Zetterberg, Forsman et al. 2013, Richter, Zetterberg et al. 2015, Zetterberg, Richter et al. 2015)

In more recent work, the relationship between the force of ciliary muscle contraction and trapezius muscle activity has been studied under free gaze conditions during performance of dynamic natural working tasks (Domkin, Forsman et al. 2015).

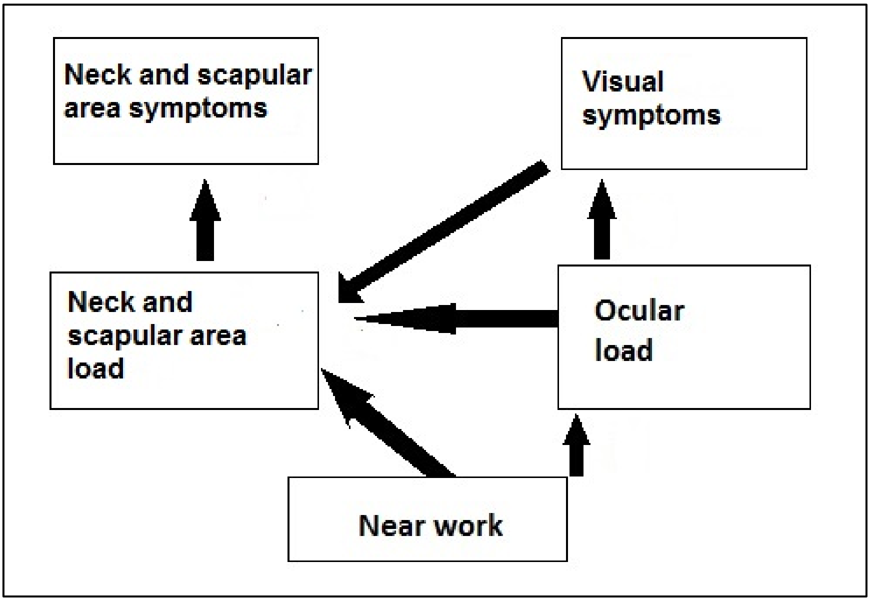

Figure 6. The conceptual gaze control model: Near work may influence neck muscles directly by a shared motor program or indirectly by ocular load or induced visual symptoms. Long-term load on specific neck muscles without sufficient time for recovery may result in self-reported symptoms. Illustration: C. Zetterlund

In total, this resulted in a conceptual model: the *gaze control model* (Figure 6). This model postulates an interaction between active muscles in and around the eyes and muscles used for adjusting and maintaining head posture (Mon-Williams, Burgess-Limerick et al. 1999, Franzén, Richter et al. 2000), where visual goals are hypothesized to overrule the discomfort of fatiguing postures and muscle fatigue in the neck and scapular area. This model reflects the need for continuous lens accommodation and convergence in order to produce satisfying visual images, which may be at the expense of freedom of movement for varied posture.

Chronic pain may initially be partly explained by monotonous and sustained load on low-threshold muscle fibres, as described by the Cinderella hypothesis, namely that the muscle fibres which are activated first are also the last to be deactivated and are thus not given adequate amounts of time to recover, leading to muscle damage (Johansson and Sojka 1991); indeed, these symptoms are highly related to computer vision syndrome during long working hours (Knave B.G. 1985, Izquierdo, Garcia et al. 2007, Rempel 2007). The lack of muscle cell recovery results in exhaustion and the development of metabolic disturbances, giving rise to a degenerative process and pain sensitivity.

With existing visual deficits or visual decline, similarly elevated and sustained tension may occur, maintaining the same posture, and employing the same muscle fibres, which also fits this theory (Johansson and Sojka 1991, Johansson 2003). The gaze control model embraces the previously mentioned risk factors for musculoskeletal neck and scapular area symptoms (Figure 6).

Furthermore, current scientific understanding of the control of eye movements and the impact of various deficiencies in the oculomotor system (for example, nystagmus, oscillations and oculomotor muscle weaknesses) lends credit to the hypothesis that visual demands take precedence over the preferred head posture in these systems (Leigh 1983).

The gaze control model is based on a speculated interaction between effectors in the neck and scapular area when a particular head posture is chosen in order to enhance the effect of convergence and lens accommodation, or by a shared motor program combining accommodation, vergence and neck/scapular muscles, directly or indirectly.

BALANCE SYMPTOMS ASSOCIATED WITH VISUAL DEFICITS

Reduced visual support

The balance system relies on visual information to support the sensory mechanisms of head, neck and upper limb proprioception, as well as information from the vestibular apparatus of the inner ear, lower limb proprioception and tactile sensation in the feet. The importance of visual support is often demonstrated by Romberg's quotient (sway with eyes open versus sway with eyes closed) (Harwood 2001, Ray, Horvat et al. 2008) where sway increases dramatically with eyes closed compared to eyes open.

Visual inputs support bodily functions such as proprioception and postural control (balance) (Harwood 2001) and contribute to prehension (the act of seizing and grasping an object) during locomotion, known as *adaptive locomotion* (Higuchi 2013). Adaptive locomotion is the interaction between the visual system looking at a target and the information about the location coded into eye-based coordinates (Higuchi 2013). During locomotion towards the target, simultaneous guided information is based on both distance information in limb coordinates and directed visual fixation the target.

The visually guided control of limb coordinates can easily be disturbed , making it difficult for VI individuals to achieve what could be considered normal capacity, resulting in greater efforts for administer visual information and tension in activated muscles controlling limbs (Buckley, Heasley et al. 2005, Lord 2006). In the long run, people with VI therefore demonstrate increased risk of fall accidents (Lord 2000, Harwood 2001, Lee and Scudds 2003, Ray, Horvat et al. 2008, Szabo, Janssen et al. 2008) and must place a greater reliance on somatosensory and vestibular information.

Stabilizing gaze

A combination of reflexes allows the individual to maintain a steady gaze during head rotation. These voluntary coordinated movements of our head and eyes are stimulated from the labyrinths and the neck proprioceptors to produce vestibulo-ocular (head–eye), cervico-ocular (neck–eye) and vestibulocollic (head–neck) reflexes. The eye movement produced by the muscles holding the orbit is equal but opposite to the head movement. Each of these acts to stabilize gaze in response to movements. These reflexes underline the dominance and necessity of gaze control for proprioception as they neurophysiologically and functionally link the oculomotor system with the neck and shoulder muscles (Armstrong, McNair et al. 2008).

Sensory receptors in the extraocular muscles

There are two types of sensory receptors found in the human extraocular muscle tissues: *muscle spindles* and *myotendinous cylinders*. The muscle spindles are situated in the proximal and the distal part of the extraocular muscles at a very high density and assist in fine motor control. The myotendinous cylinders are only found in the extraocular muscles. The structure of these receptors and their innervation is different from other human skeletal muscles and from other species as well. Increasing evidence suggests that these receptors are important in three broad areas:

1) oculomotor control
2) development and maintenance of normal binocular function
3) spatial localization by providing information about the position of the eye within the orbit and determining visual direction (Leigh 1983).

The muscle spindles influence head proprioception (Armstrong, McNair et al. 2008) and can be defined as small gyroscopes and accelerometers that send information to the central nervous system about their current position. These receptors are involved in nearly all sensorimotor-driven motions, where proprioceptive inputs from tendons and joints interact with visual information in order to contribute to the fused, integrated, perceptual map of the surroundings (Donaldson 2000, Weir, Knox et al. 2000, Loftus, Servos et al. 2004, Mon-Williams and Bingham 2007).

Asymmetry in the cervical flexor muscles

The earlier mentioned head over trunk misalignment can also result in a skewed use of specific neck scapular muscles. In the context of neck and scapular area symptoms, some studies have identified deficient motor control in the deep and superficial cervical flexor muscles in people with chronic neck pain. This is characterized both by delayed and altered muscle activation, with reduced activity in the deep cervical muscles and increased activity in the superficial cervical flexor muscles (Falla 2004). Reduced balance is also commonly found in these patients (McPartland, Brodeur et al. 1997, Falla 2004, Yahia, Ghroubi et al. 2009). McPartland et al. therefore postulate that atrophy in the muscles of the cervical region could be caused by an insufficient level of activity or the overuse of alternative muscles for certain head postures (McPartland, Brodeur et al. 1997), similar to the earlier mentioned head over trunk misalignment caused by continuous squinting or not properly adjusted eye wear correction . Specific muscle atrophy may reduce proprioceptive input and further exacerbate neural over activity. This could be perceived as chronic pain and lead to limited neck movements (Kreczy, Kofler et al. 1999, Yahia, Ghroubi et al. 2009).

Impact of deficient visual inputs

It has been observed that prehension is more successfully executed under binocular viewing conditions than monocular viewing (Loftus, Servos et al. 2004). Fine motor skill is therefore less accurate and more time consuming in amblyopia than in normally sighted people (Webber, Wood et al. 2008). The difference in skill is explained by the lack of information from convergence and vertical disparity information, with a reduced number of cues for calibration and approximation of the distance to the object.

The use of magnifying aids combined with poor visual input also interferes with visuomotor control, where the sensory mapping of distances from tendons and joints conflicts with visual input from the virtual image that does not correspond to real physical measurements (Johnston 2003, Macnaughton 2005, Matheron and Kapoula 2011).

The need to identify musculoskeletal and balance symptoms related to visual deficits

During the normal aging process, the neural feedback from tendons and joints successively declines. This may obscure the true relationship between visual and musculoskeletal symptoms in older patients with VI, because their symptoms might be attributed to normal decline with age (Lee and Scudds 2003, Rosenbloom 2007, Dagnelie 2013). Thus, this relationship warrants further investigation.

The prevalence of musculoskeletal symptoms, such as neck/scapular area symptoms, and poor postural control, in people with VI may have an impact on their ability to go to work, participate in social activities and find pleasure in leisure pursuits. With increased isolation and decreased quality of life, these problems constitute major costs both for the individual as well as for health services and health insurance providers. It is consequently an important issue to develop and improve interventions aimed at reducing these problems. In order to identify those at risk, a specially designed questionnaire could be used as a screening instrument.

There are many questionnaires available that focus on visual function and quality of life, but few that are suitable for individuals with VI. The main problems are the large number of questions and the chosen print size in the printed questionnaires, which makes it hard for VI respondents to complete the form without assistance from others. Before the studies in this thesis were conducted, there was also a lack of psychometrically evaluated questionnaires on musculoskeletal and balance symptoms specifically suitable for VI respondents. Thus, there was a need for a validated instrument to assess visual, musculoskeletal and balance symptoms in people with VI.

The goal of this thesis was to fill this knowledge gap through the development of such questionnaire and to specifically examine visual, musculoskeletal and balance symptoms implications in VI.

AIMS

An overarching aim was to explore the associations between optometric factors and visual, musculoskeletal and balance symptoms in people with VI. The specific aims were:

- to identify the features that have the deepest impact on visual, musculoskeletal and balance symptoms (Studies I, III, IV and V).

- to develop and evaluate the reliability and validity of the 15–item Visual, Muscular, and Balance (VMB) symptoms questionnaire (Study II).

- to investigate age differences in visual, musculoskeletal and balance symptoms in patients with VI compared to age-matched controls with normal vision (Study III).

- to investigate visual, musculoskeletal and balance symptoms in patients with AMD compared to age-matched controls with normal vision (Study IV).

- to explore how visual, musculoskeletal and balance symptoms change in AMD patients and controls with normal vision over a period of 3–5 years, and how their self-rated general health was affected (Study V).

METHODS

Participants and procedures

The five studies included in this thesis contain data from three different groups of participants. Four of the five studies were cross-sectional studies but were reinforced by test-retest methods, especially in Study II (Table 3).

Table 3. Overview of study designs

STUDY	I	II	III	IV	V
Design	Cross-sectional	Cross-sectional, Test-retest	Case-control, cross-sectional	Case-control, cross-sectional	Case-control, longitudinal
Data collection period	1986–1989	2009–2011	2009–2011	2008–2011	2008–2012
Place	Stockholm	Örebro	Örebro	Örebro	Örebro
N	3971	1249	77	48	(88 [a]) 55[b]
Age	18–64	18–104	18–71	61–87	67–89
Men **Women**	2551 945	424 825	26 52	23 25	16 39
Cases **Controls**	-		41 37	53 33	37 18
Statistical methods	Logistic regression	CFA, Chi-square, Rasch	Chi-square, Tukey's HSD Logistic regression	Mann-Whitney U, Multiple regression	Chi-square, Wilcoxon, Mann-Whitney U, GEE

[a] Baseline

[b] Follow up

CFA = Confirmatory factor analysis

GEE = General estimation equations (an extension of generalized linear models).

Study I

Participants were recruited from a large workplace survey of all 3971 employees (2551 men and 945 women) who worked at a computer for at least one hour per day. All employees were asked to participate when they visited the optometrist for a regular visual examination. Data collection took place between 1986 and 1989.

