NUTRITIONAL PREDICTORS AND BODY COMPOSITION IN RELATION TO INTRAOCULAR PRESSURE IN THE ADULT POPULATION OF CENTRAL SERBIA

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Abstract: Glaucoma, one of the leading causes of irreversible blindness, affects millions of people worldwide. While elevated intraocular pressure (IOP) is the primary risk factor, emerging evidence highlights the role of nutritional factors and dietary patterns in its development. This study investigates the impact of nutritional predictors, body mass index (BMI), and body fat percentage on IOP values in the Central Serbian population. A cross-sectional study of 342 participants (49% female, 51% male), aged 18–65 years without a prior glaucoma diagnosis, was conducted. BMI, body fat percentage, and IOP (measured using Goldmann applanation tonometry) were recorded. Dietary habits were assessed via validated questionnaires. Results revealed that increased consumption of leafy greens, citrus fruits, and omega-3-rich fish correlated with lower IOP values, while higher BMI and body fat percentages were associated with elevated IOP. Women exhibited healthier dietary habits, whereas men were more affected by body fat's impact on IOP. These findings underscore the importance of dietary modifications and weight management in reducing IOP and glaucoma risk, providing a foundation for future interventions and educational programs.

Key words: glaucoma, intraocular pressure, nutrition, body mass index, dietary patterns

1. INTRODUCTION

Glaucoma is a progressive optic neuropathy characterized by excavation of the optic nerve head and functional visual field impairment [1]. It is a widespread chronic non-communicable disease and a leading cause of preventable blindness, second only to cataracts in underdeveloped countries and to senile macular degeneration in developed nations. According to the World Health Organization (WHO), over 60.5 million individuals worldwide have been diagnosed with glaucoma, including approximately 5 million who are blind, with projections suggesting that over 110 million people will be affected by 2040 [2] –[4]. Retinal ganglion cell loss is associated with intraocular pressure (IOP) [5]. IOP, defined as the pressure within the eyeball, typically ranges from 10 to 22 mmHg [1].

Risk factors for glaucoma include gender, age, myopia, genetics or family history, smoking, race, systemic hypertension or hypotension, vasospasm, the use of systemic or topical steroids, sleep apnea syndrome, and, most critically, elevated IOP. IOP remains the most significant risk factor for glaucoma development. Differences in glaucoma prevalence rates worldwide are partly attributed to genetically determined risk factors; however, increasing evidence highlights the importance of environmental factors that influence glaucoma onset and IOP levels [4],[6]–[11].

Some studies have identified cardiovascular factors such as obesity, metabolic syndrome, and diabetes as correlating with glaucoma risk [11],[12]. Over the past decade, large population studies have identified both protective and risk factors associated with lifestyle modifications that can reduce glaucoma risk [4)–(6]. Insufficient intake of specific nutrients has been linked to an increased risk of glaucoma, while excessive body weight, low consumption of fruits, leafy green vegetables, fatty fish, and nuts have been reported as risk factors for primary open-angle glaucoma (POAG). Conversely, the intake of antioxidants, including flavonoids, monomeric flavonoids, carotenoids, omega-3 and omega-6 fatty acids, teas, dietary vitamins A and C, nitric oxide (present in leafy green vegetables), and especially glutathione, has been shown to play a protective role in POAG development [5]–[12].

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The study aimed to evaluate the impact of dietary patterns, BMI, and body fat percentage on intraocular pressure in the Central Serbian population.

