

Effects of overweight on luminal diameter, flow velocity and intima-media thickness of carotid arteries

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PURPOSE

To the best of our knowledge, there are only a few previous studies on the effects of overweight on extracranial carotid arteries. We aimed to investigate the effects of overweight on flow velocities, luminal diameters and intima media thicknesses (IMTs) of the common and internal carotid arteries (CCA, ICA).

MATERIALS AND METHODS

A prospective study on color duplex sonography of the extracranial arteries was performed in 71 adults, ages between 25-58 years old. The body mass index (BMI) was found to be normal in 24 (group 1) and high in 47 (group 2) subjects of the study group. Flow velocity (FV), luminal diameter and IMT of carotid arteries of all the participants were measured.

RESULTS

There were significant differences between group 1 and group 2 in the following parameters; luminal diameters of the right CCAs were significantly larger in group 2, peak-systolic FV of ICAs were significantly lower in group 2 than in group 1 and ICA end-diastolic FVs were significantly lower in group 2 than in group 1.

CONCLUSION

The present data shows that there is a correlation among carotid artery luminal diameter, FVs and overweight. In the overweight subjects, the increased luminal diameter and decreased FVs can point at the early stage of atherosclerosis. The influence of adiposity on atherosclerosis is very complex and varies with gender and age, therefore we need larger series and further investigation.

Key words: • carotid arteries • body mass index • ultrasonography • color Doppler

Obesity is steadily becoming the greatest health problem in the developed world. The prevalence of overweight and obesity has reached pandemic proportions worldwide. It has recently been estimated that 1.1 billion people are overfed and overweight (1). It causes impaired function of the large arteries, which might be the consequence of metabolic dysregulation, inflammatory pathways, obstructive sleep apnea, or other mechanisms (2, 3).

Overweight becomes obesity when excess fat has accumulated to the extent that it may adversely affect health and is most commonly defined by the use of criteria involving the body mass index (BMI = kg/m²). BMI ≥ 25 can be associated with a reduced life expectancy and a risk of exacerbating many diseases (4).

Obesity is thought to be a major risk factor in stroke. Doppler ultrasonography offers noninvasive investigation of hemodynamics in the carotid arteries, and has assisted in the diagnosis of stroke (5, 6).

The purpose of this study was to investigate the effects of overweight on flow velocities, luminal diameters, and intima media thickness (IMT) in the common carotid arteries (CCAs) and internal carotid arteries (ICAs), as well as to detect any possible relationship to the early stage of arteriosclerosis.

Materials and methods

A prospective study with color duplex sonography of the extracranial carotid arteries was performed with 71 adults aged 25-58 years (mean age: 40.61 ± 8.13 years). Volunteers with BMI values between 20 and 24.99 were included in group 1 and those with a BMI of 25-29.99 were placed in group 2. Among the 71 participants, BMI was found to be normal in 24 subjects (group 1: 11 males and 13 females; mean age: 39.29 ± 8.50 years) and was high in 47 subjects (group 2: 22 males and 25 females; mean age: 41.23 ± 7.88). The mean BMI values in groups 1 and 2 were 23.17 ± 1.53 kg/m² and 27.62 ± 1.71 kg/m², respectively.

All the subjects were healthy and had an active life. Informed consent to participate in the study was obtained from all subjects, and the study was approved by the local ethical committee.

Blood samples were obtained between 8 am and 10 am from subjects who had been fasting since 9 pm from the previous evening. Subjects were allowed to rest for 15 min just before blood was drawn. All subjects refrained from heavy exercise, smoking, and alcohol or caffeine-containing beverages for at least 3 h before being examined. Analysis of leukocyte count, hemoglobin, platelet count, blood glucose, serum cholesterol, and serum triglycerides was performed with an Olympus AU600 (Opticus Co. Ltd. Japan) test device.