Study IIa: In 2009, an invitation to participate was sent to 3063 patients, aged 18–104 years, registered at the low vision clinic in Örebro. Of these, 1249 agreed to participate and completed the VMB questionnaire.

Study IIb: A subsample of 52 VI patients (10 men and 42 women) from the original total sample in Study IIa gave their consent to participate in the further tests of convergent validity of the VMB questionnaire.

Study III

Thirty-nine VI patients (25 women and 14 men) aged 18–71 years, median 46, from the low vision clinic in Örebro (VI category I–III), were compared to 37 age- and gender-matched participants (26 women and 11 men), median age 51, with normal vision and without any known disability that could induce neck or scapular area symptoms. All participants gave written informed content.

Studies IV

Twenty-four AMD patients, (10 men and 14 women, aged 61–85 years, were recruited from the queue system for renewed contact with the low vision clinic. Patients were compared with a group of 24 controls, 13 men and 11 women, without visual problems.

Participants underwent visual examinations and completed two questionnaires.

Study V

Of the original 88 participants at baseline 2008–2009 there remained 55 individuals at follow-up three to four years later. Of these, 37 were AMD patients (28 women and 9 men) and 18 were controls (11 women and 7 men). They were invited to the follow-up period by phone and, if they agreed to participate, the same procedure as during the baseline estimates was used.

Data collection consisted of visual assessments, self-rated visual function, self-rated visual, musculoskeletal and balance symptoms, and perceived general health.

Measures and data collection

Most of the included measures were based on the standard tests conducted during an ordinary visual examination at the low vision clinic. The following measures were available for all participants in the studies included in this thesis:

Best-corrected visual acuity (BCVA) was assessed in both monocular and binocular conditions at distance using the Early Treatment Diabetic Retinopathy Study (ETDRS) test chart, or the Ortho KM four-letter visual acuity chart to capture VA beyond 1.0 logMAR (available at: http://www.syntavlor.se). The used BCVA estimate refers here to binocular conditions, as most of the patients have a worse-affected eye with minimal vision.

Difference in BCVA between the left and right eye (BCVA-diff) refers to the precision-measured difference in BCVA between the *left and right* eye with the individual's existing correction. In order to capture a true difference with a possible impact on symptoms, the BCVA-diff was considered to exceed two lines on the ETDRS chart.

Anisometropia was determined from mean sphere with the correction normally used by the participant. Briefly explained, this refers to the mean result from highest sphere combined with cylinder in the prescription of the right eye compared to the same estimate calculated for the left eye. The clinically normal cut-off is based on a refractive difference exceeding 1 dioptre between the left and right eye (Donahue 2005, McCarthy 2013).

Visual field was compared with previous records from the ophthalmologic eye examination at Örebro University Eye Clinic, describing dysfunction in the retina, optic nerve or the brain, based on or combined with measures from visual field perimetry.

Refractive correction referred to the everyday use of refractive correction in eyeglasses or contact lenses.

Eyeglasses: This variable was dichotomized according to daily continuous use of refractive correction in eyeglasses, versus not wearing eye-glasses.

Contact lenses: This variable was also dichotomized, according to the normal use of refractive correction in contact lenses versus not using contact lenses. As contact lenses can be used only as an alternative to eyeglasses, this measure refers to the daily continuous use of this refractive aid.

Minimal readable print size. This variable can normally be derived from two measures: the smallest print size that supports a reading speed close to the maximum reading speed, and reading acuity, which refers to the smallest print size that can be read at all. As two of the studies included in this thesis are based on older people with AMD, whose reading speed is slow, the first measure was less meaningful for these studies. . In this thesis, minimal readable print size is therefore based on the print size the patient can accept for comfortable reading using normal visual enhancement aids and illumination.

Reading distance, refers to the distance in centimetres from the eyes to the text during reading. Participants were instructed to adjust their posture to as comfortable as they would normally manage during near work with their most appropriate visual enhancement aids. When the patient had found this position, reading distance was measured with a measuring tape.

Near work time refers to time in hours spent on visually demanding near work each day, according to subjective estimates given verbally. This variable can give some indication of the risk of periods of bad posture during visually demanding tasks, which in previous studies has been observed to influence musculoskeletal problems other symptoms (Anshel 2007).

Visual, musculoskeletal and balance symptoms were assessed using the VMB questionnaire, containing five questions in each domain. The visual symptoms domain (VMB-V), focuses on visual or eye-related symptoms in near activities, the musculoskeletal symptoms domain (VMB-M) focuses on vision-related neck or scapular area symptoms and the balance symptoms domain (VMB-B) focuses on vision-related balance and postural control symptoms.

Near visual functioning was assessed with the Visual Functioning Questionnaire Near Activities Subscale (VFQ-NAS), where the participants rated their near visual functioning by answering six questions related to near activities. The VFQ-NAS is part of the 25-item National Eye Institute Visual Functioning Questionnaire, NEI-VFQ-25; it is frequently used and has been shown to give valid and reliable results (Mangione, Lee et al. 2001).

Neck Disability Index. A self-rated musculoskeletal symptom questionnaire was used in order to validate the results from the questions about neck pain in the VMB questionnaire. The Neck Disability Index (NDI) (Vernon 2008) is a 10-item, condition-specific, self-report measure that pertains to pain intensity, personal care, lifting, reading, headaches, concentration, work, driving, sleeping and recreation, with the aim of illustrating the impact on activities of daily living and social life. Due to the participants' VI, items concerning driving a car were provided with an additional alternative: "not applicable." Each item is rated on a scale from 0 to 5; thus, total NDI scores can vary from 0 to 50.

Perceived general health was assessed by a single yes/no question added to the VMB questionnaire in Studies III, IV and V. The question was, "Do you generally consider yourself to be healthy?" If the answer was "No", there was a follow-up question to elicit the specific health problem.

Statistical analyses

Because the data included a mix of clinical measures and self-reported symptoms, including results from questionnaires, variables could contain nominal, ordinal or interval data. Because of this both parametric, and, in the occurrence of skewed data, nonparametric tests were used, as they are more robust under these circumstances.

Ethical considerations

All participants included in these studies gave written consent after receiving written and verbal information explaining the current part of the study, confidentiality of their data, their right to withdraw participation at any time, and how data were going to be published.

The vast majority of the included measures were based on the routine tests conducted at the low vision clinic. A few VI patients may have found it embarrassing to admit to problems with balance, or with neck and scapular area pain, as these symptoms are most often associated with old age. However, the majority expressed their genuine gratitude for our interest in their otherwise ignored problems.

Study I. The study was performed at a workplace during the 1980s, where the participants gave their consent to participate. The data collection consisted of anonymized data.. According to statements from the ethical committee, this type of research did not at that time need ethical approval.

Study II was approved by the Regional Committee Review Board in Uppsala: dnr2010/ 206 (30 June 2010).

Study III was approved by the Regional Ethics Committee Review Board in Uppsala. dnr 2010/ 156 (19 May 2010).

Study IV was approved by the Regional Ethics Committee Review Board in Uppsala dnr 2008/ 129 (21 May 2008).

Study V was approved by the Regional Ethics Committee Review Board in Uppsala: dnr 2012/ 413 (11 Dec 2012).

RESULTS

Study I

Approximately one third (25–35%) of the people working with computers at the telecom workplace reported visual symptoms. A similar number of participants reported neck and scapular area symptoms (35%). All of these symptoms occurred coherently or simultaneously. Regression analyses indicated that visual symptoms increased the risk of reporting neck/scapular area symptoms, in that higher levels of visual symptoms were associated with higher levels of neck/scapular area symptoms and vice versa (OR 2.8, $p<0.001$). These results demonstrated a functional connection between visual and neck/scapular area symptoms.

Both visual and neck/scapular area symptoms were more pronounced at an older age, and in women more than in men. Most pronounced were visual symptoms during monotonous typing, programming, and other near work. The use of eyeglasses, especially in combination with reduced visual acuity (beneath 1.0 MAR decimal), reached significant ORs for reporting both visual and neck/scapular area symptoms.

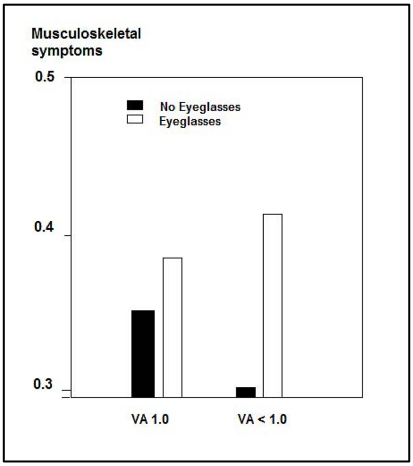

Figure 7. Self-reported musculoskeletal symptoms in office workers with or without reduced visual acuity. The white bars represent participants who used eyeglasses and the black bars represent those without eyeglasses. VA= visual acuity in MAR decimal.

Based on the original figure printed in Work 38 (2011).Copied by permission.

The more working hours per day that were spent on near work, the higher was the self-reported level of neck/scapular area symptoms (OR 1.4). Higher OR for symptoms was also observed in association with use of eyeglasses, regardless of the level of VA (Figure 7) or binocular deficiencies (vergence errors).

Study II

Study II a Construct validity, reliability and scale properties of the VMB questionnaire:

Sixty-one percent of the participants reported symptoms in all three subscales. CFA supported the *a priori* three-factor structure of the VMB questionnaire. The factor loadings of the items on their respective domains were statistically significant. Rasch analysis indicated a disordered rating scale and the original 10–point scale was subsequently replaced with a five-point scale.

Each VMB domain fitted the Rasch model, showing good metric properties including unidimensionality, person separation (1.86–2.29) and reliability (0.87–0.94). The domains showed good item fit (in-fit mean square > 0.72 and out-fit< 1.47), targeting (0.30–0.50 logits).

The test showed excellent differential item functioning (DIF) for age and gender (all DIF's <0.5). However a minimal DIF (0.55 logits) was noticed in visual status, (item 4 in the musculoskeletal domain), where adult VI found it easier to endorse than adults with presbyopia.

Study II b Convergent validity of the VMB questionnaire

The mean scores in VMB-V (the visual domain) correlated with visual clinical assessments and VFQ-NAS results. Mean scores in VMB-M (the musculoskeletal domain) correlated with perceived pain during palpation on the right-side trapezius muscle, but not on the left side. Mean scores from VMB-B (the balance domain) correlated significantly with static and dynamic balance assessments, with greater time required to walk 10 metres, shorter functional reach and a shorter time able to stand on one leg, with greater reported VMB-B symptoms. The three VMB domains then showed significant and adequate convergent validity.

The VMB questionnaire could now be considered to constitute a simple, valid and reliable method for evaluating concurrent visual, muscular, and balance symptoms and their correlation with clinical findings. Thus, the VMB questionnaire may also constitute a useful contribution to epidemiological and intervention research with potential clinical implications for the field of health services and visual rehabilitation.

Study III

In an age comparison, younger adults with VI reported significantly more symptoms in all VMB domains compared to age-matched controls, who reported hardly any symptoms at all(Figure 8).

Simultaneously with increased levels of visual and musculoskeletal symptoms, older adults in the reference group (who had passed the stage for onset of presbyopia) showed visual decline and a need of more visual enhancement aids, compared to younger adults. This age difference was not noticed in VI patients, where higher, but similar levels of symptoms were reported in both age groups (Figure 8).

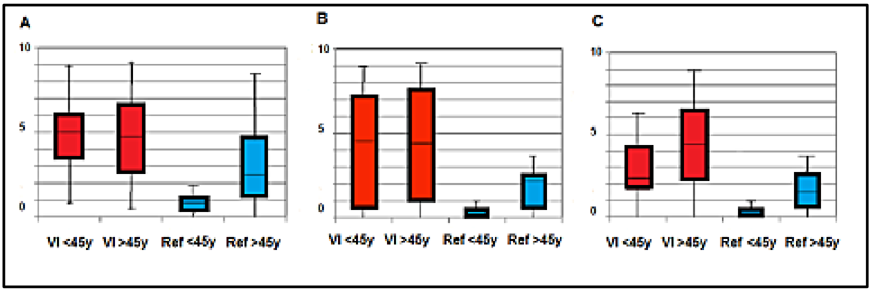

Figure 8. Box plots illustrating age differences (dichotomized into under and over the age of 45) in reported symptoms in adults with visual impairment (red bars) compared to an age-matched reference group (blue bars) Boxplots show quartiles and median values, with whiskers showing range. A = visual symptoms, B = musculoskeletal symptoms and C = balance symptoms.

The three multiple logistic regression analyses showed that the use of eyeglasses was highly correlated with both visual, musculoskeletal and balance symptoms (OR ranging from 5.4 to 10.6).

Waring eyeglasses and anisometropia were both accentuated visual properties that demonstrated significant OR for symptoms in all three domains.

