Screening of Diabetes Retinopathy in Optometry: Assessment of a Web-based Training Protocol

Marianne Aamodt and Vibeke Sundling

National Centre for Optics, Vision and Eye Care, Department of Optometry, Radiography and Lighting Design, Faculty of Health and Social Sciences, University College of Southeast Norway, Kongsberg, Norway.

Received April 25, 2016, accepted June 27, 2017.
Keywords: Diabetic retinopathy, screening, optometrists, training
Correspondence: vibeke.sundling@usn.no

Abstract

Diabetic retinopathy is a sight threatening complication of diabetes mellitus. Regular eye examinations by trained health professionals can help prevent this. Although ophthalmologists have screening responsibility in Norway today, Norwegian optometrists regularly examine the ocular health of a large part of the population. The exact number of people with diabetes in Norway is unknown, and many are likely undiagnosed. Optometrists should be able to detect and grade diabetic retinopathy and ensure proper management of these patients. Previous studies in Norway have shown that optometrists need improved diagnostic skills to provide screening according to recommended standards. This study investigated the effect of web-based targeted training on the optometrists' ability to detect, classify and manage patients with diabetic retinopathy. The study had an experimental prospective design. Eighteen optometrists working in optometric practice in Norway participated in a web-based survey "Visual Identification and Management of Ocular Conditions" (VIMOC) related to diabetic retinopathy before and after a minimal web-based training protocol. In the VIMOC, the optometrists assessed 14 retinal digital photographs of people with known diabetes. An ophthalmologist's assessment and grading of the images was considered as the gold standard. The prevalence of retinopathy in the sample was set to 50% to prevent false high specificity. The web-based training significantly improved the optometrists' diagnostic sensitivity, but did not significantly improve specificity. The diagnostic sensitivity before training was 71.4% (SD = 19.6). After training, the sensitivity was 85.71% (SD = 12.9). However, only six (33%) of the optometrists achieved the recommended screening standard; sensitivity of 80% or better and specificity of 95% of better. Web-based training in screening for diabetic retinopathy significantly improved optometrists' screening and grading skills. Specific training in diabetes and screening for diabetic retinopathy are of great importance for detection and management of patients with diabetes by optometrists.

Sammendrag

Diabetes retinopati er en synstruende senkomplikasjon av diabetes mellitus. Regelmessige undersøkelser av øynene hos trent helsepersonell kan forebygge dette. Selv om øyeleger har hovedansvaret for screening i dag undersøker norske optikere regelmessig øyehelsen til en stor del av befolkningen. Det er antakelig store mørketall for hvor mange som har diabetes i Norge. Optikere bør på bakgrunn av dette være godt skikket for å oppdage og gradere diabetes retinopati, for videre å sikre korrekt håndtering av pasientene. Tidligere studier i Norge har vist at optikerne i snitt ikke hadde god nok sensitivitet og spesifisitet for diabetes retinopati ved screening, og kunne derfor ikke påta seg et kvalitetssikret screeningansvar. I denne studien har man derfor undersøkt om målrettet web-basert undervisning kan bedre optikeres evne til å oppdage, klassifisere og håndtere pasienter med diabetes retinopati. Studiet er en eksperimentell prospektiv valideringsstudie. 18 optikere som arbeidet i norsk optometrisk praksis gjennomgikk en nettbasert undersøkelse «Visual Identification and Management of Ocular Conditions» (VIMOC) før og etter målrettet undervisning. Optikerne ble spurt om å screene 14 et-felts fundusfotografier med mulig diabetes retinopati. En øyeleges vurdering av bildene var gullstandard. Prevalensen av diabetes retinopati var 50% for å unngå tilfeldig falsk høy spesifisitet. Undervisningen som optikerne gjennomgikk ga signifikant bedring i sensitivitet (71,4%, SD = 19,6 versus 85,71% SD = 12,9), men ikke signifikant bedret spesifisitet. Totalt sett nådde kun seks (33%) av optikerne den anbefalte screeningstandarden på over 80% sensitivitet og 95% spesifisitet. Undervisningen innen screening av diabetes retinopati økte optikernes presisjon ved screening og gradering signifikant. Spesifikk trening innen diabetes og screening av diabetes retinopati er av stor betydning for oppdagelse og oppfølging av pasienter med diabetes.

