Research Article

Association of Dyslipidemia with Severity of Meibomian Gland Dysfunction and Type of Dry Eye Disease

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Abstract

The meibomian gland is physiologically involved in lipid secretion; thus, abnormalities in systemic lipid levels may be related to meibomian gland lipid secretion. Meibomian gland dysfunction (MGD) has been strongly associated with dry eye disease (DED), especially the evaporative type. The MGD has been known to increase cholesterol levels, mainly cholesterol ester, in meibomian gland secretions, which is associated with the pathology of MGD. The aim of the study is to assess the association of dyslipidemia with MGD and DED. This was a cross-sectional population-based study using consecutive sampling. Data was taken from the database of the Smart Health Study conducted in Mendalanwangi, Sidorahayu, and Cepokomulyo Village, Malang, from July to November 2019. There were 867 subjects aged ≥40years old with risk of MGD. Assessment of DED ocular surface disease index (OSDI) score, tear breakup time (TBUT), Tear Meniscus (TM), MGD, and dyslipidemia (level of Triglycerides (TG) and High-Density Lipoprotein (HDL)) was performed. The majority of subjects were female with no DED or dyslipidemia. Most respondents had MGD grade 1. Patients with dyslipidemia had a 1.4-fold risk for evaporative dry eye (EDE) compared to patients with normal lipid levels [OR 1.417 (95% CI: 1.0-2.070)]. Patients with MGD had a lower risk of aqueous deficiency dry eye (ADDE) [OR 0.160 (95% CI: 0.699 – 0.366)]. There was no significant association between dyslipidemia and MGD and DED. Patients with dyslipidemia had a 1.4-fold risk of EDE compared to patients with normal lipid levels.

Keywords: *aqueous deficiency dry eye, evaporative dry eye, mixed type, dyslipidemia, population-based.*

Hubungan Dislipidemia dengan Tingkat Keparahan Disfungsi Kelenjar Meibom dan Jenis Penyakit Mata Kering

Abstrak

Kelenjar meibom secara fisiologis terlibat dalam sekresi lipid, sehingga kelainan sistemik lipid mungkin terkait dengan kelenjar meibom. Disfungsi kelenjar meibom telah diketahui berhubungan dengan penyakit mata kering. Peningkatan kadar kolesterol, terutama kolesterol ester, dalam sekresi kelenjar meibomian dikaitkan dengan patologi disfungsi kelenjar meibom. Penelitian ini berbasis populasi pertama yang menilai hubungan dislipidemia dengan disfungsi kelenjar meibom dan penyakit mata kering. Penelitian ini merupakan penelitian berbasis populasi, cross-sectional dengan pengambilan sampel secara consecutive sampling. Data diambil dari basis data Studi Kesehatan Cerdas yang dilakukan di Desa Mendalanwangi, Sidorahayu, dan Cepokomulyo, Malang. Terdapat 867 subjek berusia ≥ 40 tahun dengan risiko disfungsi kelenjar meibom. Penilaian penyakit mata kering (Ocular Surface Disease Index (OSDI) score, Tear Breakup Time (TBUT), Tear Meniscus (TM), dan disfungsi kelenjar meibom)) dan dislipidemia (kadar Trigliserida (TG) dan High-Density Lipoprotein (HDL)). Mayoritas subjek adalah perempuan tanpa penyakit mata kering atau dislipidemia. Sebagian besar responden memiliki disfungsi kelenjar meibom tingkat 1. Pasien dengan dislipidemia memiliki risiko 1,4 kali lipat untuk mengalami evaporative dry eye (EDE) dibandingkan dengan pasien dengan kadar lipid normal [OR 1,417 (95% CI: 1,0-2,070)]. Pasien dengan disfungsi kelenjar meibom memiliki risiko lebih rendah untuk mengalami aqueous deficiency dry eye (ADDE) [OR 0.160 (95% CI: 0.699 - 0.366)]. Tidak ada hubungan yang signifikan antara dislipidemia dengan disfungsi kelenjar meibom dan penyakit mata kering. Pasien dengan dislipidemia memiliki risiko 1,4 kali lipat mengalami EDE dibandingkan pasien dengan kadar lipid normal.

