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Relationship between body mass index, waist-to-hip ratio and Meibomian gland morphology

Abstract

Background: Despite the rising prevalence of evaporative dry eyes among young adults in Malaysia, the association between obesity-related factors like BMI, WHR and Meibomian gland loss (MGL) remains unclear. This study investigates the relationship between body mass index (BMI), waist-to-hip ratio (WHR) and Meibomian gland dysfunction (MGD) in young adults.

Methods: A total of 66 right eyes of subjects were divided into underweight, normal weight, overweight, and obesity groups based on their BMI and WHR. Meibomian gland examinations of the upper eyelids were performed using Oculus Keratograph 5M corneal topographer (Oculus Optikgerate, Germany). MGL was calculated using ImageJ software (Version 1.51).

Results: Among the 66 subjects enrolled, there were 29 males [44%] and 37 females [56%] with the mean age of 22.39 ± 1.98 years. The mean body mass index (BMI) was 23.40 ± 6.13 while the mean waist-to-hip ratio (WHR) was 0.79±0.06. Pearson correlation revealed no statistically significant difference in BMI and MGL (r(64)= 0.023, p= 0.857), BMI and MG tortuosity (r(64)= 0.124, p= 0.321), WHR and MGL (r(64)= -0.093, p= 0.457), WHR and MG tortuosity (r(64)= 0.151, p= 0.226).

Conclusion: No significant association in BMI and WHR with either MGL or Meibomian gland (MG) tortuosity. These results suggest that targeting BMI and WHR alone may not be sufficient for addressing MGD, highlighting the need to explore other potential contributing factors.

Keywords: body mass index, meibography, Meibomian glands, imageJ

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Abbreviations: MGL, Meibomian gland loss; BMI, body mass index; WHR, waist-to-hip ratio; MGD, Meibomian gland dysfunction; TFOS, Tear Film and Ocular Surface Society; DEWS, Dry Eye Workshop

Introduction

The Meibomian glands are located in both the upper and lower tarsal plates and are a type of sebaceous gland.[1] Their secretions form the lipid layer on the surface of the tear film, which plays a crucial role in preventing dry eye by reducing ocular surface water evaporation and preventing tear film collapse. The obstructive form of MGD is thought to be a major cause of evaporative dry eye disease.[2]

Meibomian gland dysfunction refers to a condition in which the Meibomian glands fail to function properly. This dysfunction typically arises from blockages in the glandular ducts or changes in glandular secretion. The main causes of these blockages include excessive skin cell buildup in the duct lining and meibum thickening.[3] Consequently, MGD can disrupt the tear film, manifesting symptoms like eye irritation, inflammation, and ocular surface disorders.[4] Importantly, MGD often goes unnoticed and is often a significant factor in the onset of dry eye disease.[3]

The Tear Film and Ocular Surface Society (TFOS) Dry Eye Workshop (DEWS) II report outlines two main types of dry eye: aqueous deficiency and evaporative. Within the evaporative dry eye category, the report highlights MGD-related lipid layer deficiency as a distinct sub-type. This sub-type is further categorized into conditions such as absent glands, posterior blepharitis, and anterior blepharitis.[5]

Body Mass Index (BMI) is determined by dividing an individual's weight by the square of their height, expressed in kg/m^2.[6] This measure assesses excess body weight relative to height and is a simple, cost-effective, and non-invasive method of evaluation. Traditionally, BMI has been the preferred metric for diagnosing underweight and overweight conditions.[7] However, alternative measures that reflect abdominal fat, such as waist circumference, waist-to-hip ratio, and weight-to-height ratio (WHR), have been proposed as better predictors of cardiovascular disease risk.[8]

The Meibomian glands play a pivotal role in maintaining the health of the ocular surface by producing the lipid layer of the tear film. Concurrently, BMI and WHR are central to evaluating systemic health and obesity-related risks. Given the rising prevalence of both obesity and evaporative dry eye in the Klang Valley, investigating the interplay between BMI, WHR, and MGD is of increasing importance.

Material and methods

This cross-sectional study employed convivence sampling method and was designed to examine the relationship between body mass index (BMI), waist-to-hip ratio (WHR), and Meibomian gland dysfunction (MGD) in young adults aged 18 to 26 years.

All subjects recruited for the study were residents of Klang Valley who had not worn contact lenses within the past three months. Participants with conditions such as acne rosacea, medical allergic disease, Graves' disease, systemic lupus erythematosus, Sjögren's syndrome, Stevens-Johnson syndrome, or other autoimmune diseases affecting the tear film were excluded. Additionally, those who had not used tretinoin or isotretinoin were included. Pregnant or breastfeeding women were also excluded, along with individuals with active eye infections or allergies, lid deformities, or movement disorders. Subjects with a history of eye surgery, ocular trauma, or chemical burns were also excluded. Furthermore, individuals requiring continuous medication or eye drops (except artificial tears), those taking lipid-lowering drugs, or those undergoing estrogen replacement therapy were not eligible for the study.