Background

Diabetic retinopathy is a microvascular late complication of diabetes mellitus, and is the most common cause of visual impairment in the working-age population (Porta & Bandello, 2002). Diabetic retinopathy causes 6.3 to 9.7% of the cases of visual impairment in the western world (Bamashmus, Matlhaga, & Dutton, 2004). Diabetic retinopathy develops gradually and symptoms do not necessarily occur before the advanced stage, as retinopathy often does not affect the macula in the initial phase (Bek, 2012). Regular retinal examination and timely treatment reduce the incidence of vision loss (Backlund, Algvere, & Rosenqvist, 1997; Kristinsson, Hauksdottir, Stefansson, Jonasson, & Gislason, 1997; Stefansson et al., 2000; Zoega et al., 2005). The increased prevalence of diabetes in the population predicts an increase in diabetic retinopathy (Delcourt, Massin, & Rosilio, 2009). The Norwegian Diabetes Association estimates that 375,000 Norwegians have diabetes. The prevalence of diagnosed diabetes in Norwegian population is 4%, that is about 200,000 people (Diabetesforbundet, 2014). In Norway, mainly ophthalmologists carry out screening for diabetic retinopathy. A report published by the Norwegian Ophthalmological Association (2012) stated a yearly total of 6116 diabetes related ophthalmologist consultations in Norway in 2009 and a total of 4007 laser-treatments of diabetic retinopathy (Norsk Oftalmologisk Forening, 2012). These figures suggest that many patients with diabetes do not receive eye examinations according to the recommended screening program. Further, the report estimates a 20% increase in consultations related to diabetes towards 2030 (Norsk Oftalmologisk Forening, 2012). This will lead to major challenges in the screening for and treatment of diabetic retinopathy in patients with diabetes.

Six studies have examined the prevalence of diabetic retinopathy in patients with diabetes in Norway. These studies found a prevalence between 11 and 29% (Bertelsen et al., 2013; Cooper et al., 2013; Hapnes & Bergrem, 1996; Kilstad et al., 2012; Sundling et al., 2008; Sundling et al., 2012). Studies from Australia and the UK have shown that specially trained optometrists are able to detect and grade diabetic retinopathy and show good diagnostics for sight threatening diabetic retinopathy, with sensitivity between 73 % and 93% and specificity between 83% and 99% (Gibbins, Owens, Allen, & Eastman, 1998; Harvey, Craney, Nagendran, & Ng, 2006; Hulme, Tin, Hardy, & Joyce, 2002; Prasad, Kamath, Jones, Clearkin, & Phillips,

2001; Schmid, Swann, Pedersen, & Schmid, 2002). A study of the general Norwegian optometrist population without specific training found a lower sensitivity (67%) and specificity (84%) (Sundling, Gulbrandsen, & Straand, 2013). However, there are no studies on the effect of specific training of Norwegian optometrists in screening for diabetes retinopathy.

The aim of this study is to evaluate the effect of a minimal web-based training protocol for screening of diabetic retinopathy by optometrists in terms of diagnostic sensitivity and specificity.

Methods

The population studied was authorised optometrists working in private practice in Norway. The optometrists were recruited through The Norwegian Association of Optometry and the head offices of the optical chains in Norway. Participation was voluntary. Only optometrists working in Norwegian optometric practice and having a bachelor degree in optometry or equivalent were included in the study. Optometrists working in ophthalmologist practices and hospitals were excluded. The training protocol consisted of three parts, and included two questionnaires, a study guide, two journal articles, three digital learning resources and three internet-based assessments Visual Identification and Management of Ocular Conditions (VIMOC) related to diabetes and screening for diabetic retinopathy.

The initial part included an online questionnaire asking the optometrists about key points regarding their optometric background and clinical experience with emphasis on patients with diabetes and an assessment of screening skills. The assessment of screening skills was a pre-training VIMOC assessment containing 14 retinal images. The optometrists had to assess the manifestations of diabetic retinopathy, identify clinical signs of diabetic retinopathy, grade the severity of diabetic retinopathy and state how they would manage the patient. The optometrists did not have information about the patients' history of general or ocular health. However, they had the information that all retinal images were of people with diabetes not regularly examined by an ophthalmologist. The optometrists did not use a grading scale for assessment. When assessing the retinal images, the optometrists could assess the images in both colour and in black/white. Further, the optometrists had the opportunity to go back and forth between the images if needed. There was no time limit on how long the optometrists could view the images, but the time spent on the assessment was recorded. Half of the retinal images did not have diabetic retinopathy. The prevalence of diabetic retinopathy of 50% was chosen to reduce the possibility of false high specificity.