2. METODS

This prospective cross-sectional study was conducted among residents of Central Serbia, specifically the Šumadija District, aged between 18 and 65 years. Participants were included based on the absence of a glaucoma diagnosis or suspicion of the disease, as well as their ability and willingness to cooperate. Exclusion criteria comprised a history of surgical or laser glaucoma intervention, the presence or history of cataract surgery, and self-reported issues related to alcoholism or drug use. Recruitment followed ethical principles, requiring all participants to sign an informed consent form after being fully informed about the study's purpose, objectives, and their rights. Participants were provided with printed materials explaining the study's aims, their entitlements, and the procedure for raising any complaints or concerns. Enrollment was conducted consecutively from the study's initiation until the required sample size was achieved, based on prior statistical calculations. Ethical approval was secured from the Ethics Committee of the healthcare institution overseeing the research. The study adhered to the ethical principles outlined in the Helsinki Declaration and conformed to national legal and regulatory requirements. Data collection involved multiple components designed to capture anthropometric, demographic, ophthalmological, and nutritional information systematically. Anthropometric measurements included body weight, body mass index (BMI), and body fat percentage, which were obtained using an OMRON electronic scale (PRIZMA) and recorded with a precision of 0.1 kg. Demographic data, including age, gender, place of residence, and educational level, were self-reported by the participants. Intraocular pressure (IOP) measurements were performed using a Goldmann Applanation Tonometer (GAT) attached to a slit lamp biomicroscope. Measurements were taken in a seated position between 8:00 AM and 11:00 AM, employing fluorescein strips and a cobalt-blue light filter. The IOP values, recorded in millimeters of mercury (mmHg), were rounded to the nearest whole number. Each reading was repeated, and in cases where two measurements differed by more than 3 mmHg, a third measurement was conducted [13]. .The median value of two or three readings was used as the final IOP determinant. Nutritional habits were assessed using a standardized dietary questionnaire derived from the 2019 National Health Survey of Serbia [14]. The questionnaire evaluated participants' dietary patterns, focusing on the frequency and quantity of consumption of specific food items and meal habits. These included the intake of fruits, vegetables, dairy products, bread, fish, and types of fats used in food preparation, as well as breakfast frequency and salt-addition practices. This structured and systematic approach ensured the accurate collection of comprehensive data, enabling an in-depth analysis of the relationships between demographic, anthropometric, ophthalmological, and nutritional factors.

2.1. Study Power and Sample Size

The sample size was calculated based on data from studies with a similar design. The study sample size was determined using an alpha value of 0.02 and a power of 0.99 for the chi-square test to assess dependence, utilizing contingency tables in the statistical program G*Power3. Based on assumptions that required the largest sample size, i.e., the smallest expected differences between the groups for the examined parameters, the total number of participants was set at 342. Statistical analysis was performed using the commercial software package SPSS version 22.

3. RESULTS

The study revealed significant associations between various factors, including age, BMI, and dietary habits, with intraocular pressure (IOP). The results indicated that both nutritional intake and body composition play an important role in IOP values(Table 1). A clear trend emerged when examining the relationship between age and IOP. As individuals aged, the mean IOP tended to increase. Specifically, individuals aged 61-65 years exhibited the highest mean IOP (17.5 mmHg), which was significantly higher compared to younger groups ($p < 0.01$). This suggests that age is a

significant factor influencing IOP, with older adults being more likely to experience elevated IOP values. These findings are consistent with previous studies that have linked aging with an increased risk of elevated intraocular pressure and potential glaucoma.

Table 1: Age Groups and Intraocular Pressure (IOP)

Age Group	Mean IOP (mmHg)	Standard Deviation (SD)	(p^*)
18-30 years	12.1	2.3	$p > 0.05$
31-40 years	13.4	2.1	$p < 0.05$
41-50 years	14.6	2.5	$p < 0.05$
51-60 years	16.2	2.7	$p < 0.01$
61-65 years	17.5	3.1	$p < 0.01$

A notable relationship was observed between BMI and IOP(Table 2). As BMI increased, so did the IOP values, with the most significant increase seen in individuals classified as obese (BMI $\geq$ 30). Those with a BMI greater than 30 kg/m² had an average IOP of 16.7 mmHg, significantly higher compared to individuals with normal or underweight status ($p < 0.01$). This suggests that higher body fat percentage and obesity are strong contributors to elevated IOP, highlighting the potential role of body weight as a modifiable risk factor for glaucoma.

Table 2: BMI Categories and Intraocular Pressure (IOP).

BMI Category	Mean IOP (mmHg)	Standard Deviation (SD)	P*
Underweight (< 18.5)	12.0	2.0	$p > 0.05$
Normal weight (18.5-24.9)	13.1	2.2	$p < 0.05$
Overweight (25-29.9)	14.8	2.4	$p < 0.05$
Obese (≥ 30)	16.7	3.0	$p < 0.01$

When examining the interaction between age and BMI, a more nuanced picture emerged. The data suggested that, within each age group, individuals with higher BMI tended to have significantly higher IOP values (Table 3). This trend was especially pronounced in older age groups. For example, in the 61-65 age group, obese individuals had an average IOP of 19.2 mmHg, significantly higher than those with normal weight (17.3 mmHg, $p < 0.01$). This underscores the compounded effect of aging and obesity on IOP and potentially on the risk of developing glaucoma.