A total of 66 participants provided consent to participate in the study. A brief medical and ocular history was taken, including details on contact lens use, systemic medical conditions, current medications, and lifestyle factors such as smoking. Participants were asked about ocular symptoms, including dryness, foreign body sensation, pain, fatigue, blurred vision, discharge, epiphora, puffy eyelids upon waking, sticky sensation, and a history of chalazion or hordeolum. If symptoms were present, participants specified their timing. Each symptom was recorded for both eyes.

BMI measurement

The height and weight of each participant were measured to determine their BMI category. Measurements were taken using a wall-mounted stadiometer and the Xiaomi Smart Scale 2. BMI was calculated using the formula shown below and were divided into four BMI groups according to the World Health Organization (WHO) classification, as shown in Table 1.[9]

$$BMI = \frac{Weight(kg)}{[Height(m)]^2} \quad (1)$$

Table 1 Classification of BMI groups

BMI group	BMI (kg/m²)
Under weight	<18.5 kg/m²
Normal weight	Between 18.5 kg/m² and 24.9 kg/m²
Over weight	Between 25.0 kg/m² and 29.9 kg/m²
Obesity	>30 kg/m²

Meibomian Gland Loss (MGL) and tortuosity assessment

The final phase involved assessing and documenting MGL and Meibomian gland tortuosity grades using the Oculus Keratograph 5M corneal topographer (Oculus Optikgerate, Germany). All examinations were conducted on right eye[10–12] and the upper eyelid where it is reported that the early changes in Meibomian gland tortuosity are observed.[13]

Images were captured with the Oculus Keratograph K5 software, and MGL was calculated using ImageJ software. MGL was defined as the proportion of the Meibomian gland area relative to the total upper eyelid area and was calculated using the formula as shown below

$$MGL = \frac{\text{Meibomian Gland Area Loss} \times 100}{\text{Total Area of Meibomian Gland}} \quad (2)$$

Grading of Meibomian Gland Loss and Tortuosity

MGL and tortuosity were graded using the meiboscore as shown in Table 2 and Table 3.[14]

Table 2 Grading of Meibomian gland loss

Meiboscore	Meibomian gland loss
Grade 0	No loss of Meibomian glands
Grade 1	Area of loss <33.33% of total area
Grade 2	Area of loss between 33.33% and 66.66% of total area
Grade 3	Area of loss >66.66% of the total area

Table 3 Grading of Meibomian gland tortuosity

Meiboscore	Meibomian Gland Tortuosity
Grade 0	No distortion of Meibomian glands
Grade 1	1-4 Meibomian glands with >45° distortion
Grade 2	>5 Meibomian glands with >45° distortion

Data analysis

The data were analysed using SPSS version 29.0. Descriptive analysis determined the mean age, BMI, waist-to-hip ratio, and meiboscore for MGL and Meibomian gland tortuosity. Normality was evaluated with the Shapiro-Wilk test, skewness, and coefficient of variance tests. A paired t-test compared BMI and WHR, and one-way ANOVA assessed the relationships between BMI and MGL, BMI and Meibomian gland tortuosity, WHR and MGL, and WHR and Meibomian gland tortuosity.

Results

A total of 66 right eyes of healthy participant (29 males [44%] and 37 females [56%]), were assessed during the study with the mean age of the participants was 22.39 ± 1.98 years. The mean body mass index (BMI) was 23.40 ± 6.13 while the mean waist-to-hip ratio (WHR) was 0.79±0.06. The mean meiboscore for Meibomian gland loss (MGL) was 1.11±0.31. Among the participants, 59 (89%) had a meiboscore of 1 with a mean of 1.11±0.31, and 7 (11%) had a meiboscore of 2 with a mean of 1.88±0.33. For gland tortuosity, the mean meiboscore was 1.39±0.49. Specifically, 40 participants (61%) had a meiboscore of 1 with the mean of 1.39±0.49, and 26 participants (39%) had a meiboscore of 2 with the mean of 1.61±0.49. Table 4 presents the descriptive analysis for this study.

Table 4 Descriptive analysis of age, BMI, WHR, MGL and Meibomian gland tortuosity

Variable (N=66)	Mean ± Std. deviation
Age	22.39±1.98
Body Mass Index	23.40±6.13
Waist-to-Hip Ratio	0.79±0.06
MGL (Total Meiboscore)	1.11±0.31
MGL (Grade 1)	1.11±0.31
MGL (Grade 2)	1.88±0.33
Tortuosity (Total Meiboscore)	1.39±0.49
Tortuosity (Grade 1)	1.39±0.49
Tortuosity (Grade 2)	1.61±0.49

The Pearson correlation was conducted to explore the relationship between BMI and MGL, BMI and Meibomian gland tortuosity, WHR and MGL, and WHR and Meibomian gland tortuosity. No significant relationships were identified among any of the tested parameters ($p > 0.05$), as shown in Table 5.

