Smoking and vascular dysfunction in Africans and Caucasians from South Africa

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Summary

Background: Smoking is an important modifiable risk factor for cardiovascular disease, with limited research having been done in Africans. We aimed to determine the association between smoking and measurements of vascular function in Africans and Caucasians.

Methods: We determined anthropometric and cardiovascular variables, serum cotinine and C-reactive protein (CRP) in African and Caucasian participants from South Africa (n = 630).

Results: Africans had significantly lower body mass index (BMI), higher blood pressure and lower socio-economic status (SES) than Caucasians. Only African smokers showed increased arterial stiffness and a significant correlation between smoking and arterial stiffness. African smokers had increased and Caucasian smokers decreased high-density lipoprotein cholesterol (HDL-C) than the non-smokers. After adjusting for confounders, smoking showed few correlations, mainly with heart rate and CRP. In Africans, smoking also correlated positively with HDL-C, with the opposite result in Caucasians.

Conclusion: African smokers had significantly increased arterial stiffness, which was not found in Caucasian smokers. Africans generally demonstrated more associations between smoking and cardiovascular dysfunction than Caucasians.

Keywords: smoking, vascular dysfunction, socio-economic status, ethnicity, Africans, Caucasians

It is well known that smoking has negative health consequences and it is the main avoidable cause of illness and death worldwide. Smoking causes many premature deaths annually in the world. Despite the negative effects of smoking, the continuous use of tobacco products is rising. Globally, the prevalence of smoking-related cardiovascular diseases (CVDs) is higher in Africans than Caucasians. In South Africa, factors such as age, gender, ethnicity, cultural and economic characteristics influence the prevalence of smoking. There is a high prevalence of smoking in adults, mostly white males and those earning a low income. However, it has been shown that poorer smokers are more likely to quit than smokers who are more affluent.

Many studies have reported on the effect of smoking on the metabolic syndrome, which is a highly prevalent cluster of disorders that are relatively common in Africans. Smoking and the metabolic syndrome together cause dyslipidaemia, increased C-reactive protein (CRP) levels and endothelial dysfunction. Smokers are therefore characterised by high serum triglycerides (TG) and low-density lipoprotein cholesterol (LDL-C), with significantly lower high-density lipoprotein cholesterol (HDL-C) than non-smokers.

Nicotine in cigarette smoke increases heart rate (HR) and cardiac output (CO) through cardiac beta-adrenergic effects, leading to increases in blood pressure (BP). Carbon monoxide decreases the oxygen-carrying capacity of the blood and may lead to ischaemia and hypoxia of the tissues. This stimulates increased red blood cell production, which contributes to increased viscosity and consequently inflammatory and coagulatory processes. Both inflammation and coagulation are associated with atherosclerosis and coronary heart disease. All these factors therefore contribute negatively, in one way or the other, to increased risk for CVD.

Nicotine is broken down metabolically into various metabolites that include cotinine and nicotine-N-oxide. The most important metabolite of nicotine is cotinine, which is a vital biological marker of smoking and has been used to identify smokers. Serum cotinine levels of smokers are consequently significantly higher than non-smokers.

The association between smoking and CVD has been well documented in developed countries. However, limited data exist in low- and middle-income countries such as South Africa. The aim of this study was to determine if there are ethnic differences regarding the association between smoking and measures of cardiovascular function between African and Caucasian people of South Africa.

Methods

This was a sub-study based on data from the SAfEIC study (South African study on the influence of sex, age and Ethnicity on Insulin sensitivity and Cardiovascular function). The SAfEIC study was a cross-sectional study with 630 participants (apparently healthy African and Caucasian men and women) from urban areas of the North West Province of South Africa, aged 20 to 70 years. Exclusion criteria for this sub-study were diabetes (type 1 and 2), or persons on diabetic medication, pregnant or breast-feeding women, and those testing positive for the human immunodeficiency virus (HIV).

The Ethics committee of the North-West University (Potchefstroom campus) approved this study. The participants signed informed consent forms after all procedures were explained to them. An interpreter was available to relay the information to the African subjects in their home language.

