Linnéuniversitetet
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Master's Thesis

The relationship between uncorrected vertical heterophoria and headache disorders: A clinical perspective

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University: Linnaeus University

Term: VT25-HT25
Subject: Optometry
Level: Master's

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Abstract

Background: Vertical heterophoria is a form of binocular vision dysfunction associated with symptoms of headache and asthenopia. Headache disorders, including migraine, are highly prevalent worldwide. Although vertical heterophoria and migraine present with overlapping symptoms, such as headache, visual strain and dizziness, vertical heterophoria is not routinely screened in patients presenting with headache disorders in optometry clinics. Despite the clinical overlap, research exploring the association between these conditions remains limited.

Aim: The aim of this thesis was to investigate whether subtle vertical heterophoria is underdiagnosed among individuals with headache disorders. To that end, we estimated the frequency, magnitude, and associated symptoms of vertical heterophoria in individuals with headache disorders compared to a headache-free control group.

Method: In this case-control study, individuals with migraine and/or frequent headache (N = 32) were examined for vertical heterophoria and compared with a control group (N = 17). All participants underwent assessments of vertical dissociated and vertical associated phoria using standard clinical procedures. Symptoms profiles were evaluated using the Binocular Vision Dysfunction Questionnaire (BVDQ) and Symptom Severity Index (SSI).

Results: The case group demonstrated a higher proportion ($p < 0.001$) and larger median value ($p < 0.001$) of vertical associated phoria (i.e. fixation disparity) compared with control group. However, no statistically significant differences were found between the groups regarding dissociated phoria tests. The case group also had significantly higher median scores on the BVDQ ($p < 0.001$) and the SSI ($p < 0.001$) compared with controls. Multiple regression analysis revealed a clear association between group affiliation and symptom severity for both BVDQ ($p = 0.002$) and SSI ($p < 0.001$) but no significant relationship with presence of vertical associated heterophoria.

Conclusion: The findings suggest that vertical associated heterophoria is more prevalent among individuals with headache disorders and highlights the importance of including screening for vertical heterophoria in the evaluation of patients with headache and migraine.

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Sammanfattning

Bakgrund: Vertikal heterofori är en form av samsynsproblem som är associerad med symptom av huvudvärk och asthenopi. Huvudvärkssjukdomar, inklusive migrän, är vanligt förekommande i hela världen. Även om vertikal heterofori och migrän uppvisar överlappande symtom, såsom huvudvärk, visuell ansträngning och yrsel, ingår inte screening för vertikal heterofori rutinmässigt i undersökningens av patienter med huvudvärks problematik hos optiker. Trots den kliniska symptomöverlappningen är forskningen som undersöker sambandet mellan dessa tillstånd fortfarande begränsad.

Syfte: Syftet med denna studie var att undersöka om vertikal heterofori är underdiagnostiserat hos individer med huvudvärkssjukdomar genom att studera förekomst, magnitud och associerade symptom hos individer med huvudvärkssjukdomar jämfört med en huvudvärksfri kontrollgrupp.

Metod: Denna fall-kontrollstudie undersöktes individer med migrän och/eller frekvent huvudvärk (N = 32) avseende vertikal heterofori, resultaten jämfördes med en kontrollgrupp (N = 17). Samtliga deltagare genomgick tester av dissocierad och associerad vertikal fori. Symptom utvärderades med Binocular Vision Dysfunction Questionnaire (BVDQ) och Symptom Severity Index (SSI).

Resultat: Fall-gruppen uppvisade en större andel ($p < 0.001$) och högre medianvärde ($p < 0.001$) av vertikal associerad fori (fixationsdisparitet) jämfört med kontrollgruppen. Däremot sågs inga statistiskt signifikanta skillnader mellan grupperna avseende de dissocierade testen. Fall-gruppen hade även signifikant högre värden på både BVDQ ($p < 0.001$) och SSI ($p < 0.001$) jämfört med kontrollgruppen. Multipel regressionsanalys bekräftade ett tydligt samband mellan grupptillhörighet och symtomnivå för både BVDQ ($p = 0.002$) och SSI ($p < 0.001$).

Slutsats: Fynden tyder på att associerad vertikal heterofori är vanligare hos individer med huvudvärkssjukdomar och understryker vikten av att inkludera screening för vertikal heterofori vid utredning av patienter med huvudvärk och migrän.

Nyckelord: Vertikal heterofori, huvudvärk, migrän, samsynsproblem, associerad fori fixationsdisparitet, optometri

Acknowledgements

Writing this thesis initially felt like an impossible task, but as the project progressed, it gradually provided me with valuable insights and new knowledge. Throughout the process, I have discovered how enjoyable, stimulating, and rewarding research can be, and I have come to appreciate that learning is a continual journey.

I would like to express my sincere gratitude to my supervisor, Senior Lecturer **Kabilan Pitchaimuthu** at Linnaeus University, for his insightful guidance and constructive support throughout this work. I am equally grateful to Professor **Antonio Teixeira Macedo**, examiner and head of the Master's programme at Linnaeus University, whose dedication to research opened my eyes to the field and encouraged me to pursue this thesis.

My heartfelt thanks also go to all **participants in the study**. Your willingness to take part made this research possible and has contributed to a deeper understanding of vertical heterophoria and headache disorders. I am especially grateful to my husband, **Andreas**, who has stood by my side throughout this process. His support, care, and encouragement have meant more to me than words can express. Finally, I wish to thank my employer, **Marie Nilsson Hansson** at Svedala Optik, for her unwavering support during moments of low motivation, as well as for providing access to the facilities that made all examinations in this thesis possible.

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Introduction

Vertical heterophoria

Vertical heterophoria is a form of latent strabismus and binocular vision dysfunction characterized by a vertical misalignment of the visual axes, in which one eye perceives the image higher than the other. Vertical heterophoria can be classified as either hyperphoria, an upward deviation, or hypophoria, a downward deviation of the eye. If one eye is hyperphoric, the fellow eye will be hypophoric[1]. It is widely accepted to diagnose vertical heterophoria by referring to the eye exhibiting the upward deviation as the hyperphoric eye (Scheiman and Wick, 2020). Vertical heterophoria is compensated by activation of the elevator and depressor extraocular muscles to avoid diplopia, however, chronic compensatory effort may lead to muscular strain and fatigue (Weigel, 2012). The proprioceptive nerve fibers from the extraocular muscles provide feedback regarding ocular position, contributing to fine adjustments that correct minor misalignments. These signals are transmitted via the ophthalmic branch of the trigeminal nerve to the visual cortex (Digre, 2018). Research suggests that these proprioceptive signals may simultaneously stimulate the trigeminal nerve, which innervates the face and ocular structures. This neuroanatomical connection has been proposed as a potential pathway linking binocular vision dysfunction to headache related symptoms (Karpecki, 2018).

Symptoms of vertical heterophoria include asthenopia, headache, intermittent diplopia, blurred vision, motion sickness and reading difficulties. Additional associated signs include migraine, head tilt, dizziness, neck pain, anxiety and light sensitivity (Doble et al., 2010; Scheiman and Wick, 2020). Resent research has demonstrated that symptoms traditionally attributed to vertical heterophoria, such as diplopia, monocular eye closure, and overlapping vision,

[1] This is due to Hering's law of equal innervation to yoked muscles. This is followed in all cases of vertical deviation except in cases of dissociated vertical deviation (Evans, 2021).

are reported by only 23.4–39.5% of affected individuals. In contrast, the most common symptoms, reported by 71.1–86.8%, include headache, neck pain, dizziness, and light sensitivity (Feinberg et al., 2020; Rosner et al., 2016), all symptoms frequently associated with migraine. This may indicate a potential association between the two conditions.

The etiology of vertical heterophoria is often related to congenital facial asymmetry, in which one eye is positioned slightly superior to the other (Evans, 2021; Rosner and Feinberg, 2012). It may also arise from traumatic brain injury, damage to cranial nerve IV, or paresis of the ocular muscle superior oblique (Doble et al., 2010). In cases of cranial nerve VI paresis or lesion, the vertical deviation is typically large, with associated excyclorotation that becomes larger in downward gaze and varies with gaze direction (Lyons and Lambert, 2022). By contrast, a vertical phoria typically measures less than 3.0 prism diopters (pd) and, because it is unaffected by convergence, is generally consistent at both near and far distance fixation (Evans, 2021).

The prevalence of vertical heterophoria is estimated to be approximately 20% in the general population (Jackson and Bedell, 2012; Scheiman and Wick, 2020). Reported prevalence varies considerably across studies, largely due to differences in measurement techniques, sample characteristics, and the operational definition of vertical heterophoria. Vertical heterophoria up to 0.50 pd at distance and near are generally considered within normal limits (Elliott, 2014), although some studies regard values up to 1.0 pd as physiologically normal (Matheron et al., 2007; Matheron and Kapoula, 2011).

Vertical heterophoria is commonly managed with vertical prism correction, which has been shown to effectively reduce symptoms (Evans, 2021; Feinberg et al., 2020; Rosner et al., 2016; Weigel, 2012). Even a prism correction as small as 0.50 pd may produce substantial improvement in patient comfort and binocular function (Weigel, 2012). In contrast, visual training aimed at improving vertical vergence has not demonstrated consistent therapeutic benefit (Evans, 2021).