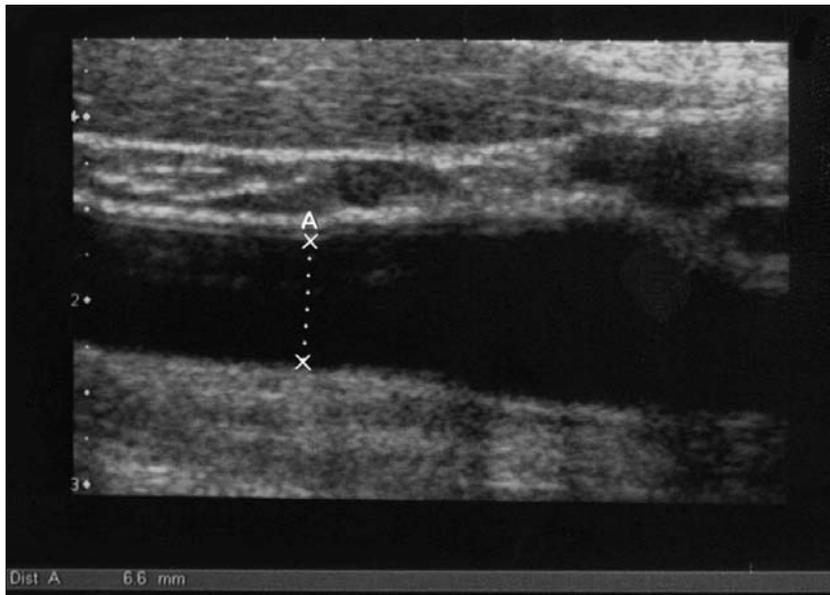


Figure 1. The luminal diameter of the common carotid artery was measured on a magnified B-mode sonographic image between the bright internal layers of the parallel vessel walls.

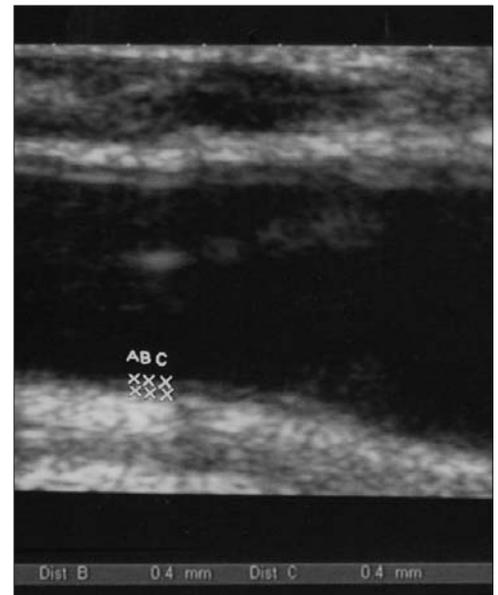


Figure 2. When an optimal longitudinal sonographic image was obtained, this image was magnified and intima media thickness was measured from a segment 1 cm proximal to the carotid bulb.

Blood pressure was measured after 5 min of rest in the sitting position and each measurement was repeated within 5 min. The same nurse took all measurements using the same equipment in the early morning (between 7:30 AM and 9 AM).

Each subject was in the supine position in a dark and quiet room, and the Doppler US evaluations were done following 5 to 10 min of resting on the bed. CCAs and ICAs were explored using a 7.5-MHz linear-array transducer (Toshiba SSH 140 A, Toshiba, Tokyo, Japan). All measurements were performed by the same radiologist. The subjects were in the supine position with their heads slightly elevated and turned to the contralateral side 10° for CCA, and 25°-40° for the ICA measurements. Flow velocity (FV) measurements were most frequently taken 1.5 to 2 cm below the carotid bulb in the CCA, and 1 to 2 cm above the carotid bulb in the ICA. The sampling gate was placed at the center of arterial axis, and FVs were recorded only after the signals were stabilized. Peak-systolic and end-diastolic FVs were measured in the CCA and ICA with the insonation angle adjusted between 45° and 60° to the course of the vessel.

We performed the study by recording the images in cine view mode and

chose images with the best color filling for standard measuring of luminal diameter and IMT. The luminal diameter of the CCAs and ICAs were measured on magnified B-mode images between the bright internal layers of the parallel vessel wall's, on exactly the same location of velocity measurement (Figure 1). All subjects had an IMT measurement at the far wall of both CCAs (Figure 2). The IMT was defined as the distance between the leading edge of the luminal echo and the leading edge of the media/adventitia echo. When an optimal longitudinal image was obtained, this image was magnified and frozen. IMT was measured over a length of 1 cm, just proximal to the bulb. Only the far walls of the artery were used for calculation. The measurements were revised 3 times and the mean value was noted.