For a period of seven weeks, 10 to 20 participants visited the facility daily (consisting of 10 bedrooms, two bathrooms, a living room and kitchen) on the Potchefstroom campus of the North-West University. They arrived at 07:00 and four field
workers accompanied the African participants, who were introduced to the setup. Each subject received a 'participant sheet', which guided him/her through the different research stations where the various measurements were done.

During the course of the morning, basic health, demographic and lifestyle questionnaires were completed. Participants were requested to indicate their income per month according to the codes in the questionnaire and they also had to specify the duration of smoking (in years) or use of tobacco products. A fasting blood sample was taken by a registered nurse from the antebrachial vein using sterile winged infusion sets and syringes, and anthropometric measurements were taken in a private room. Blood pressure (BP) and pulse-wave velocity (PWV) measurements were also taken in a private bedroom.

When all questionnaires were completed and all cardiovascular measurements taken, each participant received breakfast as well as a small financial compensation. In the event of a subject being identified with any abnormalities (such as hypertension or diabetes), the subject was referred to his/her local clinic, hospital or physician. Each subject received a short report containing his/her health information.

Height, body mass, waist circumference (WC) and hip circumference of each subject were taken according to standard procedures. The circumferences were measured in triplicate. Maximum height was measured to the nearest 0.1 cm using the Invicta Stadiometer (IP 1465, UK). Weight was measured to the nearest 0.1 kg using a digital scale (Precision Health Scale, A & D Co, Japan). A flexible metallic measuring tape was used to measure the circumferences, taken with the subjects standing upright, with the face directed towards the observer and the shoulders relaxed. The WC was measured at the thinnest visible point (below the last rib) of the trunk of the body. The hip circumference was measured at the broadest point over the gluteal muscles. Body mass index (BMI) was determined with the formula: body mass/body height^2.

After a 10-minute rest in the sitting position, BP (systolic and diastolic) and HR were measured using the OMRON HEM-757 apparatus, with the BP cuff on the left upper arm. The appropriate cuff sizes were used for obese subjects. Two measurements were taken, with a five-minute rest interval.

PWV (both carotid-radialis and carotid-dorsalis pedis) was measured using the Compilor SP apparatus. The following two distances were measured on the left side of each subject: carotid-radialis (from the suprasternal notch to the radial artery in the wrist) and carotid-dorsalis pedis (from the suprasternal notch to the dorsalis pedis artery in the foot). The subtraction method was used, i.e. the distance from the carotid artery to the suprasternal notch was subtracted from the measurement to the dorsalis pedis or the radialis.

Cardiovascular parameters were monitored, making use of the Finometer™ device (FMS, Finapres Medical Systems, Amsterdam, Netherlands). This entailed a five-minute continuous recording of each subject's cardiovascular parameters under resting, yet awake conditions. After the first two minutes the upper arm pressure was calibrated with the finger pressure for each individual subject (i.e. return-to-flow systolic calibration). The last two minutes of each recording were used to calculate the average of the cardiovascular variables, namely stroke volume (SV), cardiac output (CO), total peripheral resistance (TPR) and Windkessel arterial compliance (Cwk).

Biochemical analyses

Plasma and serum samples were prepared using standard methods and stored at –80°C until analysis. High-sensitivity C-reactive protein (hs-CRP) and serum lipids were determined on a Konelab 20i (Lab systems Clinical Laboratory Division, Vantaa, Finland) clinical chemistry analyser. Cotinine analyses were performed using the IMMULITE 2000 nicotine metabolite assay (Siemens Medical Solutions Diagnostics Ltd, Los Angeles, CA, USA) and a solid-phase competitive chemiluminescent immunoassay (Catalog Number L2KNM6). HIV status was determined immediately after blood sampling with a rapid test, according to the protocol of the National Department of Health of South Africa. Serum was used for testing with the First Response test and was repeated with the Pareeshak test for confirmation.

