

# Correlation between body mass index and ocular parameters

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**Purpose:** To investigate the relationship between BMI and selected ocular parameters.

**Subjects and methods:** Fifty-three left eyes of normal weight subjects and 67 age-sex matched overweight subjects were studied. Inclusion criteria for the normal weight and overweight groups included BMI between 18.5–22.9 and 23.0–29.9 kg/m<sup>2</sup>, respectively. Subjects with a history of systemic disease, ocular disease or surgery, or disability were excluded. All subjects underwent a medical history interview, arterial blood pressure, height, weight, waist circumference and hip circumference measurements, and BMI and waist-hip ratio calculation. The intraocular pressure (IOP) and anterior corneal curvature were measured by non-contact tonometry and corneal topography, respectively. Measurement of anterior and posterior segment parameters of the eye, including central corneal thickness, anterior chamber depth (ACD), anterior chamber angle, macular thickness (MT), ganglion cell thickness (GCT), retinal nerve fiber layer thickness, cup to disc ratio, and choroidal thickness was performed by enhanced depth-imaging optical coherence tomography.

**Results:** There was a positive correlation between ACD and BMI (Univariate analysis;  $\beta = 0.198$ ,  $P = 0.030$ , Multivariate analysis;  $\beta = 0.410$ ,  $P = 0.005$ ) and between BMI and IOP (Univariate analysis;  $\beta = 0.269$ ,  $P = 0.003$ ). The IOP of the overweight group was found to be significantly higher than of the normal weight group (12.80±3.40 and 11.86±2.12 mm Hg, respectively,  $P = 0.002$ ). Also, there was a significant difference found between the GCT and the MT of the two groups ( $P = 0.036$  and  $0.009$ , respectively).

**Conclusion:** It was found that BMI strongly correlated with ACD and IOP. Also, the degree of obesity was found to be a significant factor; therefore, the relationship between these ocular parameters and the severity of obesity should be further investigated.

**Keywords:** BMI, overweight, intraocular pressure, anterior chamber depth

## Introduction

Obesity is currently a major worldwide public health problem that is increasing in prevalence in most countries. A 2016 study by the WHO found that worldwide, more than 1.9 billion and 650 million people are, respectively, overweight or obese.<sup>1</sup> In Thailand, it has been reported that 4.9% of the population is obese.<sup>2</sup> BMI is commonly used to classify degree of obesity. The WHO has developed a BMI classification system defining underweight, normal body weight, overweight, and obesity as a BMI of 18.5 kg/m<sup>2</sup> or lower, 18.5–22.9 kg/m<sup>2</sup>, 23–29.9 kg/m<sup>2</sup>, and 30 kg/m<sup>2</sup> or greater, respectively.<sup>3</sup>

Obesity is not only a critical risk factor for several chronic diseases including diabetes mellitus, hypertension, cardiovascular disease, stroke, sleep apnea syndrome but also affects quality of life.<sup>4–6</sup> It has been found that obesity may be

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linked to a reduction in visual acuity.<sup>7</sup> Moreover, several lines of evidence indicate that obesity is associated with several ocular diseases including cataract, age-related macular degeneration, diabetic retinopathy, and glaucoma.<sup>8–13</sup> Several processes and risk factors, or oxidative stress, may induce pathophysiology resulting in anterior and/or posterior segment disease in the obese.<sup>9</sup> Previous studies have found a correlation between BMI and anterior segment parameters in obese individuals. For example, it was found that anterior chamber depth (ACD) and anterior chamber angle (ACA) were negatively correlated with BMI.<sup>14</sup> Other studies have investigated relationships between retinal nerve fiber layer thickness (RNFLT), BMI, and age.<sup>15,16</sup> In addition, a positive correlation between BMI and choroidal thickness (CT) changes has been found in obese women.<sup>17</sup> It seems that previous studies focused on either anterior segment or posterior segment parameters associated with obesity, but not both. The impact of obesity on both the anterior and posterior segment parameters of the eye has not been well documented, and information regarding their relationship with BMI is unclear. Moreover, all parameters of the eye are clinically important, as they may provide valuable data that could be used to analyze the pathophysiological mechanisms associated with any increased risk of ocular pathology in obese individuals.

