Body Mass Index and Age-Related Cataract

The Shihpai Eye Study

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Objective: To investigate the association between body mass index (BMI) (calculated as weight in kilograms divided by the square of height in meters) and cataract in a metropolitan Asian elderly population.

Design: Population-based cross-sectional study. Age-related cataract was defined as any type of lens opacity (ie, nuclear, cortical, and posterior subcapsular opacity) with a Lens Opacities Classification System III grade of more than 2 in one or both eyes. Weight and height were measured by intensively trained interviewers.

Results: A total of 2045 subjects 65 years and older in Shihpai, Taipei, were invited to participate, and 1361 (66.6%) completed the survey. Of the subjects, 806 were diagnosed as having age-related cataracts. With a BMI of less than 21.3 as a reference point (odds ratio [OR], 1.00), a U-shaped relationship between BMI and nuclear opacity was demonstrated. A reverse U-shaped relationship was shown for cortical opacity. In the final multiple logistic regression models, BMI and BMI² were significantly related to nuclear opacity (BMI data: OR, 0.73 [95% confidence interval {CI}, 0.54-0.98]; and BMI² data: OR, 1.01 [95% CI, 1.00-1.01]) and cortical opacity (BMI data: OR, 1.52 [95% CI, 1.04-2.34]; and BMI² data: OR, 0.99 [95% CI, 0.98-0.99]). Neither BMI nor BMI² was related to posterior subcapsular opacity.

Conclusion: Body mass index is an independent risk factor for nuclear and cortical opacities, but in reverse direction to each other.

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METHODS

The Shihpai Eye Study is a population-based survey of vision and eye diseases among non-institutionalized subjects 65 years and older in the Shihpai community of the Peitou district. The baseline examination was conducted between July 1, 1999, and December 31, 2000. A 3-year follow-up examination of a fixed cohort is ongoing.

Details of sample selection and methods for the Shihpai Eye Study have been described previously. In summary, residents 65 years and older were identified by the household registration system in Taiwan. The household registration system is designed and administered by the government to collect and supply demographic information and to officially recognize personal status and relations for efficient city planning and competent socioeconomic developmental programs.

According to the official household registration in 1999, the total number of residents at least 65 years of age in Shihpai was 4750. Excluding vacant households, mortality of subjects before contact, and institutionalized persons, 3746 persons were eligible for the study and 2045 were randomly selected to be invited to participate in the study.
The study consisted of a structured questionnaire conducted at home followed by a comprehensive standardized ophthalmic examination at Taipei Veterans General Hospital. The household interview was conducted based on the questionnaire and was designed to cover demographic data (age, sex, marital status, and education), personal medical history (hypertension, diabetes mellitus, cardiovascular disease, and others previously diagnosed by a physician), family history, and lifestyle (cigarette smoking and alcohol intake). Blood pressure, weight, height, and waist and hip circumferences were measured by well-trained interviewers.

Those who were interviewed were invited to participate in the eye examination conducted by experienced ophthalmologists, including initial and best-corrected Snellen visual acuity, tonometry, slitlamp biomicroscopy, and direct and indirect ophthalmoscopy. Informed consent was obtained from each subject before enrollment in the study.

This study was approved by the Institutional Review Board of the Taipei Veterans General Hospital.

**DEFINITIONS**

Height and weight were measured in metric units and was recorded to the nearest one-tenth kilogram for weight and the nearest one-tenth centimeter for height.

Waist girth was measured at the minimum circumference, while hip girth was measured at the maximum circumference, to the nearest one-tenth centimeter. A high waist-to-hip ratio was defined as 0.92 or more for men and 0.88 or more for women.

The criteria for obesity were in accordance with the classification of the World Health Organization: severely thin, a BMI of less than 16.00; moderately thin, a BMI of 16.00 to 16.99; mildly thin, a BMI of 17.00 to 18.49; normal, a BMI of 18.50 to 24.99; mildly overweight, a BMI of 25.00 to 29.99; moderately overweight, a BMI of 30.00 to 39.99; and severely overweight, a BMI of 40.00 or more.

Hypertension and diabetes mellitus were defined as positive if a subject had previously been diagnosed as having the disease by a physician.

Lens condition was assessed by slit lamp and graded into 3 principal types of opacity (nuclear sclerosis, cortical opacity, and posterior subcapsular opacity) according to the Lens Opacities Classification System III (LOCS III). Subjects were classified as having an age-related cataract if any type of opacity of LOCS III grade of greater than 2 was present in at least 1 eye. When both eyes of a subject had age-related cataracts, the more affected eye was analyzed.