Statistical analysis

All statistical analyses were performed using Statistica version 8 (Statsoft, Inc, Tulsa, OK, 2007). Statistical results are presented as means, standard errors and 95% confidence intervals (CI). Variables that were not normally distributed were logarithmically transformed, namely TG and hs-CRP. An independent t-test and analysis of covariance (ANCOVA) were performed to compare the variables between the two ethnic groups and to determine significant differences. Self-reported smokers were included in the smoking group for statistical analyses.

Similar tests were performed to compare the variables between smokers and non-smokers within each ethnic group, and also while adjusting for age, gender, BMI and WC. Mean arterial pressure (MAP) was included as an adjustment variable while comparing PWV data. The Chi-square test was used to determine significant differences between categorical variables. We performed correlations and partial correlations between smoking and cardiometabolic values within each ethnic group. Complete datasets were not available for all participants during the statistical analysis, hence small discrepancies in participant numbers in the tables.

Results

The characteristics of the African and Caucasian subject groups are compared in Table 1. Most variables differed significantly between the two groups (p ≤ 0.001). The African group had a higher proportion of smokers, whereas height, weight, BMI and WC levels were significantly higher in the Caucasians. Africans showed a more detrimental cardiovascular profile.

Caucasians had significantly lower hs-CRP values than the Africans, who presented a more favourable lipid profile than the Caucasians. Cotinine levels were significantly higher in Africans compared to their Caucasian counterparts, which was expected, due to higher numbers of reported smokers among the Africans. The results also revealed significant differences in socio-economic status (SES), in that the majority of African subjects were living on low incomes. A total of 90% of Africans earned less than R1 000 per month. By contrast, the majority of the Caucasian group (65.6%) was living on more than R5 000 per month.

Table 2 compares the African smokers and non-smokers. Smokers were older than non-smokers and had significantly lower weight, BMI and WC than non-smokers. Smokers showed significantly higher PWV, TG and cotinine levels than in non-smokers. CO was significantly higher in smokers than non-smokers.
The relationships between cotinine levels and cardiovascular variables in the whole African group before adjustment for age, gender, BMI and WC were somewhat weaker in the whole African group. A further analysis was performed in which smoking was considered as a continuous variable. Cotinine was positively and significantly related to smoking in the African group. Furthermore, HDL-C levels remained higher in African smokers than non-smokers. Furthermore, HDL-C levels remained higher in African smokers than non-smoking counterparts, even after adjusting for age, gender, BMI and WC.

In Table 3 the Caucasian smokers and non-smokers are compared. There were fewer Caucasian smokers than non-smokers. HR and CO values were higher in the smokers, whereas TPR and Ckw values were lower in the smokers after adjustments were made. Smokers had lower HDL-C and higher TG and hs-CRP levels. Cotinine differed significantly throughout, with significantly higher values in smokers, as expected.

Further analyses were performed in which smoking was correlated with cardiovascular variables (SBP, DBP, HR, CO, Ckw, PWV), hs-CRP and lipid (HDL-C, LDL-C, TG) levels. To correlate smoking with these variables, smoking was viewed as either chronic exposure, using the subjects' duration of smoking (obtained from questionnaires), or acute exposure, using serum cotinine values.

Table 4 correlates smoking with the above variables in Africans. The results showed that chronic exposure to smoking (smoking duration) had significant correlations with most cardiovascular variables in the whole African group before adjustments were made. This trend remained quite similar after dividing the African group according to gender. PWV (Fig. 1), CO and Ckw also showed strong, significant correlations with smoking duration (p ≤ 0.001).

