The influence of retrobulbar adipose tissue volume upon intraocular pressure in obesity

Uticaj retrobularnog masnog tkiva na intraokularni pritisak kod gojaznih osoba

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Abstract

Background/Aim. It is known that glaucoma is associated with elevated intraocular pressure and obesity, yet the precise etiology remains unclear. The aim of this study was to determine whether there is a potential causality between the volume of retrobulbar adipose tissue and the level of intraocular pressure in obese subjects compared with non-obese.

Methods. A total of 100 subjects were divided according to the body mass index (BMI), into two groups: normal weight (n = 50, BMI = 18–24.9 kg/m²) and obese (n = 50, BMI ≥ 30 kg/m²) subjects. Anthropometric measurements, body composition analysis, measurement of intraocular pressure, as well as magnetic resonance imaging (MRI) of the head at the level of the optic nerve, and the derived retrobulbar adipose tissue volume, were undertaken in all subjects.

Results. The obese subjects, as compared with normal weight ones, had a significantly higher mean retrobulbar adipose tissue volume (6.23 cm³ vs 4.85 cm³, p < 0.01) and intraocular pressure (15.96 mmHg vs 12.99 mmHg, p < 0.01). Furthermore, intraocular pressure correlated positively with retrobulbar adipose tissue volume.

Conclusion. In obese people, elevated intraocular pressure may be caused by changes in ocular blood flow, affected by the physical pressure exerted by higher retrobulbar adiposity, and/or by internal vascular changes secondary to complications of obesity. These findings indicate the need for more frequent measurement of intraocular pressure in obese individuals to earlier detect glaucoma, and in so doing prevent irreversible blindness.

Key words: orbit; adipose tissue; intraocular pressure; obesity; magnetic resonance imaging; glaucoma.

Apstrakt

Uvod/Cilj. Zna se da je glaukom povezan sa povišenim vrednostima očnog pritiska i gojaznošću, ipak tačna etiologija je i dalje nepoznata. Cilj ove studije bio je da se utvrdi da li postoji uzročna povezanost između zapremine retrobularnog masnog tkiva i visine očnog pritiska kod gojaznih osoba u porodenju sa normalno uhranjenim osobama.

Metode. Istraživanjem je bilo obuhvaćeno 100 ispitanika podeljenih na osnovu indeksa telesne mase [body mass index (BMI)] na grupu normalno uhranjenih (n = 50, BMI = 18–24,9 kg/m²) i grupu gojaznih (n = 50, BMI ≥ 30 kg/m²) ispitanika. Kod svih ispitanika sprovedena su antropometrijska merenja, analiza telesnog sastava, merenje očnog pritiska, kao i snimanje glave u nivou optičkog živca magnetnom rezonancijom (MR), na osnovu kojeg je izračunata zapremina retrobularnog masnog tkiva.

Rezultati. Gojazni ispitanici u porodenju sa normalno uhranjenim imali su značajno više srednje vrednosti očnog pritiska (15,96 mmHg vs 12,99 mmHg, p < 0,01). Takođe, utvrđena je pozitivna korelacija vrednosti visine očnog pritiska i zapremine retrobularnog masnog tkiva.

Zaključak. Kod gojaznih osoba povišene vrednosti očnog pritiska mogu biti izazvane promenama u krivotoku oka do kojih dolazi zbog povećanog fizičkog pritiska retrobularnog masnog tkiva i zbog vaskularnih promena, kao sekundarnih komplikacija gojaznosti. Ovakvi rezultati ukazuju na potrebu češćeg merenja očnog pritiska kod gojaznih osoba, u cilju ranog otkrivanja glaukome i sprečavanja pojave ireverzibilnog slepila.

Ključne reči: orbita; masno tkivo; intraokularni pritisak; gojaznost; magnetska rezonanca, snimanje; glaukom.

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Introduction

The diagnosis of glaucoma and the principles of its treatment rest largely upon the measurement of intraocular pressure (IOP), and an understanding of the anatomy and physiology governing the inflow and outflow of aqueous humor.