Common clinical tests for evaluating vertical heterophoria include cover test, dissociated phoria tests, associated phoria tests, vertical fusional vergence and prism flipper test. A combination of these tests is necessary, as no single test reliably predicts the true magnitude of the vertical phoria (Feinberg et al., 2020; Weigel, 2012). Dissociated tests, such as Maddox rod, Von Graefe and modified Thorington tests, measure phoria by disrupting fusion, whereas associated tests, such as fixation disparity testing, maintains fusion during testing (Scheiman and Wick, 2020). The vertical fixation disparity test has long been considered the gold standard for determining the optimal vertical prism correction, as the amount of prism required to reduce fixation disparity to zero can be safely prescribed to alleviate symptoms (Rutstein and Eskridge, 1986).

Examining and diagnosing vertical heterophoria can be challenging since traditional methods are not always reliable for estimating its true magnitude and direction (Casillas and Rosenfield, 2006). The direction of head tilt, when present, was found by Feinberg et al., (2020) and Rosner et al., (2016) as the most reliable indicator of vertical phoria direction. Diagnosis is further complicated by muscle tension, which may mask a latent heterophoria during routine testing. Occlusion of one eye for 24 hours has been shown to unmask the total vertical phoria (Surdacki and Wick, 1991). A latent heterophoria may decompensate due to stressors affecting the visual system or overall physiological state, leading to symptoms in patients who were previously asymptomatic (Evans, 2021).

Although Swedish optometrists possess knowledge of binocular vision dysfunction, relatively few actively assess or manage such conditions. Among those who do, tests for vertical heterophoria is seldom included since the focus is primarily on horizontal heterophoria and accommodative dysfunction (Janse, 2011; Shakirova and Pullola, 2021). This presents a significant risk that individuals experiencing headache and asthenopic symptoms due to vertical heterophoria may remain both undiagnosed and untreated.

Headache disorders

Headache disorder is very common and can present in different forms. These are divided into several distinct categories and are classified as either primary or secondary. The primary headache types include migraine, tension-type headache, and trigeminal autonomic cephalalgias (e.g., cluster headache) (Headache Classification Committee of the International Headache Society (IHS), 2013). Asthenopia is a common form of secondary headache and is defined as a condition characterized by ocular fatigue accompanied by subjective symptoms such as eye strain, discomfort, tearing, and headache that arise during visual tasks. Individuals with asthenopia may experience pain in or around the eyes, headaches, fatigue, and dizziness, along with secondary symptoms such as nausea, periocular muscle twitching, and migraine ("Asthenopia - EyeWiki," 2025).

Prevalence of migraine is high, and it is considered the third most common disease globally. Tension-type headache is also highly prevalent, affecting 30-78% of the population at some point during their lifetime. The most affected group is women aged 15-49 years (Headache Classification Committee of the International Headache Society (IHS), 2013). In Sweden, the estimated prevalence of migraine is approximately 15% in the general population, with women representing 65% of affected individuals (Sundholm and Linde, 2025).

Migraine is a neurological disorder with a genetic component, characterized by recurrent episodes of moderate to severe headache lasting 4-72 hours. The headache is typically unilateral, is exacerbated by physical activity, and is frequently accompanied by nausea as well as light and sound sensitivity (Pescador Ruschel and De Jesus, 2025). The condition is divided into several subtypes that may occur independently or concurrently. The two most common subtypes are migraine without aura and migraine with aura. Aura can present in various forms, affecting visual perception, sensory function, speech, motor function, or brainstem-related processes (van Dongen and Haan, 2019).

Tension-type headache is experienced as a mild to moderate, pressing or tightening pain, usually bilateral, and lasting from minutes to days. It is often described as feeling like a tight band around the head, with pressure over the crown or forehead. The pain does not worsen with physical activity and is not typically accompanied by nausea or sensitivity to light or sound ("Spänningshuvudvärk - Vårdgivare Skåne," 2024). Distinguishing tension-type headache from mild migraine without aura can be challenging, partly because many individuals with recurrent headaches experience both conditions simultaneously. Unilateral headache combined with light and sound sensitivity is often used to differentiate migraine from other headache types (van Dongen and Haan, 2019).

The pathophysiology of migraine and tension-type headache is not yet fully understood. Tension-type headache is believed to result from physical and psychological stressors that influence cerebral blood flow and modulate both peripheral and central pain mechanisms (Linde, 2025). Migraine, by contrast, is considered a neurological disorder involving an inherited susceptibility to abnormal sensory signal processing (Sundholm and Linde, 2025). The trigeminal nerve and the trigeminovascular system, which innervate blood vessels in parts of the meninges, are thought to play a central role in the migraine pain mechanism (Digre, 2018). During a migraine attack, these systems become activated, leading to dilation of meningeal blood vessels and stimulation of nociceptive fibers, which contributes to pain ("Migrän - Vårdgivare Skåne," 2024).

Treatment options for headache and migraine vary widely and aim both to alleviate symptoms and to prevent future attacks. Migraine is primarily treated with pain-relieving medications such as non-steroidal anti-inflammatory drugs (NSAIDs), while triptans and Calcitonin Gene-Related Peptide (CGRP) antagonists are also commonly used. Preventive strategies may include lifestyle modifications, beta-blockers, antidepressants, antiepileptic medications, and botulinum toxin injections (Pescador Ruschel and De Jesus, 2025). For tension-type headache, physiotherapy is recommended as the first-line intervention, including relaxation techniques, stress-reduction exercises, and massage. For occasional episodes, pain-relieving medications such as paracetamol and NSAIDs may be used, and in severe or chronic cases, antidepressants, hypnotics, or centrally acting analgesics can be considered as preventive treatments (Linde, 2025).

Motivation for the thesis

Previous studies investigating the relationship between migraine and binocular vision dysfunction have produced inconclusive results. Early case–control studies did not demonstrate clear differences in vertical heterophoria between individuals with migraine and controls (Evans et al., 2002; Harle and Evans, 2006). However, more recent research on vertical heterophoria has highlighted substantial symptom overlap with migraine and demonstrated marked symptom reduction following prismatic correction, even in cases of subtle vertical deviations (Doble et al., 2010; Feinberg et al., 2020; Rosner et al., 2016). Despite this, the prevalence and magnitude of subtle vertical heterophoria in individuals with headache disorders remain insufficiently investigated.

Aim

The aim of this thesis was to identify whether vertical heterophoria is underdiagnosed and more prevalent among individuals with headache disorders compared to a control group. More specifically, this thesis aimed to answer the following questions:

1. Is the proportion of individuals with vertical heterophoria higher in a group with migraine and/or frequent headache compared to a control group without headache disorder?

2. Is the magnitude of vertical heterophoria greater in individuals with migraine and/or frequent headache compared to a control group without headache disorder?

3. Are symptoms associated with vertical heterophoria more severe in individuals with migraine and/or frequent headache compared to a control group without headache disorder?

Based on the questions above, the following hypotheses were formulated:

H1: The proportion of individuals with vertical dissociated or vertical associated heterophoria is higher in individuals with migraine and/or frequent headache compared to controls.

H2: The magnitude of vertical dissociated and vertical associated heterophoria is greater in individuals with migraine and/or frequent headache compared to controls.

H3: Individuals with headache disorder will have higher scores in the Binocular Vision Dysfunction Questionnaire (BVDQ) and Symptom Severity Index (SSI) compared to controls.

Method

Design

This thesis is a case-control study comparing measurements of vertical heterophoria in individuals with migraine and/or frequent headache with a control group without headache disorder.

Recruitment

Participants were recruited through advertisements posted on social media where information about the thesis was shared in groups dedicated to migraine and headache, as well as in local community groups on Facebook, Instagram and LinkedIn. Posters with study information and invitations to participate were displayed at nearby health centers. The poster can be seen in Appendix I. In addition, individuals who had independently booked an eye examination at Svedala Optik were invited to participate. Recruitment and data collection took place between February and November 2025 at Svedala Optik in Svedala, Sweden.

Participants with migraine, both self-reported and formally diagnosed, and/or headache occurring ≥ 2 days per week during the past three months were included in the case group. Individuals with past or ongoing medical treatment for migraine were not excluded. Participants in the control group were age matched. Individuals in the control group had no history of migraine, reported no subjective headache complaints, or indicated only rare occurrences of headache.

In both groups, individuals were excluded if they had any known or suspected eye disease, history of strabismus treatment (patching or surgery), previously known binocular vision dysfunction, monocular best corrected visual acuity <1.0 decimal or suppression in one eye, see Table 1.

Table 1: Inclusion and exclusion criteria

Inclusion criteria	• Age 18 - 60 years • Case group: Reoccurring migraine and/or headache ≥ 2 days per week • Control group: No history of migraine and no to rare occurrences of headache
Exclusion criteria	• Known or suspected eye disease • History of strabismus • Known binocular vision dysfunction • Monocular visual acuity < 1.0 decimal • Supression of one eye

The sample size was based on results from Harle and Evans (2006), who investigated heterophoria in people with migraine. Although they measured both horizontal and vertical phoria using the Maddox rod test, they did not report vertical dissociated phoria. Therefore, the sample size calculation was based on their data for dissociated horizontal phoria. Their results showed that 19 of 24 (79%) individuals with migraine had horizontal phoria, compared to 8 of 25 (32%) in the control group. Using these data, with an alpha level of 0.05 and a power of 80% to detect a difference in proportions between two independent groups using Fisher's exact test, it was estimated that 21 participants per group were required. As vertical phoria was expected to be less prevalent than horizontal phoria, we aimed to recruit a minimum of 30 participants in each group.

