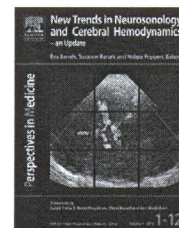


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Morphological, hemodynamic and stiffness changes in arteries of young smokers

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KEYWORDS

Smoking;
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Abstract

Aim: The aim of our investigations was to detect the acute and chronic effects of cigarette smoking on arterial wall thickness and stiffness in young, healthy volunteers. We also performed a one-year follow-up to define the possible changes.

Subjects: We recruited 25 non-smoking and 25 smoking university students aged 19–33. Exclusion criteria were any known diseases, abnormally high cholesterol levels and body mass index (BMI) above 30 kg/m².

Methods: We defined the intima-media thickness on both common carotid arteries by using B-mode ultrasonography and we measured the hemodynamic and stiffness parameters with the help of arteriograph. In case of smokers we also investigated the acute effects after smoking one cigarette. In the follow-up study we measured 15 non-smokers and 13 smokers again.

Results: In the smoking group morphological, stiffness and hemodynamic parameters showed significantly higher values compared to non-smokers. Concerning the acute effects we detected a significant increase in stiffness and hemodynamic parameters after smoking one cigarette. Gender differences were also found in the smoking group. Unadjusted to age, gender and smoking status there was a significant correlation between intima-media thickness and pulse wave velocity. We could not find any progression in smokers after one year, while there was an improvement in intima-media thickness and augmentation index in non-smokers.

Conclusion: Early atherosclerotic processes due to smoking can be detected even at a young age, in healthy university students. One year regular smoking does not result in detectable changes.

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Abbreviations: Aix, augmentation index; BMI, body mass index; HR, heart rate; IMT, intima-media thickness; PWV, pulse wave velocity; sBP, systolic blood pressure.

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Introduction

Tobacco is one of the most important preventable causes of premature death worldwide. Smoke leads to an increased risk of stroke, heart disease, atherosclerosis and peripheral vascular disease even at the lowest level of exposure. About 5 million tobacco-related deaths occur a year worldwide and it is expected to reach 8 million a year by 2030 [1].

The higher carotid intima-media thickness (IMT) confirms the atherogenic effects of smoking. Several studies attest that there is a dose- and time-dependent relationship between carotid IMT and smoking with the highest value in current smokers, lower in former and the lowest in never smokers [2,3]. The aim of our study was to investigate whether only a few years of smoking results in measurable morphological and stiffness changes on arteries in young healthy students without any other cardiovascular risk factors. Besides the chronic alterations we also measured the acute effects of cigarette smoking on hemodynamic and stiffness parameters.

We intended to define whether any progression could be detected due to smoking after a short period of time by repeating the whole measurement on the same subjects after one year.

Materials and methods

We recruited 25 non-smoking and 25 smoking healthy university students aged 19–33 for our study. Exclusion criteria were any known diseases, abnormally high cholesterol levels and BMI above 30 kg/m².

Students who have smoked for at least half a year, at least 5 cigarettes per day, belonged to the smoking group. The average duration of smoking was 6.5 years with an amount of 10.2 cigarettes per day. Participants were not allowed to smoke 6 h before the investigations.

After performing laboratory tests we used B-mode ultrasonography to define the intima-media thickness (IMT) on both common carotid arteries and we measured the hemodynamic (heart rate, blood pressure) and stiffness parameters (pulse wave velocity, augmentation index) with an oscillometric method (TensioMed Arteriograph). In case of smokers we repeated the measurement with the arteriograph after smoking one cigarette to detect the acute effects of smoking, too.

We measured the IMT R-synchron, 1 cm before the bifurcation, 6 times on each ultrasound picture, then we calculated an average which was used for the statistical analysis.

Two examiners separately performed the investigations and the subjects were called back after one week to repeat the whole procedure.