Statistical analyses were made with SPSS Version 11.0 for Windows (Statistical Package for Sciences Institute, Cary, NC). Descriptive analysis, including mean and standard deviation for quantitative variables and frequency, were performed with chi-square test. Side-to-side differences and differences between groups 1 and 2 were tested with paired Student T test. The correlation of all parameters for ages was determined using Pearson's correlation

coefficient and Spearman's rank correlation coefficient.

Results

The color duplex examination of luminal diameter and IMT measurements were performed in all the CCAs and ICAs of all 71 subjects. The mean values \pm standard deviation (\pm SD) of all data are given in Tables 1 and 2. Significant differences were found between groups 1 and 2; the luminal diameter was significantly larger in group 2 than in group 1 in right CCAs, (Figure 3), peak-systolic FV was significantly lower in group 2 than in group 1 in ICAs, and ICA end-diastolic FVs were significantly lower in group 2 than in group 1.

There were no significant differences between the 2 groups' heights (group 1: 168.70 \pm 7.51 cm; group 2: 167.76 \pm 7.36 cm; $p = 0.614$). We did not detect any correlation between subject height and blood pressure, cholesterol level, triglycerides, carotid artery luminal diameter, flow velocity, and IMT.

There were no significant differences between the 2 groups for side-to-side flow velocities, luminal diameter, or IMT in the paired CCAs and ICAs, except for CCA luminal diameter. The right CCA luminal diameters were significantly larger than the left ones.

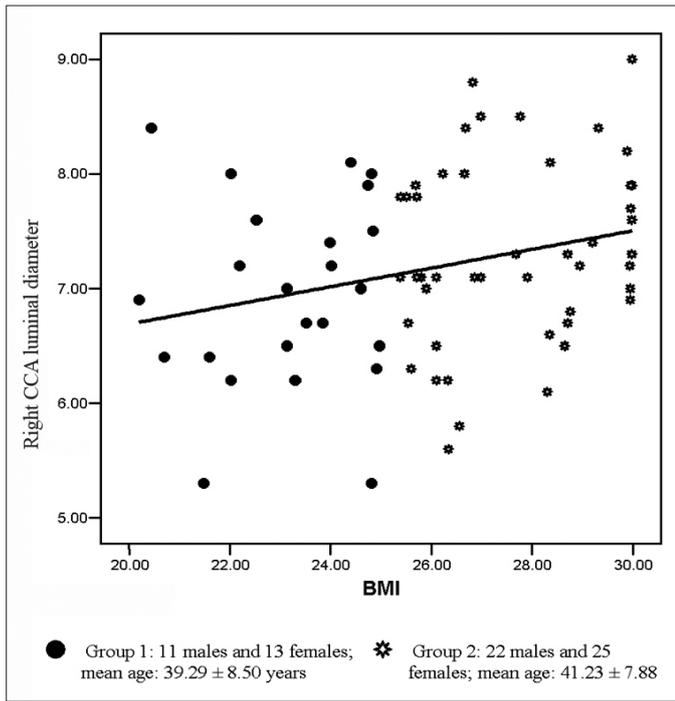


Figure 3. The graphic shows the relationship between BMI and right CCA luminal diameter. (BMI: body mass index)

Table 1. The summary of the mean values of luminal diameters and IMTs of the subjects.

Luminal diameter and IMT (mm)	Group 1 (mean values ± SD)	Group 2 (mean values ± SD)	p value
R CCA luminal diameter	6.90±0.93	7.40±0.79	0.04
L CCA luminal diameter	6.85±0.72	7.13±0.77	0.10
R ICA luminal diameter	5.25±0.83	5.15±0.87	0.50
L ICA luminal diameter	5.55±1.13	5.10±0.93	0.08
R CCA IMT	0.61±0.17	0.64±0.15	0.31
L CCA IMT	0.63±0.14	0.67±0.17	0.35

R: right CCA: common carotid artery ICA: internal carotid artery
L: left IMT: intima-media thickness SD: standard deviation

Table 2. Peak-systolic and end-diastolic velocity of the CCA and ICA.