In the context of glaucoma, "normal" eye pressure is one that does not lead to glaucomatous damage of the optic nerve head. Unfortunately, such a definition can not be expressed numerically, as not all eyes react identically to the same values of IOP. According to Kanski, in a population study, the mean value of IOP was 16 mmHg, with two standard deviations giving a normal range of 11–21 mmHg. These values represent the "normal" level of IOP, yet should be taken with caution, as a normal value of IOP in one person can lead to optic nerve head damage and blindness in another. If there is a damage to the optic nerve head, the state is defined as glaucoma.

Glaucoma is a significant health problem, which if not detected and treated in time may lead to irreversible blindness. After cataract, glaucoma is the second commonest cause of blindness in the world, but is second to none as a cause of irreversible blindness.

In recent years there has been a significant progress in methods of both diagnosis and treatment of glaucoma, and yet it remains a disease of both increasing prevalence and unknown etiology. Despite many studies having confirmed that glaucoma is associated with ocular hypertension, insulin resistance, systemic hypertension and hyperlipoproteinemia – all of which are comorbidities of obesity – the exact cause remains unknown.

By modern definition, obesity represents an increase of fat tissue in the body, deleterious to health and occurring as a result of the imbalance between energy intake and expenditure. Its diagnosis is most reliably based upon the value of BMI. Because of the lack of a standardized method of measurement, nor are there well-defined factors which have an impact on changes in fat mass, such as gender, age, race and ethnicity, or level of physical activity.

Obesity as a systemic disease affects multiple organ systems. Hence there is a need to investigate the impact of obesity upon eyes. Different studies have identified links between obesity and ocular hypertension, cataract, age-related macular disease (ARMD), diabetic retinopathy, and diseases of oculomotor nerves.

As obesity is defined by the increase of fat mass, the consequences of obesity develop as a consequence of morphological and functional changes within the adipose tissue. Morphological changes refer to enlargement of the total mass of adipose tissue with a characteristic distribution which determines the specific complications of obesity. In functional terms, obesity leads to inflammatory changes and changes in basic metabolic and endocrine function of adipose tissue.

In this study we investigated the volume of retrobulbar adipose tissue (RAT). Adipose tissue fills the orbit, being situated between the walls of the orbit and the eyeball and subsidiary organs. It surrounds the eyeball, muscles, nerves and blood vessels within the orbit. It extends from the apex of the orbit to the eyelids, just behind the orbital septum. The adipose tissue of the orbit is divided anatomically into retrobulbar (intraconal) and parabulbar (extraconal) parts. RAT is more developed in the parabulbar area, filling the space behind the eyeball. Orbital adipose tissue is limited by the peripheral muscle cone into a lattice-like structure, the margins of which consist of the four oculomotor muscles (superior, inferior, medial and lateral rectus muscles) which divide the adipose tissue into four sheets. RAT histologically belongs to white (unilocular) fat tissue. This type of fat is found under the skin, in the mesentery, around joints, under the skin of palms and soles, in breasts, tongue, and trachea. White adipose tissue is of a yellowish color and comprises fat cells (adipocytes or steatocytes) which form connective lobuli which are incompletely separated compartments.

The aim of this study was to determine the impact of volume RAT upon IOP in non-obese and obese subjects.

Methods

This cross-sectional study involved a 100 subjects divided into the control and the study group, each of 50 subjects. The criteria for inclusion used to select participants were as follows: age 18–60 years of either gender; stable body weight for the previous 6 months; free from diagnosed malignant disease of any localization, endocrine and metabolic disorders and glaucoma; not in receipt of any drug therapy which may affect body fat composition or IOP; and pacemaker-free, owing to incompatibility with magnetic resonance imaging (MRI) and bioelectrical impedance analysis (BIA). All the subjects were volunteers and a signed consent was obtained from all who took part in the study.

