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# Correlation between body mass index and corneal thickness in emmetropic subjects

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**Background:** Body mass index (BMI) uses a person's weight and height to estimate body fat as an indication of an individual's health status. Several studies have suggested that BMI (calculated as weight in kilograms divided by the square of height in metres) was related to central corneal thickness (CCT) in non-emmetropic subjects; however, there is limited information about the possible correlation between BMI and the CCT in healthy emmetropic eyes.

**Aim:** This study aimed to investigate the correlation between CCT and BMI in healthy emmetropic eyes.

**Setting:** The study was performed by the GIAVAL research group of the Faculty of Medicine and Odontology, University of Valencia, Spain.

**Methods:** The emmetropic eyes of 81 (mean age ± standard deviation [s.d.]: 21.8 ± 1.8 years) adults were included in this retrospective study. Ophthalmic CCT measurements were measured using non-invasive scanning-slit corneal topography. The height and weight of all subjects, using a standard tape measure and weight scale, were recorded, and BMI was calculated.

**Results:** There were no significant correlations between CCT and the BMI values in the 81 emmetropic adults ($r = 0.16$; $p = 0.135$), between CCT values and BMI (18.5 to < 25) ($r = 0.21$; $p = 0.724$) and between CCT values and BMI (25.0 to < 30) ($r = -0.28$; $p = 0.465$). In addition, no correlation occurs between the CCT values and BMI in both women ($r = 0.22$; $p = 0.160$) and men ($r = -0.14$; $p = 0.412$). A weak negative correlation does seem to present with age and CCT ($r = -0.29$; $p < 0.05$). However, the coefficient of determination suggests that only 8% ($r^2 = 0.08$) of the variance is shared between age and CCT.

**Conclusion:** The results do not show a correlation between CCT and BMI values in young subjects with healthy emmetropic eyes.

**Contribution:** This study has revealed that the CCT values are not correlated with the BMI values in healthy emmetropic eyes of young subjects without obesity. In addition, normative data for the CCT in normal anatomic eyes has been reported, which will serve as a baseline for future comparative studies in non-emmetropic eyes.

**Keywords:** body mass index; central corneal thickness; non-contact scanning-slit corneal topography; emmetropia; correlation analysis.

## Introduction

In recent years, there has been a considerable increase in interest in quantitative methods applied to anatomical studies as studies that use quantitative anatomy have a particular emphasis on the analysis of size linked to differences by gender, ethnicity, growth and development, social class, occupation, ageing, etc.[1] Research in quantitative anatomy begins with the collection of numerical data; later, the analysis of these is carried out, and finally, inferences are made that can answer the hypotheses and objectives of the studies.[1]

Body mass index (BMI) indicates an individual's health status. According to the definition of adult overweight and obesity by the Centers for Disease Control and Prevention,[2] a BMI of less than 18.5 implies being underweight, a BMI ranging from 18.5 to < 25 indicates a healthy weight, a BMI ranging from 25.0 to < 30 indicates overweight and a BMI ≥ 30.0 indicates obesity. The BMI thus allows for weight categories that can lead to health problems.[3,4] The WHO[5] has found that 1.9 billion people are classified as overweight, and 650 million people are obese. Obesity is not only a risk factor for several systemic diseases, but evidence shows that it is also associated with anterior segment ocular disease, such as negative correlations between BMI and anterior chamber depth and anterior chamber angle.[6,7] In addition, posterior ocular diseases, namely cataracts, age-related macular degeneration and glaucoma associated with obesity, may affect an individual health status.[7,8]

In this context, some authors have analysed the possible relationship between BMI and central corneal thickness (CCT) with contradictory conclusions.[7,9,10,11,12,13,14,15,16] In addition, the aforementioned studies have been carried out in non-emmetropic subjects mainly because CCT studies are usually carried out before excimer laser refractive surgery[17,18] and in subjects with corneal and intraocular pathologies because of the relationship between the CCT and the tonometry values.[19,20,21] As a result, few CCT studies are carried out on healthy emmetropic subjects. No information exists about the possible correlation between BMI and CCT in healthy emmetropic eyes.

Following this, the present research investigated whether the CCT and BMI values correlated in healthy emmetropic eyes. A secondary objective of this research considered the correlation between age and CCT values.