A pilot study was performed about 1 month before starting the main fieldwork to provide a field test of lens grading procedures, and has been described previously. Interobserver reproducibility of lens grading (grade, >2 vs ≤2) was obtained between 2 participating ophthalmologists. For cataract diagnosis, agreement was high, with a κ statistic of 0.85 for nuclear opacity, 0.86 for cortical opacity, and 0.82 for posterior subcapsular opacity. Intraobserver reproducibility was also excellent for both ophthalmologists. Agreement for reproducibility of grading cataracts (grade, >2 vs ≤2) was 0.86 for nuclear opacity, 0.83 for cortical opacity, and 0.80 for posterior subcapsular opacity for one ophthalmologist, and 0.84, 0.87, and 0.85, respectively, for the other ophthalmologist.

**STATISTICAL ANALYSIS**

To assess the relationship between BMI and different types of cataract, crude and multivariate adjusted odds ratios (ORs) and their 95% confidence intervals (CIs) were evaluated. The 3 different types of cataract were considered independently (ie, subjects with a nuclear sclerosis grade of >2 were compared with subjects with a nuclear sclerosis grade of ≤2 regardless of the state of cortical and posterior subcapsular opacity). Potentially confounding factors evaluated included sex (female vs male), age (≥75 vs 65-74 years), education (<high school vs ≥high school), smoking status (current smoker vs nonsmoker and ex-smoker vs nonsmoker), history of hypertension (yes vs no), and history of diabetes mellitus (yes vs no). To illustrate the range of cataract risk associated with BMI, ORs were calculated for every 3.5-point change (1 SD) from the mean of 24.8. The adjusted ORs for different types of cataract were then plotted against BMI to explore the magnitude and direction of their association.

From the graphs, BMI and age-related cataract fit a quadratic relationship. Hence, separate multiple logistic regression models were constructed with the 3 types of cataract as the dependent variable; BMI and BMI² were included as independent variables and were adjusted with all the previous covariates. Statistical analysis was performed using SAS statistical software, version 6.12 (SAS Institute Inc, Cary, NC).

Of the 2045 subjects, 1361 (66.6%) participated in the study and completed the questionnaire and eye examination. Six hundred eighty-four subjects were not examined. Among them, 677 (33.1%) cooperated only for the household interview and 7 (0.3%) could not be contacted after 3 attempts of household visits. Subjects participating in the eye examination were younger (mean, 72.2 vs 74.3 years; P < .001), more likely to be men (P = .001), and had a higher level of education (P = .001) than those who refused. There was no significant difference in the other variables (marital status and history of diabetes mellitus and hypertension) between the 2 groups, including whether subjects have had contact with ophthalmic services before the study and whether they had been diagnosed as having age-related cataract by a physician (P > .05).

Among the 1361 participants, women were more likely to be nonsmokers and to be less educated. The BMI was significantly higher in women than in men (ie, women were more likely to be overweight than men in this elderly group). Moreover, all 3 types of cataract were significantly more prevalent in women (Table 1).

The mean ± SD BMI of our participants was 24.8 ± 3.5, and the BMI distribution of our participants is shown in Table 2. Most participating subjects were in the normal or mildly overweight group.

**Table 3** demonstrates the association between BMI and known risk factors for age-related cataracts using univariate analyses. A higher BMI was associated with younger age, female sex, and ex-smokers. Participants with a higher BMI were also more likely to have a history of hypertension.

Eight hundred six subjects were diagnosed as having age-related cataracts. One hundred seventy-five participants had undergone cataract surgery before the survey and were excluded in the analysis. To illustrate the range of cataract risk associated with BMI, ORs were calculated for every 3.5-point change (1 SD) from the mean of 24.8. The crude and adjusted ORs of BMI for the 3 types of cataract were evaluated. With a BMI of less than 21.3...
as a reference point (OR, 1.00), a BMI of 1 SD higher (21.3-24.8) had an adjusted OR of 0.67 (95% CI, 0.46-0.98) for nuclear opacity. A BMI of 2 SDs higher (24.8-28.3) produced an OR of 0.56 (95% CI, 0.37-0.83), and a BMI of 3 SDs higher (28.3-31.8) had an OR of 0.96 (95% CI, 0.57-1.62). A BMI above 31.8 produced an OR of 0.37 (95% CI, 0.15-0.89). The results demonstrated a U-shaped relationship between BMI and nuclear opacity (Figure 1).

On the other hand, the relationship between BMI and adjusted OR for cortical opacity showed a reverse U-shape (Figure 2). There was no statistically significant relationship between BMI and posterior subcapsular opacity (P=.47; OR, 1.19; 95% CI, 0.78-2.00).