Anthropometric measurements were taken to assess nutritional status and to estimate the distribution of adipose tissue. The following parameters were determined: height, weight, and the derived BMI. For measurement of body height the Harpenden anthropometer (Holtain Ltd, Crosswell, UK) was used with 0.1 cm accuracy of measurement. During measurement the subjects were standing with arms hanging by their sides and heels together.

Body weight measurement of the subjects wearing only underwear was performed in a medical decimal scale, with 0.1 kg precision. The obtained values were expressed in kg.

The degree of nutritional status was assessed by BMI, which represents the ratio of body weight (BW) in kilograms by the square of body height (BH) in meters (BMI = BW[kg] / BH[m²]). The subjects were divided into groups according to

to BMI (Table 1). Fifty normal-weight subjects with a BMI = 18–24.9 kg/m$^2$ represented the control group, while a subjects with BMI $\geq$ 30 kg/m$^2$ formed the study group. The classification of nutritional status degree was as recommended by the WHO $^{20}$. BIA was employed for body composition analysis. The equipment used was Omron BF300. It comprises two sensors in the form of electrodes, by the held subjects in their hands. BIA is based on measurements of the body's electrical resistance which provides an indirect estimate of body adipose mass. For this measurement it was necessary to take into account height, weight, age and gender of the subjects$^{1}$. In order to evaluate as precisely as possible body adipose mass, the following requirements were set: the subjects were not to eat nor drink for at least 4 h before examination, physical activity avoided at least 12 h before measurement; the bladder voided 30 min beforehand; alcohol consumption forbidden 48 h prior to measurement, and not to take diuretic drugs for 7 days leading to examination.

The principle of measurement is as follows: subjects hold the electrodes of the appliance in both hands in a position of abduction in relation to the longitudinal axis of the body. A measurement takes 7–15 sec, after which fat mass is read as a percentage of a total body mass (FAT %) and total body fat mass [FAT (kg)].

The IOP of both eyes of all the subjects was measured 4 times a day (at 8 am, 10 am, 12 pm and 2 pm) using a Goldmann’s applanation tonometer. For each individual patient, the measured IOP values of each eye were added together then divided by 2, and so expressed as a mean value in mmHg.

Following anthropometric measurement, MRI axial scanning of the head at the level of optic nerve was undertaken for all subjects. The subjects were imaged on a Magnetom Avanto 1.5T (Siemens, Erlangen, Germany). Each subject had to undergo transverse fluid-attenuated inversion recovery (FLAIR) scanning at the level of optic nerve using predefined technical parameters identical for all the subjects: repetition time (TR) 8,500 ms, echo time (TE) 15 ms, field of view (FOV) 25 × 25 cm, matrix and rectangular FOV factor was 320×220. MRI slice thickness was 0.5 cm. The imaging time was approximately 18 min. During scanning, each subject was placed in an 8-channel head matrix coil in order to achieve a constant signal in the antero-posterior direction.

The images obtained were processed using Adobe Photoshop CS5 software (Waltham, MA) for Microsoft and analyzed by the method introduced by Gronemeyer et al. $^{21}$. Adipose tissue is visually distinguished from other tissues through its density. From the drop-down menu on the initial image (Figure 1) the application threshold was used to select a threshold signal intensity value above which RAT was white and all other tissues were black (Figure 2). These pixels were scored as RAT. Then, using the application histogram, following the prior selection of the lateral and medial half of RAT in relation to the optic nerve, the RAVvalue in pixels was obtained (RATpx). The same method was applied to the other eye. The values of the areas of RAT in pixels (RATpx) for both eyes were then inserted into the formula for calculation the real value of the volume in cm$^3$. The RATpx value was multiplied by the section thickness (0.5 cm) and the value of pixel area (0.0088 cm$^2$):

$$V (cm^3) = RATpx \times 0.5 cm \times 0.0088 cm^2$$

Statistical analysis was performed using Statistica software for Windows, version 10.0 (StatSoft Inc, Tulsa, OK) including the following descriptive parameters: mean ($\mu$), standard deviation (SD), minimum (min), maximum (max) and coefficient of variation (CV). To test the differences between the two groups, we used the paired-samples Student’s $t$-test. Pearson’s product moment correlation was used for correlation coefficient ($r$). A $p$-value less than 0.05 was considered statistically significant in all the tests. The results are presented in tables and figures.