## Material and methods

The study used a prospective observational and quantitative design. An initial research sample of 229 volunteers (100%) agreed to participate in the study. We used the same previous exclusion criteria of our group[22]: prior corneal and/or ocular surgery, corneal disease, clinical corneal changes and Goldmann applanation tonometry (GAT) ≥ 21 mmHg, presence of systemic diseases such as diabetes mellitus, cardiovascular, renal, neurological or thyroid disease, visual acuity < 20/20 and subjects taking any medication. The inclusion criteria were emmetropic subjects (volunteers with manifest sphere and manifest cylinder of ± 0.5 dioptres [D]) with an age range of 20 to 30 years old. After applying the inclusion and exclusion criteria, 148 volunteers (64.6%) were excluded from the study. Thus, the CCT and BMI of 81 emmetropic subjects (35.4%) were measured 2 weeks after the ophthalmologic evaluation without using corneal anaesthetic eye drops.

Using a standard tape measure and weight scale, BMI was calculated as weight in kilograms divided by the height in metres squared ($kg/m^2$). Subjects with a BMI less than 18.5 were indicated as underweight, a BMI ranging from 18.5 to < 25 indicated a healthy weight, a BMI ranging from 25.0 to < 30 suggested overweight and a BMI ≥ 30.0 were labelled as obese.[2]

All subjects underwent comprehensive ophthalmic examinations, including visual acuity, slit-lamp biomicroscopy, fundus tests and intra ocular pressure (IOP). No corneal anaesthetic eye drops were used for CCT measurements as measurements were carried out using non-contact scanning-slit corneal topography that allows one to perform measurements without anaesthesia. The CCT values were obtained using scanning-slit corneal topography. Two drops of saline were instilled into the right and left eyes of subjects, who were asked to blink before measurements to avoid any bias because of possible corneal dryness. Three minutes after instillation, the CCT was measured and three consecutive measurements were taken, with the average being recorded as the CCT value. All measurements were performed between 10:00 and 13:00 in a specific room with a temperature that ranged from 18 °C to 22 °C and relative humidity that ranged from 38% to 45%.[23]

Only the data of one eye were randomly chosen for the statistical analysis. Data were entered and stored in an MS Excel file and then transferred to SPSS® version 23 software (SPSS Inc., Chicago, Illinois, United States [US]) and STATISTICA (TIBCO Software, California, US) for statistical analysis. The normality of the data distribution was determined by using the Kolmogorov–Smirnov test. Continuous variables were presented as means ± standard deviation, ranges and 95% confidence intervals (95% CI). Count and percentage expressed categorical variables. Two-sided $p < 0.05$ was considered statistically significant. Intraclass correlation coefficient (ICC) estimates and their 95% CIs were calculated using a two-way mixed-effects model. Intraclass correlation coefficient values less than 0.5 are considered to be indicative of poor reliability, values between 0.5 and 0.75 indicate moderate reliability, values between 0.75 and 0.9 indicate good reliability and values greater than 0.90 indicate excellent reliability.[24] Correlations were assessed visually using correlation plots, Pearson's correlation coefficient ($r$), the coefficient of determination ($r^2$) and 3D scatter plots.

### Ethical considerations

This study conformed to the tenets of the 2013 Declaration of Helsinki, and the waiver was approved by the Higher Degrees and Ethics Committees of the Faculty of Medicine and Odontology, University of Valencia, Spain. Written informed consent was obtained from an initial research sample of 229 volunteers, after being explained the study protocol and the procedures to be performed by the GIAVAL research group of the Faculty of Medicine and Odontology, University of Valencia, Spain.

## Results

The mean age of the sample was 21.8 ± 1.8 years old (range: 20–25 years old; 95% CI: 21.2–22.4 years old) and presented mean tonometry of 16.0 ± 1.9 mmHg (range: 12 mmHg – 19 mmHg; 95% CI: 15.6 mmHg – 16.4 mmHg).

The 3D scatter plots have been drawn to visually represent the data set on one graph. Figure 1a represents the data, with BMI on the $y$-axis, CCT on the $x$-axis and age on the $z$-axis; visually, no distinct correlation can be easily identified between CCT, BMI and age. In Figure 1b, BMI has been divided into body weight (kg) ($x$-axis) and height ($m^2$) ($y$-axis), and again, no correlation can be seen between CCT ($z$-axis) and body weight or height.