Study IV

In AMD patients, visual symptoms and neck and scapular area symptoms correlated significantly. Spearman's rho showed significant correlation between visual and musculoskeletal symptoms for the AMD patients and control group combined (Spearman's $\rho=0.50$ $p<0.001$), as well as for each group separately ($\rho=0.60$, $p=0.002$) in patients and ($\rho=0.59$, $p=0.004$) in age-matched controls.

Stepwise multiple regression analysis supported the hypothesized effect of visual symptoms on musculoskeletal symptoms ($r^2=0.42$, $p<0.05$), where *minimum readable typefaces* had the most impact on musculoskeletal symptoms.

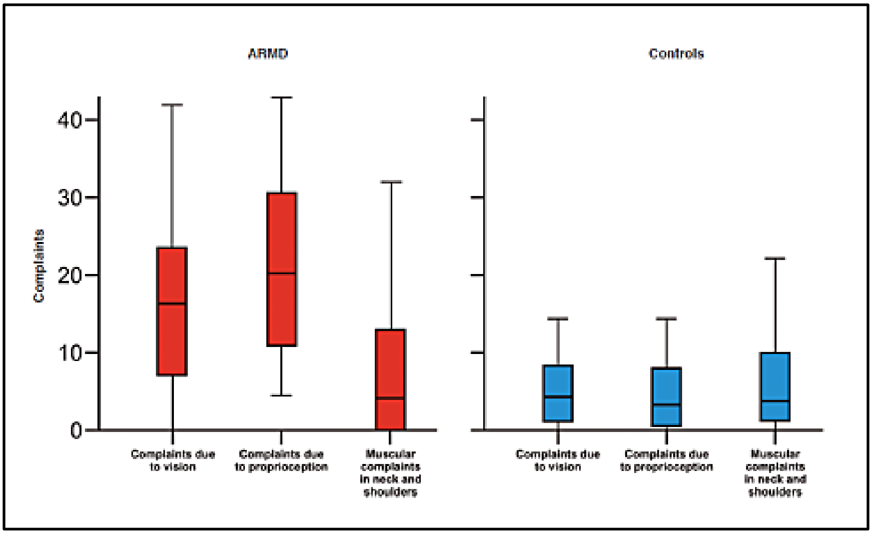

Figure 9. Box plots illustrating the results from the VMB questionnaire. Boxplots show quartiles and median values, with whiskers showing range and numbered outliersAge-related macular degeneration (ARMD) patients are shown in red and age-matched controls in blue. The plots show, for each group, visual symptoms (left), balance symptoms (middle) and musculoskeletal symptoms in the neck and scapular area (right). Copied by permission. *Journal of Optometry 2009;2:127-133*

Regarding all symptoms, AMD patients reported significantly higher levels of both visual and balance symptoms than controls (Figure 9). Some AMD patients reported high levels of visual symptoms without reporting any musculoskeletal symptoms at all, which is why a follow-up study (Study V) including more AMD patients was planned, to explore these results further.

Study V

AMD patients and age-matched controls demonstrated at baseline (Study IV) a significant correlation in visual and musculoskeletal symptoms in both groups together and separately. All reported symptoms (visual, musculoskeletal and balance symptoms) increased significantly from baseline to follow-up in AMD patients. In the control group, the symptoms remained quite stationary compared to baseline (Figure 10).

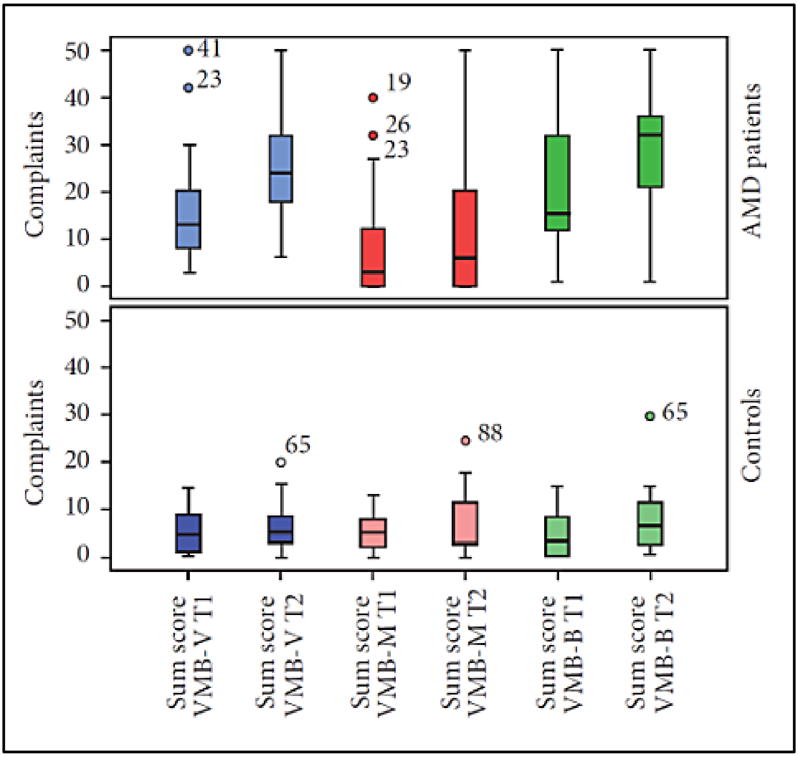

Figure 10: Box plots illustrating the change in self-reported visual, musculoskeletal and balance symptoms at baseline in Study IV (T1) and at follow-up 3–5 years later in Study V (T2) in patients (top) and age-matched controls (bottom). Blue boxes represent visual symptoms, red boxes represent musculoskeletal symptoms and green boxes represent balance symptoms. Boxplots show quartiles and medianvalues, with whiskers showing range and numbered outliers (AMD = Age-related macular degeneration.)

Self-rated decreased near visual function (VFQ-NAS), reduced VA, need for larger print (critical print size) and need for larger magnification were all found to have higher OR for visual symptoms.

An extra need for magnification (such as the extreme magnification provided by EVES) was the single item most associated with increased musculoskeletal and balance symptoms.

In the control group, decreased VA, use of bifocals and decreased levels of self-rated near visual function (VFQ-NAS) were associated with increased symptoms of visual and balance symptoms.

The study also found an elevated mortality in AMD patients compared to controls. Among the 27 cases that were not represented at follow-up, 16 had died. In the control group, on the other hand, only one person had died.

According to the Wilcoxon signed-rank test on the remaining participants, the proportion who rated themselves as healthy decreased significantly in the AMD group, from 72% to 49% (p=0.007). Visual symptom markers for decreased self-rated health were identified by univariate logistic regression conducted on each group separately. This revealed a significant impact of the variable *Minimal readable font size* on visual symptoms (VMB-V) in both groups; in addition, this variable was associated with an increased level of musculoskeletal symptoms (VMB-M) in AMD patients and an increased level of balance symptoms (VMB-B) in controls.

Visual deterioration was thus considered a risk marker for increased levels of visual, musculoskeletal and balance symptoms and also a risk marker for decreased perceived health.

DISCUSSION

The overarching aim was to explore the associations between optometric factors and visual, musculoskeletal and balance symptoms in adults with VI.

Study I showed a relationship between musculoskeletal symptoms and visual symptoms originating from deficient vision. This relationship was more profound in adults who used visual enhancement aids such as eyeglasses. The VMB questionnaire was developed to more specifically study these relationships in adults with VI.

In Study II, the VMB questionnaire was psychometrically tested and found to be a reliable and valid instrument for studying visual, musculoskeletal and balance symptoms in adults with VI.

Study III showed that these symptoms were more pronounced in adults with VI, particularly in younger VI adults, compared to adults with normal vision.

Study IV showed that older adults diagnosed with AMD had significantly more problems with visual and balance symptoms compared to an age-matched reference group with normal vision.

At follow-up four years later, Study V showed that these symptoms had increased significantly in the AMD group but not in the age-matched reference group.

All four studies involving patients with VI confirmed that they were at a higher risk of visual, musculoskeletal and balance symptoms.

Optometric measures

Minimal readable print size was a critical variable concerning the risk of developing musculoskeletal symptoms. If minimal readable print size does not allow the person to read 8-point typeface at 80 words per minute, this measure could be used as an indicator of unsatisfactory near vision or an unsatisfactory visual enhancement aid. During-, onset- and after vision decline, this measure was linked to both musculoskeletal and balance symptoms.

According to previous clinical research, reading rate depends on both VA and contrast sensitivity, which are interrelated; together they may give a wider perspective on visual capacity, especially in combination with visual deficiencies (Latham and Tabrett 2012).

In Study V, the level of VA *per se* was not identified as a marker for lower perceived health; the specific marker was rather the need for larger print size, which is a related measure of poor VA. The inability to read normal print size, sometimes referred to as *near VI* and often considered a key risk factor for reduced communication, autonomy and social life, and has previously been shown to have most impact on perceived health (Lamoureux, Fenwick et al. 2009).

Anisometropia was another optometric variable that in all three domains of the VMB questionnaire was found to be associated with elevated symptoms. Anisometropia is a condition in which the visual cues from each eye give incongruent information, where congruence is necessary for stabilizing gaze. This may have an effect on both convergence and accommodation and could result in a continuous innervation, with slight, continuous contraction of the muscles involved. In accordance with these results and the hypothesized effects, Zetterberg et al. demonstrated in a laboratory study that incongruence in accommodation and vergence between the left and right eye was influenced by elevated EMG activity in the trapezius muscle (Zetterberg, Forsman et al. 2013).

Visual enhancement aids

Refractive solutions for VI patients often include strong levels of dioptric power; these patients' visual representation and comfort is already decimated, and visual aberrations and other visual side effects may worsen their visual discomfort.

The overall use of eyeglasses was found to be highly associated with visual, musculoskeletal and balance symptoms. This result was at first glance somewhat surprising; however, it is consistent with the gaze control model, where eyeglasses usually affect head posture, and with other studies that show involvement and integration of visual enhancement aids on visual, vestibular and proprioceptive systems. (Kapoula, Gaertner et al. 2012). Kapoula and colleagues demonstrated that use of any eye correction involving optical lenses had a destabilizing effect on postural control. In particular, positive spherical lenses prescribed to improve accommodation were shown to decrease postural stability.

Eyeglasses in people with normal vision are the most common visual enhancement aid for reducing refractive deficiencies. These are also often prescribed to eliminate or reduce refractive deficiencies from presbyopia.

During incipient presbyopia the refraction changes quickly and dramatically, and the eyeglass prescription may not be renewed soon enough. Bifocal eyeglasses are more often reported to be associated with symptoms than progressive solutions. During visual decline, bifocals are often gradually used more as the need for higher near correction increases (an addition exceeding 4 dioptres); this is because progressives very seldom have an addition exceeding 3.5 dioptres. Both bifocals and progressives demand similar gaze directions, as the maximum focal power is positioned beneath the visual centre in the correction lens, giving the best near visual image representation while gazing downwards or tilting the head backwards. However, bifocals are more often associated with higher near additions that consequently have more restrictive limits for the acquired reading distance. Gazing downwards at a specific close-up distance involves increased risk of neck/scapular area symptoms (Horgen, Aarås et al. 1989, Mon-Williams, Burgess-Limerick et al. 1999, Aaras, Horgen et al. 2001, Falla 2004, Aaras, Horgen et al. 2005, Rempel 2007). Both bifocals and progressives may also limit the scope for varying head posture (Horgen, Aarås et al. 1989). Thus, as shown in this thesis, the use of eyeglasses increases the risk of VMB symptoms.

Adults with VI in study III, IV and V predominantly used more visual enhancement aids (such as EVES or handheld magnifiers) than the normally sighted adults in the reference groups. These aids were also found to be more associated with both musculoskeletal and balance symptoms. The combination of visual and musculoskeletal problems associated with VDU work (computer vision syndrome) described in study I support these findings, as the use of EVES involves similar visual ergonomics as VDU work.

The work of Bowers and colleagues is unique in studying problems while manoeuvring other visual enhancement aids (handheld magnifiers), while reading (Bowers, Cheong et al. 2007). In their studies they investigated common problems related to navigation performance They also observed possible interactions from reduced motor skill or visual decline. Eyeglasses and visual enhancement aids are prerequisites for better performance among people with reduced VA, which is supported by Domkin and colleagues' laboratory study showing that prehension (guided hand movements) was reduced as an effect of VA (Domkin, Richter et al. 2015).

Influence of age on VMB symptoms

The results of this thesis show that, as people get older, balance symptoms increase as an effect of visual decline, which is consistent with contemporary research (Radvay, Duhoux et al. 2007, Ray, Horvat et al. 2008, Salzman 2010). As shown in Study III, adults younger than 45 years with normal vision had almost no VMB symptoms. Those older than 45 years with normal vision reported more symptoms, which is consistent with visual decline due to the onset of presbyopia at approximately 45 years of age. The normal increase in VMB symptoms with age was accompanied by a need for a greater reading distance and for assistive reading aids.

The influence of age was not as clear among adults with VI. High levels of VMB symptoms were common even in younger VI adults, with older VI adults only reporting slightly more VMB symptoms.

