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# Ocular Vasodynamic Changes in Adolescent Smokers

## Key words:
Color Doppler ultrasonography,
ocular blood flow,
adolescent

## Abstract

**Introduction:** Cigarette consumption has many effects on human body emerging in the acute and chronic periods that are related to the amount and duration of cigarette smoking.

**Aim:** A prospective, randomized study to evaluate the effects of smoking on ocular hemodynamics in adolescents was carried out.

**Method:** Peak systolic flow velocities (PSV), end diastolic flow velocities (EDV) were obtained from the ophthalmic, central retinal, and lateral and medial posterior ciliary arteries by using color Doppler ultrasonography. The resistive index (RI) was calculated as RI: (VS-VD)/VS. In addition, systolic and diastolic blood pressures and pulses of adolescents were recorded.

**Results:** The systolic and diastolic blood pressures of smoking adolescents were found to be higher than non-smoking adolescents and the difference was statistically significant (p=0.008 and p=0.041, respectively). When both groups are compared, though higher pulse per min values were obtained from smokers, a statistically significant difference could not be determined. A statistically significant difference with regards to flow values in orbital vascular structures between both groups could not be established.

**Conclusion:** Cigarette use can cause effects in acute and chronic settings, according to the data obtained from our study acute systemic effects of smoking are observed, however, it did not lead to changes in flow parameters of orbital vascular structures.



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# Introduction

Smoking has a wide spectrum of effects such as sympathoadrenal system activation[1], vascular endothelial damage[2,3], and changes in coagulation factors[4,5]. Furthermore, cigarette contains numerous chemical substances that are harmful to the body[6]. Therefore, many studies are needed to investigate the effects caused by cigarette on human body. Chronic cigarette use is a known risk factor for several ocular vascular pathologies like hypertensive retinopathy, age related macular degeneration, anterior ischemic optic neuropathy[7]. The field of application of ocular color Doppler ultrasonography has expanded widely since the definition of normal and abnormal flow patterns of orbital vessels by Erickson *et al.* in 1989, and currently it has acquired an important place in the evaluation of the effects of various pathologies (localized ocular pathologies and systemic diseases) on orbital vascular structures and the resulting flow alterations.

The pathogenic mechanisms of the relationship between ocular vascular pathologies and smoking could not be understood fully yet. Also, different endpoints are reached in some studies carried out in this subject.[9,10,11]

# Aim of the Study

The objective of this study was to determine whether there are changes in the flow parameters of orbital vascular structures in adolescent smokers and compare them with the flow values in orbital vascular structures in non-smoking adolescents.

# Method

## Patients

The study was conducted prospectively in the radiology clinics of our hospital. The patient and control groups in this study consisted of adolescents referred to us by the pediatrics clinics of our hospital. All adolescents included in the study were patients presenting to the pediatrics clinics for various complaints, without evidence of any kind of pathology after investigations. A total of 38 adolescents (25 male, 13 female) smoking at least five cigarettes a day for at least one year duration as the patient group and 57 healthy control subjects (19 male, 38 female) were examined in this study. No systemic (thyroid pathologies, cardiac pathologies, anemia etc.) or local disease was present. None of these patients were taking any chronic systemic/topical medications.

Ophthalmologic examinations of all adolescents were done before color Doppler ultrasonography and patients in which any ocular pathology was found were excluded from the study. None of the adolescents participating in the study wore glasses.

Doppler studies were carried out after the patients rested for 15 minutes in the sitting position. The blood pressure (systolic and diastolic, *mm Hg*) and pulses *(per min)* were obtained immediately before the study. It was cared that all subjects in the patient and control groups did not eat any food or consume drinks containing alcohol or caffeine.

## Color Doppler Sonography

Only one eye was used for investigation and it was selected randomly. All investigations were carried out by the same radiologist and he did not know to which group the subject belonged. All examinations were carried out while the patients were in supine position with eyes closed. The ultrasound transducer was applied to the closed eyelids using a small amount of sterile coupling gel, and care was taken not to apply pressure to the eye to avoid iatrogenic errors in the flow measurements (A thick layer of gel was applied over the closed superior eyelid).