Ethics

The thesis was conducted as part of a master's program and was therefore covered by the student exception in the Ethical Review Act. Nevertheless, the thesis adhered the ethical principles of the Declaration of Helsinki to ensure participants rights, safety, and well-being.

Participation in the study was voluntary, and participants could withdraw at any time without providing a reason. All participants were adults and informed about the study's purpose and procedures, both verbally and in writing, before any tests were conducted. Written consent was obtained from all participants, the information letter and consent form are provided in Appendix II. Collected personal data were coded and stored separately from the results to ensure confidentiality.

Instruments and procedure

To assess symptoms related to vertical heterophoria, participants completed the Binocular Vision Dysfunction Questionnaire (BVDQ) along with the accompanying Symptom Severity Index (SSI) (Feinberg et al., 2021), see Appendix III. The questionnaires are designed to identify individuals at risk for vertical heterophoria and other binocular vision dysfunctions. Participants completed the questionnaires prior to the assessment of vision-related parameters to ensure unbiased reporting of symptoms.

All examinations were performed under standardized conditions, utilizing the same examination room, identical equipment, and conducted by the same licensed optometrist to ensure consistency. Refraction and phoria measurements were conducted using the Zeiss Visuphor 500 at six meters. A cover-uncover test followed by alternating cover test was used to detect presence and direction of phoria and to exclude participants with tropia. The cover test was performed without correction, regardless of whether the participant normally used glasses or contact lenses. Both objective findings and the subjective responses were noted. Subjective refraction was determined using the fogging technique, applying maximum plus power for best visual acuity. Remaining tests were performed with the final refraction in the phoropter.

Dissociated phoria, horizontal and vertical, was assessed using the Von Graefe method and the Maddox rod test. Horizontal phoria was recorded in increments of 1.0 pd while vertical phoria in increments of 0.25 pd. Smooth vergence testing, performed at distance with Risley prisms, evaluated horizontal fusional vergence, positive and negative, and vertical fusional vergence, infra and supra. Prism values for horizontal vergence were recorded at blur, break, and recovery in increments of 1.0 pd, while for vertical vergence, break and recovery values were recorded in increments of 0.25 pd.

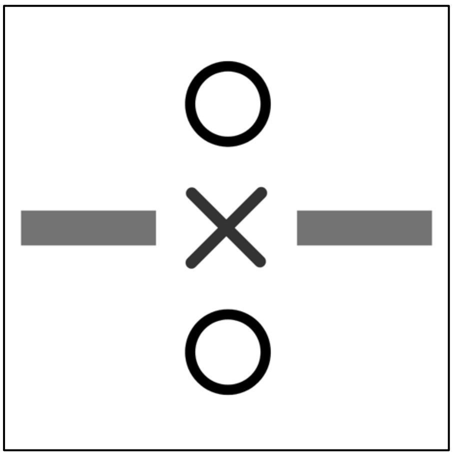

Figure 1: Mallett vertical fixation disparity target. Patients viewed the target while looking through polarized filters, both eyes seeing OXO which servs as a fusion lock. The right eye saw the right horizontal bar and the left eye saw the left bar. If the bars appear misaligned a vertical associated phoria is present.

Vertical associated phoria at distance was measured using a fixation disparity test. A chart with a central fixation target was used, see Figure 1, and polarizing filters were placed over both eyes. The smallest prism correction that reduced the fixation disparity to zero, using increments of 0.25 pd, was recorded. A detailed protocol for the method is provided in Appendix IV.

Statistical methods

Collected data were compiled in Microsoft Excel for Mac 2025 (Version 16.93). The data were later imported and analyzed with JASP (Version 0.95.3) (JASP Team, 2025). Descriptive statistics were performed, presenting counts and proportions for each category of qualitative variables, as well as median and interquartile ranges (IQR) for the quantitative variables.

To determine if the data were normally distributed, we used the Shapiro-Wilks test. Hypothesis H1, the differences in proportions between the groups, were analyzed using Fisher’s exact test. Hypotheses H2 and H3 was tested using the Mann-Whitney U test to assess whether there was a statistically significant difference in magnitude of phoria and symptom scores respectively between the groups.

Multiple linear regression analyses were conducted to examine whether presence of vertical associated phoria and group affiliation independently or collectively predicted symptom scores.

Results

Participant demographics

A total of 49 participants living in southern Sweden were included in the study. The case group consisted of 32 individuals, aged 19 to 59 years, who suffered from migraine and/or recurrent headache. Within the case group, 24 participants reported migraine in combination with headache, while 8 reported frequent tension-type headache. The frequency of migraine ranged from twice per year to several times per week. The age-matched control group comprised 17 individuals who did not experience migraine. Four of them reported rare occurrence of headache while thirteen reported no headache as far as they could remember. Both groups consisted predominantly of women. Demographic information is presented in Table 2.

Table 2: Demographics of the participants, median and Intra Quartile Range (IQR)

	Cases, n = 32	Controls, n = 17
Age*, median (IOR)	43.5 (32.8-47.0)	39.0 (33.0-49.0)
Sex, n (%)		
Female	28 (88)	13 (76)
Male	4 (12)	4 (24)

* Mann-Whitney U-test showed no statistically significant difference

Proportions of associated and dissociated vertical heterophoria

Vertical fixation disparity test revealed that 63% of participants in the case group demonstrated a vertical associated phoria, whereas only 12% of participants in the control group did so. The Von Graefe method showed that 84% of participants in the case group demonstrated a vertical dissociated phoria, compared to 71% in the control group. When assessed with the Maddox rod test, vertical dissociated phoria was detected in 72% of participants in the case group, compared to 59% of in the control group, see Table 3.

Table 3: Distribution of vertical phoria, divided by method and group affiliation

	Cases, n (%)		Controls, n (%)		
	Hyper	Ortho	Hyper	Ortho	p-value
Vertical Fixation disparity	20 (63)	12 (37)	2 (12)	15 (88)	<0.001
Vertical Von Graefe	27 (84)	5 (16)	12 (71)	5 (29)	0.285
Vertical Maddox rod	23 (72)	9 (28)	10 (59)	7 (41)	0.523

A statistically significant difference was observed between the groups regarding proportions of associated phoria measured with vertical fixation disparity test (Fisher's exact test; $p < 0.001$). The case group had a higher proportion of vertical associated heterophoria compared to controls. Additionally, 13 participants in the case group presented a vertical associated phoria >0.25 pd, while none of the controls did so, see inset panel in Figure 2. This difference was statistically significant (Fisher's exact test; $p = 0.002$). No significant differences were found regarding proportions of dissociated tests between the groups, Von Graefe (Fisher's exact test; $p = 0.285$) and Maddox rod (Fisher's exact test; $p = 0.523$). The results are summarized in Table 3, and the proportions are illustrated in Figure 2.

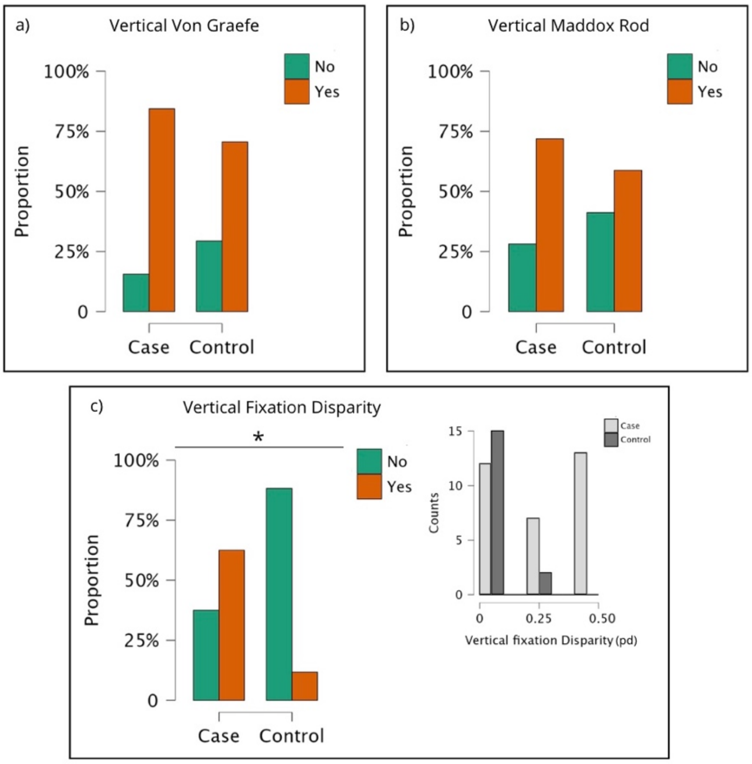

Figure 2: Proportions of participants exhibiting the presence ("Yes") or absence ("No") of vertical phoria, stratified by group. a) The Vertical Von Graefe test b) Vertical Maddox rod test c) Vertical Fixation Disparity, the inset panel illustrates the distribution of vertical associated phoria at each level for each group.

Magnitude of vertical heterophoria

The median vertical associated phoria in the case group was 0.25 pd (IQR 0.00-0.50), which differed significantly (Mann-Whitney U-test; $U = 423$, $p < 0.001$) from the control group, where the median value was 0.00 pd (IQR 0.00). For Von Graefe test, the median value was 0.50 pd (IQR 0.25-0.75) in the case group, compared with 0.25 pd (IQR 0.00-0.50) in the control group. This difference was not statistically significant (Mann-Whitney U-test; $U = 327.5$, $p = 0.235$). Similarly, no statistically significant difference was found between groups for the vertical Maddox rod test (Mann-Whitney U-test; $U = 329$, $p = 0.221$). The median value in the case group was 0.50 pd (IQR 0.00-0.75), compared to 0.25 pd (IQR 0.00-0.50) in the control group. Median values and IQRs are presented in Table 4, and the distribution of hyperphoria for each method is illustrated by boxplots in Figure 3.