The second part of the protocol was the web-based training protocol. The Study Guide had links to three online video lectures and two review articles about diabetes mellitus, diabetic retinopathy and screening for diabetic retinopathy (Sundling, 2012; 2013). After completing each video lecture, the optometrists had to answer five multiple-choice questions to allow for self-assessment of understanding. There were no restrictions to how many times the lectures could be viewed within the two-week time-window allowed to complete the training.

The final part included a post-training VIMOC. After completing the training, the optometrists assessed the same 14 retinal images as presented in the initial assessment however, the images presentation was in a different order and the optometrist did not know that the images were the same. After completing the assessment, the optometrist received the VIMOC with correct answers to allow for personal feed-back on grading and assessment. Additionally, the optometrists assess the web-based training protocol and the value for their clinical practice. Informed consent in written form was obtained from all the participants. The Norwegian Social Science Data Services (NSD) approved the study.

Data collection took place February to March 2015. Google docs was used to collect data for the online questionnaires, and Question Writer HTML5 was used to assess the optometrist screening using a VIMOC format with multiple-choice questions (Aakre & Svarverud, 2011). The retinal images used in the study were selected from a database of a population study of people with diabetes with and without diabetic retinopathy (Sundling, 2012). An ophthalmologist had assessed and graded all images and we considered the ophthalmologist grading as the gold standard. All images were 45-degree-field images focusing on the macula and optic nerve.

The VIMOC and digital learning resources had been developed by one of the authors (VS). The VIMOC and teaching materials were available online to facilitate a low threshold for participation. The participants were encouraged to use computers with Windows 7 or newer, and recommended to optimise their screen with regard to lighting, colour and contrast by using the operating system calibration solution. The recommended screen resolution was 1024×768 pixels and above, and a minimum screen size of 15" was recommended.

Microsoft Excel (2010) and (IBM) SPSS version 22.0 were used for statistical analysis. The data was analysed in frequency and summation tables. Group association and training effect on sensitivity and specificity were calculated with two-tailed student t-test, considering a p-value < 0.05 as significant. Cases with non-normally distributed data were analysed by Wilcoxon signed rank test and McNemar test.

Results

Twenty-one optometrists responded and wanted to take part in the study. However, three optometrists withdrew during the study period, two due to illness and one for other reasons. In all 18 optometrists completed the study (age 25–61 years), 12 (67%) were women. The participants had a mean of 20 years professional experience (range 4–39) and examined a mean of six patients per day (range 2–12). The majority of the optometrists (89%) had legal rights to requisite and use ocular diagnostic drugs. Four participants (22%) reported diabetes as a field of academic interest. Table 1 describes the characteristics of the optometrists.

Table 1: *Characteristics of the participating optometrists.*

	Number (%)
Formal education	
Bachelor degree in optometry or equivalent	13 (72)
Master of science in optometry	5 (28)
Diagnostic drugs available	16 (89)
Type of optometric practice	
Corporate store	8 (44)
Member owned store	7 (39)
Independent store	3 (17)
Practice by national health region	
East	14 (78)
South	3 (17)
North	1 (6)
Middle	0 (0)
South	0 (0)

Most optometrists (89%) had access to a fundus camera, indirect and direct ophthalmoscope and the majority used more than one examination method for examining the retina. Moreover, 61% had access to wide-field ophthalmoscopy (Optomap)

and 17% had access to optical coherence tomography (OCT). All optometrists used fundus photography as a method of retinal examination. Undilated fundus photography was the preferred method for retinal examination (72%), followed by undilated indirect ophthalmoscopy using slit lamp and Volk-lens (28%). In total, 67% reported to use mydriatic drugs; however, the optometrists rarely performed dilated retinal examination, Table 2. Only 12 of the 16 optometrists (75%) with legal rights for use of diagnostic drugs used the opportunity to perform dilated retinal examination.