This study aim was to investigate the relationship between the BMI and selected ocular parameters, via a comparison of findings between normal weight and overweight Thai subjects. Parameters studied included central corneal thickness (CCT), intraocular pressure (IOP), anterior corneal curvature (ACC), ACD, ACA, macular thickness (MT), ganglion cell thickness (GCT), RNFLT, cup to disc ratio (CDR), and CT.

## Subjects and methods

This study was conducted in accordance with the tenets of the Declaration of Helsinki, and the experimental protocol was approved by the Ethical Committee of Naresuan University, Phitsanulok, Thailand (COA No. 352/2016). The participant consent was written informed consent.

## Subjects

One hundred and twenty left eyes of 120 subjects were divided into two groups. Fifty-three eyes were in the normal weight group (21–69 years old), of whom 35.85% were male. The overweight group consisted of 67 age-sex matched (21–61 years old), of whom 49.25% were male.

Inclusion criteria for the normal weight and overweight groups were a BMI between 18.5–22.9 and 23.0–29.9 kg/m<sup>2</sup>, respectively. Subjects with a diagnosis of systemic diseases such as diabetes mellitus, hypertension, ocular disease (of both anterior and posterior segments), cataract or glaucoma, etc.; subjects with a history of ocular surgery or insufficiently cooperative for OCT measurement; or those with a history of any condition that could potentially impact BMI were excluded from this study.

## Methods

All subjects underwent a physical examination including medical history, arterial blood pressure, height, weight, waist and hip circumference measurement, and waist-hip (W/H) ratio calculation. The BMI was calculated as weight in kilograms divided by the height in meters squared (kg/m<sup>2</sup>). Intra-ocular pressure was measured using a Canon TX-20P non-contact tonometer, and ACC was measured using an ATLAS model 9000 corneal topographer.

Measurement of anterior and posterior segmental parameters of the eye, including CCT, ACD, ACA, MT, CDR, GCT, RNFLT, and CT were performed using a CIRRUS HD-OCT 5000 optical coherence tomographer (OCT). Subfoveal CT was recorded using the enhanced depth imaging mode as the vertical distance between the choroidal and retinal pigment epithelium layers.<sup>18</sup>

## Statistical analysis

The distribution of data from left eyes was analyzed using the Kolmogorov–Smirnov test and shown as mean ± SD or median ± IQR, frequencies or absolute numbers and percentage (%). The group differences of continuous variables were compared using an independent *t*-test or Mann–Whitney U test. Univariate comparisons were computed using Chi-square test for categorical variables. The degree of association between BMI and selected ocular parameters was calculated using simple regression and stepwise multiple regression analysis. The statistical significance level was *P*-value <0.05. All data were analyzed using the SPSS 17.0 software.

## Results

The demographic characteristics of subjects are shown in Table 1. The systolic blood pressure (SBP) and diastolic blood pressure (DBP) of the overweight group were significantly higher than those of the normal weight groups (SBP; 129.78±17.09 and 119.58±15.71 mm Hg

**Table 1** Demographic data

Characteristics	Total (N=120)	Normal weight (N=53)	Overweight (N=67)	P-value
Age (years)	47.00±14.00	45.60±11.51	47.00±15.00	0.649 <sup>b</sup>
Sex (male%)	43.33%	35.85%	49.25%	0.14 <sup>c</sup>
SBP (mmHg)	125.28±17.19	119.58±15.71	129.78±17.09	0.001 <sup>a*</sup>
DBP (mmHg)	80.78±11.79	76.45±8.56	84.20±12.88	0.000 <sup>a*</sup>
Alcohol (yes%)	35.83%	45.28%	28.36%	0.055 <sup>c</sup>
Current smoker (yes%)	10.83%	7.53%	13.43%	0.303 <sup>c</sup>
<b>Body compositions</b>				
BMI (kg/m <sup>2</sup> )	23.42±6.24	20.89±1.15	26.67±5.26	0.000 <sup>b*</sup>
W/H ratio	0.88±0.09	0.85±0.09	0.89±0.06	0.000 <sup>b*</sup>

**Notes:** \*Statistically significant; <sup>a</sup>independent Student's t-test; <sup>b</sup>Mann–Whitney U test; <sup>c</sup> Chi-square test.