Kata kunci: *aqueous deficiency dry eye, evaporative dry eye, tipe campuran, dislipidemia, berbasis populasi.*

Introduction

Meibomian gland dysfunction (MGD) is a chronic eye disease with a prevalence ranging from 3.5 to 70% depending on geographic location. Several multivariable analyses show that male sex, age, and use of lipid-lowering drugs are independent factors of MGD. Previous study found that the prevalence of MGD in a predominantly Caucasian population was lower than in the Asian population, and approximately 20% of patients aged ≥45 years old showed symptoms of dry eye.[1-3]

The meibomian gland is physiologically involved in lipid secretion; thus, abnormality in systemic lipid levels may be related to meibomian gland lipid. Increased cholesterol levels, mainly cholesterol esters, in meibomian gland secretion are associated with MGD pathology. Total cholesterol consists of 3 main types of lipoprotein, i.e, low-density lipoprotein (LDL), high-density lipoprotein (HDL), and triglyceride (TG). Dyslipidemia is an abnormality of one of the three components.[4,5]

This is a population-based study assessing the association of dyslipidemia with MGD and dry eye disease (DED) in Indonesia. The result of this study was expected to show that TG and HDL may serve as practical biomarkers for assessing lipid-related risk in the general population. This study aims to investigate the relationship between dyslipidemia and the occurrence of MGD and DED in the Indonesian population.

Methods

This study had been approved by the Ethical Committee of the Faculty of Medicine, Universitas Brawijaya, No.211/EC/KEPK/07/2019. Informed consent was taken from each subject. This study used consecutive sampling and a cross-sectional design. Data was collected in 3 villages, with two rounds of data collection conducted in each village between July and November 2019. The data were obtained from the database of the Biomarker Study “Smart Health,” conducted in the villages of Mendalanwangi, Sidorahayu, and Cepokomulyo. A total of 867 subjects aged ≥40 years who fulfilled the inclusion criteria were included. The inclusion criteria were all residents of Mendalanwangi, Sidorahayu, and Cepokomulyo villages who are part of the SmartHealth population and meet the risk factor criteria for MGD and DED related to age (over 40 years), and who are willing to undergo DED (Ocular Surface Disease Index (OSDI) score, Tear Breakup Time (TBUT), Tear Meniscus(TM), and MGD) and dyslipidemia (Triglycerides (TG) and High-Density Lipoprotein (HDL)) examinations until completion.

Devices used in this study were the Inami slit lamp, Optiglo fluorescein strips, and a translated version of the OSDI questionnaire. The lipid fraction studied was the fasting venous blood level of TG and HDL. Respondents with unfinished examinations, inconclusive examination results, or other ocular surface disorders such as pterygium, corneal ulcer, and infection were excluded.

Multivariate logistic regression was used to evaluate the association between dyslipidemia and both MGD and DED subtypes, as well as between MGD and DED. Ordinal regression analysis was used to assess the association of dyslipidemia with the severity of MGD. The data were described in tabular form using STATA version 14.

Results

This study was conducted on 867 residents of Cepokomulyo, Mendalanwangi, and Sidorahayu village. Table 1 shows that the percentages of patients with DED and without DED were similar (57% and 43%, respectively). The most frequent types of DED were no DED (56.98%) and EDE (19.14%). Almost all respondents (97.1%) had MGD. Among patients with MGD, most had MGD grade 1 (41.63%). The majority of respondents were female and had no dyslipidemia (76.35% and 71.5%, respectively).