Table 5 Statistical comparison between BMI and MGL, BMI and MG tortuosity, WHR and MGL, WHR and MG tortuosity with pearson correlation

Correlation pair		Coefficient (r)	Sample size (n)	p-value
BMI	MGL	0.023	66	0.857
	MG Tortuosity	0.124	66	0.321
WHR	MGL	-0.093	66	0.457
	MG Tortuosity	0.151	66	0.226

Discussion

This study investigated the relationship between BMI, WHR, MGL, and Meibomian gland tortuosity in young adults aged 18–26 years, a population with limited prior research and high exposure to electronic devices. Young adults increasingly rely on gadgets for education, entertainment, and communication, paralleling trends seen in children.[15,16] The focus on the upper-lid of the right eye was guided by evidence suggesting that the upper lid provides greater diagnostic efficacy for MGD than the lower lid and that eye dominance does not significantly impact gland structure.[10,13]

Relationship between BMI, WHR, and MGL

The results showed no significant association between BMI or WHR and MGL in young adults, aligning with previous studies on similar populations.[17,18] This could be attributed to the young age of participants, as age is a critical factor in MGL progression. Studies have shown that MGL increases with age due to cumulative gland dropout, likely influenced by age-related changes in lipid profiles and increased prevalence of comorbid conditions such as hypertension, diabetes, and postmenopausal status.[3,19–21]

Additionally, visceral adiposity, rather than general fat accumulation, may play a more significant role in obesity-related complications.[22] Since this study focused on general measures of obesity (BMI and WHR) rather than visceral fat, the lack of significant associations with MGL is consistent with previous findings. These results suggest that factors beyond BMI and WHR, such as local fat distribution and other metabolic factors, may be more influential in MGL progression.

Relationship between BMI, WHR, and gland tortuosity

Similarly, no significant relationship was observed between BMI, WHR, and Meibomian gland tortuosity. These findings are consistent with prior research suggesting that gland tortuosity is an early morphological change, often preceding gland dropout.[23,24] For example, in paediatric populations, higher BMI percentiles have been associated with increased gland tortuosity, potentially reflecting early-stage glandular architectural changes rather than gland atrophy.[25] Changes in meibum viscosity caused by increased gland obstruction could trigger the progression from tortuosity to gland dropout. However, in young adults, significant gland dropout may not yet be observable, as gland architecture remains relatively resilient in this age group. Lifestyle factors such as increased physical activity or screen time may influence gland function, potentially offsetting early structural change

Comparison with existing literature

Methodological differences may also explain inconsistencies between studies. The present study used the Oculus Keratograph 5M to assess MGL and ImageJ software to quantify gland loss, following standardized grading systems.[14] However, prior studies have noted significant inter-observer variability in meiboscore measurements using the Oculus Keratograph 5M, often due to image quality issues such as blurriness, overexposure, and improper eyelid eversion.[26]

While computerized methods like ImageJ offer improved reliability over subjective grading scales,[27] manual outlining of the gland areas remains a source of variability. The need for operator input to define the tarsal plate and gland areas can introduce discrepancies between measurements, even when standardized protocols are applied.[28,29]

Lifestyle and environmental factors

Lifestyle and environmental factors may have also influenced the study findings. While the present study controlled for smoking and contact lens use, other factors such as dietary habits, time spent outdoors, and screen usage were not assessed. The increasing use of electronic devices among young adults may contribute to higher rates of MGD. In Southeast Asia, 70% of children report using mobile games compared to 56% in the United States, reflecting a broader shift toward screen-based activities.[30,31] These regional trends could partially explain differences in findings between this study and those conducted in other populations.

Limitations

This study has several limitations. First, the cross-sectional design allowed for only a single time-point assessment, which may not fully capture the progression of MGD. Longitudinal studies with serial imaging could provide more comprehensive insights into the natural history of gland atrophy. Second, while ImageJ software improved measurement reliability compared to subjective grading methods, its reliance on manual contouring may have introduced operator variability. Future studies should explore automated quantification tools to reduce inter- and intra-observer differences. Finally, while the study controlled for some lifestyle factors, others—such as diet, screen time, and environmental exposure—were not accounted for, limiting the generalizability of the findings.

Conclusion

In conclusion, this study found no significant associations between BMI, WHR, and MGL or MG tortuosity in young adults. These findings suggest that BMI and WHR are not key contributors to MGD in this population. Instead, other factors, including local adiposity, lifestyle, and environmental influences, may play a more critical role in gland morphology. Further longitudinal research is needed to better understand the progression of MGD and the influence of these factors on gland structure and function.

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Conflicts of interest

The author declares that there are no conflicts of interest.

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