Original

The Relationship between Body Mass Index, Pulse Rate and Intraocular Pressure

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Abstract

Background: Body mass index (BMI), pulse rate, and intraocular pressure (IOP) are key indicators of general well-being. This study investigated the relationship between these parameters of health to determine the effect of body mass index and pulse rate on intraocular pressure.

Method: The research involved 80 participants (44 males and 36 females) at the Nigeria Army Eye Centre in Bonny Camp, Lagos state. Assessments conducted include blood pressure, pulse rate, height, weight, and IOP. Blood pressure was measured with a Sphygmomanometer and a stethoscope to listen for Korotkoff sounds. Pulse rate was recorded by palpating the radial artery. Body weight was measured with a calibrated scale and height was measured using a meter rule attached to a wall. BMI was calculated by dividing the weight in kilograms by the height. IOP was assessed using a Pulsair non-contact tonometer. A One-Way analysis of Variance (ANOVA) was employed to analyze the data, with the use of the Statistical Package for Social Sciences (SPSS version 22.0).

Results: The results showed that IOP was significantly correlated with BMI ($p = 0.011$) and pulse rate ($p = 0.000$). However, pulse rate had a higher and more linear correlation with IOP. Multiple linear regression using IOP as dependent variable, and BMI, pulse rate and age as predictors, showed a statistically significant model ($p = 0.000$) with an R squared value of 51.4%. IOP was also significantly influenced by obesity as the mean IOP increased steadily across the different BMI weights groups: underweight (13.88 mmHg), normal weight (16.13mmHg), overweight (16.25mmHg), obese (17.00mmHg).

Conclusion: IOP increases with increasing BMI and is significantly different between underweight and obese normotensive subjects. Pulse rate has a stronger linear relationship with IOP than BMI and age, hence may be a better predictor of changes in intraocular pressure. It is advised to strictly monitor the intraocular pressure of individuals who are obese and individuals with abnormal pulse rates to prevent occurrences of high IOP.

Keywords: Body Mass Index (BMI), Pulse Rate, Intraocular Pressure, Relationship.

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Introduction

Body mass index, pulse rate, and intraocular pressure are important markers of physiologic well-being that provide information about body composition, cardiovascular health, and ocular health, respectively.[1,2,3]

Intraocular pressure (IOP) denotes the pressure within the eye, sustaining the eye's spherical form through the production and drainage of aqueous humor.[4] Crucial for eye structure and function, IOP is notably linked to conditions such as glaucoma, ranking as the second leading cause of preventable blindness worldwide.[5] As a dynamic factor, IOP demonstrates positive associations with age, central cornea thickness, systolic blood pressure, a family history of glaucoma, and elevated body mass index.[6,7]

Pulse rate signifies the number of heart beats per minute, typically ranging between 60-100 beats per minute,[8] while body mass index is one of the most specific and objective methods of measuring obesity.[9] BMI is calculated from a person's weight and height and it offers a dependable indication of underweight, overweight, and obesity in adults, aiding in identifying weight categories associated with potential health issues.[3]

Obesity, a widespread global disorder, is recognized as a significant risk factor for various eye diseases such as cataracts, diabetic retinopathy and glaucoma.[10] It also elevates the risk of both increased intraocular pressure and systemic vascular conditions like hypertension and atherosclerosis.[11] A body mass index of more than 21 kg/m^2 is thought to be associated with approximately 58% of diabetes mellitus and 21% of ischemic heart disease globally.[12] Obesity has been found to elevate blood viscosity by boosting the number of red blood cells.[13,14] The increased resistance to outflow through the episcleral veins, increased viscosity of blood, and more fat surrounding the eyes are among the possible causes for the association between body mass index and intraocular pressure.[15]

The study by George and Ajayi observed an association between BMI and IOP, where a significant increase in IOP was seen in obese individuals.[16] Similarly, Mufti et al discovered that an increased BMI is associated with a higher risk of elevated intraocular pressure.[17] In contrast to these findings, a study conducted at the University of Port Harcourt, Nigeria, found no statistically significant relationship between BMI and IOP ($P=0.473$; $r^2=0.02$).[18] This suggests that BMI variations in their study did not significantly affect IOP

Consequently, this study was undertaken to examine the nature of the association between intraocular pressure (IOP), pulse rate, and body mass index (BMI) across different weights and age groups. Additionally, due to the lack of sufficient research exploring the relationship between IOP and pulse rate, this study also holds particular significance in addressing this gap in knowledge. Examining their relationships and possible connections between them could help us better understand their effect on general health. This could reveal important and significant relationships that will have an impact on preventive and therapeutic options.