Table 1. Respondents' Characteristics in Cepokomulyo, Mendalanwangi, and Sidorahayu Villages

Characteristics	n	%
Dry eye disease		
Yes	373	43.02
No	494	56.98
Classification of DED		
No DED	494	56.98
ADDE	100	11.53
EDE	166	19.14
Mixed type	107	12.34
MGD		
Yes	842	97.11
No	25	2.89
Severity of mgd		
Non MGD	25	2.89
MGD grade 1	361	41.63
MGD grade 2	312	35.98
MGD grade 3	114	13.14
MGD grade 4	55	6.34
Dyslipidemia		
No	620	71.51
Yes	247	28.48
Sex		
Male	205	23.64
Female	662	76.35
Age		
40 - 49 years	145	16.7
50 - 59 years	265	30.6
60 - 65 years	198	22.8
>65 years	259	29.9

DED: dry eye disease; ADDE: aqueous-deficient dry eye; EDE; evaporative dry eye; MGD: meibomian gland dysfunction

Table 2 describes factors affecting MGD. There was no significant association between dyslipidemia, gender, age, or DED with MGD. Table 3 shows that, among all variables, age was the only factor significantly associated with DED. Each one-year increase in age was linked to a 1.015-fold increase in the risk of DED [Odds Ratio (OR) 1.015; 95% Confidence Interval (CI): 1.000–1.131], with a p-value < 0.05.

Table 2. Contributing Factors to Meibomian Gland Dysfunction

Characteristics	OR (95% CI)	p value
Dyslipidemia		
No	Reference	
Yes	0.899 (0.380 – 2.127)	0.809
Sex		
Male	Reference	
Female	1.674 (0.683 – 4.100	0.259
Age	1.020 (0.975 – 1.-068)	0.378
DED		
No	Reference	
Yes	0.682 (0.306 – 1.519)	0.348

Table 3. Risk Factor of Dry Eye Disease

Characteristics	OR (95% CI)	p value
Dyslipidemia		
No	Reference	
Yes	1.081 (0.800 – 1.459)	0.610
Sex		
Male	Reference	
Female	0.922 (0.664 – 1.280)	0.630
Age	1.015 (1.000 – 1.-31)	0.039*
MGD		
No	Reference	
Yes	0.682 (0.306 – 1.519)	0.350

Multivariate analysis revealed a significant association between age and the severity of MGD (Table 4). Additionally, patients with DED were found to have a lower likelihood of presenting with grade 1 MGD [Odds Ratio (OR): 0.294; 95% Confidence Interval (CI): 0.670–1.129].

Table 4. Contributing Factors to Meibomian Gland Dysfunction

Characteristics	MGD Grade 1		MGD Grade 2		MGD Grade 3		MGD Grade 4	
	OR(95%CI)	p	OR(95% CI)	p	OR(95%CI)	p	OR(95%CI)	p
Dyslipidemia								
No	Reference		Reference		Reference		Reference	
Yes	0.820 (0.338 – 1.985)	0.660	0.958 (0.407 – 2.379)	0.974	0.882 (0.343 – 2.270)	0.796	1.080 (0.385 – 3.028)	0.882
Sex								
Male	Reference		Reference		Reference		Reference	
Female	1.704(0.678 – 4.284)	0.256	1.624 (0.647 – 4.071)	0.301	1.457 (0.548 – 3.875)	0.450	2.741 (0.895 – 8.390)	0.077
Age								
	0.995 (0.948 – 1.044)	0.844	1.023(0.975 – 1.037)	0.337	1.051 (1.000 – 1.105)	**0.048***	1.074 (1.018 – 1.134)	**0.009***
DED								
No DED	Reference		Reference		Reference		Reference	
DED	0.294(1.129 – 0.670)	**0.00***	1.206	0.653	1.599 (0.666 – 3.839)	0.293	0.642 (0.247 – 1.677)	0.368

Table 5. Contributing Factors to the Classification of DED

Characteristics	ADDE		EDE		Mix Type	
	OR(95%CI)	p	OR(95% CI)	p	OR(95% CI)	p
Dyslipidemia						
No	Reference		Reference		Reference	
Yes	0.753 (0.446 – 1.269)	0.287	1.417 (1.0 – 2.070)	**0.05***	0.971 (0.602 – 1.565)	0.904
Sex						
Male	Reference		Reference		Reference	
Female	1.072 (0.607 – 1.893)	0.809	0.950 (0.620 – 1.456)	0.817	0.781(0.481 – 1.269)	0.319
Age						
	0.977(0.951 – 1.003)	0.092	0.193(0.998 – 1.039)	0.052	1.040(1.018 – 1.065)	**0.00***
MGD						
No MGD	Reference		Reference		Reference	
MGD	0.160 (0.699 – 0.366)	**0.00***	20159 (0)	0.983	1873	0.986