**Abbreviations:** SBP, systolic blood pressure; DBP, diastolic blood pressure; BF, body fat; W/H ratio, waist–hip ratio.

( $P=0.001$ ), DBP;  $84.20\pm 12.88$  and  $76.45\pm 8.56$  mm Hg ( $P<0.001$ ), respectively). The BMI and W/H ratio of the overweight group were significantly higher than those of the normal weight group (BMI;  $26.67\pm 5.26$  kg/m<sup>2</sup> and  $20.89\pm 1.15$  kg/m<sup>2</sup>, W/H ratio;  $0.89\pm 0.06$  and  $0.85\pm 0.09$ , respectively,  $P<0.001$ ) There was no significant difference in age, gender distribution, percentage of alcohol consumption, and current smoking status between the two groups.

Regarding the anterior segment (AC) parameters, it was found that the IOP of the overweight group was significantly higher than that of the normal weight group ( $12.80\pm 3.40$  and  $11.86\pm 2.12$  mm Hg, respectively,

$P=0.002$ ). There was no significant difference in other AC parameters (HACC, VACC, CCT, ACD, and ACA) between groups (Table 2).

Regarding the posterior segment parameters, a significant difference between overweight and normal weight groups was found in both GCT and MT ( $P=0.036$  and  $0.009$ , respectively). No significant difference in RNFLT, CT, or CDR was found between groups (Table 3).

Univariate analysis found a correlation between the BMI and IOP ( $\beta =0.269$ ,  $P=0.003$ ) as well as BMI and ACD ( $\beta =0.198$ ,  $P=0.030$ ). Multivariable analysis found that BMI correlated with ACD ( $\beta =0.410$ ,  $P=0.005$ ). No

**Table 2** Comparison of anterior segment parameters of eyes between groups

Parameters	Total (N=120)	Normal weight (N=53)	Overweight (N=67)	P-value
HACC (mm)	7.76±0.29	7.76±0.29	7.77±0.29	0.854 <sup>a</sup>
VACC (mm)	7.67±0.28	7.67±0.28	7.67±0.28	0.859 <sup>a</sup>
IOP (mmHg)	12.30±3.20	11.86±2.12	12.80±3.40	0.002 <sup>b*</sup>
CCT (μm)	527.45±34.54	523.64±33.70	530.46±35.15	0.282 <sup>a</sup>
ACD (mm)	2.79±0.34	2.76±0.33	2.81±0.35	0.387 <sup>a</sup>
ACA (degree)	29.80±8.47	30.67±9.45	29.10±7.61	0.326 <sup>a</sup>

**Notes:** \*Statistically significant; <sup>a</sup>independent Student's t-test; <sup>b</sup>Mann–Whitney U test.

**Abbreviations:** HACC, horizontal anterior corneal curvature; VACC, vertical anterior corneal curvature; IOP, intraocular pressure; CCT, central corneal thickness; ACD, anterior chamber depth; ACA, anterior chamber angle.

**Table 3** Comparison of posterior segment parameters of eyes between groups

Parameters	Total (N=120)	Normal weight (N=53)	Overweight (N=67)	P-value
MT (μm)	241.00±25.50	237.00±19.50	247.36±20.61	0.009 <sup>b*</sup>
GCT (μm)	85.00±7.75	84.00±8.50	86.00±9.00	0.036 <sup>b*</sup>
RNFLT (μm)	100.00±11.75	99.00±13.00	99.63±10.18	0.589 <sup>b</sup>
CDR	0.53±0.15	0.53±0.16	0.53±0.14	0.855 <sup>a</sup>
CT (μm)	441.74±60.24	445.36±64.17	438.88±57.28	0.566 <sup>a</sup>

**Notes:** \*Statistically significant; <sup>a</sup>independent Student's t-test; <sup>b</sup>Mann–Whitney U test.

**Abbreviations:** MT, macular thickness; GCT, ganglion cell thickness; RNFLT, retinal nerve fiber layer thickness; CDR, cup disc ratio; CT, choroid thickness.