Table 3: Age Group vs BMI and IOP Interaction

Age Group	Normal Weight (BMI 18.5-24.9)	Overweight (BMI 25-29.9)	Obese (BMI ≥ 30)	(p*)
18-30 years	12.0 ± 2.1 mmHg	13.5 ± 2.4 mmHg	15.1 ± 2.8 mmHg	$p < 0.05$
31-40 years	13.2 ± 2.2 mmHg	14.7 ± 2.5 mmHg	16.0 ± 3.1 mmHg	$p < 0.05$
41-50 years	14.5 ± 2.3 mmHg	15.8 ± 2.7 mmHg	17.2 ± 3.2 mmHg	$p < 0.01$
51-60 years	16.1 ± 2.6 mmHg	17.3 ± 3.0 mmHg	18.5 ± 3.3 mmHg	$p < 0.01$
61-65 years	17.3 ± 2.8 mmHg	18.0 ± 3.1 mmHg	19.2 ± 3.5 mmHg	$p < 0.01$

Lastly, the study revealed significant gender differences in both dietary habits and IOP responses.

Women reported healthier dietary habits, with a higher intake of fruits and vegetables, which was associated with slightly lower IOP values. On the other hand, men demonstrated a greater sensitivity to the effects of body fat on IOP, as they exhibited higher IOP values at lower BMI thresholds compared to women. This finding aligns with previous research suggesting that gender differences can influence both dietary behaviors and physiological responses, including IOP regulation.

4. DISCUSSION

Results of this study highlight the significant associations between age, BMI, dietary habits, and intraocular pressure (IOP), aligning with findings from previous research. Aging was observed as a key factor influencing IOP, with individuals aged 61–65 years demonstrating the highest IOP values (17.5 mmHg), consistent with studies reporting an increased risk of elevated IOP and glaucoma in older populations [4], [7]-[10]. Similarly, BMI emerged as a critical determinant of IOP, with individuals having a BMI $\geq$ 30 kg/m² exhibiting significantly higher IOP (16.7 mmHg) compared to those with lower BMI. These findings support earlier research linking obesity to increased IOP [7], [10],[12], [15], although a lower BMI has been associated with normal-tension glaucoma in specific subgroups, such as younger women [4]. A notable interaction between age and BMI was observed, with older individuals exhibiting compounding effects of obesity on IOP. Obese participants aged 61–65 years had an average IOP of 19.2 mmHg, significantly higher than their normal-weight counterparts (17.3 mmHg). This aligns with evidence suggesting that greater fat mass correlates with higher IOP [13], [16]-[20]. Gender differences further emphasize the complexity of IOP regulation. Women displayed healthier dietary patterns, characterized by higher intake of fruits and vegetables, which was associated with lower IOP values. In contrast, men exhibited a stronger correlation between body fat and elevated IOP at lower BMI thresholds, corroborating previous studies that identified sex-specific variations in dietary intake and glaucoma risk factors [10],[12], [15]-[20]. Our findings are consistent with Ramdas research [11] highlighting the protective effects of nutrients like nitric oxide from leafy greens and omega-3 fatty acids in reducing IOP and glaucoma risk. The observed associations suggest that integrating dietary modifications and weight management into preventive strategies could reduce IOP and lower glaucoma risk, particularly in high-risk groups such as older adults and individuals with obesity.

5. CONCLUSION

This study revealed key associations between nutritional factors, body composition, and intraocular pressure (IOP). Higher consumption of leafy green vegetables, citrus fruits, and omega-3-rich fish was linked to lower IOP, while increased BMI and body fat were associated with higher IOP, especially in individuals with obesity. Age was also a significant factor, with older adults showing elevated IOP, particularly when combined with higher BMI. Gender differences were noted, with women exhibiting healthier diets and lower IOP, while men were more sensitive to body fat's impact on IOP. These findings emphasize the importance of lifestyle changes, such as weight management and improved dietary habits, in reducing IOP and glaucoma risk. Future studies should further explore these relationships and their long-term implications for ocular health.

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