Peak systolic and end-diastolic velocities and resistivity index were measured from the ophthalmic, central retinal, and lateral and medial posterior ciliary arteries. The resistivity index (RI) was then calculated according to Pourcelot's formula (Planiol *et al.* 1972): RI= PSV-EDV/PSV.

All measurements were performed using a CDI set: Logiq S6 (GE Medical System, Milwaukee, Wisconsin, USA) using a linear phase array transducer.

The ophthalmic artery was traced approximately 10-15 mm behind the globe, nasal to the optic nerve after their crossing. The ophthalmic artery was typically identified as a larger-caliber, pulsating vessel.

The central retinal artery was recognized with the color mode, blood flow velocities in the central retinal artery were measured within the optic nerve 2-3 mm behind the posterior margin of the globe (to examine CRA, the B-scan gray scale image of the optic nerve was used as a landmark). Medial and lateral posterior ciliary artery measurements were carried out within 5 mm of the posterior wall of the globe. Arteries were distinguished from veins by their pulsatility. Color and pulsed Doppler examinations were performed with medium- and low-flow settings.

The total examination time was approximately 10-15 minutes for each patient.

## Statistics

We compared the systolic and diastolic arterial blood pressures and heart rate, peak systolic and end diastolic velocities and resistive indexes of ophthalmic, central retinal, and lateral and medial posterior ciliary arteries in smoker and non-smoker adolescent orbits.

We used independent samples T test to compare the results of the measurement of orbital vascular structures of the patient and control groups. All statistics in this study were analyzed using SPSS for Windows 13.0 (SPSS Inc, Chicago, IL, USA). Data are presented as mean ± SD. The basic level of significance was chosen as $P<0.05$.

# Results

In this study, flow parameters in orbital vascular structures (ophthalmic, central retinal, and lateral and medial posterior ciliary arteries) of a total of 95 adolescent consisting of 38 smokers (40%) and 57 non-smokers (60%), were evaluated with Color Doppler ultrasonography. Of 95 adolescents 44 were male (46,3%) and 51 were female (53,7%). The patient group aged between 16-18 years (mean: 17.02 ± 0.75) and consisted of 25 males and 13 females. The control group aged between 14-18 years (mean: 16.08 ± 1.13) and consisted of 38 females and 19 males (Fig. 1).

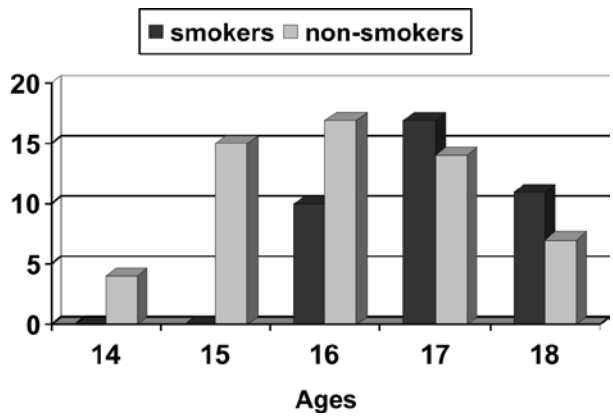


**Figure 1.** Smokers and non-smokers adolescents age characteristics

The duration of smoking of adolescents in the patient group was ranged from a minimum of 12 months to a maximum of 60 months (mean: 22.5±12.1). Daily cigarette consumption ranged between 5 and 20 (mean: 9.3±4.1).

Systolic BP (mm Hg) of smoking adolescents (mean: 113.3±6.8), when compared to the systolic BP values (mean: 109.0±8.7) of the control group, found to be higher and the difference was statistically significant (P= 0.008).

Similarly, when diastolic BP (mm Hg) is compared, the diastolic BP values of smoking adolescents (mean: 75.8±5.4) were higher than that of the non-smoking adolescents (mean: 73.1±6.9), and a statistically significant difference was found between the two groups (P= 0.041).

When the pulse rates per min of the smoking and non-smoking adolescents are compared, though the pulse rate per min of the patient group was higher, a statistically significant difference could not be determined (P= 0.051) (Fig. 2).