Table 4: Median values and IQR of vertical phoria between groups

	Cases		Controls		
	Median	IQR	Median	IQR	p-value
Vertical Fixation disparity	0.25	0.00-0.50	0.00	0.00	<0.001
Vertical Von Graefe	0.50	0.25-0.75	0.25	0.00-0.50	0.235
Vertical Maddox rod	0.50	0.00-0.75	0.25	0.00-0.50	0.221

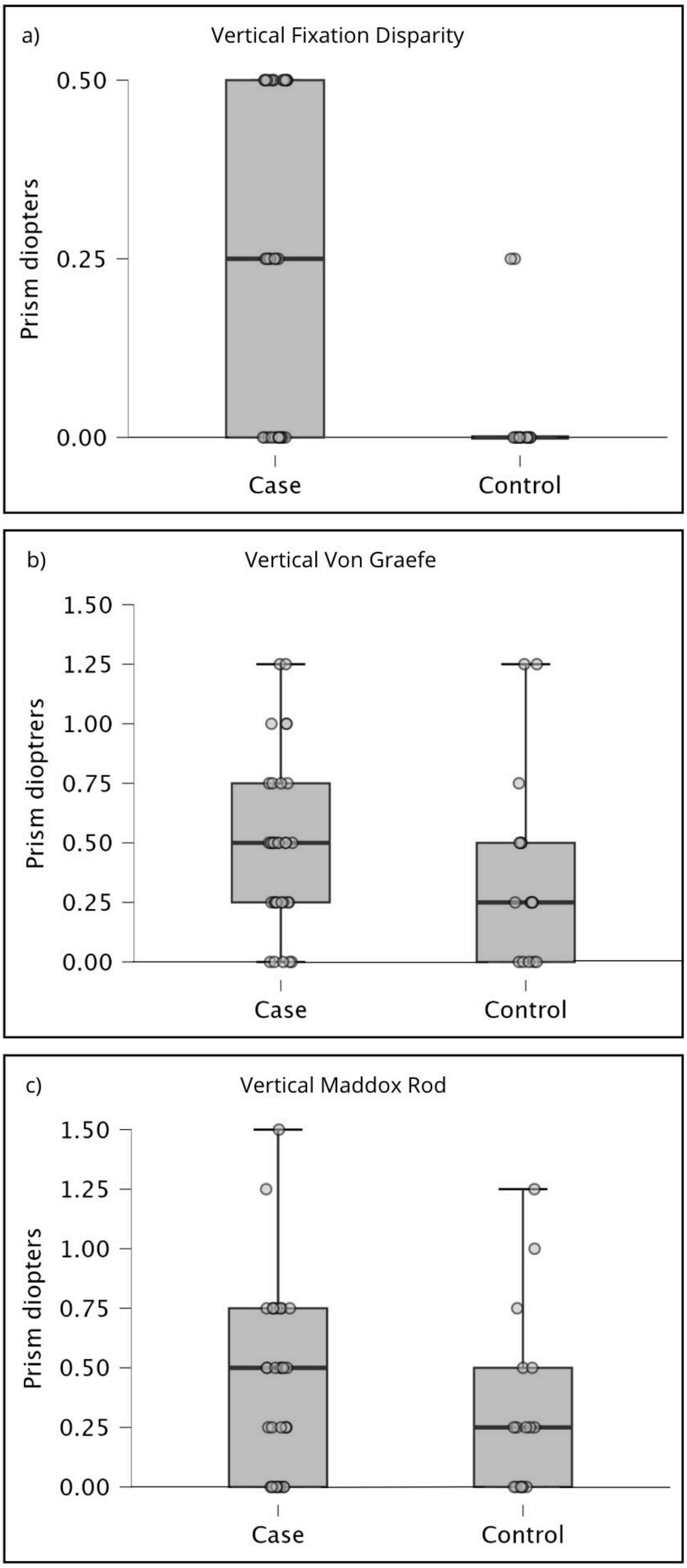

Figure 3: Box plots illustrating the distribution of hyperphoria among groups regarding the different methods, (a) Vertical fixation disparity (b) Vertical Von Graefe and (c) Vertical Maddox rod. The y-axis display magnitude of hyperphoria in prism diopters (pd). The horizontal line within each box represents the median, while the upper and lower edges of the box indicate the 75th and 25th percentiles. Whiskers extend to values within 1.5 times the interquartile range. Each gray dot represents an individual data point.

Symptom questionnaire scores

The questionnaires were used to relate the subjective symptoms to the presence of vertical heterophoria. Two participants from the case group did not fulfill Sheard's criteria[2] for horizontal vergence reserves. Since their symptoms could be attributed to the horizontal phoria, their results were removed from the analysis.

Table 5: Median and IQR of symptom questionnaires

	Cases		Controls		
	Median	IQR	Median	IQR	p-value
BVDQ	17.5	13.0-28.8	6.0	4.0-12.0	<0.001
SSI	25.0	12.0-35.25	3.0	1.0-5.0	<0.001

A Mann-Whitney U-test was conducted to compare median questionnaire scores between groups, see Table 5. The case group had a median score of 17.5 points (IQR 13.0-28.8) on the BVDQ, whereas the control group had 6.0 points (IQR 4.0-12-0). This difference was statistically significant (Mann-Whitney U-test; $U = 469$, $p < 0.001$). For the SSI, the median score for the case group was 25.0 points (IQR 12.0-35.5), compared to 3.0 points (IQR 1.0-5.0) in the control group, a statistically significant difference (Mann-Whitney U-test; $U = 477$, $p < 0.001$). Boxplots of questionnaire scores are shown in Figure 4.

[2] Sherd's criteria states that the compensating fusional vergence reserve should be at least twice as large as the phoria.

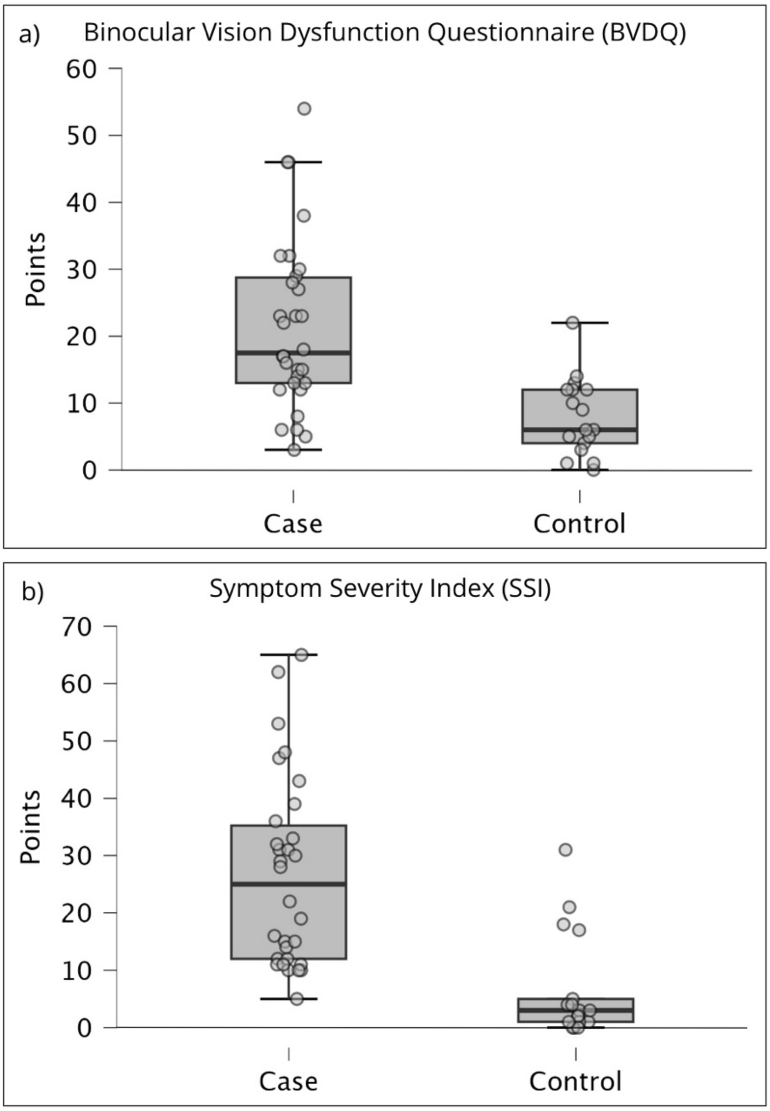

Figure 4: Box plots illustrating the distribution of questionnaire scores among groups for (a) Binocular vision Dysfunction Questionnaire, BVDQ and (b) Symptom Severity Index, SSI. The y-axis shows the scores of the questionnaires. The horizontal line within each box represents the median, while the upper and lower edges of the box indicate the 75th and 25th percentiles. Whiskers extend to values within 1.5 times the interquartile range. Each gray dot represents an individual data point.