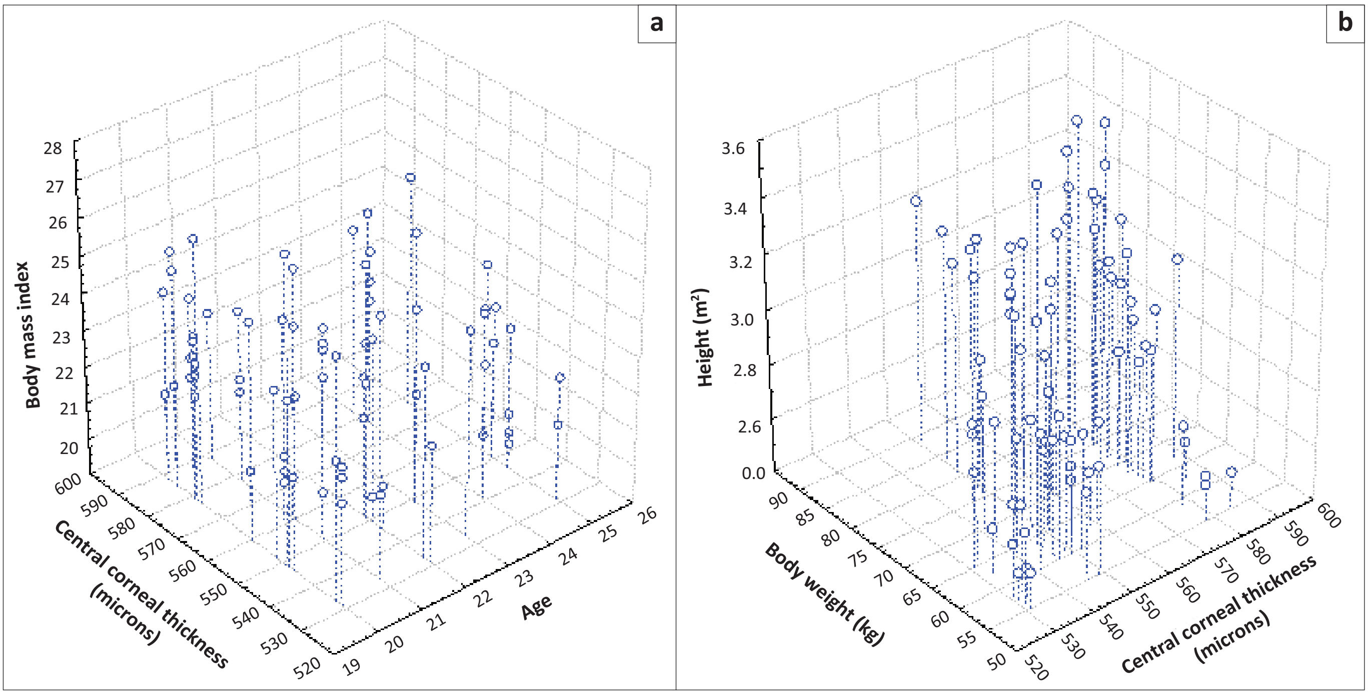
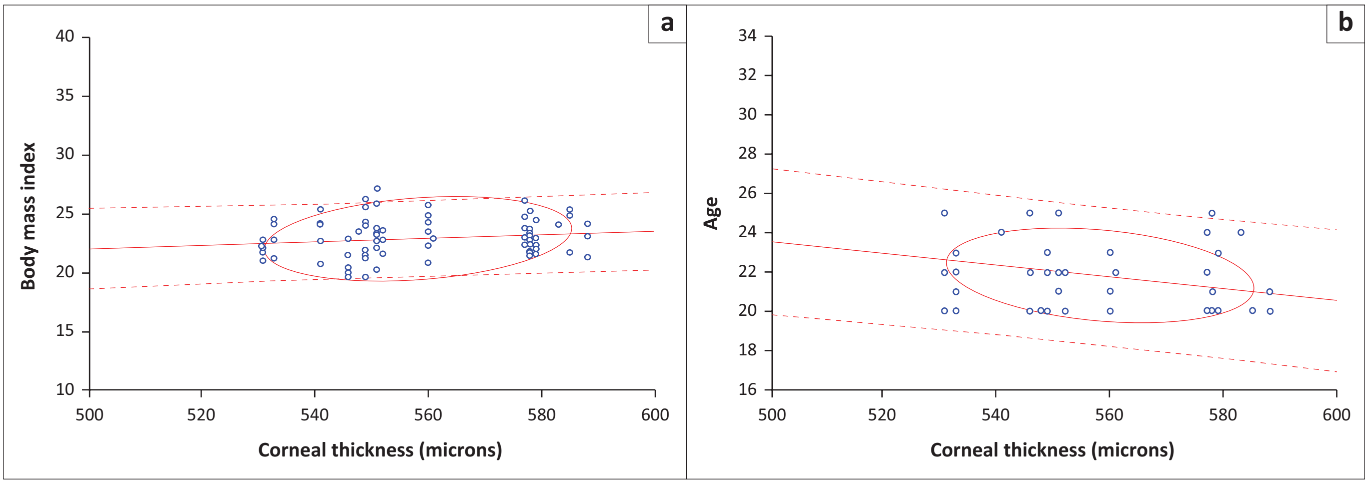



**FIGURE 1:** Three-dimensional (3D) scatter plots (a) body mass index (BMI) and central corneal thickness (CCT) and age and (b) body weight (kg), height (m²) and central corneal thickness.