Method

Setting

The study was conducted at the Nigeria Army Eye Centre, Bonny Camp, Lagos State. This center serves as the primary eye care facility for individuals both within and outside the military base where it is located. Its strategic location attracts a wide-ranging population with varying demographics, providing a rich pool of variables essential for the study.

Study design

This was a cross-sectional experimental study. It was chosen because it allows for the simultaneous collection of data on multiple variables (body mass index, pulse rate, and intraocular pressure) at a single point in time. This design is ideal for identifying potential relationships or associations between these variables without requiring long-term follow-up.

Study Population

The study included subjects aged 20 to 65 years, encompassing individuals from different age groups. The participants consisted of both military personnel and civilians, reflecting the diverse population served by the eye center, which caters to individuals both within and outside the military base.

Sample Size

A total of 80 participants were recruited, consisting of 44 males and 36 females. Eighty participants were deemed sufficient for the study as this sample size provided a significant group representative of the population attending the eye center.

Sampling Methodology

A convenient sampling technique was utilized. The convenience sampling method was chosen because it allowed the recruitment of participants who were already visiting the eye center for routine eye examinations. This approach was practical and time-efficient, as it eliminated the need for external recruitment or outreach,

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ensuring that only those who were readily available and willing to participate were included.

Research materials

The research materials consist of a sphygmomanometer, stethoscope, non-contact tonometer, meter rule and measuring scale.

Data collection procedures

Before the study commenced, participants were informed about the procedures, and those who provided consent were included. The Participants were then directed to sit comfortably in the examination chair while a brief systematic and ocular history was then taken. If wearing tight clothing, they were advised to loosen it to avoid affecting the blood pressure readings. The right hand was placed on the table with the brachial and radial arteries facing up. The cuff was wrapped around the arm, and the brachial artery palpated after which the cuff was inflated. After inflation, the cuff bladder was centered over the right upper arm overlying the brachial artery after which, the stethoscope earpiece was then positioned in the ear and the stethoscope head was placed on the brachial artery. The air valve was locked, and the cuff was inflated. Gradually unlocking the air valve, air was released slowly, listening for the Korotkoff sound. The systolic reading was determined by the first sound heard, while the diastolic reading was identified at the point when the sound disappeared. These were according to the blood pressure test procedures laid out by Guyton and Hall.[19]

The pulse rate, measured in beats per minute,[19] was assessed by palpating the radial artery. Following that, body weight measurement involved zeroing the body weight scale before the subject stepped on it. Participants were instructed to remove additional weight such as shoes, wallet, and jacket. While standing still on the scale, they were advised to look straight ahead, wait for the needle to settle, and then the weight was recorded.[19] For height measurement, a meter rule attached to the wall was used. Participants removed shoes, stood with their back against the wall, ensuring contact with the back of their feet, calves, bottom, upper back, and the back of their head. Measurements from the head to the calves were recorded.[19] Subsequently, BMI was calculated by dividing weight by height and recorded in kilograms per square meter.[19]

The measurement of intra ocular pressure was done using the pulsair non-contact tonometer in a dimly illuminated room. The participants were directed to sit in the examination chair and were positioned behind the device. They were then told to gaze straight ahead as the tonometer was switched on. Supported by the instrument holder, the tonometer was placed over the right eyelid and adjusted such that a black cross image appeared. At this alignment, the instrument was held in position until it signaled a reading had been captured. Measurements were recorded in millimeters of mercury for the right eye, and the same procedure was repeated for the left eye.

Consent was obtained from all participants after informing them about the study. This study received ethical approval from the Research and Ethics Committee of the Department of Optometry at the University of Benin, with the ethical approval number: EC/UBEN/ LSC.OPT/18/095

Data Analysis

The data collected was subjected to statistical analysis using SPSS version 22.0. Descriptive statistics, One-Way analysis of Variance (ANOVA), linear correlation (Pearson) and multiple linear regression were the statistical methods employed in analyzing the data. All tests were carried out at the 5% level of significance, a value of $p \leq 0.05$ is adjudged significant.