Two multiple regression analyses were conducted to examine whether presence of vertical associated phoria or group affiliation could predict self-reported symptoms as measured by the BVDQ and SSI questionnaires. For the BVDQ, the full model explained 27.8% of the variance in symptom scores ($R^2 = 0.278$, adjusted $R^2 = 0.245$, RMSE = 10.95), and was statistically significant ($F(2, 44) = 8.46$, $p < .001$), indicating that the predictors together accounted for a significant proportion of the variance in BVDQ scores. Group affiliation emerged as a significant predictor ($b = -12.35$, $SE = 3.76$, $t(44) = -3.28$, $p = 0.002$), suggesting that participants in the control group reported lower symptom levels than those in the case group. In contrast, presence of vertical associated phoria showed no significant effect on BVDQ scores (b = 2.38, SE = 3.66, t(44) = 0.65, p = 0.519).

A similar pattern was observed for the SSI, the full model explained 31.9% of the variance in symptom scores ($R^2 = 0.319$, adjusted $R^2 = 0.288$, RMSE = 14.57), the model was statistically significant ($F(2, 44) = 10.29$, $p < 0.001$). Again, group affiliation emerged as a significant predictor (b = −20.74, SE = 5.01, t(44) = −4.14, $p < 0.001$), whereas presence of vertical associated phoria did not show a significant effect (b = −1.48, SE = 4.87, t(44) = −0.31, p = 0.762).

Further exploratory analyses between cases and controls on other related measures such as cover test, horizontal phoria, horizontal vergence and vertical vergence are presented in Appendix V.

Results summary

The results showed that the individuals with headache disorder had a statistically significant higher proportion and greater magnitude of vertical associated phoria compared with controls. However, no statistically significant differences were found between groups for the vertical Von Graefe or Maddox rod tests in either distribution or median values.

Participants with headache disorder had significantly higher median questionnaire scores compared to controls. Multiple regression analyses showed a strong effect of group affiliation on symptoms scores, while presence of vertical associated phoria alone did not explain variation in symptoms.

While the results quantify differences in the presence, magnitude, and symptom burden associated with vertical heterophoria, their clinical and theoretical significance requires further interpretation.

Discussion

The aim of this thesis was to investigate the prevalence and degree of vertical heterophoria in individuals with headache disorder, as well as to examine potential associations between headache disorders and self-reported symptoms. By comparing a group of individuals with migraine and/or frequent headache to a control group without such complaints, this thesis sought to explore whether vertical heterophoria may represent an underrecognized contributing factor to headache disorders.

Based on previous research by Feinberg et al., (2020) and anecdotal clinical observations, it was hypothesized that the proportion of individuals exhibiting both vertical dissociated and vertical associated heterophoria would be higher in the case group compared to the control group. Furthermore, it was assumed that the magnitude of vertical heterophoria would be greater in this group, and that individuals with headache disorder would score higher on the Binocular Vision Dysfunction Questionnaire and the Symptom Severity Index, indicating a more pronounced symptom profile.

This chapter discusses the main findings of this thesis in relation to our hypotheses and previous research. The discussion also addresses potential methodological limitations, considers how the thesis's findings may be applied in optometric clinical practice and gives recommendations on future research.

Presence of Vertical Heterophoria

Vertical heterophoria occurred more frequently in the case group compared to the control group across all measurements. A statistically significant difference was found regarding associated phoria test between cases and controls. Nearly two thirds of the participants in the case group had a vertical associated phoria, compared with only twelve percent in the control group. The two groups differed in that a large proportion of participants in the case group exhibited an associated phoria > 0.25 pd, whereas none of the controls did so. The dissociated tests revealed no statistically significant differences between the groups as more than half of the participants in both groups demonstrated a small vertical heterophoria using these methods. These findings suggests that subtle binocular misalignments may be clinically relevant in this population.

Previous studies investigating a potential association between migraine and binocular vision dysfunction is limited and have shown very few cases of vertical heterophoria. In a study that evaluated the effects of colored tints on reading in individuals with migraine compared with controls, Evans et al., (2002) found no cases of vertical associated phoria in their sample and no significant difference between groups regarding vertical dissociated phoria at distance or near. The later study by Harle and Evans (2006) compared binocular vision parameters between individuals with migraine to a control group, they found one case of vertical associated phoria at distance among the migraine group and none in the control. The same study found that horizontal and vertical dissociated phoria, when combined, were more common in the migraine group compared to the controls. However, details on the number of cases with dissociated vertical heterophoria was not reported. The study concluded that individuals with migraine appear to be predisposed to subtle heterophoria, although the overall strength of the evidence was insufficient to establish a causal relationship between migraine and binocular vision dysfunction.

The findings of previous studies differ markedly from those of the present thesis, in which several cases of vertical heterophoria was identified using both associated and dissociated tests. One plausible explanation for this discrepancy is methodological variation, particularly the use of 1.0 pd prism increments in earlier studies, which may have limited the detection of subtle heterophorias in the range of 0.25 to 0.75 pd. The use of smaller prism increments in the present thesis may therefore have contributed to the higher observed proportion of vertical heterophoria. Smaller increments of prisms has earlier been used in studies to evaluate vertical heterophoria in relation to posture and balance. Matheron et al., (2007) found that 73% of his healthy participants without neurological disorders or strabismus, exhibited a vertical dissociated heterophoria inferior to 1.0 pd. The use of smaller prism increments during evaluation of vertical heterophoria is advocated by Feinberg et al., (2020) who in their research highlights that small vertical heterophoria can give rise to severe symptoms.

As none of the previous studies identified used the Von Graefe method to assess dissociated vertical heterophoria in individuals with headache disorders, direct comparison with existing literature is limited. Although the Maddox rod test demonstrates higher repeatability (Casillas and Rosenfield, 2006) and is therefore more commonly used in research (Harle and Evans, 2006; Matheron et al., 2007), the inclusion of the Von Graefe method in this thesis reflects its widespread clinical use among optometrists in Sweden (Shakirova and Pullola, 2021).

In summary, the results indicate a higher prevalence of subtle vertical heterophoria among individuals with headache disorder compared to controls. Accordingly, the null hypothesis of no difference in the proportion of individuals with a vertical associated phoria between groups was rejected. In contrast, the corresponding null hypothesis regarding dissociated tests could not be rejected.

Magnitude of vertical heterophoria

The understanding of a potential relationship between headache disorders and vertical heterophoria is further deepened when the magnitude of the phoria is analyzed. The median magnitude of vertical associated phoria was higher in the case group than in the control group. No vertical associated phoria exceeding 0.50 pd was observed in the present thesis, and all instances of a 0.50 pd fixation disparity occurred exclusively within the headache disorder group. The case group also exhibited slightly higher median values on both the Maddox rod and Von Graefe tests, however, no statistically significant differences were observed for these dissociated tests. The dissociated tests did, however, demonstrate a wider distribution of phoria magnitudes in both groups.

Comparison with previous studies indicates that the prism increment used during testing may have a substantial influence on the results. Had we employed 1.0 pd increments, as in Evans et al., (2002), and Harle and Evans (2006) the outcomes of the present thesis would likely have differed substantially, no cases of vertical associated phoria would have been detected, and only a minimal number of dissociated phoria would likely have been identified. These observations underscore that the use of 0.25 pd increments is an important methodological consideration when evaluating vertical heterophoria. This smaller step size may be particularly critical given that vertical phoria and vertical vergence amplitudes are generally smaller in magnitude than their horizontal counterparts. As a result, even a small prism increment can constitute a meaningful proportion of the total deviation, thereby influencing the sensitivity of the measurement.

The finding that vertical associated phoria is significantly greater in the case group, while dissociated tests show no such difference, can be interpreted in several ways. One interpretation is that small vertical disparities may be associated with symptoms of migraine and headache. Alternatively, the findings may indicate that vertical fixation disparity testing is more sensitive than dissociated methods in measuring vertical heterophoria among individuals with headache disorders. In either case, the findings are consistent with previously discussed results, showing a higher proportion of vertical associated phoria in the case group. The consistency between these results strengthens the interpretation that associated tests might be more sensitive when testing for vertical heterophoria among individuals with headache disorder.

The null hypothesis of no difference between groups was rejected for the associated phoria measurement but could not be rejected when vertical phoria was assessed using dissociated methods.

Questionnaire scores and group affiliation

Results from the Binocular Vision Dysfunction Questionnaire and Symptom Severity Index demonstrated statistically significant differences between the case and control groups. Participants with headache disorders reported substantially higher symptom scores on both instruments, with approximately two-thirds of the case group obtaining scores indicative of vertical heterophoria on both questionnaires, compared with only a small proportion of the control group.

The findings of this thesis indicate that individuals with headache disorders report both more frequent and more severe symptoms of vertical heterophoria and binocular vision dysfunction than those without such conditions. Although earlier research has been highly inconclusive in evidence supporting an association between migraine and binocular vision dysfunction (Harle and Evans, 2004), more recent studies indicate otherwise. Feinberg et al., (2021) and Rosner et al., (2016) showed with their studies on symptomology in individuals diagnosed with vertical heterophoria that half of their participants had been diagnosed with migraine prior to receiving treatment for vertical heterophoria. And a comorbidity between binocular vision dysfunction and headache disorders, attributed largely to overlapping symptomatology, has been emphasized in several more recent studies (Feinberg et al., 2020; Matheron and Kapoula, 2011; Sánchez-González et al., 2019).