Table 2: Comparison between African smokers and non-smokers

| Variable | African non-smokers (n = 258) | African smokers (n = 152) | p-value |
|----------|-------------------------------|--------------------------|---------|
| Age (years) | 37.5 ± 1.36 (34.8; 40.4) | 44.0 ± 0.98 (42.1; 46.0) | ≤ 0.001 |
| Height (m) | 1.62 ± 0.01 (1.60; 1.63) | 1.64 ± 0.01 (1.63; 1.65) | 0.103 |
| Weight (kg) | 71.4 ± 1.99 (67.4; 75.4) | 58.8 ± 1.15 (57.0; 61.0) | ≤ 0.001 |
| BMI (kg/m²) | 27.4 ± 0.81 (25.8; 29.0) | 22.1 ± 0.47 (21.3; 23.0) | ≤ 0.001 |
| WC (cm) | 83.0 ± 1.54 (79.9; 86.0) | 76.3 ± 0.93 (74.4; 78.2) | ≤ 0.001 |
| SBP (mmHg) | 124.2 ± 6.24 (119, 129) | 129 ± 1.55 (126, 132) | 0.079 |
| DBP (mmHg) | 84.8 ± 1.19 (81.0, 87.2) | 86.1 ± 1.02 (84.0; 88.0) | 0.393 |
| HR (beats/min) | 69.3 ± 1.15 (67.0, 72.0) | 70.3 ± 1.13 (68.0, 73.0) | 0.561 |
| SV (ml) | 80.1 ± 1.58 (75.6, 80.5) | 82.1 ± 1.72 (69.0, 75.5) | 0.005 |
| CO (l/min) | 0.513 ± 0.16 (0.49, 0.53) | 0.480 ± 0.12 (0.45, 0.50) | 0.006 |
| TPR (mmHg/s/m) | 1.28 ± 0.05 (1.18; 1.37) | 1.46 ± 0.05 (1.36; 1.57) | 0.016 |
| Ckw (ml/mmHg) | 1.76 ± 0.04 (1.66; 1.86) | 1.50 ± 0.04 (1.42; 1.58) | ≤ 0.001 |
| C-R PWV (m/s) | 8.05 ± 0.16 (7.76; 8.35) | 9.04 ± 0.12 (8.79; 9.30) | 0.539 |
| C-P PWV (m/s) | 7.57 ± 0.13 (7.25; 7.89) | 8.55 ± 0.10 (8.31; 8.79) | ≤ 0.001 |
| HDL-C (mmol/l) | 1.13 ± 0.04 (1.15; 1.17) | 1.08 ± 0.03 (1.06; 1.14) | ≤ 0.001 |
| LDL-C (mmol/l) | 2.36 ± 0.09 (2.28; 2.53) | 2.35 ± 0.07 (2.21; 2.50) | 0.962 |
| TG (mmol/l) | 1.35 ± 0.10 (0.27; 0.32) | 1.40 ± 0.10 (0.32; 0.35) | 0.015 |
| hs-CRP (mg/l) | 1.95 ± 1.04 (0.59, 0.75) | 1.88 ± 1.04 (0.55, 0.70) | 0.434 |

Values are expressed as the mean ± standard error (95% CI). The mean values for TG and hs-CRP were logarithmically transformed and geometric means used. BMI: body mass index; WC: waist circumference; SBP: systolic blood pressure; DBP: diastolic blood pressure; CO: cardiac output; TPR: total peripheral resistance; Ckw: Windkessel compliance; C-R PWV: carotid-radial pulse wave velocity; C-P PWV: carotid-dorsalis pedis pulse wave velocity; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; TG: triglycerides; hs-CRP: high-sensitivity C-reactive protein.
On adjustment for age, BMI and WC, almost all correlations became weak and non-significant. HR remained significant when correlated with chronic smoking. Hs-CRP correlated weakly with increased chronic exposure in the whole group of Africans, while cotinine levels correlated positively with smoking duration in all cases in the African group.

The Caucasian group (Table 5) generally did not show strong correlations with smoking (both chronic and acute). However, CO ($r = 0.13$), TPR ($r = -0.12$) and Cwk ($r = 0.13$) did reflect statistically significant correlations with cotinine levels in the whole Caucasian group. Most correlations disappeared after adjusting for age, BMI and WC. A significant correlation could also be seen between cotinine levels and the duration of smoking in the Caucasian group. Moreover, HR correlated positively and significantly with smoking throughout the Caucasian group.