In Study IV, older patients with AMD reported higher levels of visual and balance symptoms than the age-matched controls with normal vision. In the follow-up, reported in Study V, symptoms among the AMD patients increased even further over time, including increased musculoskeletal symptoms, whereas normally sighted controls reported a constant level of symptoms.

VI is generally found in older adults, but in Study III, younger VI adults (<45years) reported almost as pronounced symptoms as older VI adults; this indicates that age may not be the relevant influencing factor, but rather that their symptoms are a direct result of their visual problems. With further visual decline, the symptoms were still increasing, as shown in Study V.

Influence of gender on VMB symptoms

In all studies in this thesis, levels of symptoms were overall larger in women than in men. This may relate to the fact that women have a different composition of muscle fibres in the body, which gives a lower force or endurance compared to the same muscles in men (Miller, MacDougall et al. 1993, Haizlip, Harrison et al. 2015). The difference may also depend on difference in type of activities performed by men and women.

During the last fifty years, women have been more equally represented on the labour market, but very many still carry out the majority of household chores alongside their full-time employment. This double burden, combined with less time for relaxation, can give rise to both increased stress for women and a negative impact on their psychosocial wellbeing; it has been proposed that this double burden is a factor contributing to women reporting musculoskeletal discomfort and computer vision syndrome (Korhonen, Ketola et al. 2003, Larsman 2006, Wijnhoven, de Vet et al. 2006, Wiholm 2007).

Associations between perceived health and VMB symptoms

Perceived health was assessed in Study V and the results showed that fewer AMD patients at baseline rated themselves as healthy compared to age-matched controls with normal vision. At the follow-up three to four years later, the proportion of AMD patients with self-rated poor health had increased compared to the proportion of age-matched controls reporting poor health. The results also showed that an increase in visual and musculoskeletal symptoms was associated with decreased perceived health among AMD patients. Furthermore, participants with normal vision reported increased visual and balance symptoms at follow-up, which was also associated with decreased perceived health. This suggests that aspects of visual decline influence perceived health as people grow older, regardless of whether they have a VI or not. However, all symptoms were more severe in AMD patients than in the reference group, demonstrating that people with VI are at higher risk of declining health than normally sighted people.

It is notable that sixteen of the original 64 (25%) participants with AMD were deceased at follow-up, compared to only one of the original 24 (4%) in the reference group. This increased mortality has also been reported by other researchers in this area (Brody, Gamst et al. 2001, Slakter and Stur 2005, Siantar, Cheng et al. 2015). McCarty and colleagues showed that an increased mortality risk is related to decreased VA, notable already with mild VI (McCarty, Nanjan et al. 2001).

One possible explanation may be that VI may limit participation in physical activities, in both women and men. VI may also diminish self-esteem and increase the individual's need for assistance, thereby increasing the risk of choosing a more sedentary lifestyle leading to impaired health. (McCarty, Nanjan et al. 2001, Ray, Horvat et al. 2008, Dev, Paudel et al. 2014)

The gaze control model

The gaze control model provided a framework for identifying musculoskeletal symptoms. A primary finding in Study I (consisting of adults with normal vision), was that visual symptoms and musculoskeletal symptoms were positively correlated, especially for participants with longer hours of near work per day. This supports the proposed framework illustrated in the gaze control model and shows that ingrained habits or repetitive work demands can force these individuals to continue straining their eyes, neck or scapular area even though this straining interferes with their comfort and wellbeing; there is a clear need for new solutions and better habits.

Study I also confirmed a strong interaction between visual and musculoskeletal symptom in adults with normal vision who used refractive aids or had somewhat reduced VA. The most influential risk factor for musculoskeletal symptoms was visual symptoms and vice versa.

It should be noted that this model does not include balance symptoms, which are likely to be a more profound effect of reduced visual feedback during long-term deficient vision. The rest of the studies included predominantly AMD patients, who previously had quite normal vision, and whose visual decline probably had a major impact on their way of living. Successively worsening visual deficits would hamper their attempts to hold on to their familiar way of life, resulting in an intense struggle to cope, that probably leads to the first sensation of visual, musculoskeletal or balance symptoms.

Strengths and limitations

When the studies included in this thesis were conducted, there was no reported research describing associations between visual, musculoskeletal and balance symptoms among people with VI. As there was not yet any simple, reliable and valid way to screen and evaluate concurrent visual, musculoskeletal and balance symptoms, a first step was to design and validate a useful questionnaire. The VMB questionnaire was developed and used in three of the studies and its validity and reliability were confirmed in Study II.

The results from the studies in this thesis can be considered representative for VI patients and people with normal vision, as the participants were recruited without any limits other than following the queue system and the exclusion criteria. However, recruiting a larger number of participants would have increased the statistical power to identify possible risk factors. The number of participants was based on a power analysis, which indicated that 16 participants per group would be sufficient to be able to identify statistical differences between groups. Not all observed differences reached significance, probably due to the somewhat limited number of participants. This resulted in an extended period of data collection in Study V, (including a further 40 AMD patients), which later showed itself to be a necessary approach, as many of the original AMD patients had died or suffered from illness and comorbidity, with a dropout rate of 38%.

Study II took a total population approach. The VMB questionnaire was developed to better collect relevant information from people with VI. Nonetheless, the response rate was modest for individuals with the most severe impairments. This is to be expected, as reading is more difficult with increasing VI severity. A common way to handle this is to offer telephone interviews, but this was still not an option for all, as many of the older VI patients also had pronounced hearing loss.

In Studies IV and V, the vast majority of the participants in the control group were companions of the patients and tended to be slightly younger, especially in the older low-vision groups. This natural age difference increased in the longitudinal study, where the older AMD patients seemed to be stronger survivors, resulting in an even larger age difference. However, a statistical analysis to test whether their age had any impact on the items in focus for the study revealed that there was no violation of the outcome measure; therefore these older participants were not excluded.

It should also be pointed out that the original VMB questionnaire used in Studies III, IV and V was based on a response scale ranging from 0–10. The five-point scale used subsequently was proposed after Rasch analysis in Study II indicated that some thresholds were disordered, meaning that respondents were unable to reliably discriminate between the different levels in the 10-point scale. The reanalysis of the recoded five-point scale showed good threshold differences, where category probability curves also supported the reduced five-point scale. The reliability and validity of the VMB questionnaire was conducted in parallel or shortly after the data collection period in Studies III–V, which is why the proposed five-point scale was not an option.

Studies II, III, IV and V were based on patients visiting the low vision clinic in Örebro. Visual examination was performed by optometrists working at the clinic, which may have affected the responses from the patients; in particular, they may have been reluctant to report symptoms from using visual enhancement aids that they had earlier been provided with at the same clinic. At the same time, participants were recruited from the waiting list and might be inspired to report more symptoms because they were in need of visual enhancement aids and better optical solutions. In order to minimize such effects, the data collection procedures were followed strictly and involved at least one other optometrist.

CONCLUSION

The results of the present thesis show that people with VI are more predisposed to visual, musculoskeletal and balance symptoms compared to people with normal vision, irrespective of age. Furthermore, VI is a major health issue. The co-occurrence of visual, musculoskeletal and balance symptoms is associated with visually demanding near activities, with predictors typically related to VI. All these findings indicate that the occurrence of visual deficits can give rise to a disproportionate level of visual, musculoskeletal and balance symptoms.

Clinical implications

The co-occurrence of VMB symptoms

The included VI patients demonstrated that visual deficits were associated with higher risk of visual, musculoskeletal and balance symptoms. Given that these symptoms are commonly accompanied by a risk of fall accidents (Ray, Horvat et al. 2008, Szabo, Janssen et al. 2008, Tomomitsu, Alonso et al. 2013), these results support the need for interventions for postural control and balance training in accordance with the actions proposed by Dagnelie (Dagnelie 2013).

During the aging process, most people will experience discomfort related to visual, musculoskeletal and balance symptoms. From a health perspective it would therefore make sense to also implement preventive measures in order to improve prehension, proprioception and balance at an early stage, in combination with providing new visual enhancement aids. As yet, only a few studies have reported improvements and reduced discomfort when introducing interventions, including physiotherapy. (Holmberg, Rappenecker et al. 2014, Lundqvist, Zetterlund et al. 2014) In order to identify those at risk, the VMB questionnaire could be invaluable.

Prescribing visual enhancement aids

These results showing associations between visual enhancement aids and VMB symptoms call for precaution when it comes to prescribing visual enhancement aids to people with VI. A suggestion is that the aids provided must be chosen with care and prescribed with precise instructions for best visual and physical ergonomics. Visual enhancement aids do also need to be checked and adjusted frequently, where it might be necessary to implement systems for more frequent controls.

Most VI people can only read with the support of optical or technical devices that provide an enlarged visual image on the retina. The frequent use of the same specific visual enhancement aid may cause increased discomfort, as this often calls for the same specific strain, which is why it is important to administer and provide the patient with at least a couple of solutions that can be altered in order to minimize prolonged sessions coping with the same kind of strain that can exacerbate their discomfort.

Currently, our older VI patients are not really accustomed to recently introduced visual enhancement aids such as iPads or iPhones in situations where they need to read small print.

To be able to read ordinary print size in newspapers and advertisement (8-point) is of great importance, and this could be the threshold for triggering problems associated with visual discomfort and impaired balance and musculoskeletal functioning. Reaching this limit, might be the first stage in the development of long-term VMB symptoms, even in healthy people with normal vision, as demonstrated in this thesis. Even presbyopia, a natural result of the normal aging process, may result in symptoms that need to be adjusted for and continuously monitored, as inappropriate correction may have the same devastating effect.

Future research

Overall prevalence statistics are not available for visual, musculoskeletal and balance symptoms in low vision patients. A wider survey would contribute to further knowledge and at the same time increase awareness of the importance of visual ergonomics.

The majority of low vision patients are older people, for whom the normal decline in vision with age has an impact on the age-related decline in other bodily functions. However, very little is known about the prevalence and incidence of symptoms associated with low vision in children or younger individuals. Identifying these symptoms at an early stage could contribute to further and better scientific understanding of the issues and thereby contribute to better tools for helping younger VI patients undergoing habilitation or rehabilitation.

There is a need for further intervention studies involving physiotherapy in order to find better methods that at a minimum could support the improvement of sensorimotor representation and ergonomic aids for VI patients, thereby reducing bodily discomfort for the individual patient as well as improving knowledge and best practice in VI rehabilitation.

EPILOGUE

During visual decline, the information from visual inputs starts to be less accurate or insufficient for the individual's needs. This might at first only be noticed as tiny signs of visual discomfort. Through this thesis I want to highlight that these seemingly harmless signs of visual discomfort should not be neglected but examined thoroughly for potential adjustments. I hope my thesis will inspire others to continue this work, with the VMB questionnaire as a valuable tool.

SAMMANFATTNING PÅ SVENSKA

Närmare 300 miljoner människor har en synnedsättning i enlighet med WHO och ICD-10:s definition av "Visual Impairments", varav 100 000 i Sverige. Prevalensen är ganska låg i unga åldrar (ca 1.5 % under 40 år), men stiger dramatiskt till ca 30 % vid 80 års ålder. Det beror på att den största orsaken till synnedsättning är degenerativa åldersrelaterade förändringar. Det är även vanligt att personer med synnedsättning också har försämrad balans. Synen liksom den sensomotoriska återkopplingen från muskelapparaten försämras också vid normalt åldrande, vilket gör det svårt att avgöra vad som orsakats av synnedsättning och vad som orsakats av naturligt åldrande. De besvär som dessa beskriver kan till stor del bero på ansträngd syn, men de flesta tror att deras besvär är kopplade till det normala åldrandet.

I utgångsläget för de här studierna fanns ingen forskning som beskriver skillnaden av symptom från nacke skuldra och nedsatt balans hos synsvaga personer jämfört med åldersmatchade personer med normal syn. Det saknades även lämpligt instrument som kunde mäta detta på ett enkelt och övergripande sätt.

Syften:1) Undersöka om det finns samband mellan symptom från syn, nacke/ skuldra hos personer utsatta för hög grad av synbelastning i sitt arbete. 2) Designa och validera ett lämpligt instrument som kan användas för att undersöka syn, balans och symtom från nacke skuldra hos personer med nedsatt syn (VMB–questionnaire).3) Undersöka om det finns skillnader i rapporterade symptom hos personer med synnedsättning jämfört med personer med normal syn i tvärsnittstudier, samt över tid med cohort-studie av grupp be äldre synsvaga personer och åldermatchade referenser.4) Identifiera de specifika bakomliggande synrelaterade faktorer som är mest förknippade till uppkomst av VMB symptom.

Metod: Designa och pröva ett användbart instrument som kunde mäta symptom från syn, nacke skuldra och balans (VMB) hos personer med nedsatt syn. Instrumentet testades och validerades. Tre olika studier innehållande personer med synnedsättning jämfördes med åldersmatchade referenser för att identifiera eventuella skillnader i dessa upplevda symptom. Dessutom gjordes en uppföljning över tid på äldre synsvaga personer med diagnosen AMD (åldersrelaterad maculadegeneration).