Questionnaires are a commonly used tools in vision exams to screen for binocular vision dysfunction and to evaluate symptom severity. The BVDQ and its associated SSI is a relatively new instrument developed to facilitate the diagnosis of vertical heterophoria and binocular vision dysfunction (Feinberg et al., 2021). Although the BVDQ was primarily designed as a screening tool for vertical heterophoria, it also detects symptoms associated with other forms of binocular vision dysfunction. To reduce potential confounding from other forms of binocular vision dysfunction, two individuals in the migraine group were excluded from the analysis as both exhibited a decompensated horizontal heterophoria at distance and did not meet Sheard's criteria. As this thesis did not include measurements of binocular vision at near, it is possible that some of the symptom scores may be attributable to horizontal near heterophoria, such as convergence insufficiency. Previous studies have not demonstrated any significant difference between migraine and control groups regarding near horizontal associated or dissociated heterophoria (Evans et al., 2002; Harle and Evans, 2006). Based on these studies, it is reasonable to expect comparable prevalence of horizontal near heterophoria in both groups, making it unlikely that such cases account for the higher symptom scores observed in the case group. It is also unlikely that accommodative disorders had a substantial impact on the results, as the mean age of the study population indicates that most participants were partly presbyopic.

The multiple regression analyses clarified the relationship between vertical associated phoria, group affiliation and symptom scores. When considered together, vertical associated phoria and group affiliation were found to explain variance in symptom scores for both BVDQ and SSI. When tested by them self, group affiliation emerged as a significant predictor of symptom severity, whereas vertical associated phoria did not contribute uniquely to the prediction. This indicates that although associated phoria appears to correlate with symptom burden, it does not independently explain variance in symptoms beyond what is accounted for by headache status. Taken together, these findings suggest that vertical associated phoria is related to symptom severity but is unlikely to be the primary driver of binocular vision symptoms. Instead, the results imply symptom levels are driven by group affiliation rather than vertical associated phoria. One plausible explanation for the observed link between symptom scores and headache disorder involves the trigeminal system[3]. Prior studies have suggested that activation of trigeminal pathways may link ocular strain with symptoms such as headache, photophobia, and asthenopia (Digre, 2018; Karpecki, 2018). Given the trigeminal nerves central role in migraine pathophysiology and its involvement in proprioceptive

[3] The trigeminal system is the sensory and motor network associated with the trigeminal nerve (cranial nerve V), which is one of the twelve cranial nerves. It plays a crucial role in sensation and movement in the face and some parts of the head.

feedback from the extraocular muscles (Digre, 2018), individuals with migraine may be particularly susceptible to disturbances within the oculomotor system (Sundholm and Linde, 2025). The present findings therefore lend support to the notion that even subtle vertical misalignments may contribute to increased load on the extraocular muscles, potentially enhancing trigeminal stimulation and symptom development. However, the multiple regression analyses showed that associated phoria alone is not responsible for symptoms scores but likely constitutes only one component of a broader and multifactorial symptom profile.

Overall, the findings indicate that individuals with migraine and frequent headaches exhibit substantially higher levels of symptoms associated with binocular vision dysfunction, whereas the magnitude of vertical associated phoria alone does not fully account for these differences. The findings of this thesis highlights the importance of binocular vision evaluation in subjects with headache disorders and may help explain why some patients with migraine report visual discomfort despite having near to normal objective measurements of binocular vision (Feinberg et al., 2020; Rosner et al., 2016).

In summary, the results suggest a clear association between group affiliation and reported symptom levels, indicating that headache disorders predict higher scores of BVDQ and SSI questionnaires. Vertical associated phoria, in contrast, did not demonstrate a significant independent predictive effect. Thus, it appears more likely that individuals with migraine and frequent headache will exhibit elevated symptom scores than individuals merely presenting with a vertical associated phoria. Nevertheless, the hypothesis that individuals with headache disorders exhibit higher symptom questionnaire scores than controls is supported.

Limitations

The limitations of this thesis include the relatively small sample size and the lower number of participants in the control group may limit the statistical power and generalizability of the findings. However, it is worth noting that the sample size in this thesis is comparable to that of previous research investigating vertical heterophoria. In the studies of Harle and Evans (2006) and Matheron and Kapoula (2011) their samples consisted of 50 and 40 participants, which is similar to the 49 participants in this thesis. The high proportion of female participants is representative of the wider population, as women aged 15-49 years old constitute the majority of those affected by headache disorders (GBD 2021 Diseases and Injuries Collaborators, 2024; Sundholm and Linde, 2025).

Participants in the case group were primarily recruited through voluntary participation, which introduces a risk of selection bias. Individuals with more pronounced symptoms may have been more motivated to participate, potentially leading to an overestimation of symptom prevalence and severity within the case group. Beyond issues related to recruitment, the definition of the case group itself represents an additional limitation. The headache disorder group included migraine that were both self-reported and formally diagnosed, as well as recurrent tension-type headache. This limits the generalizability of the thesis, as the population consisted of several forms of headache disorder.

When answering the questionnaires several participants reported comorbid conditions such as dyslexia and ADHD. These conditions may affect abilities related to reading, concentration and sustained attention, which in turn may have contributed to elevated scores on certain questionnaire items. Consequently, it cannot be excluded that some of the observed symptom scores partly reflect factors other than binocular vision dysfunction, which may have affected the validity of the results. Regardless, all participants were instructed to respond to the questionnaires based on the symptoms they experienced, rather than their perceived underlying cause.

It should also be taken into consideration that this thesis only assessed heterophoria at distance, even though the questionnaire evaluates symptoms related to activities both at distance and near. Although previous research has not identified any significant differences in horizontal heterophoria between migraine and control groups (Evans et al., 2002; Harle and Evans, 2006), and participants with decompensated distance heterophoria were excluded from the symptom score analysis in this thesis, there remains a possibility that some of the reported symptoms may be attributable to binocular vision dysfunction related to near-work activities.

The dissociated tests used in this thesis have known limitations in terms of repeatability and sensitivity to small vertical heterophoria (Casillas and Rosenfield, 2006). Nevertheless, these methods were selected as they are commonly used in the assessment of binocular vision dysfunction by Swedish optometrists. In addition, a fixation disparity test was included, which is traditionally considered the most suitable test for evaluating vertical heterophoria (Rutstein and Eskridge, 1986). However, previous studies have shown that none of these methods are sufficiently sensitive to accurately diagnose small vertical heterophoria (Rosner et al., 2016; Weigel, 2012). These authors instead recommend that prism correction should be based on head tilt, prism challenge test, and the neutralization of target movement during the alternating cover test. It was, however, not feasible to include all these techniques within the present thesis.

Despite standardized procedures, the thesis may also be subject to researcher bias, as the researcher was not blinded to group allocation. This may have introduced unconscious bias in the assessment or interpretation of results. Unfortunately, blinding was not possible because the examiner responsible for conducting the tests was also in charge of participant recruitment. It is therefore conceivable that the outcomes might have differed had blinding been implemented.

Practical implications and clinical relevance

The findings of this thesis have several practical implications for assessment of patients presenting with recurrent headache or migraine. The higher proportion of subtle vertical associated phoria among individuals with headache disorder suggests that reliance on dissociated phoria tests alone may be insufficient to detect clinically relevant vertical misalignments.

Incorporating associated phoria testing, such as fixation disparity assessment, may improve the identification of patients with binocular vision dysfunction who would otherwise appear normal on standard examinations.

The results also indicate that subtle vertical misalignments, even within ranges traditionally considered physiologically insignificant, may be associated with a substantial symptom burden in this patient group. From a clinical perspective, this highlights the importance of screening for vertical heterophoria in patients with headache complaints, particularly when conventional ocular findings fail to explain reported symptoms. Early identification of subtle vertical heterophoria may support more targeted management strategies, including consideration of prismatic correction, and may help reduce visual discomfort in a subgroup of patients whose symptoms might otherwise be attributed solely to primary headache disorders.

Future Research

To deepen understanding within this field, further research should be conducted on the potential association between subtle vertical heterophoria and headache disorders. A larger sample with an equal number of participants in each group would increase the statistical power and generalizability of the results, thereby enabling more reliable conclusions regarding the prevalence and clinical significance of subtle vertical heterophoria among individuals with headache disorder. To provide a more nuanced interpretation of the results, future studies should also take variables such as heterophoria at near, dyslexia and ADHD into account, as these may influence the outcomes of symptom questionnaires. Moreover, examiner blinding procedures should be included to minimize the risk of bias and strengthen the credibility of the findings.

It would also be of interest to incorporate alternative assessment methods for evaluating vertical heterophoria, such as prism challenge testing, observation of head tilt, and the neutralization of subjectively perceived movement during the cover test. In addition, future studies could evaluate how prism correction affects the symptom profile of individuals with subtle vertical heterophoria and headache disorders. Such investigations would further enhance understanding of the influence of vertical heterophoria on symptoms associated with migraine and headache.

By considering these factors, future research can contribute to a more comprehensive understanding of the visual and neurological mechanisms underlying migraine and provide an evidence-based foundation for clinical assessment and treatment.

Conclusion

The results of this thesis revealed that individuals with self-reported migraine and frequent headache exhibit both a higher proportion and greater magnitude of vertical associated phoria than controls. While the dissociated tests showed no significant difference between the groups. A strong association between presence of headache disorders and elevated symptom scores was revealed and participants with headache disorder demonstrated higher scores on the symptom questionnaires.

Subtle vertical heterophoria appears to be more common among individuals with headache disorders and may be linked to their symptoms. These findings highlight the importance of incorporating associated tests, such as fixation disparity test, in the clinical assessment of patients experiencing recurrent headache or migraine. Future research with larger samples and more comprehensive diagnostic methods is recommended to confirm these results and to explore the potential benefit of prismatic correction in this population.