**Results**

The group of normal-weight subjects consisted of 50 subjects, aged 19–60 years (mean age, 42.73 ± 11.08 years), of which 26 were male and 24 female.

The obese group consisted of 50 subjects, aged 28–60 years (mean age: 47.5 ± 8.82 years), 23 of whom were male, and 27 female.

The average body weight in the normal-weight subjects was 69.01 ± 8.28 kg, while in the obese subjects the average body weight was significantly higher and reached 91.95 ±
8.93 kg ($p < 0.05$). The mean BMI in the group of normal-weight subjects was $22.83 \pm 1.83$ kg/m$^2$, while in obese subjects BMI was significantly higher, $32.62 \pm 2.82$ kg/m$^2$ ($p < 0.05$) (Table 2).

The next step was to determine the correlation of BMI and body composition with the values of IOP. In the normal-weight subjects IOP was found to range from 10 to 18 mmHg (mean value $12.99 \pm 2.07$ mmHg), while in the obese subjects the IOP range was 11–20.5 mmHg (mean value $15.96 \pm 2.3$ mmHg). There was a statistically significant difference in the value of IOP between the control and the study group ($p < 0.01$) (Table 3).

In the group of normal-weight subjects RAT was found to range from 2.49 to 6.26 cm$^3$ (mean value 4.85 ± 0.89 cm$^3$). In the obese subjects the values ranged from 4.47 to 8.26 cm$^3$ (mean value 6.23 ± 1.02 cm$^3$). A statistically significant difference was established in RAT volumes in both normal weight and obese subjects ($p < 0.01$) (Table 3).

### Table 1

**Criteria for assessment of nutritional status based on body mass index (BMI) values**

<table>
<thead>
<tr>
<th>Weight categories</th>
<th>BMI (kg/m$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight</td>
<td>&lt; 18.5</td>
</tr>
<tr>
<td>Normal</td>
<td>18.5–24.9</td>
</tr>
<tr>
<td>Overweight</td>
<td>25.0–29.9</td>
</tr>
<tr>
<td>Obese</td>
<td>≥ 30.0</td>
</tr>
</tbody>
</table>

### Table 2

**Body mass index (BMI) value and body composition analysis in the normal-weight and the obese subjects**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Normal weight subjects (n = 50)</th>
<th>Obese subjects (n = 50)</th>
<th>$p^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI (kg/m$^2$)</td>
<td>$22.83 \pm 1.83$</td>
<td>$32.62 \pm 2.82$</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>FAT (%)</td>
<td>$22.58 \pm 7.8$</td>
<td>$34.50 \pm 6.68$</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>FAT (kg)</td>
<td>$16.32 \pm 5.36$</td>
<td>$30.27 \pm 6.42$</td>
<td>&lt; 0.05</td>
</tr>
</tbody>
</table>

FAT = body fat mass; $\bar{x}$ = mean; SD = standard deviation, CV = coefficient of variation; $^*$Student’s $t$-test.

### Table 3

**Intraocular pressure (IOP) values and retrobulbar adipose tissue (RAT) volumes in the normal-weight and the obese subjects**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Normal weight subjects (n = 50)</th>
<th>Obese subjects (n = 50)</th>
<th>$p^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>IOP (mmHg)</td>
<td>$12.99 \pm 2.07$</td>
<td>$15.96 \pm 2.3$</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>RAT (cm$^3$)</td>
<td>$4.85 \pm 0.89$</td>
<td>$6.23 \pm 1.02$</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

$\bar{x}$ = mean; SD = standard deviation, CV = coefficient of variation; $^*$Student’s $r$-test.

Analysis of the values of certain components of body composition obtained by BIA, confirmed the basic classification of subjects based on the BMI.