A statistically significant negative correlation existed between smoking (both chronic and acute) and HDL-C levels before and after adjustments. TG values increased with chronic exposure to smoking, even after adjusting for age, BMI and WC. Hs-CRP levels were higher with smoking duration in all cases in the African group.

| Variable          | Caucasian non-smokers ($n = 802$) | Caucasian smokers ($n = 92$) | p-value |
|-------------------|-----------------------------------|------------------------------|---------|
| Age (years)       | 41.4 ± 0.74 (39.9; 42.8)          | 35.0 ± 1.67 (31.6; 38.2)     | $< 0.001$ |
| Height (m)        | 1.71 ± 0.01 (1.71; 1.73)          | 1.73 ± 0.01 (1.70; 1.75)     | 0.444   |
| Gender (men/women)| 127/191                           | 34/20                        |         |
| Weight (kg)       | 82.0 ± 1.12 (79.8; 84.1)          | 84.1 ± 2.75 (78.6; 89.6)     | 0.453   |
| BMI (kg/m²)       | 27.7 ± 0.34 (27.0; 28.4)          | 28.0 ± 0.81 (26.4; 29.7)     | 0.686   |
| WC (cm)           | 87.2 ± 0.85 (85.5; 88.9)          | 89.0 ± 2.19 (84.6; 93.4)     | 0.410   |
| SBP (mmHg)        | 119.0 ± 0.93 (118; 121)           | 119.1 ± 0.98 (115; 123)      | 0.909   |
| DBP (mmHg)        | 78.0 ± 0.56 (77.1; 79.3)          | 79.0 ± 1.42 (75.6; 81.3)     | 0.863   |
| HR (beats/min)    | 67.0 ± 0.53 (66.0; 68.1)          | 71.0 ± 0.14 (68.0; 73.0)     | 0.014   |
| SV (ml)           | 90.1 ± 1.36 (87.6; 93.0)          | 94.1 ± 3.43 (87.3; 101)      | 0.283   |
| CO (l/min)        | 6.04 ± 0.10 (5.85; 6.24)          | 6.57 ± 0.28 (6.01; 7.14)     | 0.046   |
| TPR (mmHg/s/ml)   | 1.07 ± 0.02 (1.03; 1.11)          | 0.96 ± 0.04 (0.89; 1.04)     | 0.027   |
| Cwk (ml/mmHg)     | 2.07 ± 0.03 (2.00; 2.13)          | 2.33 ± 0.08 (2.17; 2.48)     | 0.002   |
| C–R PWV (m/s)     | 7.62 ± 0.08 (7.46; 7.78)          | 7.62 ± 0.14 (7.34; 7.89)     | 0.982   |
| C–P PWV (m/s)     | 7.82 ± 0.07 (7.65; 7.95)          | 7.82 ± 0.15 (7.52; 8.12)     | 0.983   |
| HDL-C (mmol/l)    | 1.42 ± 0.02 (1.37; 1.47)          | 1.22 ± 0.06 (1.10; 1.33)     | $< 0.001$ |
| LDL-C (mmol/l)    | 3.76 ± 0.07 (3.62; 3.90)          | 3.80 ± 0.16 (3.47; 4.13)     | 0.837   |
| TG (mmol/l)       | 1.45 ± 0.01 (0.36; 0.39)          | 1.54 ± 0.02 (0.39; 0.47)     | 0.005   |
| hs-CRP (mg/l)     | 1.63 ± 0.02 (0.45; 0.53)          | 1.80 ± 0.05 (0.49; 0.69)     | 0.060   |
| Cotinine (ng/ml)  | 10.4 ± 0.78 (8.89; 11.9)          | 231 ± 18.5 (194; 268)        | $< 0.001$ |