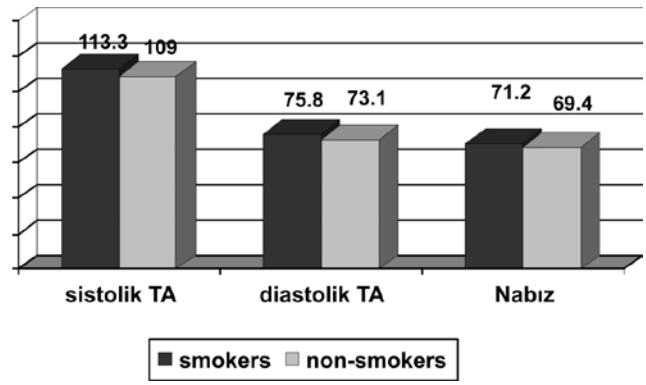


**Figure 2.** Smokers and non-smokers adolescents blood pressure (sistol, diastol mm Hg) and heart rate (min.) characteristics

When the measurements of orbital vascular structures (ophthalmic, central retinal, and lateral and medial posterior ciliary arteries) obtained with color Doppler ultrasonography are compared between patient and control groups, a statistically significant difference could not be found between the two groups with regards to PSV, EDV and RI values (Table 1).

**Table 1.**

| | Groups | Mean | St. Deviation | p Value |
|---|---|---|---|---|
| Ophthalmic artery PSV (cm/s) | s | 40.07 | 3.14 | NS (p=0.688 ) |
| | ns | 39.73 | 5.06 | |
| Ophthalmic artery EDV (cm/s) | s | 11.82 | 1.53 | NS (p= 0.898) |
| | ns | 11.87 | 2.05 | |
| Ophthalmic artery RI | s | .70 | .03 | NS (p= 0.802) |
| | ns | .70 | .03 | |
| Central retinal artery PSV (cm/s) | s | 12.65 | 1.40 | NS (p=0.461 ) |
| | ns | 12.88 | 1.60 | |
| Central retinal artery EDV (cm/s) | s | 4.05 | .57 | NS (p=0.396) |
| | ns | 4.15 | .65 | |
| Central retinal artery RI | s | .67 | .02 | NS (p=0.551) |
| | ns | .67 | .02 | |
| Lat. post. ciliary artery PSV (cm/s) | s | 12.56 | 1.29 | NS (p=0.993) |
| | ns | 12.56 | 1.41 | |
| Lat. post. ciliary artery EDV (cm/s) | s | 3.99 | .54 | NS (p=0.568) |
| | ns | 4.06 | .58 | |
| Lat. post. ciliary artery RI | s | .68 | .02 | NS (p=0.237) |
| | ns | .67 | .02 | |
| Med. Post. ciliary artery PSV (cm/s) | s | 12.57 | 1.34 | NS (p=0.885) |
| | ns | 12.52 | 1.46 | |
| Med. post. ciliary artery EDV (cm/s) | s | 4.01 | .55 | NS (p=0.775) |
| | ns | 4.05 | .59 | |
| Med. Post. ciliary artery RI | s | .68 | .02 | NS (p=0.359) |
| | ns | .67 | .02 | |

# Discussion

Today the flow parameters of orbital vessels can be assessed by color Doppler ultrasonography non-invasively[16] and is used for the investigation of flow changes in various disease conditions such as central retinal artery/vein occlusion, glaucoma, diabetes mellitus, ocular ischemic syndrome, uveitis, endophthalmitis[17,18,19].

Ophthalmic artery, which is one of the main vascular structures supplying the orbit, is the first branch of the internal carotid artery and central retinal artery is a branch originating from the ophthalmic artery[12,13]. Ophthalmic artery has a wider lumen, and higher systolic and diastolic flow rates than the central retinal artery[14]. Central retinal artery

provides about 40% of the retinal oxygen requirement[15]. Ophthalmic and central retinal arteries do not have any kind of autonomic neural system regulation, but instead a strong autoregulation[12,13,15]. The vasomotor tone and blood flow regulation of the central retinal artery is achieved completely to a great extent under the influence of factors such as nitric oxide of retinal endothelial origin, prostaglandins, and endothelin[15].