Table 2: *Methods used for examining the retina in a regular eye examination.*

	Preferred method of examination	Mean usage (scale 0–10)	Range
Retinal fundus photography	18 (100)	9	7–10
Indirect ophthalmoscopy	16 (89)	8	0–10
Direct ophthalmoscopy	13 (72)	3	0–6
Dilation	12 (67)	3	0–7
Monocular ophthalmoscopy	3 (17)	1	0–1
Binocular ophthalmoscopy	2 (11)	3	0–4

The optometrists' mean score of self-confidence in dealing with patients with diabetes were 5.4 (range 4–8) on an 11–point Likert scale, where 0 = very unsure and 10 = very sure. For retinal examination of patients with known diabetes, the majority of optometrist (89%) reported undilated fundus photography as the preferred screening method. Although, most optometrists stated that they used more than one screening method, Table 3.

Table 3: *Preferred methods of retinal examination of patients with diabetes.*

	Preferred method (%)
Undilated retinal photograpy	16 (89)
Undilated indirect ophthalmoscopy	6 (33)
Undilated direct ophthalmoscopy	2 (11)
Dilated indirect ophthalmoscopy	2 (11)
Dilated retinal photography	1 (6)
Dilated direct ophthalmoscopy	1 (6)

Nine (50%) of the optometrists reported that patient management and decision to refer patients depended on the degree of diabetic retinopathy and whether the patient was under a follow-up regime by an ophthalmologist. Three optometrists reported that they would always refer patients with diabetes to an ophthalmologist, while five reported that referral to ophthalmologist was dependent on the degree of retinopathy.

Table 4: *Optometrist pre- and post -training sensitivity, specificity and classification of diabetic retinopathy.*

	Mean (%)	Two-sided student *t*-test
Sensitivity VIMOC 1	71	$p = 0.011$
Sensitivity VIMOC 2	86	
Specificity VIMOC 1	86	$p = 0.138$
Specificity VIMOC 2	73	
Classification DR** VIMOC 1	18	$p < 0.001$
Classification DR** VIMOC 2	45	

Note: * not normally distributed; ** diabetes retinopathy

The optometrists had significantly better sensitivity for identifying retinopathy post-training than pre-training, 71.4% (SD = 19.6) versus 85.7% (SD = 12.9), *t*-test $p = 0.011$. The optometrists showed a significant improvement in correct classification of images with diabetic retinopathy after web-based training, improving from 18.3% (SD = 11.8) to 45.2% (SD = 13.2), *t*-test $p < 0.001$. There were no statistically significant changes in specificity or ability to classify non-retinopathy images correctly. In total, the percentage of correctly classified images on VIMOC assessment of diabetic retinopathy increased by 27% (95% CI, 20 to 34) from pre-training to post-training, Table 4.

The recommended screening standard, sensitivity of at least 80% combined with a specificity of at least 95% (British Diabetic Association, 1997), was met by respectively 2 and 6 of the optometrists before and after the completing the web-based training protocol, Figure 1.

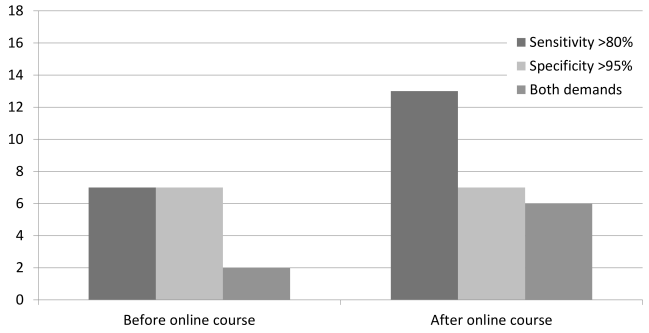

Figure 1: *The number of optometrists who met the screening standard with sensitivity higher than 80% and specificity higher than 95% before and after the online course.*

The optometrists referred when they found diabetic retinopathy. In cases of both true and false positives findings, the patients were usually referred to their general practitioner (GP) or ophthalmologist, Table 5. Because of the number of false positives, respectively 17 and 34 of 252 cases would have been unnecessarily referred to a GP or ophthalmologist in VIMOC 1 and VIMOC 2. In cases where the optometrists did not detect diabetic retinopathy, that is false negative, few of the optometrists would have referred the patients to an ophthalmologist, respectively 5 of 36 and 2 of 18 cases in VIMOC 1 and VIMOC 2, Table 5. In cases where the optometrists would not have referred despite findings of diabetic retinopathy, the patients had mild non-proliferative diabetic retinopathy or laser treated diabetic retinopathy. In cases of false negatives, which the optometrist would not have referred, the cases included both moderate non-proliferative retinopathy, diabetic macular oedema and laser treated diabetic retinopathy.