Comparison after adjustment for age, gender, BMI and WC:

| Variable          | Caucasian non-smokers ($n = 802$) | Caucasian smokers ($n = 92$) | p-value |
|-------------------|-----------------------------------|------------------------------|---------|
| SBP (mmHg)        | 119.0 ± 0.74 (118; 121)           | 120.0 ± 1.84 (116; 123)      | 0.970   |
| DBP (mmHg)        | 78.0 ± 0.46 (77.1; 78.9)          | 79.0 ± 1.14 (77.1; 81.6)     | 0.776   |
| HR (beats/min)    | 67.0 ± 0.52 (66.0; 68.0)          | 71.0 ± 1.29 (68.2; 73.2)     | 0.014   |
| SV (ml)           | 91.2 ± 1.04 (89.1; 93.2)          | 89.3 ± 2.59 (84.2; 94.4)     | 0.165   |
| CO (l/min)        | 6.11 ± 0.08 (5.95; 6.26)          | 6.26 ± 0.19 (5.87; 6.64)     | 0.012   |
| TPR (mmHg/s/ml)   | 1.06 ± 0.02 (1.03; 1.09)          | 1.04 ± 0.04 (0.96; 1.12)     | 0.011   |
| Cwk (ml/mmHg)     | 2.11 ± 0.02 (2.08; 2.14)          | 2.05 ± 0.04 (1.97; 2.13)     | $< 0.001$ |
| C–R PWV (m/s)     | 7.62 ± 0.07 (7.48; 7.76)          | 7.65 ± 0.18 (7.29; 8.01)     | 0.423   |
| C–P PWV (m/s)     | 7.79 ± 0.05 (7.69; 7.90)          | 7.98 ± 0.14 (7.71; 8.25)     | 0.423   |
| HDL-C (mmol/l)    | 1.41 ± 0.02 (1.37; 1.45)          | 1.29 ± 0.05 (1.20; 1.39)     | $< 0.001$ |
| LDL-C (mmol/l)    | 3.75 ± 0.07 (3.62; 3.88)          | 3.89 ± 0.17 (3.57; 4.22)     | 0.859   |
| TG (mmol/l)       | 1.45 ± 0.01 (0.36; 0.38)          | 1.54 ± 0.02 (0.40; 0.47)     | 0.002   |
| hs-CRP (mg/l)     | 1.62 ± 0.02 (0.45; 0.52)          | 1.84 ± 0.04 (0.52; 0.70)     | 0.029   |
| Cotinine (ng/ml)  | 10.2 ± 3.06 (4.23; 16.3)          | 232 ± 7.47 (218; 247)        | $< 0.001$ |

Values are expressed as the mean ± standard error (95% CI). The mean values for TG and hs-CRP were logarithmically transformed and geometric means used. PWV was also adjusted for MAP BMI: body mass index; WC: waist circumference; SBP: systolic blood pressure; DBP: diastolic blood pressure; SV: stroke volume; CO: cardiac output; TPR: total peripheral resistance; Cwk: Windkessel compliance; C–R PWV: carotid-radialis pulse wave velocity; C–P PWV: carotid-dorsalis pedis pulse wave velocity; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; TG: triglycerides; hs-CRP: high-sensitivity C-reactive protein.

Fig. 1. The relationship between duration of smoking and arterial stiffness in Africans and Caucasians. C–R PWV: carotid-radialis pulse wave velocity; C–P PWV: carotid-dorsalis pedis pulse wave velocity.
Discussion

Smoking is associated with vascular dysfunction.\(^1\)\(^{12}\)\(^{24}\) Since studies were designed to investigate ethnic differences with regard to the association between smoking and cardiometabolic markers. The cardiovascular markers related to smoking were generally higher in African smokers, compared to non-smokers. Significant differences were observed and were in most cases consistent with findings in the literature.\(^21\)\(^{28}\) Regular cigarette smoking increases HR and CO acutely throughout the day,\(^2\) a finding evident especially in the Caucasian smokers. The increases in HR and CO are mediated by the beta-adrenergic effects of nicotine.\(^1\) Although nicotine does constrict some peripheral vascular beds,\(^4\) it is likely that with increased HR and CO, nicotine appears to dilate other vascular beds through stimulation of epinephrine release,\(^1\)\(^4\) thereby decreasing TPR, as well as a defense mechanism in Africans against the oxidative stress induced by smoking.\(^2\)\(^2\)\(^2\)