BIA showed that the average value of a total body fat mass was significantly higher in the obese compared with the normal-weight individuals ($p < 0.05$). Fat mass as a percentage of total body mass in the obese patients was $34.50 \pm 6.68\%$, while the normal-weight subjects' fat mass was $22.58 \pm 7.8\%$ of total body mass.

Fat mass in the obese subjects was $30.27 \pm 6.42$ kg, while in the normal weight subjects this value was $16.32 \pm 5.36$ kg. The difference in body fat mass between the control and the subject groups was statistically significant ($p < 0.05$) (Table 2).

In the group of normal weight subjects IOP was found to range from 10 to 18 mmHg (mean value $12.99 \pm 2.07$ mmHg), while in the obese subjects the IOP range was 11–20.5 mmHg (mean value $15.96 \pm 2.3$ mmHg). There was a statistically significant difference in the value of IOP between the control and the study group ($p < 0.01$) (Table 3).

In the group of normal-weight subjects the measured values of the volume of RAT ranged from 2.49 to 6.26 cm$^3$ (mean value 4.85 ± 0.89 cm$^3$). In the obese subjects the values ranged from 4.47 to 8.26 cm$^3$ (mean value 6.23 ± 1.02 cm$^3$). A statistically significant difference was established in IOP values and retrobulbar adipose tissue (RAT) volumes in the normal-weight and the obese subjects ($p < 0.01$) (Table 3).
The correlation between BMI and RAT in the normal-weight subjects showed insignificantly negative correlation ($r = -0.11, p > 0.05$), while in obese subjects the correlation was positive and highly statistically significant ($r = 0.48, p < 0.01$) (Figure 4). We also investigated the correlation between the fat mass value as a percentage of total body mass (FAT %) and the volume of RAT. In the normal weight subjects, a negative correlation of no statistical significance was found ($r = -0.10, p > 0.05$), while in the obese individuals a positive and statistically insignificant correlation was found ($r = 0.25, p > 0.05$).

![Fig. 4 – Correlation of RAT volume measurement and BMI in obese subjects.](image)

**Fig. 4 – Correlation of RAT volume measurement and BMI in obese subjects.**

RAT – retrobulbar adipose tissue; BMI – body mass index; $r$ – coefficient of correlation.

We investigated the relationship of IOP values and the volume of RAT in both groups. In normal-weight subjects a positive correlation was found, but without statistical significance. The value of correlation in this group was $r = 0.21 (p > 0.05)$. In the obese subjects a positive and statistically significant correlation was found ($r = 0.37, p < 0.05$) (Figure 5).

![Fig. 5 – Correlation of IOP values and RAT volume in obese subjects.](image)

**Fig. 5 – Correlation of IOP values and RAT volume in obese subjects.**

IOP – intraocular pressure; RAT – retrobulbar adipose tissue; $r$ – coefficient of correlation.

**Discussion**

Bearing in mind that the exact cause of elevated IOP is still a major scientific challenge, we conducted this research to determine a possible connection between IOP and the volume of RAT and the eventual impact of RAT deposition and obesity upon IOP.

Whilst undertaking the background research, we did not find studies on a possible connection of retrobulbar fat volume and IOP.

Elevated IOP is associated with numerous intraorbital diseases. There are four primary pathophysiological mechanisms that cause elevation of IOP: structural anomalies – congenital and hereditary diseases which lead to disruption of the anatomic integrity of eyeball and orbital tissues; the effect of masses such as tumors and pseudotumors, and of diseases leading to the infiltration of tissues causing compression of ocular and orbital structures; vascular diseases which disrupt eyeball and orbit drainage; inflammatory processes – cellulitis and other forms of orbital inflammation which change the anatomical structure of the orbit and influence vascular function. RAT could be placed into the mechanism of "mass effect", since its presence can directly or indirectly influence episcleral venous pressure which could lead to changes in the Schlemm’s canal, thereby inducing IOP elevation. This mechanism is exemplified by orbital space lesions, such as hyperthyroid ophthalmopathy and carotid-cavernous fistula. In support to this theory, a simple example of retrobulbar injection of anesthetic can lead to elevated IOP. Increased intraorbital pressure may have an impact on IOP due to compression of episcleral and orbital venous blood vessels, leading to increased venous pressure.