Multivariate analysis of DED variables revealed that patients with dyslipidaemia had a 1.4-fold increased risk of developing EDE compared to those with normal lipid profiles [Odds

Ratio (OR): 1.417; 95% Confidence Interval (CI): 1.000–2.070]. Conversely, patients with MGD were less likely to develop ADDE [OR: 0.160; 95% CI: 0.366–0.699]. Among all factors analyzed, age was the only variable significantly associated with mixed-type DED. Each one-year increase in age was associated with a 1.015-fold increase in the risk of developing DED (Table 5).

Discussion

Most patients in this study had no DED (59.68%). A study of patients with type 2 diabetes mellitus participating in the Prolanis program in Semarang also showed that 54.8% had no DES.[6] The majority of patients with no DED had lower use of video display terminals (VDTs) such as laptops, computers, or smartphones.[7] Cigarette smoke exposure is one of the risk factors of DED. Low cigarette smoke exposure is related to no DED. Cigarette smoke may cause irritation of the ocular surface and loss of growth factor components needed for epithelial differentiation, thus inducing DES.[6]

Almost all patients in this study (97.11%) had MGD. A previous study conducted in France also reported that more than half of the participants (54%) were diagnosed with MGD and obtained a SPEED (Standard Patient Evaluation of Eye Dryness) score of ≤18.8. In this study, MGD was associated with age. Aging is among the important risk factors of MGD. Aging leads to atrophy of acinar epithelial cells, resulting in reduced lipid production and altered meibomian gland composition, characterized by changes in both neutral and polar lipid profiles.[9]

Most patients in this study were classified as MGD grades 1 and 2 (41.63% and 35.98%, respectively). Findings from research conducted in the Indian population demonstrated that the majority of individuals also had MGD grade 1 and 2 (13.44% and 46.67%, respectively).[10] Low-grade MGD is frequently found in patients with low triglyceride levels. Approximately 1-2% of meibomian gland secretion consists of triglyceride. Increased triglyceride levels may increase meibomian melting points and viscosity.[10]

Of 620 patients (71.51%), 71.51% had no history of dyslipidemia. A previous study in patients with type 2 diabetes mellitus also showed similar results, with 69.0% of patients having no history of dyslipidemia.[6] The majority of patients in this study had a healthy lifestyle with no alcohol consumption and adequate physical activity, and had no history of corticosteroid, oral contraceptive, and beta blocker drug use.[11]

Female patients predominated in the study population (76.25%). Research conducted on the correlation between tear production and dry eye syndrome has also shown a similar trend, with approximately two-thirds of patients being female.[12] This female predominance is associated with the role of estrogen and androgen. Androgen plays an important role in the regulation of the ocular surface and adnexa; therefore, androgen deficiency predisposes to lacrimal gland dysfunction, which in turn increases risk factors of MGD related to EDE and ADDE.[13,14]

This study found that dyslipidemia, sex, age, and DED were not significantly associated with the development of MGD. Sex was not significantly associated with DED due to the imbalance of the male-to-female ratio in this study. Steroid sex hormones, such as androgens, are important in the development of MGD, causing a higher prevalence of MGD in postmenopausal women.15 DED was not significantly associated with MGD because patients with no DED were more frequently found.