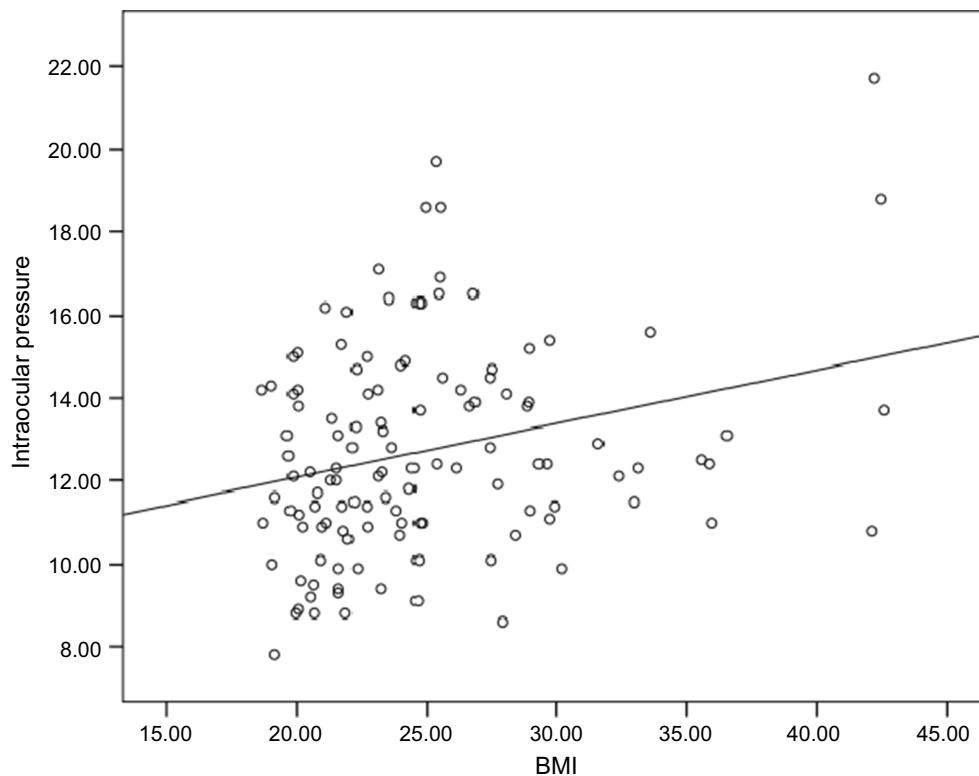
correlation was found between BMI and posterior segment ocular parameters (Table 4). A correlation between BMI and IOP, positive correlation between BMI and ACD, is shown on the scatterplot distribution (Figures 1 and 2).

**Table 4** Correlation between BMI and parameters of eyes

Parameters	Univariate analysis			Multivariate analysis		
	$\beta$	95% CI	P-value	$\beta$	95% CI	P-value
<b>Anterior segment parameters</b>						
HACC (mm)	0.079	-1.859 – 4.710	0.392	–	–	–
VACC (mm)	-0.014	-3.667 to 3.155	0.882	–	–	–
IOP (mmHg)	0.269	0.193 to 0.916	0.003*	–	–	–
CCT ( $\mu$ m)	0.048	-0.020 to 0.035	0.606	–	–	–
ACD (mm)	0.198	0.302 to 5.788	0.030*	0.410	0.008 to 0.045	0.005*
ACA (degree)	-0.030	-0.131 to 0.094	0.747	–	–	–
<b>Posterior segment parameters</b>						
GCT ( $\mu$ m)	0.089	-0.055 to 0.162	0.332	–	–	–
MT ( $\mu$ m)	0.102	-0.020 to 0.072	0.266	–	–	–
RNFLT ( $\mu$ m)	0.023	-0.058 to 0.074	0.807	–	–	–
CT ( $\mu$ m)	-0.004	-0.016 to 0.015	0.964	–	–	–
CDR	0.070	-3.830 to 8.610	0.448	–	–	–