Immense differences in SES between the two groups could be the contributing factor in this regard. Cheaper mentholated tobacco brands used by Africans had more nicotine, whereas the non-mentholated, lighter brands smoked by the Caucasians had less effect on vascular function.\(^1\) Our results further revealed that the African smokers were older than the non-smokers, weighed less, and had lower BMI and WC values. Nicotine accelerates lipid breakdown\(^1\) and this may lead to weight loss in smokers. Some smokers use tobacco smoke for this purpose,\(^2\)\(^2\)\(^2\)\(^4\) and urbanised South African women are no exception.\(^2\)\(^2\) The LDL-C and TG levels were higher in Caucasians compared to Africans, a feature supported by the literature.\(^2\)\(^6\)\(^{27}\)

The differences between smokers and non-smokers regarding cardiovascular risk factors were also investigated in both ethnicities. Significant differences were observed and were in most cases consistent with findings in the literature.\(^21\)\(^{28}\) Regular cigarette smoking increases HR and CO acutely throughout the day,\(^2\) a finding evident especially in the Caucasian smokers. The increases in HR and CO are mediated by the beta-adrenergic effects of nicotine.\(^1\) Although nicotine does constrict some peripheral vascular beds,\(^4\) it is likely that with increased HR and CO, nicotine appears to dilate other vascular beds through stimulation of epinephrine release,\(^1\)\(^4\) thereby decreasing TPR, as was found in our study groups.

A finding of this study that was not consistent with the literature was higher HDL-C levels in African smokers, and this result is in direct contrast to the significantly lower HDL-C values in Caucasian smokers. Furthermore, HDL-C values correlated positively with smoking in Africans, and negatively in Caucasians. The literature is sparse regarding this finding, although increased HDL-C levels in smoking Africans with cardiovascular disease have been mentioned.\(^2\)\(^6\)\(^{29}\) The high HDL-C levels possibly serve as a defense mechanism in Africans against the oxidative stress induced by smoking.\(^2\)\(^2\)\(^2\)
caused by smoking, as they are generally known to have higher HDL-C levels than Caucasians.26 Moreover, the infrequent use of cigarettes and more use of snuff in Africans with lower SES than in Caucasians has revealed no change in HDL-C values between smokers and non-smokers.32,33 This is a finding that is likely to apply in our population.24 Variations in HDL-C levels are due to nicotine-mediated lipolysis and also increased corticosteroid and growth hormone levels, inducing insulin resistance,1,4 especially in smokers who are also snuff users.1 The weak correlations in Caucasians may be explained by the less nicotine-packed brands they use and their generally lower arterial stiffness and TPR compared to Africans.6,26 The higher TG levels of the smokers in this study is a finding consistent with the literature.1,4,13,34 Increased TG levels are due to nicotine-mediated lipolysis and also increased corticosteroid and growth hormone levels, inducing insulin resistance,1,4 especially in smokers who are also snuff users.1