Our findings show that increased RAT volume affects the level of IOP. In the normal-weight subjects the mean IOP was 12.99 mmHg, while in the obese subjects the value was 15.96 mmHg.

Considering that obese people have an increased amount of adipose tissue as compared to normal-weight individuals, we analyzed the relationship between RAT volume in the obese subjects and the controls. In the normal-weight subjects the mean RAT volume was 4.85 cm$^3$, while in the obese the mean value was 6.23 cm$^3$. A difference in RAT volume of the normal weight and obese subjects was statistically significant ($p < 0.01$). In available researches, RAT volume was not studied in details, and there are noticeable differences in estimation of the amount of retrobulbar adipose depot.

Tian et al. studied the volumes of intraorbital structures. In their study, the measurement of RAT was performed by MRI. Their results showed that the average total volume of RAT was 21.59 cm$^3$. According to the results of Forbes et al., the mean RAT volume in men was 11.19 cm$^3$, while in women it was 10.10 cm$^3$. Peyerst et al. used computed tomography (CT) scan to measure RAT volume. Their results differ from those of Forbes et al. According to their measurements, RAT volume in the normal-weight group measured 8.16 cm$^3$, while in the obese subjects it was 11.34 cm$^3$. Regensburg et al. in their research demonstrated the results of RAT assessment volume based on CT images of 160 orbits. Their results showed statistically significant differences in the volume of adipose tissue in the orbit regarding sex: the mean volume was 16.1 cm$^3$ in men, and 14.0 cm$^3$ in women.

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Considering the presented results of total RAT volume determination we come to a conclusion that our values correspond to the volume of RAT, because they are related only to a segment of RAT in the thickness of a 5 mm MRI scan slice.

Observing the relationship between IOP value and RAT volume, a positive correlation was found. In the group of normal weight subjects the value of correlation (r) was 0.22 (p < 0.05), while in the obese individuals that value was higher and statistically significant (r = 0.37, p < 0.05). Unfortunately, there is no available literature data on this kind of comparison, so we cannot compare our results with others.

Due to its simplicity, BMI is commonly used in clinical practice for diagnosing obesity. However, BMI is only an indicator of increasing total body mass, and not of fat mass. Fat from lean body mass cannot be distinguished by using BMI. Being a systemic disease, obesity may increase blood viscosity and episcleral venous pressure, and therefore may lead to obstruction of aqueous humor outflow. The beaver dam eye study showed that the value of IOP increases with BMI values. The same conclusion was reached in a study of over 25,000 subjects in Japan. Cetinkaya et al. indicate that even in children obesity affects IOP elevation, and obesity is considered to be an independent factor for IOP elevation. Zafra Perez et al. also suggest that elevated IOP is associated with obesity.

In our research the mean BMI in the normal-weight subjects was 22.83 kg/m², and in the obese 32.62 kg/m². The difference was statistically significant (p < 0.05). Correlating BMI and IOP in the normal-weight subjects, we found that IOP increases with increasing BMI (r = 0.45, p < 0.05). In the group of obese subjects we also found a positive and statistically significant correlation (r = 0.31, p < 0.05). Our findings are compatible with data from the literature, and BMI could be considered to be a good predictor of IOP value in normal-weight and obese individuals.

Although it is relatively easy to diagnose obesity, a clear pathophysiological explanation for the links between obesity and IOP remains elusive. To explain this association, mechanical and vascular theories have been proposed.