Table 5: *Optometrists' retinal image evaluation and follow up of diabetes retinopathy (DR).*

	Images with DR $n = 126$ Sensitivity		Images without DR $n = 126$ Specificity	
	True positive (%)	False negative (%)	True negative (%)	False positive (%)
VIMOC 1				
Optometrists image evalutaion	90 (71)	36 (29)	108 (86)	18 (14)
Further management				
None/Routine follow up	5 (4)	26 (21)	81 (64)	1 (1)
Referral/rapport to general practitioner	25 (20)	5 (4)	18 (14)	10 (8)
Referral/rapport to ophthalmologist	60 (48)	5 (4)	9 (7)	7 (6)
VIMOC 2				
Optometrists image evalutaion	108 (86)	18 (14)	92 (73)	34 (27)
Further management				
None/Routine follow up	2 (2)	9 (7)	50 (40)	0 (0)
Referral/rapport to general practitioner	33 (26)	7 (6)	39 (31)	13 (10)
Referral/rapport to ophthalmologist	73 (58)	2 (2)	3 (2)	21 (17)

Discussion

The aim of this study was to assess whether optometrists achieve standards for screening of diabetic retinopathy by use of a web-based training programme. There were several optometrists who reached the requirements for sensitivity after having undergone training, but for specificity the number optometrist who met the requirement criteria was unchanged. However, higher specificity may come at the cost of a low sensitivity, which can result in major consequences for patients if sight-threatening retinopathy is undetected and left untreated. This may further have economic consequences for the society in a long-term perspective. Screening and preventive treatment of diabetic retinopathy is very cost-effective measured in Quality Adjusted Life-Years (Javitt & Aiello, 1996). For Norwegian optometrists to be able to take on a role in screening responsibility, the web-based training programme needs to be extended to ensure that clinical skills and diagnostic sensitivity and sensitivity meet the required screening standard.

The optometrists in our study showed significantly improved sensitivity after training. This suggests that the optometrists improved their skills in correctly identifying diabetic retinopathy. However, the specificity fell slightly, but this change was not significant. This may indicate that the optometrists became better at detecting diabetic retinopathy at the expense of an increased over-diagnosis. This is not an unusual effect when screening is performed (Wilson & Jungner, 1968). A high number of false positives may also indicate that optometrists are careful when managing patients with diabetes assuming that they are afraid to miss sight-threatening retinopathy. Studies of optometrists in other countries have shown that optometrists can achieve good sensitivity and specificity for screening for diabetic retinopathy through extensive training. In an Australian study, optometrists achieved a screening sensitivity and specificity of respectively 94% and 93.6% and they correctly classified retinopathy in 69% of cases (Schmid et al., 2002). A reason why the results of the Australian study are better than our study may be differences in study design and training protocol. The Australian optometrists were gathered in one study centre where they underwent clinical training. This ensured virtually identical conditions for examination and grading for all participants. Guidelines were also available during the examinations. In our study the optometrists did the grading in their own office on their own computer and computer screen, therefore equal screening conditions were difficult to secure. Moreover, the optometrist in our study did not use grading scales.

Our study also showed an improvement in the optometrists' ability to grade diabetic retinopathy after web-based training. Being able to classify diabetic retinopathy correctly is essential, as it will secure proper follow-up and timely treatment. This is especially important in patients with potentially sight-threatening diabetic retinopathy and for patients who need medical treatment to preserve their vision. Optometrists' ability to classify diabetic retinopathy is also essential in ensuring good and precise communication between optometrists and ophthalmologists, and other health professionals. The optometrists' ability to grade and assess diabetic retinopathy has in previous studies shown to be good, but in these studies, the optometrists were specially trained. A Norwegian study using the same study design and method as our study, but without the web-based training protocol, showed a slightly lower sensitivity and specificity of 67% and 84%, respectively (Sundling, 2013) compared to the sensitivity of 71.4% and specificity of 85.7% achieved after completion of web-based training in our study. Another difference in our study design is the implemented red-free images as well as colour images. This may have improved the detection of retinopathy as the use of red-free images enhances detection of retinal microaneurysms and haemorrhages. It has also been shown that assessment of red-free retinal images is better than retinal slit-lamp examination, but the best results were achieved by grading colour images (Olson et al., 2003).