Results

The data in Table 1 reveals that the subjects in the study exhibit a wide range of ages, weights, heights, BMIs, pulse rates, and intraocular pressures. The average age of 37.94±12.93 years indicates a predominantly young to middle-aged adult sample. The range of BMI indicates the presence of both underweight and overweight individuals. The pulse rate and intraocular pressure values are within normal physiological limits, with minimal variation between the right and left eyes. The table show no significant difference in means between intraocular pressure in both eyes ($t = 0.206$, $p = 0.837$), hence we proceeded with the rest of analysis using only intraocular pressure recorded for the right eyes of the subjects.

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Table 1: Demographic and descriptive statistics of the recorded variables

Variable	Frequency	Percentage	Maximum	Minimum	Mean ± SD
Age (years)					
20-30	14	17.50			
31-40	29	36.25			
41-50	25	31.25			
51-60	9	11.25			
61-70	3	3.75			
Total	80	100	65	20	37.94 ± 12.93
Weight (kg)					
30-50	8	10.00			
51-70	40	50.00			
71-90	24	30.00			
91-110	8	10.00			
Total	80	100	100	35	64.40 ± 14.81
Height (m)					
0.5-1	15	18.75			
1.1-2	65	81.25			
Total	80	100	1.89	1.37	1.6143 ± 0.1259
BMI (kg/m2)					
10-20	14	17.50			
21-30	48	60.00			
31-40	18	22.50			
Total	80	100	39.26	14.76	24.789 ± 5.32
Pulse rate (b/min)					
50-60	7	8.75			
61-70	10	12.50			
71-80	40	50.00			
81-90	13	16.25			
91-100	10	12.50			
Total	80	100	96	52	73.18 ± 10.92
IOP (mmHg) (OD)					
10-15	30	37.50			
16-20	50	62.50			
Total	80	100	20	11	16.09 ± 2.57
IOP (mmHg) (OS)					
10-15	26	32.5			
16-20	54	67.5			
Total	80	100	20	12	16.04 ± 2.29

Table 2 shows the gender-wise linear correlations between body mass index, pulse rate and intraocular pressure. The results shows that body mass index was significantly correlated with intraocular pressure in male subjects ($r = 0.333$, $p = 0.027$) but not in female subjects ($r = 0.161$, $p = 0.350$), while pulse rate was significantly correlated with intraocular pressure in both genders, male ($r = 0.399$, $p = 0.007$), females ($r = 0.625$, $p = 0.000$), although the correlation was higher in females.

To determine the relationship between body mass index, pulse rate, intraocular pressure and age, multiple linear regression was deployed, using intraocular pressure as the dependent variable while body mass index, pulse rate and age were entered as predictors. A statistically significant model (equation 1) was obtained ($F = 9.100$,

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p = 0.000) with an R squared (predictive power) value of 0.514 i.e. 51.4%. The R squared value shows that 51.4% of the variation (increase or decrease) in intraocular pressure is explained by body mass index, pulse rate and age of a normotensive subject. However, only pulse rate was a significant predictor of intraocular pressure ($p < 0.05$)

Table 2: Gender-wise linear correlations between body mass index, pulse rate and intraocular pressure

		BMI (kg/m2)	Pulse rate (b/min)	IOP (mmHg)
Male				
BMI (kg/m2)	Pearson Correlation	1	.516**	.333*
	Sig. (2-tailed)		.000	.027
Pulse rate (b/min)	Pearson Correlation	.516**	1	.399**
	Sig. (2-tailed)	.000		.007
IOP (mmHg) (OD)	Pearson Correlation	.333*	.399**	1
	Sig. (2-tailed)	.027	.007	
	N	44	44	44
Female				
BMI (kg/m2)	Pearson Correlation	1	.465**	.161
	Sig. (2-tailed)		.004	.350
Pulse rate (b/min)	Pearson Correlation	.465**	1	.625**
	Sig. (2-tailed)	.004		.000
IOP (mmHg) (OD)	Pearson Correlation	.161	.625**	1
	Sig. (2-tailed)	.350	.000	
	N	36	36	36

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

The figure shows the mean intraocular pressure increased steadily across the four groups (Fig. 2); underweight (13.88mmHg), normal weight (16.13mmHg), overweight (16.25mmHg), obese (17.00mmHg). The results of this study also revealed a statistically significant difference in mean intraocular pressure exists between the four groups (F = 2.778, p = 0.047).