**Note:** \*Statistically significant.

**Abbreviations:** HACC, horizontal anterior corneal curvature; VACC, vertical anterior corneal curvature; IOP, intraocular pressure; CCT, central corneal thickness; ACD, anterior chamber depth; ACA, Anterior chamber angle; GCT, ganglion cell thickness; MT, macular thickness; RNFLT, retinal nerve fiber layer thickness; CT, choroidal thickness; CDR, cup disc ratio.



**Figure 1** Correlation between BMI and intraocular pressure.

## Discussion

This research is the first study of the association between both anterior and posterior segment ophthalmic parameters and BMI in a Thai population. We found that the BMI and the W/H ratio of the overweight subjects were significantly higher than those in the normal subjects ( $P<0.001$ ). The SBP and the DBP of the overweight group were both significantly higher than in normal group.

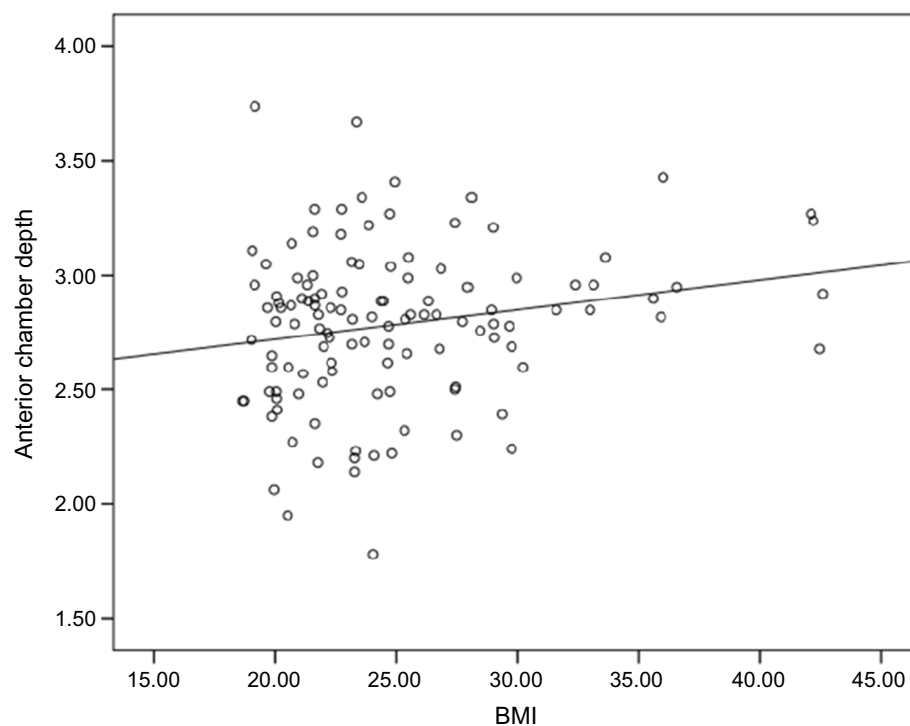
It was demonstrated that the IOP, GCT, and MT in overweight subjects were significantly higher than in normal weight subjects. Interestingly, the BMI showed a significant correlation with IOP and ACD, whereas the HACC, VACC, CCT, ACD, ACA, RNFLT, CT, and CDR values between the overweight and normal weight subjects were similar.