The BMI fit a quadratic relationship with nuclear and cortical opacity. After adjusting for age and sex, BMI (OR, 0.70; 95% CI, 0.52-0.93) and BMI² (OR, 1.01; 95% CI, 1.00-1.01) were significantly related to nuclear opacity; BMI (OR, 1.47; 95% CI, 1.02-2.23) was significant for cortical opacity, whereas BMI² (OR, 0.99; 95% CI, 0.98-1.00) was of borderline significance. In the final multiple logistic regression models with the 3 types of cataract as the dependent variable, BMI and BMI² were not significant for any association with age-related cataract, but no significant relationship was found.

### COMMENT

Our results demonstrated that BMI is related to nuclear and cortical opacity, in a quadratic fashion but in opposite direction to each other. Risk of nuclear opacity decreases in a gradual manner as BMI increases from 21. This protective effect ceases when BMI approaches 22. Risk of cortical opacity increases as BMI progresses to obese levels. Conversely, risk of cortical opacity increases as BMI increases from 21, and when BMI is greater than 28, risk of cortical opacity decreases. Body mass index is not related to posterior subcapsular opacity in our study.

As opposed to our population-based study, 2 hospital-based case-control studies found that a low BMI was associated with nuclear opacity. In hospital-based studies, cortical opacity would be underestimated because this type of opacity seldom affects vision and patients may not seek medical help. A study in Punjab, India, found that a higher prevalence of cataract was associated with short height, low weight, and low weight-height ratio, but the type of cataract was not specified. Furthermore, the lens examination was done with a unilocular loupe and direct ophthalmoscopy through an undilated pupil.

Our participants were similar in age to those in the Salisbury Eye Evaluation (SEE) project. This project also found that BMI was associated with nuclear and cortical opacity. Similarly, nuclear and cortical opacity were related to BMI, but in reverse direction to each other. In the SEE project, risk of nuclear opacity was greater in those with a lower BMI and risk of cortical opacity was greater in those with a higher BMI. The disparity in results may be due to racial differences (18.4% African American and 81.6% white) and a different lens opacity grading system (the Wilmer grading scheme). Moreover, risk factors for each cataract type were compared with no cataract at all in their study. Also, BMI distribution was different in the 2 studies (mean±SD, 28.0±5.5 among participants of the SEE study vs 24.8±3.9 among our participants).

The Framingham longitudinal studies using the Taylor and West lens grading system suggested that higher levels of average BMI and increasing BMI over time were risk factors for cortical opacity. Increasing BMI over time was also associated with posterior subcapsular opacity. No association was found between BMI and nuclear lens opacity.

The Physicians’ Health Study recruited male physicians and relied on self-reported weight and height. Cataract was confirmed by medical record review and a best-corrected visual acuity of 20/30 or worse. Their survey found that the greatest elevation in risk was associated with posterior subcapsular cataract. Substantial elevations in risk of nuclear sclerotic cataract were also associated with a higher BMI. The same result was noted at the 9-year follow-up.

The Nurses’ Health Study also relied on self-reported anthropometric measurements. Lens status was evaluated using LOCS III, but different criteria for defining cataract from ours were used. In their study, eyes were considered to have nuclear, cortical, or posterior subcapsular opaci-
ties if the associated grade was 2.5 or more, 1.0 or more, or 0.5 or more, respectively. The study noted that women with a BMI of 30 or more had a higher prevalence of posterior subcapsular opacities than those with a BMI of less than 25. Moreover, women with a waist circumference of 89 cm or more had a higher prevalence of posterior subcapsular opacities than those with a waist circumference of less than 80 cm. Overweight and abdominal opacity were not related to nuclear and cortical opacities.

On the other hand, the Beaver Dam Eye Study found no association between BMI levels and risk of cataract surgery. In their 5-year follow-up examinations, waist-hip ratio was more strongly associated with age-related eye disease (age-related maculopathy and cataract) than BMI in women.

The 5-year follow-up of the Blue Mountains Eye Study noted that obesity (BMI, ≥30) was significantly associated with increased incidence of cortical (OR, 1.6; 95% CI, 1.2-2.2) and posterior subcapsular (OR, 2.1; 95% CI, 1.2-3.7) cataract.

In the Barbados Eye Studies, 2609 African American participants who had no nuclear opacities at baseline had an increased 4-year risk of nuclear opacities with leaner body mass. Persons with a high body mass had a decreased risk

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<th>Table 2. Prevalence of Thinness and Overweight in Shihpai, Taipei, Taiwan, From 1999 to 2000*</th>
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<td><strong>Grades of Thinness (BMI)</strong></td>
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Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by the square of height in meters).