Resultat: I alla delstudier kunde resultaten belysa att det fanns ett samband mellan symptom från synen och symptom från nacke/skuldra liksom koppling till nedsatt balans. Personer med synnedsättning hade redan före 45 års ålder nästan lika hög grad av symptom som de äldre synsvaga patienterna. Symptomen ökade även över tid vilket de inte gjorde i referensgruppen som behöll ganska stabil nivå av symptom över tid. Symptomen noterad ha hög koppling till användandet av olika synhjälpmedel.

Slutsats: Personer med synnedsättning har mer VMB symptom och är i större grad utsatta för faktorer som kan inverka på ökad grad av symptom relaterade såväl till syn, nacke/skuldra och balans.

ACKNOWLEDGEMENTS

This thesis represents a learning process including experiences that have been challenging but also fruitful.

This work would not have been possible without support from a lot of people around me. I want to express my warm and sincere gratitude to you all! My journey has been long, and I might fail to remember all of those who have encouraged and assisted me, but I will give it a try:

Örebro University and FoU (Forskning och Utveckling) for initially supporting my studies.

Uppsala-Örebro Regional Research Council [Regionala Forskningsrådet (RFR) and FoU] for supporting my research through several funds and grants through the years.

I must also mention financial support from RESAM, who have financed projects parallel or close to my research, which have made my research more genuine and thorough.

My former manager Barbro Carlsson, who first inspired me to start this journey. Thank you for believing in me!

My two supervisors, for taking me into your team and trusting me to work with you!

Lars-Olov“Olle”Lundqvist, my main supervisor, my closets collaborator during these years. Thank you for mentoring and encouraging me, always with new and better ideas. You are a skilled statistician, writer and scientist with endless ideas on how to better present data with exciting methods.

My second supervisor, Hans O. Richter (who also supervised me during my master thesis). Thank you for introducing me into your research team and thank you for your thorough guidance through the years!

All patients and participants in the studies. You have always shown faith in me and given me feedback and energy to continue.

My colleagues at the former Centre for Rehabilitation Research (HFC) and all my new colleagues at the Örebro University Health Care Research Center (UFC). My new manager Margareta Möller who has made it possible for me to continue my work in the final phase.

I give especially warm and hearty thanks to Dr Helen Lindner, who was my room-mate for several years, supporting me in all everyday tasks, especially in editing and writing proper English.

My gratitude goes also to Dr Gustav Jarl who has supported me in many ways! You have always been very generous, efficient, energetic and supportive. Thank you!

All who have assisted my research: administrative assistance (Rose-Marie Andersson, Camilla Zetterlund and Johanna Zetterlund), statistician Hans Högberg, co-writer Dmitry Domkin and researchers at UFC.

Catriona Chaplin, CMC Scientific English for Publication, for excellent work with the correction of the publication.

My present manager at Syncentralen Örebro (SCN), Ewa Nielsen, for believing in me, giving me mental strength and positive support in many ways.

My dear colleagues at SCN, both present and former colleagues that have supported me with help in my research and in my normal work.

Last but not the least: my friends and family!
I have many dear friends and a warm family, consisting of both older and younger members and relatives. I appreciate you all for giving my leisure time a “golden air”.

Björn, my dear and loving husband. Thank you for your endless love, support, patience and encouragement during these years.

Camilla and Johanna (my daughters), who have both served as research assistants during short periods in my research work and are still interested in future research on your own. I am very proud of both of you. You bring the sunshine into my life!

Thank you all!

Att vara doktorand är en lärandeprocess där vägen ibland känns både krokig, backig och otroligt lång, men det råder inget tvivel om att jag lärt mig ett och annat under resans gång – även om det naturligtvis finns mycket som jag skulle kunna ha gjort bättre. Jag vill rikta ett stort och varmt tack till ***alla*** som på något sätt varit mig behjälplig och bidragit till att avhandlingen nu slutligen blivit färdig. Det är lätt att glömma någon i skrivandets stund, men här vill jag tacka alla som känner att ni hjälpt och stöttat mig på min väg.

Tack!

References

Aaras, A., G. Horgen, H. H. Bjorset, O. Ro and M. Thoresen (1998). "Musculoskeletal, visual and psychosocial stress in VDU operators before and after multidisciplinary ergonomic interventions." Appl Ergon **29**(5): 335-354.

Aaras, A., G. Horgen, H. H. Bjorset, O. Ro and H. Walsoe (2001). "Musculoskeletal, visual and psychosocial stress in VDU operators before and after multidisciplinary ergonomic interventions. A 6 years prospective study--Part II." Appl Ergon **32**(6): 559-571.

Aaras, A., G. Horgen, O. Ro, E. Loken, G. Mathiasen, H. H. Bjorset, S. Larsen and M. Thoresen (2005). "The effect of an ergonomic intervention on musculoskeletal, psychosocial and visual strain of VDT data entry work: the Norwegian part of the international study." Int J Occup Saf Ergon **11**(1): 25-47.

Akinci, A., A. Guven, A. Degerliyurt, E. Kibar, M. Mutlu and M. Citirik (2008). "The correlation between headache and refractive errors." J AAPOS **12**(3): 290-293.

Anshel, J. R. (2007). "Visual ergonomics in the workplace." AAOHN J **55**(10): 414-420; quiz 421-412.

Armstrong, B., P. McNair and D. Taylor (2008). "Head and neck position sense." Sports Med **38**(2): 101-117.

Berger, W. J., Fine,L.S., Maguire,G.M. (1999). Age related macualr degeneration. St Louis Missouri, Mosby

Blehm, C., Vishnu,S.,Khattak,A.,Mitra,S.,Yee,R.W. (2005). "Computer vision syndrome: a review." Surv Ophthalmol **50**(3): 253-262.

Borsting, E., C. H. Chase and W. H. Ridder, 3rd (2007). "Measuring visual discomfort in college students." Optom Vis Sci **84**(8): 745-751.

Borsting, E., C. Tosha, C. Chase and W. H. Ridder, 3rd (2010). "Measuring near-induced transient myopia in college students with visual discomfort." Optometry and Vision Science **87**(10): 760-766.

Boström, W., Karlsson (2006). Hälsa på lika villkor, Swedish National Institute of Public Health

Bowers, A., A. M. Cheong and J. E. Lovie-Kitchin (2007). "Reading with optical magnifiers: page navigation strategies and difficulties." Optometry and Vision Science **84**(1): 9-20.

Brewer, S., D. Van Eerd, B. C. Amick, 3rd, E. Irvin, K. M. Daum, F. Gerr, J. S. Moore, K. Cullen and D. Rempel (2006). "Workplace interventions to prevent musculoskeletal and visual symptoms and disorders among computer users: a systematic review." J Occup Rehabil **16**(3): 325-358.

Brody, B. L., A. C. Gamst, R. A. Williams, A. R. Smith, P. W. Lau, D. Dolnak, M. H. Rapaport, R. M. Kaplan and S. I. Brown (2001). "Depression, visual acuity, comorbidity, and disability associated with age-related macular degeneration." Ophthalmology **108**(10): 1893-1900; discussion 1900-1891.

Bucci, M. P., M. Vernet, C. L. Gerard and Z. Kapoula (2009). "Normal speed and accuracy of saccade and vergence eye movements in dyslexic reader children." J Ophthalmol **2009**: 325214.

Buckley, J. G., K. J. Heasley, P. Twigg and D. B. Elliott (2005). "The effects of blurred vision on the mechanics of landing during stepping down by the elderly." Gait Posture **21**(1): 65-71.

Charman, W. N. (2008). "The eye in focus: accommodation and presbyopia." Clin Exp Optom **91**(3): 207-225.

Chase, C., C. Tosha, E. Borsting and W. H. Ridder, 3rd (2009). "Visual discomfort and objective measures of static accommodation." Optom Vis Sci **86**(7): 883-889.

Christensen, K., G. Doblhammer, R. Rau and J. W. Vaupel (2009). "Ageing populations: the challenges ahead." Lancet **374**(9696): 1196-1208.

Christoforidis, J. B., N. Tecce, R. Dell'Omo, R. Mastropasqua, M. Verolino and C. Costagliola (2011). "Age related macular degeneration and visual disability." Curr Drug Targets **12**(2): 221-233.

Ciuffreda, K. J., M. Rosenfield and H. W. Chen (1997). "The AC/A ratio, age and presbyopia." Ophthalmic Physiol Opt **17**(4): 307-315.

Dagnelie, G. (2013). "Age-related psychophysical changes and low vision." Invest Ophthalmol Vis Sci **54**(14): ORSF88-93.

Dev, M. K., N. Paudel, N. D. Joshi, D. N. Shah and S. Subba (2014). "Impact of visual impairment on vision-specific quality of life among older adults living in nursing home." Curr Eye Res **39**(3): 232-238.

Domkin, D., M. Forsman and H. O. Richter (2015). "Ciliary muscle contraction force and trapezius muscle activity during manual tracking of a moving visual target." J Electromyogr Kinesiol.

Domkin, D., H. O. Richter, C. Zetterlund and L. O. Lundqvist (2015). "Effect of reduced visual acuity on precision of two-dimensional tracing movements." J Optom.

Donahue, S. P. (2005). "The relationship between anisometropia, patient age, and the development of amblyopia." Transactions of the American Ophthalmological Society **103**: 313-336.

Donaldson, I. M. (2000). "The functions of the proprioceptors of the eye muscles." Philos Trans R Soc Lond B Biol Sci **355**(1404): 1685-1754.

Drew, S. A., E. Borsting, L. R. Stark and C. Chase (2012). "Chromatic aberration, accommodation, and color preference in asthenopia." Optom Vis Sci **89**(7): E1059-1067.

Duane,A.(1922)."Studies in Monocular and Binocular Accommodation, with Their Clinical Application. ." Transactions of the American Ophthalmological Society **20**: 132–157.

Ehrlich, R., A. Harris, N. S. Kheradiya, D. M. Winston, T. A. Ciulla and B. Wirostko (2008). "Age-related macular degeneration and the aging eye." Clin Interv Aging **3**(3): 473-482.

Falla, D. (2004). "Unravelling the complexity of muscle impairment in chronic neck pain." Man Ther **9**(3): 125-133.

Fejer, R., K. O. Kyvik and J. Hartvigsen (2006). "The prevalence of neck pain in the world population: a systematic critical review of the literature." Eur Spine J **15**(6): 834-848.

Franzén, O., H. Richter and L. Stark, Eds. (2000). Accommodation and vergence mechanisms in the visual system. Basel, Birkhäuser Verlag.

Garcia-Munoz, A., S. Carbonell-Bonete and P. Cacho-Martinez (2014). "Symptomatology associated with accommodative and binocular vision anomalies." J Optom **7**(4): 178-192.

Gilmartin, B. (1986). "A review of the role of sympathetic innervation of the ciliary muscle in ocular accommodation." Ophthalmic Physiol Opt **6**(1): 23-37.

Glimne, S., R. L. Brautaset and G. O. Seimyr (2015). "The effect of glare on eye movements when reading." Work **50**(2): 213-220.

Gold, J. E., D. M. Hallman, F. Hellstrom, M. Bjorklund, A. G. Crenshaw, M. Djupsjobacka, M. Heiden, S. E. Mathiassen, G. Piligian and M. F. Barbe (2016). "Systematic review of biochemical biomarkers for neck and upper-extremity musculoskeletal disorders." Scand J Work Environ Health **42**(2): 103-124.

Gordon, G. E., E. P. Chronicle and P. Rolan (2001). "Why do we still not know whether refractive error causes headaches? Towards a framework for evidence based practice." Ophthalmic Physiol Opt **21**(1): 45-50.

Gowrisankaran, S. and J. E. Sheedy (2015). "Computer vision syndrome: A review." Work **52**(2): 303-314.

Haizlip, K. M., B. C. Harrison and L. A. Leinwand (2015). "Sex-based differences in skeletal muscle kinetics and fiber-type composition." Physiology (Bethesda) **30**(1): 30-39.

Hamm, L. M., J. Black, S. Dai and B. Thompson (2014). "Global processing in amblyopia: a review." Front Psychol **5**: 583.

Harle, D. E. and B. J. Evans (2004). "The optometric correlates of migraine." Ophthalmic Physiol Opt **24**(5): 369-383.

Harwood, R. H. (2001). "Visual problems and falls." Age Ageing **30 Suppl 4**: 13-18.

Hayes, J., Sheedy,J.,James E.,Stelmack,J and Heaney C. (2007). "Computer Use, Symptoms, and Quality of Life." American Academy of Optometry **84**(8).

Hemmel, P. L. a. S. B. V. (2002). Visual Impairments:Determination Eligibility for Social Security Benefits. Washington DC, National Academy Press.