Evidence indicates that both ocular and systemic factors are associated with the development of MGD.[16] Ocular factors specifically related to MGD are the use of contact lenses and glaucoma drugs, while systemic conditions include increasing age, lower androgen levels, Rosacea, and Sjogren syndrome.[16]

The prevalence of MGD has been reported to be higher in men across all age groups (OR=1.30; 95% CI: 1.35–1.79), in postmenopausal women (OR=1.64; 95% CI: 1.19–2.33), in individuals with pinguecula (OR=2.43; 95% CI: 2.08–2.85), in those with elevated diastolic blood pressure (OR = 1.32; 95% CI: 1.08–1.62), and among users of angiotensin II receptor inhibitors (OR=4.02; 95% CI: 1.74–9.27).[17]

Consistent findings have demonstrated that MGD severity tends to increase with advancing age. The risk of MGD is also greater in individuals with hypertension, diabetes mellitus, and in postmenopausal women. Elevated LDL cholesterol levels further increase MGD risk.[18]

Analysis of DED risk factors in this study showed that age was the only factor significantly associated with DED. A one-year increase in age was related to a 1-fold increase in risk of DED. A previous study found that age was related to the severity of dry eye in male subjects (p=0,004). With aging, tear secretion decreases and tear evaporation increases, thus inducing DED.[19]

Elderly individuals have been reported to be more susceptible to depression, which shows a significant association with dry eye disease (DED). This was also related to a higher Schirmer test score. [20] Female sex and urban residence were also significantly related to the incidence of DED in this study. Increase of ω-6:ω-3 fatty acid content in food is regarded as an important cause of increased incidence of DED and severe depression. Increased ω-6:ω-3 ratio induces production of proinflammatory cytokines such as IL-1, IL-6, and tumor necrosis factor (TNF)-α. Those cytokines provoke ocular surface inflammation in DED and trigger negative moods by affecting neurotransmission and signal transduction.[20]

Age-related changes in anatomy and inflammation affect all components of the lacrimal gland functional units, including the lacrimal gland, conjunctiva, meibomian glands, and ocular surface. Aging is a risk factor for DED and is also associated with a weakened immune system in the elderly. The levels of inflammatory mediators and related T cells, such as IL-1β, IL-6, TNF-α, IL-17, and IFN-γ, are elevated in the conjunctiva and tears of patients with DED. Activation of the local immune environment is another universal feature of dry eye, with increased HLA-DR+ expression frequently observed. Other features of dry eye include increased matrix metalloproteinase (MMP) production, increased levels of chemokines and proteins involved in oxidative stress, release of squamous metaplasia from ocular surface epithelium, loss of goblet cells, and increased endoplasmic reticulum stress.[21]

Evidence indicates that MGD is strongly correlated with older age, female sex, contact lens use, smoking habits, diabetes mellitus, prolonged use of video display terminals, rheumatoid arthritis, and the use of systemic or topical medications such as anti-allergy, antihypertensive, antidepressant, and antiglaucoma drugs ($p<0.05$).

Greater MGD severity has also been associated with serum triglyceride levels above 150 mg/dL, total cholesterol levels above 200 mg/dL, LDL levels above 130 mg/dL, and HDL levels below 40 mg/dL.[22] Consistent findings have shown that advancing age is significantly related to increased severity of MGD.

In humans, aging has been shown to reduce meibocyte differentiation and alter cell cycle activity, contributing to the development of MGD.[23] It also showed that a change in PPARγ (Peroxisome Proliferator–Activated Receptor γ) signaling led to acinar atrophy and the development of MGD due to age-related hyposecretion. The activity of PPARγ appears relevant to the changes in the ocular surface observed in age-related MGD. Androgen is proven to affect the expression of meibomian gland genes, and women with androgen insensitivity show an alteration of meibomian gland lipid profile that might act through the PPARγ gene. An abnormal ocular surface is associated with increased levels of regulatory proinflammatory cytokines, such as IL-1 and TNF-α. The severity of MGD also increases with age.[23]