According to the mechanical theory, it is believed that obesity causes IOP elevation due to the increased volume of retrobulbar fat, increased episcleral venous pressure, increased blood viscosity and aqueous humor outflow disorders. It is evident that ocular hypertension is linked with comorbidities of obesity, such as systemic hypertension, diabetes, lipid disorders and insulin resistance. High blood pressure can lead to increased filtration fraction of aqueous humor due to increased pressure in the ciliary artery, while hyperglycemia may lead to disruption of osmotic pressure within the eye which may result in elevated IOP. The vascular theory argues that eyes with genetically poor blood supply to the optic nerve head are more prone to elevated IOP. Recently, more attention has been paid to oxidative stress as a possible cause of elevated IOP. It is known that hyperleptinemia, which occurs in obesity, is associated with oxidative stress. Hyperleptinemia in obesity may be considered as a trigger in the cascade of pathological changes leading to increased IOP.

RAT, a fat tissue depot, is clearly limited by the orbital space. Because of this limitation there is no possibility of expansion, as available to other fat tissue depots in the body. According to our results, the correlation between the volume of RAT and BMI in the normal weight subjects was found to be negative and statistically insignificant (r = -0.11, p > 0.05), whereas in the obese group the correlation was positive and statistically significant (r = 0.48, p < 0.01). Therefore, BMI can be considered as a good predictor of RAT only in obese subjects. These results lead to a conclusion that retrobulbar fat depot correlates with body mass, as do subcutaneous and visceral adipose tissue depots.

Janssen et al. clearly point out that BMI is a reliable parameter in predicting visceral, subcutaneous and total adipose tissue. Kamel et al. also consider noted BMI as anthropometric parameter which correlates mostly with intraabdominal adipose tissue.

BIA is a relatively simple, rapid and noninvasive technique widely used in clinical practice. This method can measure a total fat mass and a percentage of fat mass to total body weight.

According to the results of Srđić, fat mass as measured by BIA was significantly higher in obese compared to normal weight subjects, as was the case in our study. Using BIA, our results showed that the average total body fat mass in normal weight subjects was 16.32 kg, compared to 30.27 kg (p < 0.05) in the obese group. In addition, BIA also showed a good correlation with the level of IOP, especially in a group of normal weight subjects (r = 0.55, p < 0.01). In the group of obese subjects the correlation was also positive, but statistically insignificant (r = 0.15, p > 0.05). Our results indicate that the values of IOP may depend on increased volume of adipose tissue in normal-weight subjects and not in the obese.

RAT is a dynamic tissue. RAT volume is different in obese compared to normal-weight subjects. In the obese the volume is far greater, as is the case with other adipose depots of the human organism. Our research confirmed that such adiposity increases in obese individuals. The percentage of body fat mass, measured using BIA, showed a positive correlation with the volume of RAT in obese patients, and this was statistically insignificant (r = 0.25, p > 0.05). In the group of normal-weight subjects the correlation was negative and statistically insignificant (r = -0.10, p > 0.05). Our findings suggest that the BIA is not valid for determination of enlarged RAT volume in normal weight and obese subjects.

In most studies on orbital soft tissue elements, computed tomography (CT) is widely used. MRI used in our study provides safe and accurate measuring of adipose tissue. Different studies state MRI is a gold standard in determination of adipose tissue volume. Although MRI and the special technique of RAT volume determination used in our study provide an accurate assessment of this depot volume, the method is extremely expensive and demanding, in terms of both technical equipment and well-trained staff, and for these reasons is impractical for everyday use in rou-

tine clinical practice. However, MRI can be used to determine adipose tissue deposits, the calibration of different techniques for measuring adipose tissue depots and anthropometric parameters for certain population groups, and in cases requiring clinical diagnostics, such as Graue's ophthalmopathy.

Conclusion

According to our results, obese individuals have significantly higher volumes of RAT positively correlated with higher IOP. These results suggest that elevated in obese subjects, IOP may be caused by altered blood flow through ocular vessels, this potentially being mediated by the external physical pressure contingent upon an increased RAT volume, together with internal vascular and metabolic changes occurring as complications of obesity. This therefore recommends a more frequent measurement of IOP in obese individuals, so as to promote early detection and management of any increase in pressure, and in so doing prevent glaucoma and irreversible blindness.

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