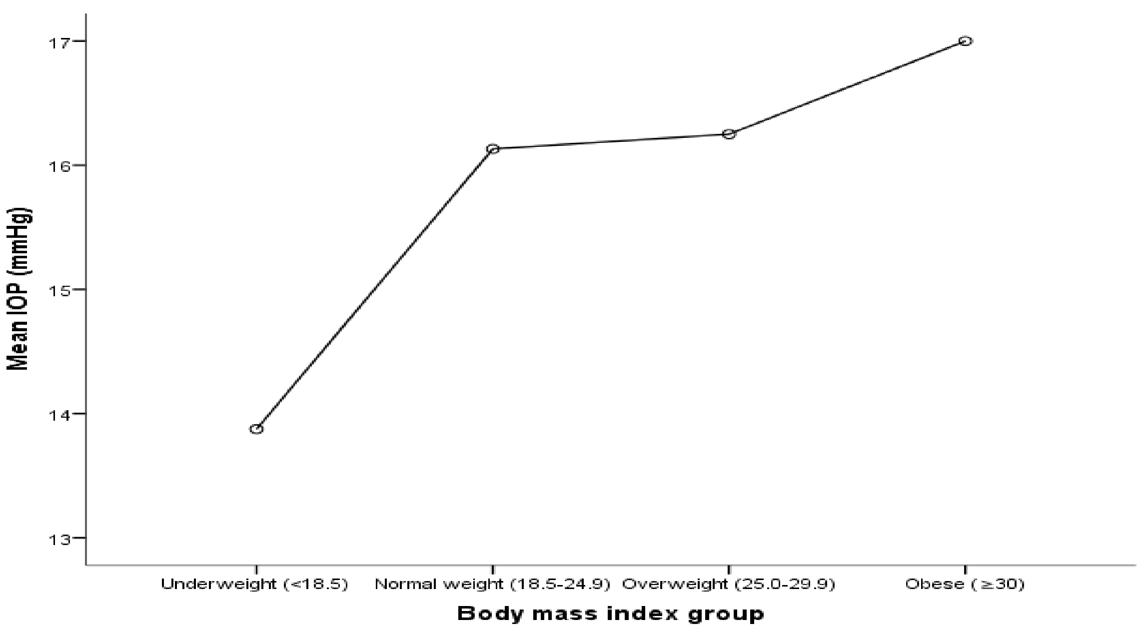

Figure 1: Distribution of mean intraocular pressure in the body mass index groups

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Table 3 shows the multiple comparison test results. It indicates that the significant difference in mean intraocular pressures of the four groups occurred between underweight and obese subjects (p = 0.029). The comparisons reveal that IOP in the obese group (BMI ≥ 30) is significantly higher than in the underweight group (BMI < 18.5), with a mean difference of 3.125 (p = 0.029). Other comparisons between BMI groups, such as between underweight and normal weight, underweight and overweight, and normal weight and obese, do not show statistically significant differences in IOP, as indicated by p-values greater than 0.05.

Table 3: Multiple comparison test of Intraocular Pressure (IOP) by body mass Index (BMI) group, using the Turkey HSD post-hoc test

					95% Confidence Interval	
Body mass index Group (I)	**Body mass index Group (J)**	**Mean Diff (I-J)**	**Std. Error**	**Sig.**	**Lower Bound**	**Upper Bound**
Underweight (<18.5)	Normal weight (18.5-24.9)	-2.257	.966	.099	-4.79	.28
	Overweight (25.0-29.9)	-2.375	1.039	.110	-5.10	.35
	Obese (≥30)	-3.125*	1.101	.029	-6.02	-.23
Normal weight (18.5-24.9)	Underweight (<18.5)	2.257	.966	.099	-.28	4.79
	Overweight (25.0-29.9)	-.118	.686	.998	-1.92	1.68
	Obese (≥30)	-.868	.777	.680	-2.91	1.17
Overweight (25.0-29.9)	Underweight (<18.5)	2.375	1.039	.110	-.35	5.10
	Normal weight (18.5-24.9)	.118	.686	.998	-1.68	1.92
	Obese (≥30)	-.750	.866	.822	-3.02	1.52
Obese (≥30)	Underweight (<18.5)	3.125*	1.101	.029	.23	6.02
	Normal weight (18.5-24.9)	.868	.777	.680	-1.17	2.91
	Overweight (25.0-29.9)	.750	.866	.822	-1.52	3.02

*. The mean difference is significant at the 0.05 level.

Table 4 presents the results of a multiple linear regression analysis where intraocular pressure is the dependent variable, and age, body mass index, and pulse rate are the independent variable. In this model, pulse rate (t-value: 4.362 and p-value:0.000) has the strongest and most significant impact on IOP among the variables studied.