Optometrists in Norwegian optometric practice examine mainly healthy patients, as ophthalmologists take care of patients with retinal findings. Therefore, optometrists do not get the same amount of experience as they would have acquired if they assessed pathology more frequently. A UK study showed that optometrists working in hospitals have a higher sensitivity and specificity than optometrists working in optometric practice (Hulme et al., 2002). The improved diagnostic skills may be explained by more experience in number and varying degrees of diabetic retinopathy. Hospital settings experience will not be achieved in ordinary Norwegian optometric practice. However, proper training and regular examination of a substantial number of patients could secure high quality of screening in optometric practice.

Mydriasis or pupillary dilation provides a better view of the retina and improves image quality, positively affecting the optometrists' diagnostic abilities to detect diabetic retinopathy (Murgatroyd et al., 2004; Scanlon, Foy, Malhotra, & Aldington, 2005). In a previous Norwegian study, only 23% of optometrists reported that they performed dilated retinal examination in patients with diabetes (Sundling, 2013), which was consistent with our own findings. This practice conflicts with current clinical guidelines issued by The Norwegian Association of Optometry (Norges Optikerforbund, 2010). As our study used retinal photos of high quality, the sensitivity achieved in our study is likely higher than the actual sensitivity for detecting diabetic retinopathy in Norwegian optometric practice. This is supported by a previous Norwegian study, which reported a considerably lower number of patients with suspected diabetic retinopathy in optometric practice compared to the prevalence found in population-based studies (Sundling et al., 2008).

The optometrists included in our study represent a heterogeneous group of optometrists, reflecting Norwegian optometrists in general (Sundling et al., 2007). This may indicate that some optometrist chose to take part in the study because they feel they have little knowledge about diabetes or took part because they were already interested in diabetes or education in general. The medium mean self-confidence score (5.4 on a 0–10 Likert scale) in management of people with diabetes may reflect such heterogeneity.

The training protocol could have been improved to increase optometrists' competency in screening for diabetic retinopathy. For instance, introducing practical demonstrations, discussions and clinical workshops in screening for diabetic retinopathy in addition to the web-based training programme may have improved the diagnostic skills. However, such a training protocol may not have recruited the same population as the web-based training protocol, as long-distance travel would have been required for some of the optometrists to participate. Similar studies in countries like the UK had clinical practice as part of their curriculum. The studies showed sensitivity between 72% and 76% and specificity between 77% and 99% (Hulme et al., 2002; Olson et al., 2003; Prasad et al., 2001). These results were somewhat poorer in sensitivity, but better in specificity than our results. However, the studies are not directly comparable as they utilized different screening methods. In particular, the specificity was higher, which may be explained by clinical practice being included in the training programme. In a centralized and clinical screening setting like in the UK studies, the optometrists have the opportunity to ask questions directly and discuss cases; this may improve clinical reasoning and screening competency.

Conclusions

Our study showed a potential for Norwegian optometrists to improve their diagnostic skills for detection of diabetic retinopathy. Targeted training in diabetes screening and diabetic retinopathy for practicing optometrists significantly improved diagnostic sensitivity and correct classification of diabetic retinopathy. Future studies should assess whether implementation of clinical workshops and use of grading scales in the training program will further improve diagnostic quality and meet the screening standard for diabetic retinopathy.

Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

MAA participated in designing the study, acquired and statistically analyzed the data and drafted the manuscript. VS conceived the study, participated in its design and critically revised the manuscript. Both authors read and approved the final manuscript.

Availability of Data and Materials

The datasets supporting the conclusions of this article are available in the FigShare repository (https://figshare.com/s/54d3674ef8569a8e97c5).

Acknowledgement

We thank the optometrists that participated in the study. MAA thanks Krogh Optikk for financial support during the study period.

References

Aakre, B. & Svarverud, E. (2011). Utdanning for klinisk kompetanse (Education for clinical competence). *Optikeren 2011*, *5;* 52–53.