Flow velocity (FV) (cm/s)	Group 1 (mean values ± SD)	Group 2 (mean values ± SD)	p value
R CCA peak-systolic FV	78.91±17.03	73.27±16.70	0.18
R CCA end-diastolic FV	21.50±5.67	19.82±4.67	0.19
L CCA peak-systolic FV	76.58±12.49	76.74±18.03	0.96
L CCA end-diastolic FV	20.41±5.14	20.62±5.11	0.87
R ICA peak-systolic FV	50.00±11.23	41.82±11.21	0.005
R ICA end-diastolic FV	19.83±6.20	15.12±5.70	0.002
L ICA peak-systolic FV	45.91±10.93	37.82±11.21	0.006
L ICA end-diastolic FV	18.16±5.53	14.16±5.53	0.003

R: right CCA: common carotid artery FV: flow velocity
L: left ICA: internal carotid artery SD: standard deviation

There were no significant differences between women and men with respect to FV, luminal diameter, and IMT in the extra cerebral carotid vessels, except for CCA luminal diameter. The CCA luminal diameters were significantly smaller in women than in men (6.87 ± 0.77 mm vs. 7.28 ± 0.89 mm; $p = 0.04$).

The correlation between age and FV measurement or the luminal diameter was statistically significant in both groups. FV significantly decreased with age and the luminal diameter significantly increased both in CCA and ICA. There were no significant differences between groups 1 and 2 in the mean IMT of the CCAs. There was no significant difference in age between the 2 groups ($p = 0.91$).

Blood levels of triglycerides were significantly higher in group 2 than in group 1 (211.5 ± 84.8 mg/dl vs. 133.6 ± 91.4 mg/dl; $p = 0.011$). Blood levels of cholesterol were significantly higher in group 2 than in group 1 (220.72 ± 38.61 mg/dl vs. 181.8 ± 32.12 mg/dl; $p = 0.041$).

The systolic and diastolic blood pressures were significantly higher in group 2 than in group 1 (136 ± 17.4 mm Hg vs. 122.6 ± 15.2 mmHg; $P = 0.033$ and 82.2 ± 11.6 mmHg vs. 74.3 ± 7.6 mmHg; $p = 0.046$). Other laboratory examinations, including serum glucose, leukocyte count, hemoglobin, and platelet count, were found to be normal in both groups.

Discussion

Obesity damages health, reduces quality of life, and leads to premature death. Adiposity increases oxygen consumption through increased tissue mass and metabolic demands; therefore, it increases cardiac output, stroke volume, and total blood volume. The increase in the systemic vascular resistance leads to hypertension, and the increase in preload and postload leads to left ventricular dilatation and hypertrophy (7). Atherosclerosis develops in association with the dyslipidemia of obesity. The increase in the prevalence of myocardial infarction and stroke are the 2 major causes of premature death in the obese (8).

Several studies have suggested that arterial wall area, or arterial diameter in conjunction with wall thickness, may provide useful information for understanding atherosclerosis progression, vascular injury, or vascular

vulnerability (9, 10). It is well-known that atherosclerosis and atherosclerotic risk factors are associated with arterial diameter (11) and recent studies have suggested arterial remodelling frequently occurs in association with vulnerable plaques (10).

The enlargement of human atherosclerotic arteries has been demonstrated in pathoanatomic studies of postmortem specimens (12) and duplex scanning of the carotid arteries (13). Most of these studies examined arterial sites with moderate and large atherosclerotic plaques, and thus, it is not known if the compensatory enlargement starts at this or at an earlier stage (14).