Table 4: Multiple Linear Regression Analysis of Intraocular Pressure (IOP) with Age, BMI, and Pulse Rate

		Unstandardized Coefficients		Standardized Coefficients		
Model		**B**	**Std. Error**	**Beta**	**t**	**Sig.**
1	(Constant)	7.164	1.783		4.019	.000
	Age (years)	-.002	.020	-.012	-.114	.909
	BMI (kg/m^2)	.021	.056	.044	.378	.707
	Pulse rate (b/min)	.116	.027	.494	4.362	.000

a. Dependent Variable: IOP

Discussion

This study aimed to investigate the relationship between body mass index, pulse rate, and intraocular pressure, in order to determine the effect of body mass index and pulse rate on eye pressure. We found that an increase in BMI is associated with increased IOP and that there is a

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significant positive correlation between BMI and IOP. Additionally, pulse rate was identified as a statistically significant predictor of IOP. The study also highlighted gender differences in the relationship between BMI, pulse rate, and IOP.

The findings of this study showed that increase in intraocular pressure is associated with increasing body mass index and that there is a positive correlation between BMI and IOP. This finding is in line with the findings of George and Ajayi.,[16] Baisakhiya et al.,[20] and Farnaz et al.,[21]

George and Ajayi in their study,[16] observed an association between BMI and IOP, where a significant increase in IOP was seen in overweight and obese individuals, characterized by BMI ≥ 30.0 for obese and BMI 25.0-29.9 for overweight. Similarly, Baisakhiya et al discovered that intraocular pressure increases with higher body mass index.[20] Specifically, the mean IOP values in their study were 14.72 mmHg in the underweight group, 14.74 mmHg in the normal weight group, 15.46 mmHg in the overweight group, and 17.9 mmHg in the obese group. Comparatively, a study exploring the relationship between changes in body mass index and intraocular pressure found a correlation between BMI and IOP.[22] BMI in their study was positively associated with changes in IOP as a reduction of 2.86 kg/m² in BMI corresponded to a 1 mm Hg decrease in IOP.

However, this study is particularly different from that of Farnaz et al.[21] in that normotensive subjects were used in this study while Farnaz et al used diabetic (with or without hypertension) subjects.[21] Thus, this study recorded more significant correlation between BMI and intraocular pressure ($p = 0.000$) than that recorded by Farnaz et al ($p = 0.006$ and $p = 0.001$ for diabetics with hypertension subjects and diabetic without hypertension subjects, respectively).[21] Also, the present study with 80 subjects recorded a lower mean BMI (24.79±5.32kg/m2) compared to Farnaz et al.[21] who recorded mean BMI of 29.86±5.87kg/m2 for diabetic subjects with hypertension and 27.49±4.99kg/m2 for diabetic subjects without hypertension, using a total of 101 subjects. Poonam et al suggested that high BMI is an independent risk factor for IOP in both cross sectional and longitudinal studies.[23] Akinci et al reported similar results in a study done on children where higher IOP was observed in obese children, hence it was concluded that in addition to its indirect effect on IOP via blood pressure change, obesity is an independent risk factor for increased IOP.[24]

Gender-wise, this study also found BMI to be significantly correlated with IOP only in male subjects but not in female subjects, this may be due to the nature of physical activities engaged in by the subjects as body mass index has been negatively correlated with physical demand in male subjects,[24] and physical demand has been linked to acute decrease in intraocular pressure.[26,27] Similar finding was reported by Lee et al in a study done on Korean population.[28] The study concluded that BMI had a significantly positive correlation with IOP only in men and not in women.

The significant change in IOP between the BMI groups; underweight, normal weight, overweight and obese reported in this study is at variance with the findings reported in Karadag et al who found no statistically significant difference between groups in terms of IOP.[29] Specifically, the present study reported a significant difference in mean IOP between underweight and obese subjects, this finding was also at variance with the findings of Albuquerque et al, in a study done on children where it was reported that there was no significant difference in the IOP of children with or without obesity.[30]