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<th>Table 3. Associations Between BMI and Other Risk Factors for Cataract in Shihpai, Taipei, Taiwan, From 1999 to 2000</th>
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Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by the square of height in meters).

*Data are given as percentage of each group.
†Obtained using the χ² test.
‡The difference is significant (P<.05, test for trend).
A survey targeted at adult Chinese persons in Tanjong Pagar of Singapore found that a lower BMI was associated with cortical cataract and any cataract. People in the lowest quintile (BMI, 13.6-20.4) have 1.8 (95% CI, 1.1-2.9) times the risk of cortical opacity (LOCS III grade, ≥1) than those in the highest quintile (BMI, 26.4-41.5). With a definition of grade 4 or more for nuclear opacity, people with lower quintiles of BMI had higher odds of nuclear cataract (test for trend, \(P = .03\)).

Opinions are diverse on BMI effect on the directionality and types of cataract involved. However, most studies, including ours, are consistent that BMI is an independent predictor of cataract. Similar to the SEE study, our study showed that there is some trade-off between nuclear and cortical opacities.

We also explored other anthropometric measures, including waist-hip ratio (which indicates abdominal adiposity and visceral fat), height, and weight, but failed to find any significant relationship with lens opacity. This is in opposition to the Physicians’ Health Study, which found that a higher adult height and waist-hip ratio are associated with a higher incidence of cataract. The Nurses’ Health Study demonstrated that women with a higher waist circumference had a higher prevalence of posterior subcapsular opacity. The SEE study also noted that taller individuals were at greater risk for nuclear opacities after adjustment for other known risk factors. Our results showed that BMI is the only independent anthropometric predictor for age-related cataract.

Our survey was population based, with well-equipped instruments; high interobserver and intraobserver reproducibility was obtained and, hence, provides an accurate assessment of the relationship between BMI and age-related cataracts. Weight and height were measured by intensively trained personnel as opposed to self-reported anthropometric measurement. Moreover, the grading system of age-related cataract was in accordance with the widely used LOCS III, as opposed to self-reported data with visual acuity taken as diagnostic criteria, in the Physicians’ Health Study. There was no detailed analysis of the 3 subtypes of lens opacity in the Punjab study. On the other hand, self-selection bias, which was inherent to the population-based study, could not be eliminated. Moreover, because of the nonprospec-


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tive design of the study, it is also plausible that the presence of cataract led to a change in lifestyle and, hence, BMI. Also, BMI and age-related cataract may be related to a third unidentified factor, like nutritional status. Our sample size decreased from 2045 to 1361 participants, who were more likely to be younger, men, and more highly educated. On the other hand, female participants had a higher BMI and a higher prevalence of cataract, suggesting that our results may underestimate the relationship between BMI and age-related cataract. Among the 175 participants who had cataract surgery before the survey, there were more women than men (15.4% vs 11.2%; \( P = .02 \)), which may also lead to underestimation. This is especially true for nuclear and posterior subcapsular opacities, which are more commonly associated with visual loss and, hence, cataract surgery.

Cataract is the leading cause of blindness throughout the world.\(^1\) The only effective therapy available is lens extraction. The growing need for surgical resources is critical in developing countries. Demand highly exceeds supply, and only a few of those visually disabled by cataract can be treated.\(^2\) On the other hand, cataract surgery is widely available in industrialized countries, and is the most common surgical procedure in these countries for those 65 years and older. The economic impact of cataract could not be overlooked, with an estimated cost to Medicare of $3.4 billion in 1991 in the United States.\(^3\) It is also the most common ophthalmic surgery performed in Taiwan, and occupied the highest expenditure in the ophthalmic sector of National Health Insurance. More than 15 million persons available in industrialized countries, and is the most common surgical procedure in these countries for those 65 years and older. The economic impact of cataract could not be overlooked, with an estimated cost to Medicare of $3.4 billion in 1991 in the United States.\(^3\) It is also the most common ophthalmic surgery performed in Taiwan, and occupied the highest expenditure in the ophthalmic sector of National Health Insurance. More than 15 million persons worldwide are estimated to be blind from cataract. By 2025, this number will increase to 40 million in the absence of new or more efficiently delivered interventions.\(^7\) Hence, the identification of modifiable risk factors is urgent. In the United States, the National Eye Institute estimated that a 10-year delay in the onset of cataract would result in a 50% reduction in the prevalence of cataract.\(^8\)

Although the precise mechanism of BMI on cataractogenesis is not clear, BMI is one of the few potentially modifiable risk factors for cataract formation. A further longitudinal study is being undertaken to determine the effect of changing BMI on cataract formation.

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