Hendricks, T. J., D. E. B. J, F. G. van Der Horst, F. Hendrikse and J. A. Knottnerus (2007). "Relationship between habitual refractive errors and headache complaints in schoolchildren." Optom Vis Sci **84**(2): 137-143.

Heuer, H., M. Bruwer, T. Romer, H. Kroger and H. Knapp (1991). "Preferred vertical gaze direction and observation distance." Ergonomics **34**(3): 379-392.

Higuchi, T. (2013). "Visuomotor control of human adaptive locomotion: understanding the anticipatory nature." Front Psychol **4**: 277.

Holmberg, C., J. Rappenecker, J. J. Karner and C. M. Witt (2014). "The perspectives of older women with chronic neck pain on perceived effects of qigong and exercise therapy on aging: a qualitative interview study." Clin Interv Aging **9**: 403-410.

Horgen, G., A. Aarås, H. E. Fagerthum and S. Larsen (1989). The work posture and the postural load of the neck/shoulder muscles when correcting presbyopia with different types of multifocal lenses on VDT-workers. Proceedings of the third international conference on human-computer interaction, Vol.1 on Work with computers: organizational, management, stress and health aspects. M. J. Smith and G. Salvendy. Amsterdam, Elsevier: xii, 698.

Hoy,D.G.,M.Protani,R.De and R.Buchbinder (2010)."The epidemiology of neck pain." Best Pract Res Clin Rheumatol **24**(6): 783-792.

Izquierdo, J. C., M. Garcia, C. Buxo and N. J. Izquierdo (2007). "Factors leading to the computer vision syndrome: an issue at the contemporary workplace." Bol Asoc Med P R **99**(1): 21-28.

Jackson, A. J. W., James S. (2007). Low vision manual. J. Jacksson. Edingburgh New York, Butterworth Heinemann/Elsevier

Jager, R. D., W. F. Mieler and J. W. Miller (2008). "Age-related macular degeneration." N Engl J Med **358**(24): 2606-2617.

Johansson, H. and P. Sojka (1991). "Pathophysiological mechanisms involved in genesis and spread of muscular tension in occupational muscle pain and in chronic musculoskeletal pain syndromes: a hypothesis." Med Hypotheses **35**(3): 196-203.

Johansson, H., Windhorst, U., Djupsjöbacka,M. & Passatore,M. (2003). Chronic work related myalgia. Gävle, Gävle University Press.

Johansson, J., T. Pansell, J. Ygge and G. O. Seimyr (2014). "The effect of contrast on monocular versus binocular reading performance." J Vis **14**(5): 8.

Johnston, A. W. (2003). "Understanding how simple magnifiers provide image enlargement." Clin Exp Optom **86**(6): 403-408.

Jose, R. T. (1985). Understanding Low vision. New York, America, American foundation for the blind.

Kapoula, Z., C. Gaertner and E. Matheron (2012). "Spherical lenses and prisms lead to postural instability in both dyslexic and non dyslexic adolescents." PLoS One **7**(11): e46739.

Knave B.G., W. R. I., Voss M. Hedström L.D and Bergqvist U.O. (1985). "Work with video display terminals among office employees." Scand J Work Environ Health **11**(6): 457-466.

Korhonen, T., R. Ketola, R. Toivonen, R. Luukkonen, M. Hakkanen and E. Viikari-Juntura (2003). "Work related and individual predictors for incident neck pain among office employees working with video display units." Occup Environ Med **60**(7): 475-482.

Kreczy, A., M. Kofler and A. Gschwendtner (1999). "Underestimated health hazard: proposal for an ergonomic microscope workstation." Lancet **354**(9191): 1701-1702.

Krimsky, E. (1967). "The seven primary positions of gaze." The British Journal of Ophthalmology **51**((2)): 105-114.

Krueger, H., P. Conrady and J. Zulch (1989). "Work with magnifying glasses." Ergonomics **32**(7): 785-794.

Lamoureux, E. L., E. Fenwick, K. Moore, M. Klaic, K. Borschmann and K. Hill (2009). "Impact of the severity distance and near vision impairment on depression and vision-specific quality of life in older people living in residential care." Invest Ophthalmol Vis Sci.

Larsman,P.,Sandsjö,L.,Klipstein,A.,VollenbockHutten,M.,Christiensen, H. (2006)."Perceived work demands, felt stress, and musculo-skeletal neck/shoulder symptoms among elderly female computer users.The NEW study." Eur J Appl Physiol(96): 127-135.

Latham, K. and D. R. Tabrett (2012). "Guidelines for predicting performance with low vision AIDS." Optom Vis Sci **89**(9): 1316-1326.

Lee, H. K. and R. J. Scudds (2003). "Comparison of balance in older people with and without visual impairment." Age Ageing **32**(6): 643-649.

Leigh, R. J., Zee,D.S (1983). The neurology of eyemovements. Philadelphia, F.A. Davis Company.

Lie, I. and R. G. Watten (1987). "Oculomotor factors in the aetiology of occupational cervicobrachial diseases (OCD)." Eur J Appl Physiol Occup Physiol **56**(2): 151-156.

Lie, I. and R. G. Watten (1994). "VDT work, oculomotor strain, and subjective complaints: an experimental and clinical study." Ergonomics **37**(8): 1419-1433.

Lin, J. C. and M. C. Yang (2009). "Correlation of visual function with health-related quality of life in glaucoma patients." J Eval Clin Pract.

Loftus, A., P. Servos, M. A. Goodale, N. Mendarozqueta and M. Mon-Williams (2004). "When two eyes are better than one in prehension: monocular viewing and end-point variance." Exp Brain Res **158**(3): 317-327.

Long, J. (2014). "What is visual ergonomics?" Work **47**(3): 287-289.

Lord, S. R. (2006). "Visual risk factors for falls in older people." Age Ageing **35 Suppl 2**: ii42-ii45.

Lord, S. R. a. M., Hylton B. (2000). "Visual Contributions to Postural Stability in Older Adults." Gerontology **46**(6): 306-310.

Lovie-Kitchin, J. (2011). "Reading with low vision: the impact of research on clinical management." Clin Exp Optom **94**(2): 121-132.

Lundqvist, L. O., C. Zetterlund and H. O. Richter (2014). "Effects of Feldenkrais method on chronic neck/scapular pain in people with visual impairment: a randomized controlled trial with one-year follow-up." Arch Phys Med Rehabil **95**(9): 1656-1661.

Macnaughton, J. (2005). Eye Essentials: Low Vision Assessment. London 2005, Elsevier.

Mangione, C. M., P. P. Lee, P. R. Gutierrez, K. Spritzer, S. Berry and R. D. Hays (2001). "Development of the 25-item National Eye Institute Visual Function Questionnaire." Arch Ophthalmol **119**(7): 1050-1058.

Matheron, E. and Z. Kapoula (2011). "Vertical heterophoria and postural control in nonspecific chronic low back pain." PLoS One **6**(3): e18110.

McCarthy, P. (2013). "Anisometropia: what difference does it make?" Optometry in Practice **14**(1): 1-10.

McCarty, C. A., M. B. Nanjan and H. R. Taylor (2001). "Vision impairment predicts 5 year mortality." Br J Ophthalmol **85**(3): 322-326.

McPartland, J. M., R. R. Brodeur and R. C. Hallgren (1997). "Chronic neck pain, standing balance, and suboccipital muscle atrophy--a pilot study." J Manipulative Physiol Ther **20**(1): 24-29.

Miller, A. E., J. D. MacDougall, M. A. Tarnopolsky and D. G. Sale (1993). "Gender differences in strength and muscle fiber characteristics." Eur J Appl Physiol Occup Physiol **66**(3): 254-262.

Mon-Williams, M. and G. P. Bingham (2007). "Calibrating reach distance to visual targets." J Exp Psychol Hum Percept Perform **33**(3): 645-656.

Mon-Williams, M., R. Burgess-Limerick, A. Plooy and J. Wann (1999). "Vertical gaze direction and postural adjustment: an extension of the Heuer Model." Journal of Experimental Psychology: Applied **5**(1): 35-53.

Naz, I. and Y. Yildirim (2010). "Investigation of the relationship between wearing glasses and deep cervical flexor endurance in patients with non-specific neck pain." J Back Musculoskelet Rehabil **23**(3): 143-149.

Neugebauer, A., J. Fricke and W. Russmann (1992). "Asthenopia: frequency and objective findings." Ger J Ophthalmol **1**(2): 122-124.

Nyhlen, P. (2012). Syn och belysning i arbetslivet, Prevent.

Rabbetts, R., Ed. (2007). Bennett and Rabbett's Clinical Visual Optics, 4th Edition, Butterworth-Heinemann.

Radvay, X., S. Duhoux, F. Koenig-Supiot and F. Vital-Durand (2007). "Balance training and visual rehabilitation of age-related macular degeneration patients." J Vestib Res **17**(4): 183-193.

Ray, C. T., M. Horvat, R. Croce, R. C. Mason and S. L. Wolf (2008). "The impact of vision loss on postural stability and balance strategies in individuals with profound vision loss." Gait Posture **28**(1): 58-61.

Rempel, D. W., K.,Anshel,J.Jaschinski;W: Sheedy,J. (2007). "The effect of Visual Display Distance on Accomodation, Head Posture, and Vision and Neck Symptoms." Human Factors **49** (5): 830-838.

Resnikoff, S., D. Pascolini, D. Etya'ale, I. Kocur, R. Pararajasegaram, G. P. Pokharel and S. P. Mariotti (2004). "Global data on visual impairment in the year 2002." Bull World Health Organ **82**(11): 844-851.

Richter, H. O., T. Banziger, S. Abdi and M. Forsman (2010). "Stabilization of gaze: A relationship between ciliary muscle contraction and trapezius muscle activity." Vision Research.

Richter, H. O., P. Costello, S. R. Sponheim, J. T. Lee and J. V. Pardo (2004). "Functional neuroanatomy of the human near/far response to blur cues: eye-lens accommodation/vergence to point targets varying in depth." Eur J Neurosci **20**(10): 2722-2732.

Richter, H. O., Crenshaw A.G.,Lyskov,E. (2007). "Low levels sustained accomodative/ vergence loads, eye strain and Neck-shoulder discomforts." Scand J Work Environ Health Suppl(3): 60-67.

Richter, H. O., C. Zetterberg and M. Forsman (2015). "Trapezius muscle activity increases during near work activity regardless of accommodation/vergence demand level." Eur J Appl Physiol **115**(7): 1501-1512.

Rosenberg, E. A. and L. C. Sperazza (2008). "The visually impaired patient." Am Fam Physician **77**(10): 1431-1436.

Rosenbloom, A. A. J., Ed. (2007). Vision and Aging. St.Louis, Butterworth Heinemann Elsevier.

Rosenfield, M., J. E. Hue, R. R. Huang and Y. Bababekova (2012). "The effects of induced oblique astigmatism on symptoms and reading performance while viewing a computer screen." Ophthalmic Physiol Opt **32**(2): 142-148.

Salonen, L. and S. L. Kivela (2012). "Eye diseases and impaired vision as possible risk factors for recurrent falls in the aged: a systematic review." Curr Gerontol Geriatr Res **2012**: 271481.

Salzman, B. (2010). "Gait and balance disorders in older adults." Am Fam Physician **82**(1): 61-68.

Schor, C. M. and J. C. Kotulak (1986). "Dynamic interactions between accommodation and convergence are velocity sensitive." Vision Res **26**(6): 927-942.

Schor, C. M. and T. K. Tsuetaki (1987). "Fatigue of accommodation and vergence modifies their mutual interactions." Invest Ophthalmol Vis Sci **28**(8): 1250-1259.

Sheedy, J., Hayes,J.,and Engle,J. (2003). "Is all Asthenopia the same?" Optometry and Vision Science **80**(11): 732-739.

Siantar, R. G., C. Y. Cheng, C. M. Gemmy Cheung, E. L. Lamoureux, P. G. Ong, K. Y. Chow, P. Mitchell, T. Aung, T. Y. Wong and C. Y. Cheung (2015). "Impact of Visual Impairment and Eye diseases on Mortality: the Singapore Malay Eye Study (SiMES)." Sci Rep **5**: 16304.

Slakter, J. S. and M. Stur (2005). "Quality of life in patients with age-related macular degeneration: impact of the condition and benefits of treatment." Surv Ophthalmol **50**(3): 263-273.

Stevens, G. A., R. A. White, S. R. Flaxman, H. Price, J. B. Jonas, J. Keeffe, J. Leasher, K. Naidoo, K. Pesudovs, S. Resnikoff, H. Taylor and R. R. Bourne (2013). "Global prevalence of vision impairment and blindness: magnitude and temporal trends, 1990-2010." Ophthalmology **120**(12): 2377-2384.

Szabo, S. M., P. A. Janssen, K. Khan, M. J. Potter and S. R. Lord (2008). "Older women with age-related macular degeneration have a greater risk of falls: a physiological profile assessment study." J Am Geriatr Soc **56**(5): 800-807.