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Appendix

I. Recruitment poster

II. Information letter and consent form

Information och förfrågan om deltagande i studie

Du tillfrågas härmed om att delta i en studie vars syfte är att undersöka om små dolda skelningar i höjdled (vertikala forier) är större och vanligare hos individer som lider av migrän och/eller frekvent huvudvärk jämfört med en kontrollgrupp utan dessa besvär.

Jag som genomför studien heter Evelina Johansson och är optometrist och legitimerad optiker. Studien genomförs som en del av min masterutbildning i synvetenskap och optometri vid Linnéuniversitetet i Kalmar.

De vanligaste symptomen vid vertikala forier är huvudvärk, migrän och smärta i och kring ögonen men det kan även orsaka huvudlutning, nacksmärta, yrsel och ljuskänslighet. Det har uppskattats att en femtedel av befolkningen besväras av allvarlig huvudvärk och att mer än var tionde person har återkommande migrän. Dessa symptom har ofta en negativ påverkan av den drabbades vardag och välmående.

Studien genomförs med fall-kontroll design vilket innebär att deltagarna kommer att delas in i två grupper. I fall-gruppen inkluderas individer med migrän och eller frekvent huvudvärk (huvudvärk ≥ 2 dagar per vecka under de senaste 3 månaderna), medan kontrollgruppen kommer bestå av individer utan migrän och huvudvärk max 1 dag per vecka under de senaste 3 månaderna.

Som deltagare i studien kommer du genomgå en utökad synundersökning vars syfte är att hitta och mäta dolda skelningar. Undersökningen tar ca 60 minuter och inkluderar även kontroll av synfel samt ett frågeformulär för att utvärdera symptom. Avslutningsvis kommer du få spendera 10 minuter med att testa och utvärdera en ny glasögonstyrka i en provbåge. Samtliga tester och undersökningar kommer att ske på Svedala Optik i Svedala.

Resultaten och personuppgifterna kommer att hållas åtskilda och kodas för att deltagarna inte ska kunna bli identifierade. Insamlat material kommer hanteras av studenten och dess handledare. Dina personuppgifter kommer att sparas fram till januari 2026 varefter de kommer att raderas. Ditt deltagande i studien är frivilligt och du kan när som helst avbryta ditt deltagande utan vidare motivering.

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Samtycke för att delta i studien ” Relationen mellan okorrigerad vertikal heterofori och symptom av frekvent huvudvärk: Ett kliniskt perspektiv”

Syftet med studien är att undersöka om vertikala forier kan vara en underdiagnostiserad orsak till migrän och huvudvärk. För detta ändamål syftar denna studie till att undersöka om individer som lider av migrän och/eller frekvent huvudvärk har en högre andel, högre värden samt symptom som kan kopplas till vertikala forier än kontrollgruppen. Arbetet utförs som del av en mastersutbildning inom synvetenskap och optometri vid Linnéuniversitetet i Kalmar.

Genom att skriva under det här samtycket godkänner du att dina personuppgifter behandlas inom ramen för studien som beskrivs ovan och i tillhörande informationsbrev. Du kan när som helst dra tillbaka ditt samtycke genom att kontakta någon av kontaktpersonerna nedan. Dina personuppgifter kommer därefter inte längre att bevaras eller behandlas vidare utan annan laglig grund.

De personuppgifter som kommer samlas in från dig är födelseår, kön, historik av migrän och huvudvärk, synfel och mätningar av ögonens samarbete (forier och vergenser). Dina personuppgifter kommer behandlas fram till januari 2026 varefter de kommer att raderas.

Du har alltid möjlighet att få information om vad som registrerats om dig eller ha synpunkter på behandlingen eller de uppgifter som samlats in genom att kontakta någon av kontaktpersonerna nedan eller lärosätets dataskyddsombud på dataskyddsombud@lnu.se. Klagomål som inte kan lösas med Linnéuniversitetet kan lämnas till Datainspektionen.

Jag samtycker till att deltaga:

……………………………………… ………………………………….
Underskrift Ort och datum

………………………………………
Namnförtydligande

Kontaktuppgifter

Student: Evelina Johansson, Optometrist & Leg Optiker ej223xj@student.lnu.se

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III. The Binocular Vision Dysfunction Questionnaire and Symptom Severity Index

SCREENING QUESTIONNAIRE

Binocular Vision Dysfunction Questionnaire (BVDQ™)

Directions: For each of the following questions, please check the answer that best describes your situation. If you wear glasses or contact lenses, answer the questions assuming that you are wearing them.

Always = every day **Frequently** = at least once per week
Occasionally = less than once per week **Never** = never

		ALWAYS	FREQUENTLY	OCCASIONALLY	NEVER
1	Do you have headaches and/or facial pain?				
2	Do you have pain in your eyes with eye movement?				
3	Do you experience neck or shoulder discomfort?				
4	Do you have dizziness and/or light headedness?				
5	Do you experience dizziness, light headedness, or nausea while performing close-up activities (computer work, reading, writing, etc.)?				
6	Do you experience dizziness, light headedness or nausea while performing far-distance activities (driving, television, movies, etc.)?				
7	Do you experience dizziness, light headedness, or nausea when bending down and standing back up, or when getting up quickly from a seated position?				
8	Do you feel unsteady or drift to one side while walking?				
9	Do you feel overwhelmed or anxious while walking in a large department store (Target, Wal-Mart, Costco, etc.)?				
10	Do you feel overwhelmed or anxious when in a crowd?				
11	Does riding in a car make you feel dizzy or uncomfortable?				
12	Do you experience anxiety or nervousness because of your dizziness?				
13	Do you ever find yourself with your head tilted to one side?				
14	Do you experience poor depth perception or have difficulty estimating distances accurately?				
15	Do you experience double/overlapping/shadowed vision at far distances?				
16	Do you experience double/overlapping/shadowed vision at near distances?				
17	Do you experience glare or have sensitivity to bright lights?				
18	Do you close or cover one eye with near or far tasks?				
19	Do you skip lines or lose your place when you are reading? Do you use your finger, ruler or other guides to maintain your position on the page?				
20	Do you tire easily with close-up tasks (computer work, reading, writing)?				
21	Do you experience blurred vision with far-distance activities (driving, television, movies, chalkboard at school, etc.)?				
22	Do you experience blurred vision with close-up activities (computer work, reading, writing, etc.)?				
23	Do you blink to 'clear up' distant objects after working at a desk or working with close-up activities (computer work, reading, writing, etc.)?				
24	Do you experience words running together while reading?				
25	Do you experience difficulty with reading or reading comprehension?				
	TOTALS				

For questions 1 - 25 on the front, scoring is as follows (see below). Add the scores for questions 1 - 25 to get a TOTAL score.

Always =____ x 3 Frequently =____ x 2 Occasionally =____ x 1 Never =____ x 0 **TOTAL (BVDQ)** ____

A BVDQ score of **15 or greater** is highly suggestive of a Binocular Vision Dysfunction.

On an average day, how much are you bothered by symptoms listed here?

Rate each symptom from 0 -10
0 = None of that symptom
10 = Worst

Symptom	None … Worst	Symptom	None … Worst
Dizziness	0 1 2 3 4 5 6 7 8 9 10	Neckache	0 1 2 3 4 5 6 7 8 9 10
Nausea	0 1 2 3 4 5 6 7 8 9 10	Unsteady when walking	0 1 2 3 4 5 6 7 8 9 10
Anxiety	0 1 2 3 4 5 6 7 8 9 10	Sensitivity to light	0 1 2 3 4 5 6 7 8 9 10
Headache	0 1 2 3 4 5 6 7 8 9 10	Reading difficulty	0 1 2 3 4 5 6 7 8 9 10
		Sound sensitivity	0 1 2 3 4 5 6 7 8 9 10

For the above questions, total up the 9 numbers above and total them to the right. This score is called a **SSI (or Symptom Severity Index)**. An SSI Score of **15 or greater** is highly suggestive of a Binocular Vision Dysfunction.

TOTAL (SSI) ____

IV. Instruments and procedure

Questionnaires

To assess symptoms related to vertical heterophoria, participants were asked to complete the Binocular Vision Dysfunction Questionnaire (BVDQ) along with the Symptom Severity Index (SSI), see Appendix III. The questionnaire is designed to identify individuals at risk for vertical heterophoria and other binocular vision dysfunction. It consists of 25 questions which are answered using one of four options indicating the frequency of symptoms: Always (3 points), Often (2 points), Sometimes (1 point), and Never (0 points). The total score was recorded. A result higher than 15 points indicate a strong likelihood of vertical heterophoria or other binocular vision dysfunction (Feinberg et al., 2021).

In the SSI participants were asked to rate severity of the following symptoms: dizziness, nausea, anxiety, headache, neck pain, unsteady gait, light sensitivity, reading difficulties, and sound sensitivity. The scale ranged from 0 to 10, where 0 is no symptoms and 10 is the worst. The total score was calculated and noted. A score of 15 or higher is considered a strong indication of binocular vision issues (Feinberg et al., 2021).

The questionnaire was completed at the start of the examination, before any other tests were conducted. Participants were instructed not to calculate their total scores themselves.

All examinations were performed under standardized conditions, utilizing the same examination room, identical equipment, and conducted by the same licensed optometrist to ensure consistency. Refraction and phoria measurements were conducted using the Zeiss Visuphor 500 at six meters.