In the one-year follow-up we used the same methods and restrictions as in the original study and we measured 15 non-smokers and 13 smokers again. Between-group comparisons were carried out on data averaged over measurement occasions and observers into a single-observation-per-subject structure. The method of comparison was either Student's two-sample *t* test or Wilcoxon's rank-sum test, subject to normality assumptions being satisfied. Normality was checked using the skewness-kurtosis test. For comparisons of outcomes before and after smoking in smokers

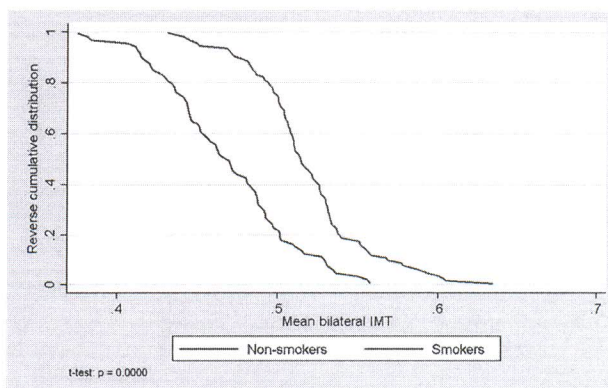


Figure 1 Differences in IMT between non-smokers and smokers. Significant increase can be seen in IMT in the smoking group compared to non-smokers ($p < 0.0001$). (Accepted by Clinical Neuroscience. One part of the results has been accepted by the Hungarian Ideggyógyászati Szemle (Clin Neuroscience). The present form is with the permission of the journal mentioned above. Supported by ETT 407-04/2009.)

Student's paired *t* test or Wilcoxon's matched-pairs signed-rank test was used, subject to normality assumptions. The relationships between average bilateral IMT and elasticity parameters were modelled using multiple linear regression adjusted for gender and smoking in interaction, and age. For one-year comparisons we used paired *t*-tests or Wilcoxon matched-pairs signed-ranks tests, subject to normality assumptions being satisfied. Stratification for smoking status was used to eliminate confounding and to reveal effect modification if present.

Results

Significant differences were found in arterial thickness, stiffness and hemodynamic values between smokers and non-smokers.

In our original study mean bilateral carotid IMT was found 0.52 ± 0.034 mm in smokers and 0.46 ± 0.036 mm in non-smokers ($p < 0.0001$). Fig. 1 shows the difference in IMT between the two groups.

The one-year follow-up confirmed this result with values of 0.51 ± 0.033 mm in smokers and 0.44 ± 0.027 mm in non-smokers ($p < 0.01$).

Pulse wave velocity (PWV) also showed significantly higher values in the smoking group compared to non-smokers. As a resting value, after the 6 h prohibition of smoking we measured 7.46 ± 1.1 m/s in smokers and 6.67 ± 0.84 m/s in non-smokers ($p < 0.01$).

After one year we got similar results (8.07 ± 2.1 m/s in smokers, 6.61 ± 0.85 in non-smokers, $p < 0.05$).

Regarding the hemodynamic parameters there was a significant difference in heart rate (HR) due to smoking. The resting value in smokers was found 72 ± 8.3 s⁻¹, while in non-smokers we measured 67 ± 8.6 s⁻¹ ($p < 0.05$). In the one-year follow-up this significance was not confirmed.

As for the acute effects of smoking we detected significant increase in PWV, heart rate and systolic blood pressure

Table 1 The acute effects of smoking one cigarette on stiffness and hemodynamic values^a. Pulse wave velocity (PWV), heart rate (HR) and systolic blood pressure (sBP) significantly increased due to the inhalation of smoke.

	Before one cigarette	After one cigarette
PWV (m/s)	7.46 ± 1.11	8.05 ± 0.99*
HR (s ⁻¹)	72.5 ± 8.3	83.3 ± 8.2*
sBP (Hgmm)	124.9 ± 9.2	132.7 ± 9.7*

* $p < 0.01$.

^a Accepted by Clinical Neuroscience. One part of the results has been accepted by the Hungarian Ideggyógyászati Szemle (Clin Neuroscience). The present form is with the permission of the journal mentioned above. Supported by ETT 407-04/2009.

after smoking one cigarette ($p < 0.01$) [Table 1], which was proven by the follow-up too.

Gender differences were also found in stiffness parameters. In our first study and also in the follow-up smoking males showed significantly faster PWV than smoking females ($p < 0.01$), while in case of augmentation index (Aix) we found the opposite ($p < 0.05$). This significance could only be seen in the smoking group.

Investigating the correlation between IMT and pulse wave velocity we found that there is a linear correlation between these two parameters [Fig. 2]. Each 0.1 unit increase in mean bilateral IMT results in a 0.64 m/s faster PWV ($p = 0.0025$). Adjusted to age, gender and smoking status this correlation disappears, which means that there is no cause-consequence relationship between IMT and PWV but if we know the IMT then we can estimate PWV.