Human arteries are dynamic conduits that respond to different stimuli by remodelling their structure and size. It has been shown that arteries enlarge with increasing age, blood flow, and heart size (15). The increase in arterial diameter in subjects with atherosclerosis is usually discussed in terms of compensatory enlargement, i.e., compensation in relation to stenosis, an increase in vessel diameter to preserve luminal area, whereas vessel diameters in plaque-free areas are studied less frequently. Vessel diameters generally increase with age (14). Eigenbrodt et al. found a larger effect of age on CCA diameter in persons with preexisting atherosclerotic disease or high cardiovascular risk factor levels compared to low risk persons (16); however, independent of age, there is a greater increase in coronary artery diameters in subjects with atherosclerosis than in subjects without atherosclerosis (17). Labropoulos et al. (14) studied vessel diameters throughout the vascular system in 67 ± 12 -year-old subjects with and without atherosclerosis, and found that all arteries dilate in the stage of early atherosclerotic plaque formation. They concluded that dilation of the artery occurs to preserve luminal area. Zebekakis et al. found that arterial diameter significantly increased with BMI in the brachial, femoral, and carotid arteries in men and women. Age did not significantly impact the relationship of the characteristics of the muscular arteries with BMI; but increased stiffening of the carotid artery with BMI was more pronounced at younger than older ages (18). None of the subjects in the present study had carotid stenosis or carotid plaques. In our study, there

were no statistically significant differences concerning age and height between the 2 groups, so that in overweight subjects, the increased luminal diameter could be evidence of the early stage of atherosclerosis.

Large vessel diameter may, in itself, lead to disturbed blood flow regulation because a larger vessel will have less ability to respond to increased blood flow, both by endothelium-dependent and non-endothelium-dependent mechanisms (19, 20) and, thereby, may possibly be a factor in promoting the development of atherosclerosis.

Vessel diameter, in itself, is a measure of vascular regulatory function. The regulation of flow and blood pressure is complex, and how it affects arterial diameters is only partially understood. A malfunction of any factor involved in vasoregulation, including baroreceptor function, could result in an increased vessel diameter. One possible cause of the luminal widening of the vessel could be the increased flow (21).

The mechanism behind the increased carotid artery vessel diameter in the overweight subjects in the present study may be related to regulatory mechanisms that were present before compensatory enlargement to preserve lumen area and, therefore, vessel diameter may be used as a risk factor indicator.

Our data showed an age-dependent decline in all FVs of the CCAs and ICAs, which is in agreement with previous studies (14, 22-27). Vascular aging is associated with different principal structural and functional changes; i.e., intima media thickening (28), arterial dilatation (29), and the deterioration of elastic wall properties with vascular stiffening (30). Each of these has an impact on vascular blood flow and the local and/or systemic hemodynamic interaction with the structure and function of the artery. Another important reason for the reduction in FV with aging may be reduced cardiac output (31). In the present study, there were significant decreases in the peak systolic and end-diastolic velocities of the ICA in the overweight subjects. This finding may be accepted as a finding of early stage atherosclerosis because there was no significant age difference between the 2 study groups; however, larger series and more studies are needed to support this finding.

In the present study, we found that CCA luminal diameters were significantly smaller in women than in men. Weskott et al. found similar gender-related differences in the luminal diameters of the CCAs (32).

As seen in a previous study on healthy children and adolescents (24), there were no relevant side-to-side differences in any of the parameters in the extracranial carotid arteries, and our results were similar, but in the present study, luminal diameter was significantly smaller in left CCAs than in those on the right. This can be attributed to the right CCA being dominant.

Increased IMT was generally considered an early marker of atherosclerosis. Cross sectional associations have been reported between IMT and cardiovascular risk and prevalent cardiovascular disease (33, 34). Bots et al. found a positive association between carotid IMT and the incidence of strokes of all types (35). Stevens et al. (36) found a positive association between BMI and carotid IMT, but we did not find any significant difference between the 2 groups in CCA IMTs. Jensen-Urstad et al. reported that CCA diameter correlated more to cardiovascular risk factors than IMT (21). Their results are similar to our findings.

There were some limitations and strengths of our study. We compared normal BMI and overweight persons in this study, but we may have collected more meaningful data had we included obese persons with BMI levels over 30 kg/m^2 . Although we measured the luminal diameter and IMT when maximum color filled the vascular lumen in our study, it might have been better to use ECG monitoring at the level of R wave. In present study, we did not evaluate body adiposity and its distributions by computerized tomography or dual energy X-ray absorptiometry.

In conclusion, the present data shows that there were correlations between carotid artery diameter, FV, and overweight. The present study shows that increased luminal diameter and decreased FV may be an indicator of early stage atherosclerosis. Although the study demonstrated a close relationship between overweight and atherosclerosis, larger series and further clarification based on comparisons of age, gender, and BMI values are needed.

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