Backlund, L. B., Algvere, P. V., & Rosenqvist, U. (1997). New blindness in diabetes reduced by more than one-third in Stockholm County. *Diabetic Medicine*, *14*(9), 732–40.

Bamashmus, M. A., Matlhaga, B., & Dutton, G. N. (2004). Causes of blindness and visual impairment in the west of Scotland. *Eye (Lond)*, *18*(3), 257–61. doi:10.1038/sj.eye.6700606

Bek, T. (2012). Øjenkomplikationer ved type 2-diabetes (ophthalmic complications in patients with diabetes type 2). *Ugeskr Læger 2012*, *174*, 2147.

Bertelsen, G., Peto, T., Lindekleiv, H., Schirmer, H., Solbu, M. D., Toft, I., … Njolstad, I. (2013). Tromso eye study: Prevalence and risk factors of diabetic retinopathy. *Acta Ophthalmol*, *91*(8), 716–21. doi:10.1111/j.1755-3768.2012.02542.x

British Diabetic Association. (1997). *Retinal photographic screening for diabetic eye disease. a british diabetic association report*. British Diabetic Association.

Cooper, J. G., Claudi, T., Thordarson, H. B., Lovaas, K. F., Carlsen, S., Sandberg, S., & Thue, G. (2013). Behandlingen av type 1-diabetes i spesialisthelsetjenesten – data fra Norsk diabetesregister for voksne (Treatment of type 1 diabetes in the specialist health service - data from the Norwegian Diabetes Register for Adults). *Tidsskrift for Den Norske Legeforening*, *133*(21), 2257–62. doi:10.4045/tidsskr.13.0153

Delcourt, C., Massin, P., & Rosilio, M. (2009). Epidemiology of diabetic retinopathy: Expected vsreported prevalence of cases in the French population. *Diabetes Metab*, *35*(6), 431–8. doi:10.1016/j.diabet.2009.06.002

Diabetesforbundet. (2014). Fakta om diabetes (Facts about diabetes). Retrieved February 23, 2015, from http://www.diabetes.no/no/Om_diabetes/

Gibbins, R. L., Owens, D. R., Allen, J. C., & Eastman, L. (1998). Practical application of the European Field Guide in screening for diabetic retinopathy by using ophthalmoscopy and 35mm retinal slides. *Diabetologia*, *41*(1), 59–64. doi:10.1007/s001250050867

Hapnes, R. & Bergrem, H. (1996). Diabetic eye complications in a medium sized municipality in southwest Norway. *Acta Ophthalmol Scand*, *74*(5), 497–500.

Harvey, J. N., Craney, L., Nagendran, S., & Ng, C. S. (2006). Towards comprehensive population-based screening for diabetic retinopathy: Operation of the North Wales diabetic retinopathy screening programme using a central patient register and various screening methods. *J Med Screen*, *13*(2), 87–92. doi:10.1258/096914106777589669

Hulme, S. A., Tin, U. A., Hardy, K. J., & Joyce, P. W. (2002). Evaluation of a district-wide screening programme for diabetic retinopathy utilizing trained optometrists using slit-lamp and Volk lenses. *Diabet Med*, *19*(9), 741–5.

Javitt, J. C. & Aiello, L. P. (1996). Cost-effectiveness of detecting and treating diabetic retinopathy. *Ann Intern Med*, *124*(1 Pt 2), 164–9.

Kilstad, H. N., Sjolie, A. K., Goransson, L., Hapnes, R., Henschien, H. J., Alsbirk, K. E., … Bergrem, H. (2012). Prevalence of diabetic retinopathy in Norway: Report from a screening study. *Acta Ophthalmol*, *90*(7), 609–12. doi:10.1111/j.1755-3768.2011.02160.x

Kristinsson, J. K., Hauksdottir, H., Stefansson, E., Jonasson, F., & Gislason, I. (1997). Active prevention in diabetic eye disease. A 4-year follow-up. *Acta Ophthalmologica Scandinavica*, *75*(3), 249–54.