Taylor, H. R., M. L. Pezzullo, S. J. Nesbitt and J. E. Keeffe (2007). "Costs of interventions for visual impairment." Am J Ophthalmol **143**(4): 561-565.

Thorud, H. M., M. Helland, A. Aaras, T. M. Kvikstad, L. G. Lindberg and G. Horgen (2012). "Eye-related pain induced by visually demanding computer work." Optom Vis Sci **89**(4): E452-464.

Tomomitsu, M. S., A. C. Alonso, E. Morimoto, T. G. Bobbio and J. M. Greve (2013). "Static and dynamic postural control in low-vision and normal-vision adults." Clinics (Sao Paulo) **68**(4): 517-521.

Ustinaviciene, R. and V. Januskevicius (2006). "Association between occupational asthenopia and psycho-physiological indicators of visual strain in workers using video display terminals." Med Sci Monit **12**(7): CR296-301.

Varma, R., T. S. Vajaranant, B. Burkemper, S. Wu, M. Torres, C. Hsu, F. Choudhury and R. McKean-Cowdin (2016). "Visual Impairment and Blindness in Adults in the United States: Demographic and Geographic Variations From 2015 to 2050." JAMA Ophthalmol **134**(7): 802-809.

Webber, A. L., J. M. Wood, G. A. Gole and B. Brown (2008). "The effect of amblyopia on fine motor skills in children." Invest Ophthalmol Vis Sci **49**(2): 594-603.

Weir, C. R., P. C. Knox and G. N. Dutton (2000). "Does extraocular muscle proprioception influence oculomotor control?" Br J Ophthalmol **84**(9): 1071-1074.

Werner, J. S., D. H. Peterzell and A. J. Scheetz (1990). "Light, vision, and aging." Optom Vis Sci **67**(3): 214-229.

Vernon, H. (2008). "The Neck Disability Index: state-of-the-art, 1991-2008." J Manipulative Physiol Ther **31**(7): 491-502.

Westheimer, G. (2014). "The law of equal innervation of both eyes: Thomas Reid preceded Hering by a century. An historical note." Vision Res **101**: 32-33.

WHO (1995). "The World Health Organization Quality of Life assessment (WHOQOL): position paper from the World Health Organization." Social Science and Medicine **41**(10): 1403-1409.

WHO. (1999). "http://www.who.int/blindness/Change%20the%20Definition%20of%20Blindness.pdf .Change in definition of blindness."

Wiholm, C., Mathiassen S-E.,Richter, H., Toomingas,A. (2007). Association between Eyestrain and Neck-shooulder Symptoms among Call Centre operators. Scandinavian J Work Environmental & Health

Wijnhoven, H. A., H. C. de Vet and H. S. Picavet (2006). "Prevalence of musculoskeletal disorders is systematically higher in women than in men." Clin J Pain **22**(8): 717-724.

Wilkins, A., Huang,J., Cao,C (2004). "Visual stress theory and its application to reading and reading tests." Journal of Research and Reading **27**(2): 152-162.

Willis, J. R., S. E. Vitale, Y. Agrawal and P. Y. Ramulu (2013). "Visual impairment, uncorrected refractive error, and objectively measured balance in the United States." JAMA Ophthalmol **131**(8): 1049-1056.

Voleti, V. B. and J. P. Hubschman (2013). "Age-related eye disease." Maturitas **75**(1): 29-33.

Wong, W. L., X. Su, X. Li, C. M. Cheung, R. Klein, C. Y. Cheng and T. Y. Wong (2014). "Global prevalence of age-related macular degeneration and disease burden projection for 2020 and 2040: a systematic review and meta-analysis." Lancet Glob Health **2**(2): e106-116.

Wu, C. and D. G. Hunter (2006). "Amblyopia: diagnostic and therapeutic options." Am J Ophthalmol **141**(1): 175-184.

Yahia, A., S. Ghroubi, S. Jribi, J. Malla, S. Baklouti, A. Ghorbel and M. H. Elleuch (2009). "Chronic neck pain and vertigo: Is a true balance disorder present?" Ann Phys Rehabil Med **52**(7-8): 556-567.

Zetterberg, C., M. Forsman and H. O. Richter (2013). "Effects of visually demanding near work on trapezius muscle activity." J Electromyogr Kinesiol **23**(5): 1190-1198.

Zetterberg, C., H. O. Richter and M. Forsman (2015). "Temporal Co-Variation between Eye Lens Accommodation and Trapezius Muscle Activity during a Dynamic Near-Far Visual Task." PLoS One **10**(5): e0126578.

Zhang, L., Y. Q. Zhang, J. S. Zhang, L. Xu and J. B. Jonas (2013). "Visual fatigue and discomfort after stereoscopic display viewing." Acta Ophthalmol **91**(2): e149-153.

PUBLICATIONS *in the series*
ÖREBRO STUDIES IN MEDICINE

1. Bergemalm, Per-Olof (2004). *Audiologic and cognitive long-term sequelae from closed head injury.*
2. Jansson, Kjell (2004). *Intraperitoneal Microdialysis. Technique and Results.*
3. Windahl, Torgny (2004). *Clinical aspects of laser treatment of lichen sclerosus and squamous cell carcinoma of the penis.*
4. Carlsson, Per-Inge (2004). *Hearing impairment and deafness. Genetic and environmental factors – interactions – consequences. A clinical audiological approach.*
5. Wågsäter, Dick (2005). *CXCL16 and CD137 in Atherosclerosis.*
6. Jatta, Ken (2006). *Inflammation in Atherosclerosis.*
7. Dreifaldt, Ann Charlotte (2006). *Epidemiological Aspects on Malignant Diseases in Childhood.*
8. Jurstrand, Margaretha (2006). *Detection of Chlamydia trachomatis and Mycoplasma genitalium by genetic and serological methods.*
9. Norén, Torbjörn (2006). *Clostridium difficile, epidemiology and antibiotic resistance.*
10. Anderzén Carlsson, Agneta (2007). *Children with Cancer – Focusing on their Fear and on how their Fear is Handled.*
11. Ocaya, Pauline (2007). *Retinoid metabolism and signalling in vascular smooth muscle cells.*
12. Nilsson, Andreas (2008). *Physical activity assessed by accelerometry in children.*
13. Eliasson, Henrik (2008). *Tularemia – epidemiological, clinical and diagnostic aspects.*
14. Walldén, Jakob (2008). *The influence of opioids on gastric function: experimental and clinical studies.*
15. Andrén, Ove (2008). *Natural history and prognostic factors in localized prostate cancer.*
16. Svantesson, Mia (2008). *Postpone death? Nurse-physician perspectives and ethics rounds.*

17. Björk, Tabita (2008). *Measuring Eating Disorder Outcome – Definitions, dropouts and patients' perspectives.*
18. Ahlsson, Anders (2008). *Atrial Fibrillation in Cardiac Surgery.*
19. Parihar, Vishal Singh (2008). *Human Listeriosis – Sources and Routes.*
20. Berglund, Carolina (2008). *Molecular Epidemiology of Methicillin-Resistant Staphylococcus aureus. Epidemiological aspects of MRSA and the dissemination in the community and in hospitals.*
21. Nilsagård, Ylva (2008). *Walking ability, balance and accidental falls in persons with Multiple Sclerosis.*
22. Johansson, Ann-Christin (2008). *Psychosocial factors in patients with lumbar disc herniation: Enhancing postoperative outcome by the identification of predictive factors and optimised physiotherapy.*
23. Larsson, Matz (2008). *Secondary exposure to inhaled tobacco products.*
24. Hahn-Strömberg, Victoria (2008). *Cell adhesion proteins in different invasive patterns of colon carcinoma: A morphometric and molecular genetic study.*
25. Böttiger, Anna (2008). *Genetic Variation in the Folate Receptor-α and Methylenetetrahydrofolate Reductase Genes as Determinants of Plasma Homocysteine Concentrations.*
26. Andersson, Gunnel (2009). *Urinary incontinence. Prevalence, treatment seeking behaviour, experiences and perceptions among persons with and without urinary leakage.*
27. Elfström, Peter (2009). *Associated disorders in celiac disease.*
28. Skårberg, Kurt (2009). *Anabolic-androgenic steroid users in treatment: Social background, drug use patterns and criminality.*
29. de Man Lapidoth, Joakim (2009). *Binge Eating and Obesity Treatment – Prevalence, Measurement and Long-term Outcome.*
30. Vumma, Ravi (2009). *Functional Characterization of Tyrosine and Tryptophan Transport in Fibroblasts from Healthy Controls, Patients with Schizophrenia and Bipolar Disorder.*
31. Jacobsson, Susanne (2009). *Characterisation of Neisseria meningitidis from a virulence and immunogenic perspective that includes variations in novel vaccine antigens.*

32. Allvin, Renée (2009). *Postoperative Recovery. Development of a Multi-Dimensional Questionnaire for Assessment of Recovery.*

33. Hagnelius, Nils-Olof (2009). *Vascular Mechanisms in Dementia with Special Reference to Folate and Fibrinolysis.*

34. Duberg, Ann-Sofi (2009). *Hepatitis C virus infection. A nationwide study of assiciated morbidity and mortality.*

35. Söderqvist, Fredrik (2009). *Health symptoms and potential effects on the blood-brain and blood-cerebrospinal fluid barriers associated with use of wireless telephones.*

36. Neander, Kerstin (2009). *Indispensable Interaction. Parents' perspectives on parent–child interaction interventions and beneficial meetings.*

37. Ekwall, Eva (2009). *Women's Experiences of Gynecological Cancer and Interaction with the Health Care System through Different Phases of the Disease.*

38. Thulin Hedberg, Sara (2009). *Antibiotic susceptibility and resistance in Neisseria meningitidis – phenotypic and genotypic characteristics.*

39. Hammer, Ann (2010). *Forced use on arm function after stroke. Clinically rated and self-reported outcome and measurement during the sub-acute phase.*

40. Westman, Anders (2010). *Musculoskeletal pain in primary health care: A biopsychosocial perspective for assessment and treatment.*

41. Gustafsson, Sanna Aila (2010). *The importance of being thin – Perceived expectations from self and others and the effect on self-evaluation in girls with disordered eating.*

42. Johansson, Bengt (2010). *Long-term outcome research on PDR brachytherapy with focus on breast, base of tongue and lip cancer.*

43. Tina, Elisabet (2010). *Biological markers in breast cancer and acute leukaemia with focus on drug resistance.*

44. Overmeer, Thomas (2010). *Implementing psychosocial factors in physical therapy treatment for patients with musculoskeletal pain in primary care.*

45. Prenkert, Malin (2010). *On mechanisms of drug resistance in acute myloid leukemia.*

46. de Leon, Alex (2010). *Effects of Anesthesia on Esophageal Sphincters in Obese Patients.*

47. Josefson, Anna (2010). *Nickel allergy and hand eczema – epidemiological aspects.*

48. Almon, Ricardo (2010). *Lactase Persistence and Lactase Non-Persistence. Prevalence, influence on body fat, body height, and relation to the metabolic syndrome.*

49. Ohlin, Andreas (2010). *Aspects on early diagnosis of neonatal sepsis.*

50. Oliynyk, Igor (2010). *Advances in Pharmacological Treatment of Cystic Fibrosis.*

51. Franzén, Karin (2011). *Interventions for Urinary Incontinence in Women. Survey and effects on population and patient level.*

52. Loiske, Karin (2011). *Echocardiographic measurements of the heart. With focus on the right ventricle.*

53. Hellmark, Bengt (2011). *Genotypic and phenotypic characterisation of* ***Staphylococcus epidermidis*** *isolated from prosthetic joint infections.*

54. Eriksson Crommert, Martin (2011). *On the role of transversus abdominis in trunk motor control.*

55. Ahlstrand, Rebecca (2011). *Effects of Anesthesia on Esophageal Sphincters.*

56. Holländare, Fredrik (2011). *Managing Depression via the Internet – self-report measures, treatment & relapse prevention.*

57. Johansson, Jessica (2011). *Amino Acid Transport and Receptor Binding Properties in Neuropsychiatric Disorders using the Fibroblast Cell Model.*

58. Vidlund, Mårten (2011). *Glutamate for Metabolic Intervention in Coronary Surgery with special reference to the GLUTAMICS-trial.*

59. Zakrisson, Ann-Britt (2011). *Management of patients with Chronic Obstructive Pulmonary Disease in Primary Health Care. A study of a nurse-led multidisciplinary programme of pulmonary rehabilitation.*

60. Lindgren, Rickard (2011). *Aspects of anastomotic leakage, anorectal function and defunctioning stoma in Low Anterior Resection of the rectum for cancer.*

61. Karlsson, Christina (2011). *Biomarkers in non-small cell lung carcinoma. Methodological aspects and influence of gender, histology and smoking habits on estrogen receptor and epidermal growth factor family receptor signalling.*

62. Varelogianni, Georgia (2011). *Chloride Transport and Inflammation in Cystic Fibrosis Airways.*

63. Makdoumi, Karim (2011). *Ultraviolet Light A (UVA) Photoactivation of Riboflavin as a Potential Therapy for Infectious Keratitis.*