It was also found that the IOP significantly increased in the overweight subjects. Moreover, the overweight subjects also had a significant positive correlation between IOP and BMI ( $\beta=0.269$ ,  $P=0.003$ ). This finding is consistent with several previous reports.<sup>14,19,20</sup> IOP elevation in overweight subjects may be due to several mechanisms. An increased presence of periorbital fat increases pressure and decreases aqueous outflow, which increases IOP.<sup>21</sup> Also, obesity may be associated with increased blood leptin levels that may cause oxidative damage to the

trabecular meshwork that reduces aqueous outflow.<sup>22</sup> Finally, blood viscosity increases associated with obesity may lead to increased episcleral venous pressure, which could reduce aqueous outflow and result in elevated IOP.<sup>23,24</sup>

The correlation between CCT and IOP is well known, with greater CCT being associated with higher IOP.<sup>25,26</sup> However, this study was found no significant difference in CCT between the two groups, a finding also reported by Sahinoglu-Keskek et al. The CCT in metabolic syndrome patients and normal subjects was similar.<sup>27</sup> On the other hand, several researchers have reported elevated CCT values in high BMI subjects.<sup>25,26</sup> Su et al suggested that cornea thickness is greater in people with high BMI,<sup>26</sup> which may elevate IOP as measured by the air puff technique. Data from this study confirmed a correlation between IOP and BMI, but found no relationship between BMI and CCT. This may be because the groups compared were age-matched, eliminating the factor of a CCT decrease of about  $5.1 \mu\text{m}$  per 10 years of aging.<sup>28</sup>

A strong correlation was found between ACD and BMI (univariate analysis:  $\beta =0.198$ ,  $P=0.030$ ; multivariate analysis:  $\beta =0.410$ ,  $P=0.005$ ), which is inconsistent with a previous study.<sup>14</sup> These may be because there was no significant age difference between the two study groups,



**Figure 2** Correlation between BMI and anterior chamber depth.

eliminating age-related crystalline lens thickening as a factor that reduces ACD.<sup>29–32</sup> A limitation of this study was the lack of the axial length data, which might provide further insights into possible ACD differences between the two groups.

The present study found higher GCT and MT values in the elevated BMI group when compared to the normal BMI group. No differences in RNFLT or CDR were found between these groups. In comparison, a reduction of CGT in obesity was reported by Pacheco-Cervera et al<sup>33</sup> while other studies found no correlation.<sup>34</sup> A study by Kocak et al also reported the decreased ganglion cell layer thickness, as well as a decrease in RNFLT thickness and an unaltered central MT in class III obesity (BMI 49.15±7.65 kg/m<sup>2</sup>).<sup>34</sup> Studies have also reported a reduction of GCT and RNFLT in patients with glaucoma,<sup>35–37</sup> as well as a relationship between obesity and elevated IOP.<sup>14,19–21,38,39</sup>

This study found no significant difference in the CDR between groups. Other studies indicate that the correlation between CDR and BMI is unclear. Xu et al reported a significantly positive correlation between neuroretinal rim area and BMI,<sup>40</sup> Pedro-Egbe CN and Awoyesuku EA did not find any association,<sup>41</sup> and Amerasinghe et al found a negative correlation between the CDR and BMI.<sup>42</sup>

We found that the CT was similar between obese and normal subjects. Yilmaz et al showed a negative correlation between the BMI and the CT.<sup>43</sup> Kocak et al reported that CT values were reduced in obese subjects.<sup>34</sup> At this time, the relationship between obesity and CT remains unclear. Previous studies suggest that a reduction of nitric oxide in obese people may cause an imbalance between vasodilation and vasoconstriction, leading to a reduction of the CT.<sup>44,45</sup> Differences in the results of our study and others may be because differences in axial length, ethnicity, and OCT instruments and software were not controlled.

## Conclusion

Univariate and multivariate analysis showed a strong positive correlation between BMI and ACD. Furthermore, BMI also positively correlated with IOP. We suspect that degree of obesity may also be important, and suggest that any possible relationship between ocular parameters and severity of obesity should be further investigated.

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## Disclosure

KL received personal fees from Allergan, Bayer, Alcon, Zeiss. The authors report no other conflicts of interest in this work.

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