Analysing the changes in IMT after one year we found that it remained unchanged in smokers and decreased significantly in non-smokers ($p = 0.0002$) [Fig. 3]. The changes of augmentation index showed similar results.

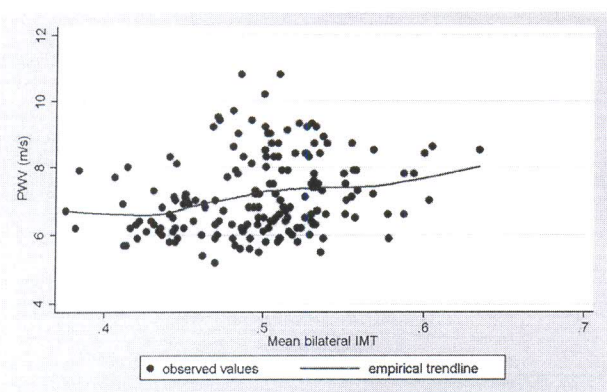


Figure 2 Linear correlation between mean bilateral IMT and PWV unadjusted to age, gender and smoking status. Each 0.1 unit increase in mean bilateral IMT results in a 0.64 m/s faster PWV ($p = 0.0025$). (Accepted by Clinical Neuroscience. One part of the results has been accepted by the Hungarian Ideggyógyászati Szemle (Clin Neuroscience). The present form is with the permission of the journal mentioned above. Supported by ETT 407-04/2009.)

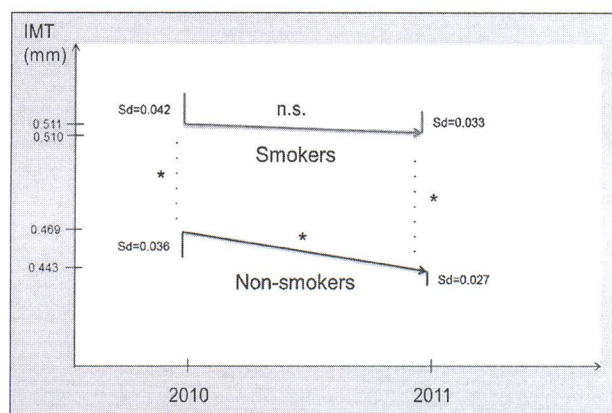


Figure 3 Changes in IMT after one year. No significant differences can be detected in smokers. In non-smokers it decreased significantly ($p = 0.0002$). n.s.: not significant; * $p < 0.05$.

Discussion

Carotid intima-media thickness (IMT), assessed by B-mode ultrasonography, is a sensitive marker for atherosclerosis and can indicate an accelerated disease process in an early stage. Being an independent predictor of stroke and cardiovascular events, IMT is valuable for clarifying CVD risk [4].

According to a 2008 study, subjects with carotid atherosclerosis have a 3-fold higher risk of ischemic stroke independent of other cardiovascular risk factors. Each increase of 1 standard deviation in carotid IMT increases the stroke risk by 43% [5].

The impact of smoking on carotid IMT is verified by several previous studies [6,7], which examined mainly subjects of middle or older age in contrast to our young groups.

Our results approve that only a few years of smoking can cause detectable morphological changes on arterial wall reflected by elevated IMT values in young smokers compared to non-smokers. Besides the wall thickening smoking has chronic effects on stiffness parameters, measured by arteriograph, resulting in faster PWV.

In addition to the long term consequences, several immediate responses are also detectable right after the inhalation of the smoke. Elevated heart rate and systolic blood pressure can be measured, and we also found an increase in PWV, which can be the result of the elevated hemodynamic values or the consequence of smoking directly. Further investigations are needed to clear this question.

According to our follow-up study one year regular smoking does not result in measurable morphological and stiffness changes in young smokers.

Regarding that smoking is a modifiable risk factor for cardio and cerebrovascular events, large forces have to be invested in the cessation of smoking and thus in the prevention of the diseases.

A recent study investigated the impact of smoking cessation on carotid atherosclerosis. According to their results quitting smoking is significantly associated with decreasing risk of the severity of carotid atherosclerosis and plaques [8].

Conclusion

Our results confirm the role of smoking in the progression of atherosclerotic processes and hemodynamic changes which can lead to severe cardio and cerebrovascular consequences and provide evidence for the importance of preventive strategies in young population.

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