Note: (a) BMI = 14.562 + 0.15*x; 0.95 prediction interval CCT (microns): BM: $r^2$ = 0.0281; $r$ = 0.1675, $p$ = 0.1349. (b) Age = 38.5225–0.0299*x; 0.95 prediction interval CCT (microns): Age: $r^2$ = 0.0874; $r$ = 0.2956, $p$ = 0.0074.

BMI, body mass index; CCT, central corneal thickness.

**FIGURE 2:** Correlation scatter plots with Pearson's correlation coefficient ($r$) and the coefficient of determination ($r^2$) representing the correlations of (a) body mass index and central corneal thickness and (b) age and CCT. In each part of the figure, 95% confidence ellipses and intervals for the data are also included.

The BMI values ranged from 19.7 to 27.2 (95% CI: 22.7–23.4), with a mean value of 23.0 ± 1.6. According to the definition of adult overweight and obesity in the CDC guidelines, there were no subjects with a BMI ≥ 30 (obesity range) and with a BMI < 18.5 (underweight range). In comparison, 9 (11.1%) had a BMI between 25.0 and < 30 (overweight range), and 72 (88.9%) had a BMI between 18.5 to < 25 (healthy weight range).[2]

We found that the mean CCT value of the sample analysed was 558 ± 17.8 µm (range: 531 µm – 588 µm; 95% CI: 554.4 µm – 562.2 µm). The intraclass correlation coefficient was 0.995 (95% CI: 0.993–0.997), reflecting excellent reliability.[24]

Correlation scatter plots with Pearson's correlation coefficient ($r$) and the coefficient of determination ($r^2$) have been applied to the data, and in Figure 2a, results show that there is little evidence for any linear relationship here between BMI and CCT ($r$ = 0.16; $p$ > 0.05). In Figure 2b, a weak negative correlation does seem to present with age and CCT ($r$ = –0.29; $p$ < 0.05). However, the coefficient of determination suggests that only 8% ($r^2$ = 0.08) of the variance is shared between age and CCT.

We found no correlation between the CCT and the BMI values in the 81 emmetropic subjects were analysed ($r$ = 0.16; $p$ = 0.135). We found no correlation between the BMI and CCT values ($r$ = 0.21; $p$ = 0.724) in the subjects with a BMI that ranged from 18.5 to < 25 (healthy weight range). No correlation was also found ($r$ = –0.28; $p$ = 0.465) with the subjects that had a BMI between 25.0 and < 30 (overweight range). In addition, we found no correlation between the BMI and the CCT values in both women ($r$ = 0.22; $p$ = 0.160) and men ($r$ = –0.14; $p$ = 0.412).

## Discussion

As observed, there is not enough information on the CCT of young emmetropic eyes because CCT studies are not usually performed on these eyes as they are not current candidates for excimer laser surgery. However, all these subjects are potential candidates for developing presbyopia in the near future, so it is also important to know the CCT of the emmetropic subjects because they are potential future patients for undergoing excimer surgery for presbyopia correction where the CCT needs to be known.[25,26]

The present work has been carried out using non-contact scanning-slit corneal topography to avoid using anaesthetic eye drops, which may vary the CCT results of some individuals by ± 30 µm.[22] Likewise, performing all the measurements with a unified temperature protocol has allowed us to avoid the possible effect of temperature changes on corneal hydration.[27] When corneal hydration is altered, CCT values are changed.[28]

In addition, it is known that CCT measurements show a significant thinning throughout the day[29] that can condition the validity of the results if they are not carried out in the same time interval and with the same temperature and humidity conditions, as we have done in this work. Furthermore, the ICC values obtained allow us to consider that our measurements are entirely valid.

A study on CCT over 30 years indicated that a wide range of values could be found for healthy adults and that values between 473 µm and 595 µm would be within normal limits.[12] We analysed young, emmetropic subjects, and the mean CCT values were 558 µm ± 17.8 µm, which is within the range of normal limits expressed by Jonuscheit et al.[12] However, as we only analysed healthy emmetropic eyes, we compared our results with the CCT results presented in myopic, hyperopic and emmetropic eyes: different authors observed that the mean CCT values in myopic eyes ranged from 529 µm ± 32 µm to 566 µm ± 44 µm,[30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45] in hyperopic eyes from 530.8 µm ± 37.2 µm to 559.71 µm ± 33.70 µm,[36,43,45] and in emmetropic eyes from 513.7 µm ± 68.5 µm to 559 µm ± 18 µm.[23,36,45,46,47,48] The results in the present study are similar to those of emmetropic, hyperopic and myopic subjects.