Meibomian gland dysfunction (MGD) is an important factor contributing to the development of DED. MGD disrupts the tear lipid layer, thereby altering the tear evaporation rate. Tear evaporation leads to tear hyperosmolarity, which in turn induces DED. DED and MGD are correlated and have overlapping risk factors, signs, and symptoms. Tear film consists of three layers: the lipid, aqueous, and mucous layers. The main component of the tear film, the lipid layer, is generated by the meibomian gland. The lipid layer prevents evaporation from the ocular surface; thus, it is crucial in maintaining a healthy ocular surface. MGD disrupts lipid secretion, increasing

tear evaporation and leading to tear hyperosmolarity. Patients with MGD are reported to have a higher tear evaporation rate compared to normal subjects. This shows that DED is directly correlated with the integrity and quality of the meibomian gland.[24]

MGD and DED can be assessed through external examination, slit lamp biomicroscopy, tear instability test, ocular surface disturbance test, and tear osmolarity test.[6] The current study assessed DED and MGD of only the right eye of the patients. A similar methodological approach has been applied in other investigations, in which tear osmolarity and cytokine levels were measured separately in the right and left eye, respectively.[25]

This study found that dyslipidemia increased the risk of EDE up to 1.4-fold, while the risk of ADDE decreased in patients with MGD. Age was significantly related to mixed-type DED. An increase of one year in age increases the risk of developing mixed-type DED by one-fold. The mechanism associated with statin use or dyslipidemia with meibomian MGD and DED remains poorly understood.[27] One of the hypotheses is related to the proinflammatory characteristic of LDL, because inflammation contributes to the pathogenesis of MGD and DED.[28] Statins act by inhibiting HMG-CoA reductase, a rate-controlling enzyme for the synthesis of sterol and isoprenoid in epithelial cells of the human meibomian gland. The risk of DED is similar across low-, intermediate- and high-intensity statin regimens, suggesting that the effect of statins is probably dose-independent. Topical statins have been used to treat blepharitis-related dry eye. The mechanism is unclear, although it may be related to its anti-inflammatory properties.[29] Meibomian gland with higher cholesterol concentration has a higher melting point, thus producing more viscous secretion and causing obstruction of the meibomian gland. Meibomian gland obstruction can disrupt the lipid layer of the tear film, increasing tear evaporation and osmolarity.[30-32]

DED is a multifactorial disease classified as ADDE, EDE, and mixed type DED. MGD is the most frequent cause of EDE and can be related to ADDE. Meibomian glands, located in the tarsal plate of the upper and lower eyelids, produce meibum, an oily secretion that builds the outer layer of the tear film, decreases tear evaporation, and contributes to the lubrication of the ocular surface. Anatomical and functional disturbance of meibomian glands and eyelid margin can cause a change in the quality and quantity of meibum.[33] This study found that patients with MGD had a lower risk of ADDE and were more prone to EDE. In EDE, tear hyperosmolarity is caused by excessive tear evaporation despite normal lacrimal function.[34]

Mixed-type DED was the second most common subtype, predominantly affecting individuals aged 60–69 years. Risk of dry eye increases with age, and the current result showed no significant association between diabetes and hypertension and increased risk of DED.[35]

Limitations of this study included the use of a cross-sectional design, which made it difficult to evaluate baseline conditions, other systemic diseases, onset, and disease duration for each subject. The cross-sectional design also led to a lack of assessment of the direct correlation between the independent and dependent variables.

Conclusion

The current study concluded that there was no significant association between dyslipidemia and MGD and DED. Patients with dyslipidemia had a 1.4-fold risk of developing EDE compared to patients with a normal lipid profile. Further study assessing other variables and more detailed DED parameters is warranted. Education and motivation are important in improving the quality of life of patients with dyslipidemia, MGD, and DED.

Ethics Statement

This study had been approved by Ethical Committee of the Faculty of Medicine, Universitas Brawijaya No.211/EC/KEPK/07/2019.

Consent for Publication

Written informed consent was obtained from the patient for publication of this report and accompanying images.

Conflict of Interest

The authors have no conflicts of interest to declare.

Authors' Contributions

RA designed the study and drafted the manuscript. YM collected clinical data and revised the manuscript. H performed data analysis and literature review. SP supervised the study and approved the final version. RR drafted the manuscript. All authors approved the final manuscript.

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