64. Nordin Olsson, Inger (2012). *Rational drug treatment in the elderly: "To treat or not to treat".*

65. Fadl, Helena (2012). *Gestational diabetes mellitus in Sweden: screening, outcomes, and consequences.*

66. Essving, Per (2012). *Local Infiltration Analgesia in Knee Arthroplasty.*

67. Thuresson, Marie (2012). *The Initial Phase of an Acute Coronary Syndrome. Symptoms, patients' response to symptoms and opportunity to reduce time to seek care and to increase ambulance use.*

68. Mårild, Karl (2012). *Risk Factors and Associated Disorders of Celiac Disease.*

69. Fant, Federica (2012). *Optimization of the Perioperative Anaesthetic Care for Prostate Cancer Surgery. Clinical studies on Pain, Stress Response and Immunomodulation.*

70. Almroth, Henrik (2012). *Atrial Fibrillation: Inflammatory and pharmacological studies.*

71. Elmabsout, Ali Ateia (2012). *CYP26B1 as regulator of retinoic acid in vascular cells and atherosclerotic lesions.*

72. Stenberg, Reidun (2012). *Dietary antibodies and gluten related seromarkers in children and young adults with cerebral palsy.*

73. Skeppner, Elisabeth (2012). *Penile Carcinoma: From First Symptom to Sexual Function and Life Satisfaction. Following Organ-Sparing Laser Treatment.*

74. Carlsson, Jessica (2012). *Identification of miRNA expression profiles for diagnosis and prognosis of prostate cancer.*

75. Gustavsson, Anders (2012): *Therapy in Inflammatory Bowel Disease.*

76. Paulson Karlsson, Gunilla (2012): *Anorexia nervosa – treatment expectations, outcome and satisfaction.*

77. Larzon, Thomas (2012): *Aspects of endovascular treatment of abdominal aortic aneurysms.*

78. Magnusson, Niklas (2012): *Postoperative aspects of inguinal hernia surgery – pain and recurrences.*

79. Khalili, Payam (2012): *Risk factors for cardiovascular events and incident hospital-treated diabetes in the population.*

80. Gabrielson, Marike (2013): *The mitochondrial protein SLC25A43 and its possible role in HER2-positive breast cancer.*

81. Falck, Eva (2013): *Genomic and genetic alterations in endometrial adenocarcinoma.*

82. Svensson, Maria A (2013): *Assessing the ERG rearrangement for clinical use in patients with prostate cancer.*

83. Lönn, Johanna (2013): *The role of periodontitis and hepatocyte growth factor in systemic inflammation.*

84. Kumawat, Ashok Kumar (2013): *Adaptive Immune Responses in the Intestinal Mucosa of Microscopic Colitis Patients.*

85. Nordenskjöld, Axel (2013): *Electroconvulsive therapy for depression.*

86. Davidsson, Sabina (2013): *Infection induced chronic inflammation and its association with prostate cancer initiation and progression.*

87. Johansson, Benny (2013): *No touch vein harvesting technique in coronary by-pass surgery. Impact on patency rate, development of atherosclerosis, left ventricular function and clinical outcome during 16 years follow-up.*

88. Sahdo, Berolla (2013): *Inflammasomes: defense guardians in host-microbe interactions.*

89. Hörer, Tal (2013): *Early detection of major surgical postoperative complications evaluated by microdialysis.*

90. Malakkaran Lindqvist, Breezy (2013): *Biological signature of HER2-positive breast cancer.*

91. Lidén, Mats (2013): *The stack mode review of volumetric datasets – applications for urinary stone disease.*

92. Emilsson, Louise (2013): *Cardiac Complications in Celiac Disease.*

93. Dreifaldt, Mats (2013): *Conduits in coronary artery bypass grafting surgery: Saphenous vein, radial and internal thoracic arteries.*

94. Perniola, Andrea (2013): *A new technique for postoperative pain management with local anaesthetic after abdominal hysterectomy.*

95. Ahlstrand, Erik (2013): *Coagulase-negative Staphylococci in Hematological Malignancy.*

96. Sundh, Josefin (2013): *Quality of life, mortality and exacerbations in COPD.*

97. Skoog, Per (2013): *On the metabolic consequences of abdominal compartment syndrome.*

98. Palmetun Ekbäck, Maria (2013): *Hirsutism and Quality of Life with Aspects on Social Support, Anxiety and Depression.*

99. Hussain, Rashida (2013): *Cell Responses in Infected and Cystic Fibrosis Respiratory Epithelium.*

100. Farkas, Sanja (2014): *DNA methylation in the placenta and in cancer with special reference to folate transporting genes.*

101. Jildenstål, Pether (2014): *Influence of depth of anaesthesia on post-operative cognitive dysfunction (POCD) and inflammatory marker.*

102. Söderström, Ulf (2014): *Type 1 diabetes in children with non-Swedish background – epidemiology and clinical outcome*

103. Wilhelmsson Göstas, Mona (2014): *Psychotherapy patients in mental health care: Attachment styles, interpersonal problems and therapy experiences*

104. Jarl, Gustav (2014): *The Orthotics and Prosthetics Users´ Survey: Translation and validity evidence for the Swedish version*

105. Demirel, Isak (2014): *Uropathogenic Escherichia coli, multidrug-resistance and induction of host defense mechanisms*

106. Mohseni, Shahin (2014): *The role of ß-blockade and anticoagulation therapy in traumatic brain injury*

107. Bašić, Vladimir T. (2014): *Molecular mechanisms mediating development of pulmonary cachexia in COPD*

108. Kirrander, Peter (2014): *Penile Cancer: Studies on Prognostic Factors*

109. Törös, Bianca (2014): *Genome-based characterization of Neisseria meningitidis with focus on the emergent serogroup Y disease*

110. von Beckerath, Mathias (2014): *Photodynamic therapy in the Head and Neck*

111. Waldenborg, Micael (2014): *Echocardiographic measurements at Takotsubo cardiomyopathy - transient left ventricular dysfunction.*

112. Lillsunde Larsson, Gabriella (2014): *Characterization of HPV-induced vaginal and vulvar carcinoma.*

113. Palm, Eleonor (2015): *Inflammatory responses of gingival fibroblasts in the interaction with the periodontal pathogen Porphyromonas gingivlis.*

114. Sundin, Johanna (2015): *Microbe-Host Interactions in Post-infectious Irritable Bowel Syndrome.*

115. Olsson, Lovisa (2015): *Subjective well-being in old age and its association with biochemical and genetic biomarkers and with physical activity.*

116. Klarström Engström, Kristin (2015): *Platelets as immune cells in sensing bacterial infection.*

117. Landström, Fredrik (2015): *Curative Electrochemotherapy in the Head and Neck Area.*

118. Jurcevic, Sanja (2015): *MicroRNA expression profiling in endometrial adenocarcinoma.*

119. Savilampi, Johanna (2015): *Effects of Remifentanil on Esophageal Sphincters and Swallowing Function.*

120. Pelto-Piri, Veikko (2015): *Ethical considerations in psychiatric inpatient care. The ethical landscape in everyday practice as described by staff.*

121. Athlin, Simon (2015): *Detection of Polysaccharides and Polysaccharide Antibodies in Pneumococcal Pneumonia.*

122. Evert, Jasmine (2015): *Molecular Studies of Radiotheray and Chemotherapy in Colorectal Cancer.*

123. Göthlin-Eremo, Anna (2015): *Biological profiles of endocrine breast cancer.*

124. Malm, Kerstin (2015): *Diagnostic strategies for blood borne infections in Sweden.*

125. Kumakech, Edward (2015): *Human Immunodeficiency Virus (HIV), Human Papillomavirus (HPV) and Cervical Cancer Prevention in Uganda: Prevalence, Risk factors, Benefits and Challenges of Post-Exposure Prophylaxis, Screening Integration and Vaccination.*

126. Thunborg, Charlotta (2015): *Exploring dementia care dyads' person transfer situations from a behavioral medicine perspective in physiotherapy. Development of an assessmement scale.*

127. Zhang, Boxi (2015): *Modulaton of gene expression in human aortic smooth muscle cells by Porphyromonas gingivalis - a possible association between periodontitis and atherosclerosis.*

128. Nyberg, Jan (2015): *On implant integration in irradiated bone: - clinical and experimental studies.*

129. Brocki, Barbara C. (2015): *Physiotherapy interventions and outcomes following lung cancer surgery.*

130. Ulfenborg, Benjamin (2016): *Bioinformatics tools for discovery and evaluation of biomarkers. Applications in clinical assessment of cancer.*

131. Lindström, Caisa (2016): *Burnout in parents of chronically ill children.*

132. Günaltay, Sezin (2016): *Dysregulated Mucosal Immune Responses in Microscopic Colitis Patients.*

133. Koskela von Sydow, Anita (2016): *Regulation of fibroblast activity by keratinocytes, TGF-β and IL-1α –studies in two- and three dimensional in vitro models.*

134. Kozlowski, Piotr (2016): *Prognostic factors, treatment and outcome in adult acute lymphoblastic leukemia. Population-based studies in Sweden.*

135. Darvish, Bijan (2016): *Post-Dural Puncture Headache in Obstetrics. Audiological, Clinical and Epidemiological studies.*

136. Sahlberg Bang, Charlotte (2016): *Carbon monoxide and nitric oxide as antimicrobial agents – focus on ESBL-producing uropathogenic E. coli.*

137. Alshamari, Muhammed (2016): *Low-dose computed tomography of the abdomen and lumbar spine.*

138. Jayaprakash, Kartheyaene (2016): *Monocyte and Neutrophil Inflammatory Responses to the Periodontopathogen Porphyromonas gingivalis.*

139. Elwin Marie (2016): *Description and measurement of sensory symptoms in autism spectrum.*

140. Östlund Lagerström, Lina (2016): *"The gut matters" - an interdisciplinary approach to health and gut function in older adults.*

141. Zhulina, Yaroslava (2016): *Crohn's disease; aspects of epidemiology, clinical course, and fecal calprotectin.*

142. Nordenskjöld, Anna (2016): *Unrecognized myocardial infarction and cardiac biochemical markers in patients with stable coronary artery disease.*

143. Floodeen, Hannah (2016): *Defunctioning stoma in low anterior resection of the rectum for cancer: Aspects of stoma reversal, anastomotic leakage, anorectal function, and cost-effectiveness.*

144. Duberg, Anna (2016): *Dance Intervention for Adolescent Girls with Internalizing Problems. Effects and Experiences.*

145. Samano, Ninos (2016): *No-Touch Saphenous Veins in Coronary Artery Bypass Grafting. Long-term Angiographic, Surgical, and Clinical Aspects.*

146. Rönnberg, Ann-Kristin (2016): *Gestational Weight Gain. Implications of an Antenatal Lifestyle Intervention.*

147. Erik Stenberg (2016): *Preventing complications in bariatric surgery.*

148. Humble, Mats B. (2016): *Obsessive-compulsive disorder, serotonin and oxytocin: treatment response and side effects.*

149. Asfaw Idosa, Berhane (2016): *Inflammasome Polymorphisms and the Inflammatory Response to Bacterial Infections.*

150. Sagerfors, Marcus (2016): *Total wrist arthroplasty. A clinical, radiographic and biomechanical investigation.*

151. Nakka, Sravya Sowdamini (2016): *Development of novel tools for prevention and diagnosis of Porphyromonas gingivalis infection and periodontitis.*

152. Jorstig, Stina (2016): *On the assessment of right ventricular function using cardiac magnetic resonance imaging and echocardiography.*

153. Logotheti, Marianthi (2016): *Integration of Functional Genomics and Data Mining Methodologies in the Study of Bipolar Disorder and Schizophrenia.*

154. Paramel Varghese, Geena (2017): *Innate Immunity in Human Atherosclerosis and Myocardial Infarction: Role of CARD8 and NLRP3.*

155. Melinder, Carren Anyango (2017): *Physical and psychological characteristics in adolescence and risk of gastrointestinal disease in adulthood.*

156. Bergh, Cecilia (2017): *Life-course influences on occurrence and outcome for stroke and coronary heart disease.*

157. Olsson, Emma (2017): *Promoting Health in Premature Infants – with special focus on skin-to-skin contact and development of valid pain assessment.*

158. Rasmussen, Gunlög (2017): *Staphylococcus aureus bacteremia, molecular epidemiology and host immune response.*

159. Bohr Mordhorst, Louise (2017): *Predictive and prognostic factors in cervical carcinomas treated with (chemo-) radiotherapy.*

160. Wickbom, Anna (2017): *Epidemiological aspects of Microscopic Colitis.*

161. Cajander, Sara (2017): *Dynamics of Human Leukocyte Antigen – D Related expression in bacteremic sepsis.*

162. Zetterlund, Christina (2017): *Visual, musculoskeletal and balance symptoms in people with visual impairments.*