Murgatroyd, H., Ellingford, A., Cox, A., Binnie, M., Ellis, J. D., MacEwen, C. J., & Leese, G. P. (2004). Effect of mydriasis and different field strategies on digital image screening of diabetic eye disease. *Br J Ophthalmol*, *88*(7), 920–4. doi:10.1136/bjo.2003.026385

Norges Optikerforbund. (2010). Retningslinjer i Klinisk Optometri (Clinical guidelines in optometry). Retrieved February 17, 2015, from http://www.optikerne.no/pop.cfm?FuseAction=Doc&pAction=View&pDocumentId=24517

Norsk Oftalmologisk Forening. (2012). KONUS-rapporten: Kartlegging og oftalmologisk nasjonal utredning av framtidig status (Mapping and ophthalmological national assessment of future status). Retrieved February 17, 2015, from http://legeforeningen.no/PageFiles/67027/KONUS-rapport%20final%202012_290812.pdf

Olson, J. A., Strachan, F. M., Hipwell, J. H., Goatman, K. A., McHardy, K. C., Forrester, J. V., & Sharp, P. F. (2003). A comparative evaluation of digital imaging, retinal photography and optometrist examination in screening for diabetic retinopathy. *Diabet Med*, *20*(7), 528–34.

Porta, M. & Bandello, F. (2002). Diabetic retinopathy a clinical update. *Diabetologia*, *45*(12), 1617–34.

Prasad, S., Kamath, G. G., Jones, K., Clearkin, L. G., & Phillips, R. P. (2001). Effectiveness of optometrist screening for diabetic retinopathy using slit-lamp biomicroscopy. *Eye (Lond)*, *15*(Pt 5), 595–601. doi:10.1038/eye.2001.192

Scanlon, P. H., Foy, C., Malhotra, R., & Aldington, S. J. (2005). The influence of age, duration of diabetes, cataract, and pupil size on image quality in digital photographic retinal screening. *Diabetes Care*, *28*(10), 2448–53.

Schmid, K., Swann, P., Pedersen, C., & Schmid, L. (2002). The detection of diabetic retinopathy by Australian optometrists. *Clinical and experimental optometry*, *85*(4), 221–228.

Stefansson, E., Bek, T., Porta, M., Larsen, N., Kristinsson, J. K., & Agardh, E. (2000). Screening and prevention of diabetic blindness. *Acta Ophthalmologica Scandinavica*, *78*(4), 374–85.

Sundling, V. (2012). Diabetes, syn og øyehelse (Diabetes, vision and eye care). Best Practice, Vol. 3. Electronic Article. Retrieved July 11, 2017, from https://bestprac.no/diabetes-syn-og-oyehelse

Sundling, V. (2013). Diabetes retinopati (Diabetes retinopathy). Best Practice, Vol. 7. Electronic Article. Retrieved July 11, 2017, from https://bestprac.no/diabetes-retinopati

Sundling, V., Gulbrandsen, P., Bragadottir, R., Bakketeig, L. S., Jervell, J., & Straand, J. (2007). Optometric practice in Norway: A cross-sectional nationwide study. *Acta Ophthalmol Scand*, *85*(6), 671–6. doi:10.1111/j.1600-0420.2007.00929.x

Sundling, V., Gulbrandsen, P., Bragadottir, R., Bakketeig, L. S., Jervell, J., & Straand, J. (2008). Suspected retinopathies in Norwegian optometric practice with emphasis on patients with diabetes: A cross-sectional study. *BMC Health Serv Res*, *8*, 38. doi:10.1186/1472-6963-8-38

Sundling, V., Gulbrandsen, P., & Straand, J. (2013). Sensitivity and specificity of Norwegian optometrists' evaluation of diabetic retinopathy in single-field retinal images – a cross-sectional experimental study. *BMC Health Serv Res*, *13*, 17. doi:10.1186/1472-6963-13-17

Sundling, V., Platou, C. G., Jansson, R. W., Bertelsen, G., Wollo, E., & Gulbrandsen, P. (2012). Retinopathy and visual impairment in diabetes, impaired glucose tolerance and normal glucose tolerance: The nord-trondelag health study (the HUNT study). *Acta Ophthalmol*, *90*(3), 237–43. doi:10.1111/j.1755-3768.2010.01998.x

Wilson, J. M. G. & Jungner, G. (1968). *Principles and practice of screening for disease*. Genève: World Health Organization.

Zoega, G. M., Gunnarsdottir, T., Bjornsdottir, S., Hreietharsson, A. B., Viggosson, G., & Stefansson, E. (2005). Screening compliance and visual outcome in diabetes. *Acta Ophthalmologica Scandinavica*, *83*(6), 687–90.