There are several studies about the effects of smoking on these structures and in one of them carried out by Williamson *et al.* it is reported that there is an association between smoking and decrease in flow velocities in the ophthalmic artery[20].

Smoking in humans involves tar and carbon monoxide in addition to a number of chemical substances and carcinogens[21]. Carbon monoxide has known effects, as heart and peripheral vascular disturbances in humans[22,23].

Furthermore, smoking is associated with an increase in coagulation by affecting both platelet functions and coagulation factors[24,25]. Fibrinogen level, which is an important component of the coagulation system, is higher in smokers than non-smokers, and it is reported that high fibrinogen leads to fibrin production and platelet aggregation, consequently causing an increase in blood viscosity[26].

On the other hand, it is known that smoking causes sympathoadrenal system activation, resulting in increase in heart rate, blood pressure, and catecholamine and corticosteroids levels in blood. It is believed that the mechanisms underlying the increase in heart rate and blood pressure associated with nicotine, is via central nervous system activation through the secretion of norepinephrine and epinephrine[1].

As a result, it is stated that heart rate increases significantly in smokers[27,28]. Kaiser HJ *et al.* reported in their study that systolic and diastolic blood pressures are lower in chronic smokers than non-smokers, however, heart rates are higher[9]. In our study, as mentioned in above studies, we found that systolic and diastolic blood pressure in smoking adolescents is higher than in non-smoking adolescents and there is a statistically significant difference between both groups. Similarly, when heart-beat rates are compared, though we determined that heart rates of smoking adolescents are higher, we could not establish a statistically significant difference between both groups. We consider that our findings are formed as a result of sympathoadrenal system activation by cigarette.

In animal studies and other studies, it has been demonstrated that chronic exposure to cigarette smoke is a significant cause of increased choroidal vascular resistance[29,30].

Morgado *et al.* have shown that there is a decrease in retinal blood flow in acute smoking subjects with laser Doppler velocimetry[31].

In a study by Kaiser HJ *et al.* using color Doppler ultrasonography it has been shown that there is an increase in blood flow velocities in ophthalmic and posterior ciliary arteries in chronic smokers[9].

In our study, we could not demonstrate a significant difference in any of the PSV (cm/s), EDV (cm/s) and RI values of ophthalmic, central retinal, and lateral and medial posterior ciliary arteries between patient and control groups.

In conclusion, it can be suggested that the changes in blood pressures and heart rates caused by cigarette consumption are due to acute systemic effects of smoking. Yet, we consider that alterations in flow parameters of orbital vascular structures can take place only after very long periods of cigarette use.

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# Вазодинамске промене у очима код адолесцентних пушача

## Кључне речи:

Колор-доплер ултрасонографија, проток крви кроз очи, адолесцент.

## Сажетак

**Увод.** Пушење има вишеструки утицај на људско тело, изазивајући акутне и хроничне промене које су у вези са дужином пушачког стажа и количином дувана.

**Циљ рада:** Проспективном рандомизираном студијом желели смо да утврдимо утицај пушења на хемодинамски статус ока код адолесцената.

**Метод.** Колор-доплер ултрасонографијом утврђени су максимална систолна брзина протока (*PSV*) и брзина протока на крају дијастоле (*EDV*) у офталмичној артерији, централној ретиналој артерији и латералним и задњим медијалним цилијарним артеријама. Индекс отпора (*RI*) је израчунат по формули *RI*: (*VS-VD*)/*VS*. Уз то, извршено је мерење систолног и дијастолног крвног притиска и пулса код адолесцената.

**Резултати.** Нађено је да су систолни и дијастолни крвни притисак код адолесцената који пуше виши него код адолесцената који не пуше и да је разлика статистички значајна ($p$=0,008 за систолни и $p$=0,041 за дијастолни притисак). Утврђена је виша фреквенција пулса код пушача, али разлика није била статистички значајна. У погледу хемодинамских вредности у васкуларним структурама орбите, није утврђена статистички значајна разлика између две групе.

**Закључак.** Пушење може да има како акутни, тако и хронични ефекат. У подацима из наше студије примећује се акутно системско деловање пушења, међутим, оно није довело до хемодинамских промена у орбиталним васкуларним структурама.

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