The mean CCT values in the present research carried out in 81 emmetropic eyes were 558 µm ± 17.8 µm and are similar to those observed in studies carried out with samples of 1000, 721, 379 and 124 emmetropic eyes.[23,45,46,47,48] However, Cosar et al.[36] observed the thinnest values (513.7 µm ± 68.5 µm), but their sample of emmetropic eyes consisted of only 28 eyes.

We have found no correlation between BMI and CCT. However, some authors have found that height,[11,12,49] weight[50] and BMI[11,50] were correlated with the CCT values, while other authors have found no correlation between the CCT values and the height,[51] weight[11,12] and BMI.[12,52] In the study by Jonuscheit et al.,[12] where the measurements were made on a Caucasian sample, a negative correlation was found between height and CCT; that is, taller people could have slightly thinner corneas. However, the measurements revealed that the interdependence between these two variables was weak and ambiguous. However, the study by Tomidokoro et al.[49] carried out in a sample of Japanese adults found a positive correlation between CCT and BMI, while Zhang et al.,[51] in their study, carried out in an adult Asian sample and did not find a statistically significant correlation between the CCT and the BMI.

Regarding the relationship between body weight and CCT, in the study by Nishitsuka et al.[50] carried out on a sample of 322 Japanese adult individuals, it was observed that CCT increased by 0.40 µm for each kilogram of weight. However, in other studies, such as the one by Elflein et al.,[11] carried out in an adult Caucasian sample, it was found that there was a positive correlation between CCT and body weight in male subjects but not in female subjects.

Contradictory results were also found in the relationship between BMI and CCT. In the study by Elflein et al.,[11] the CCT increased by 0.405 µm per unit increase in BMI, while Kelekele et al.[15] observed that with each kg/m$^2$ increase in BMI, CCT decreased by 0.72 µm. In addition, Teberik et al.[52] found that in subjects with BMI > 40 (obesity), the CCT did not differ significantly from the CCT of subjects without obesity.

Considering the age of the population of our study, we found no correlation between BMI and CCT in adults aged 20–30 years (mean age ± s.d.: 21.8 ± 1.8). However, a few studies have found contradictory results in CCT and childhood obesity. In a study conducted by Kurtul et al.[53] to compare the ophthalmic finding between obese and healthy children, 49 obese children (BMI > 95th percentile) and 33 control subjects (BMI < 85th percentile) were compared. The mean ages were 11.09 ± 2.83 years in the obese group and 12.3 ± 2.45 years in the control group. Their study demonstrated that CCT values are lower in obese children (542.5 µm ± 33.6 µm vs 560 µm ± 38.0 µm). However, a study by Albuquerque et al.[54] found no difference in corneal thickness among normal children ($n$ = 63; age ± s.d.: 12.7 ± 0.4), overweight ($n$ = 21; age ± s.d.: 12.0 ± 0.7; BMI > 85th percentile and < 95th percentile) and obese ($n$ = 12; age ± s.d.: 9.5 ± 0.4; BMI > 95th percentile). Corneal thickness values ranged from 543.20 µm ± 6.3 µm to 549.80 µm ± 10.8 µm, respectively. Koçak et al.[55] also found no significant difference in mean corneal thickness of both right and left eyes between obese ($n$ = 30; age ± s.d.: 13.5 ± 2.1; BMI > 95th percentile) and healthy ($n$ = 30; age ± s.d.: 13.3 ± 2.0) adolescents.

The present study had several limitations. Firstly, the study included a relatively small sample size. Secondly, it is a single-centre study. A larger subject group representing the general population's cultural, age, ethnic and gender diversity would yield a more robust comparative analysis.

# Conclusion

In summary, the present work has revealed that the CCT values are not correlated with the BMI values in young, healthy emmetropic subjects without obesity. In addition, normative data for the CCT in normal anatomic eyes has been reported, which will serve as a baseline for future comparative studies in non-emmetropic eyes.

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## Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

## Authors' contributions

J.A.S.-G. was the project leader; J.A.S.-G. and E.R.G. collected data and wrote the original draft. S.N. and N.H. made conceptual contributions and were responsible for review and editing.

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## Data availability

Data supporting the findings of this study are available from the corresponding author, J.A.S.-G., on request.

## Disclaimer

The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official policy or position of any affiliated agency of the authors.


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