Cover test for detection of heterophoria/tropia

Cover-uncover test followed by alternating cover test was used to detect presence and direction of phoria and to exclude participants with tropia. The cover test was performed without correction, regardless of whether the participant normally used glasses, contact lenses or previously had no correction. Participants were asked to fixate on a letter corresponding to 0.05 decimal visual acuity on the chart. Objective findings were noted. To evaluate the subjective response the participants were then asked whether the fixation object moved or remained still when the occluder alternated between the eyes. If movement was reported, participants were asked to describe whether it moved sideways, diagonally, or vertically. Direction was then specified further by asking whether the object moved in the direction of the occluder (exophoria), against it (esophoria), diagonally (combined vertical and horizontal phoria), or up/down (vertical phoria). Phoria was not quantified by this method.

Subjective refraction was determined using the fogging technique, with maximum plus power for best visual acuity. Remaining tests were performed with the refraction in the phoropter.

Quantification of heterophoria using Von Graefe method

Horizontal phoria was assessed first using the Von Graefe method. Participants fixated on a vertical line of letters equivalent to 0.5 decimal acuity at six meters. Fusion was broken by introducing 3 pd base up over the right eye and 3 pd base down over the left. The images were then separated horizontally by adding 12 pd base in over the right eye. If 12 pd base in was not enough to perceive the bottom image to the right of the upper image, prisms were increased until that occurred. Participants were instructed to focus on the upper left row. The amount of horizontal prism was then reduced by 1 pd per second until the lines aligned vertically. Results were recorded in increments of 1 pd.

Horizontal fusional vergences at distance were then measured with smooth vergence test using Risley prisms. A vertical line of letters, the same size as for phoria testing, was used. For negative fusional vergence, prism base in was introduced over the right eye at the speed of 1 pd per second until the line became blur or double. The prism was then reduced until the line became single again. Prism amounts were recorded at blur, break, and recovery. The same procedure was repeated with base out prism to test positive fusional vergence.

Vertical phoria at distance was measured using the Von Graefe method. A horizontal line of letters equivalent to 0.5 decimal acuity at six meters was used. Fusion was broken by introducing 5 pd base in in front of each eye. The lines were vertically displaced by placing 1 pd base down over the right eye. Participants were asked to focus on the left image. The vertical prism was then adjusted by 0.25 pd per second until alignment was achieved. Results were recorded in 0.25 pd increments.

Vertical fusional reserves were measured with smooth vergence test using Risley prisms. Participants fixated on a horizontal line, the same size as for vertical phoria testing. To measure infra vergence, base up prism was introduced over the right eye at a speed of 0.25 pd er second until diplopia occurred, then reduced until the line appeared single again. The procedure was repeated with base down prism to assess supra vergence. Results for break and recovery were recorded in 0.25 pd increments.

Quantification of heterophoria using Maddox rod test

Horizontal and vertical phoria were also measured using the Maddox rod test. Participants fixated on a small light source at six meters, room lights were dimmed. A red Maddox rod was first placed horizontally over the right eye to create a vertical red line. Participants were asked whether the light was centered in the red line or to the side of it. Prism was added over the right eye in 1 pd increments until alignment was reported.

The Maddox rod was then placed over the left eye, this time vertically oriented, to create a horizontal red line to assess vertical phoria. Participants were asked whether the light was in, above, or below the red line. Prism was added over the right eye in 0.25 pd increments until alignment was reported. Both horizontal and vertical results were noted.

Vertical associated phoria

Vertical associated phoria at distance was measured using a fixation disparity test. A chart with a central fixation target was used. Polarizing filters were placed over both eyes. Participants were asked to look at the cross and report whether the horizontal lines were aligned or vertically displaced. If misalignment was perceived, vertical prism was introduced in 0.25 pd increments until alignment was achieved. The smallest prism correction that eliminated the associated phoria to zero was recorded.

V. Results of exploratory comparisons

Objective and subjective responses of alternating cover test

Table 6: Results of alternating cover test, objective results and subjective results for both horizontal and vertical movement.

	Case, n (%)				Control, n (%)			
	Eso	Ortho	Exo	Vert	Eso	Ortho	Exo	Vert
Objective	1 (3)	25 (78)	6 (6)	0 (0)	2 (12)	13 (76)	2 (12)	0 (0)
Subj. Horizontal	7 (22)	7 (22)	18 (56)	-	5 (29)	9 (53)	3 (18)	-
Subj. Vertical	-	-	-	17 (53)	-	-	-	2 (12)

Horizontal dissociated phoria and vergence measurements

Table 7: Median values of horizontal measurements. Exophoria is coded as positive values while esophoria is coded as negative values. [1]Student t-test [2]Mann Whitney U-test, p-values are unadjusted for comparison.

	Cases		Controls		
	Median	IQR	Median	IQR	p-value
Von Graefe[1]	1.00	-1.00 - 2.00	0.00	-1.00 - 1.00	0.887
Maddox rod[2]	-1.00	-2.00 - 1.00	-1.00	-2.00 - 0.00	0.461
NFV blur[1]	6.00	5.25 - 6.75	6.50	5.75 - 8.00	0.678
NFV break[2]	6.00	5.00 - 7.00	7.00	6.00 - 10.00	0.066
NFV recovery[2]	4.00	3.00 - 5.00	5.00	4.00 - 6.00	0.120
PFV blur[1]	12.00	9.75 - 15.25	15.50	11.00 - 22.00	0.088
PFV break[1]	16.00	11.00 - 22.75	17.00	16.00 - 27.00	0.428
PFV recovery[2]	8.00	6.00 - 11.25	8.00	6.00 - 15.00	0.462

Vertical vergence measurements

Table 8: Median values of vertical vergence testing. [1]Student t-test [2]Mann Whitney U-test, p-values are unadjusted for comparison.

	Cases		Controls		
	Median	IQR	Median	IQR	p-value
VF Infra break[2]	1.75	1.75 - 2.25	2.25	1.75 - 2.75	0.036
VF Infra recovery[1]	1.50	1.00 - 2.00	1.75	1.00 - 2.00	0.143
VF Supra break[2]	1.75	1.25 - 1.75	1.75	1.25 - 2.25	0.338
VF Supra recovery[2]	1.25	0.69 - 1.50	1.25	1.00 - 1.75	0.325

Distribution of BVDQ and SSI scores ≥15 p

Table 9: Distribution of scores indicative of binocular vision dysfunction. [3]Fisher's exact test, p-values are not adjusted for comparison.

	Cases, n (%)	Control, n (%)	p-value
BVDQ ≥15 p[3]	20 (67)	1 (6)	<0.001
SSI ≥15 p[3]	20 (67)	4 (24)	0.006

Associations between groups by contingency tables

Potential associations between group affiliation, vertical associated phoria > 0.25 pd and scores indicative of binocular vision dysfunction were investigated by contingency tables.

Table 10 shows the relationship between vertical associated phoria > 0.25 pd and BVDQ score ≥15 points among participants. Of the participants with a vertical associated phoria > 0.25 pd 83% had BVDQ ≥ 15 p, whereas the corresponding proportion among participants with vertical associated phoria < 0.25 pd was 31%. A significant association between the groups were established (Kendall's Tau-b = 0.455, Z = 3.088, p = 0.002).

Table 10: Contingency table showing frequency of BVDQ ≥15p related to a vertical associated phoria > 0.25 pd.

	BVDQ ≥ 15p, n (%)		
Associated phoria > 0.25 pd	No	Yes	Total
No	24 (69)	11 (31)	35
Yes	2 (17)	10 (83)	12
Total	26 (53)	21 (47)	47

Table 11 shows the relationship between vertical associated phoria > 0.25 pd and SSI score ≥ 15 points among participants. Of the participants with vertical associated phoria > 0.25 pd 75% had an SSI score ≥ 15 points, compared with 43% among participants with vertical associated phoria < 0.25 pd. No significant difference was found between the variables (Kendall's Tau-b = 0.280, Z = 1.902, p = 0.057).

Table 11: Contingency table showing frequency of SSI ≥ 15p related to a vertical associated phoria > 0.25 pd.

	SSI ≥ 15p, n (%)		
Associated phoria > 0.25 pd	No	Yes	Total
No	20 (57)	15 (43)	35
Yes	3 (25)	9 (75)	12
Total	23 (49)	24 (51)	47

Table 12 show the relationship between group affiliation and BVDQ score ≥ 15 points among participants. In the case group, 67% of participants had a BVDQ score ≥15 points, compared with 6% of the control group. There was a significant association between group affiliation and BVDQ ≥15 (Kendall's Tau-b = -0.587, Z = -3.984, $p < 0.001$).

Table 12: Contingency table showing frequency of BVDQ ≥ 15p related to group affiliation.

	BVDQ ≥ 15p, n (%)		
Group affiliation	No	Yes	Total
Case	10 (33)	20 (67)	30
Control	16 (94)	1 (6)	17
Total	26 (53)	21 (47)	47

Table 13 show the relationship between group affiliation and SSI score ≥ 15 points among participants. In the case group, 67% had an SSI score ≥ 15 points, compared with 24% in the control group. There is a significant association between group affiliation and SSI ≥15 points (Kendall's Tau-b = -0.415, Z = -2.812, $p = 0.005$).

Table 13: Contingency table showing frequency of SSI ≥ 15p related to group affiliation.

	SSI ≥ 15p, n (%)		
Group affiliation	No	Yes	Total
Case	10 (33)	20 (67)	30
Control	13 (76)	4 (24)	17
Total	23 (49)	24 (51)	47