Pulse rate otherwise known as heart rate, is the number of times the heart beats per minute. This study reported a statistically significant positive linear relationship between pulse rate and intraocular pressure ($r = 0.513$, $p = 0.000$). This finding is at variance with the findings of Karabatakis et al, which concluded that pulse rate had no linear quantitative correlation with IOP decrease.[31] However, the finding agrees with the findings of Baek et al who did a longitudinal analysis of age-related changes in intraocular pressure in South Korea and found that IOP was positively associated with heart rate.[32] In their study, a cross-sectional analysis showed that IOP was negatively correlated in all age groups ($p < 0.001$). In particular, patients in their 60s-80s had a less steep decreasing slope of IOP with age than patients in their 20s-30s (correlation coefficient −0.260 and −0.168, respectively), while a longitudinal analysis showed negative trend in the slope of tendency in total subjects. However, the association between pulse rate and IOP recorded in this study ($p = 0.000$) was stronger than that recorded in Baek et al.[32] Analyzing the effect of gender on the relationship between age and IOP, females had a less steep decreasing slope of IOP with age than males by 0.05 mm Hg.

The findings of the present study also show that pulse rate was positively correlated with intraocular pressure in both male and female normotensive subjects with the correlation being significantly higher in female subjects.

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Previous studies have reported blood pressure to be significantly associated with changes in IOP.[33,34] A study by Klein et al reported significant positive correlation between systemic blood pressure and changes in IOP in subjects aged 43-86yrs.[35] Wong et al also reported significant correlation between systemic blood pressure and intraocular pressure.[36]

The multiple regression results show that between body mass index, pulse rate and age, only pulse rate was the statistically significant predictor of intraocular pressure ($t = 4.362$, $p = 0.000$). The regression model had an R squared value of 0.514, thus implying that 51.4% variation in intraocular pressure is explained by the pulse rate, body mass index and age. The study by Baek et al. reported both pulse rate and age as significant predictors of intraocular pressure,[32] while Gautam et al reported body mass index and age amongst other predictors, as significant predictors of intraocular pressure.[37] Mitchell et al postulated that increased blood pressure leads to elevated ciliary artery pressure, increasing the ultrafiltration of the aqueous humor and thus increasing IOP.[38]

This study has some limitations that includes a small sample size and a focus on normotensive subjects, which may restrict the generalizability of the findings. Furthermore, potential confounding factors were not fully controlled. These factors such as physical activity, diet and any withheld information of medications used by participants, may influence body mass index, pulse rate, and intraocular pressure independently, thereby affecting the observed relationships between these variables. Despite these limitations, the study's findings have important clinical implications, suggesting that BMI and pulse rate should be considered in the assessment of intraocular pressure, particularly in normotensive individuals. Public health initiatives could also benefit from these findings by emphasizing the importance of maintaining a healthy BMI to reduce the risk of elevated IOP.

Implications of the findings of this study

To prevent and treat eye disorders like glaucoma, this study highlights the significance of addressing systemic health factors such as body mass index and pulse rate. Regular intraocular pressure monitoring should be given top priority by medical professionals when treating patients with high body mass index and irregular pulse rates. Public health policy should provide funds for thorough evaluations at eye clinics to raise awareness of the negative effects of obesity on eye health and incorporate eye health into general health exams. Future studies should include people with hypertension to consider underlying mechanisms to evaluate how well lifestyle or medication changes affect IOP.

Conclusion

The findings of this study show that body mass index and pulse rate are linearly related to intraocular pressure in normotensive subjects. Intraocular pressure increases with increasing body mass index and there is a significant difference between mean intraocular pressure of underweight, normal weight, overweight, and obese subjects. Pulse rate has a stronger linear relationship with intraocular pressure than body mass index and age, hence may be a better predictor of changes in intraocular pressure.

Given the strong correlation between body mass index (BMI) and intraocular pressure (IOP), it is crucial to monitor the IOP of obese individuals. Those with abnormal pulse rates should also be closely monitored for elevated IOP, with immediate examination recommended upon detecting such abnormalities.

Declarations

Ethical Consideration: Ethical approval for this study was obtained from the Research and Ethics Committee of the Department of Optometry, University of Benin. All procedures performed in this study was in accordance with the Tenets of the Declaration of Helsinki for human subjects.

Authors' Contribution: Atuanya GN conceptualized the idea of the research, designed the study, prepared and proofread the manuscript. Erhumwun F. was involved in collecting data and review of literature. Idogen O.S was involved in the data collection, manuscript preparation and data analysis. Ugwu IE and Osaiyuwu AB proofread the manuscript

Conflict of interest: The authors declare no competing interests.

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Abbreviation: IOP: Intraocular Pressure; BMI: Body Mass Index; O.D: Right eye; OS: Left eye; mmHG: Millimeter mercury; kg: Kilogram.

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