**Table 5. Correlations between smoking and measures of cardiovascular function and lipids in Caucasian participants**

| Variables | Smoking duration | Cotinine | Smoking duration | Cotinine | Smoking duration | Cotinine |
|-----------|------------------|----------|------------------|----------|------------------|----------|
|           | r-value          | p-value  | r-value          | p-value  | r-value          | p-value  |
| SBP (mmHg) |                   |          |                   |          |                   |          |
| Men (n = 161) | 0.05             | 0.556    | 0.06             | 0.74     | 0.001            | 0.970    |
| Women (n = 211) | 0.14             | 0.863    | 0.20             | 0.016    | 0.09             | 0.296    |
| Whole group (n = 372) | 0.09             | 0.296    | 0.18             | 0.021    | 0.001            | 0.902    |
| DBP (mmHg) |                   |          |                   |          |                   |          |
| Men (n = 161) | 0.14             | 0.863    | 0.20             | 0.016    | 0.09             | 0.296    |
| Women (n = 211) | 0.09             | 0.296    | 0.18             | 0.021    | 0.001            | 0.902    |
| Whole group (n = 372) | 0.09             | 0.296    | 0.18             | 0.021    | 0.001            | 0.902    |
| HR (beats/min) |                   |          |                   |          |                   |          |
| Men (n = 161) | 0.18             | 0.021    | 0.18             | 0.023    | 0.20             | 0.004    |
| Women (n = 211) | 0.18             | 0.021    | 0.18             | 0.023    | 0.20             | 0.004    |
| Whole group (n = 372) | 0.18             | 0.021    | 0.18             | 0.023    | 0.20             | 0.004    |
| CO (l/min) |                   |          |                   |          |                   |          |
| Men (n = 161) | 0.10             | 0.137    | 0.10             | 0.118    | 0.09             | 0.095    |
| Women (n = 211) | 0.09             | 0.095    | 0.10             | 0.118    | 0.09             | 0.095    |
| Whole group (n = 372) | 0.09             | 0.095    | 0.10             | 0.118    | 0.09             | 0.095    |
| TPR (mmHg.s/ml) |                   |          |                   |          |                   |          |
| Men (n = 161) | 0.14             | 0.073    | 0.14             | 0.087    | 0.09             | 0.191    |
| Women (n = 211) | 0.14             | 0.073    | 0.14             | 0.087    | 0.09             | 0.191    |
| Whole group (n = 372) | 0.14             | 0.073    | 0.14             | 0.087    | 0.09             | 0.191    |
| COTinine (ng/ml) |                   |          |                   |          |                   |          |
| Men (n = 161) | 0.71             | ≤0.001   | 0.71             | ≤0.001   | 0.71             | ≤0.001   |
| Women (n = 211) | 0.71             | ≤0.001   | 0.71             | ≤0.001   | 0.71             | ≤0.001   |
| Whole group (n = 372) | 0.71             | ≤0.001   | 0.71             | ≤0.001   | 0.71             | ≤0.001   |

**Note:** PWV was additionally adjusted for MAP. SBP: systolic blood pressure; DBP: diastolic blood pressure; HR: heart rate; CO: cardiac output; TPR: total peripheral resistance; Cwk: Windkessel compliance; C-R PWV: carotid-radialis pulse wave velocity; C-P PWV: carotid-dorsalis pedis pulse wave velocity; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; TG: triglycerides; hs-CRP: high-sensitivity C-reactive protein; MAP: mean arterial pressure.
Study limitations

Limitations in scientific research are difficult to avoid, and this study is no exception. Firstly, it was not possible to match the two ethnic groups for SES. Secondly, the study made use of volunteers, and subjects were therefore not selected on a random basis. This sampling method may also have influenced the difference in the number of smokers in the two ethnic groups. Thirdly, coagulation markers did not form part of this study, especially since it is known that Africans suffer from very high levels of fibrinogen, and since smoking plays an important role with regard to coagulation.

Conclusion

African smokers had significantly increased arterial stiffness, which was not found in the Caucasian smokers. Africans also showed more associations between smoking and cardiovascular dysfunction than the Caucasians. A high degree of urbanisation among Africans, coupled with higher smoking prevalence might be to blame for the high prevalence of cardiovascular diseases in the African population.

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References

1. Benowitz NL. Cigarette smoking and cardiovascular disease: pathophysiology and implication for treatment. Prog Cardiovasc Dis 2003; 46: 91–111.
2. Gavir A. Smoking is a major cause of premature death worldwide. Evid Based Hlth Care 2004; 9: 95–96.
3. Hukkanen J, Jacob III P, Benowitz NL. Metabolism and disposition kinetics of nicotine. Pharmacol Rev 2005; 57: 79–115.
4. Ambrose JA, Barua RS. The pathophysiology of cigarette smoking and cardiovascular disease. J Am Coll Cardiol 2004; 43: 1731–1737.
5. Novotny TE, Warner KE, Kendrick JS, Remington PL. Smoking by blacks and whites: Socioeconomic and demographic differences. Am J Publ Hlth 1988; 78: 1187–1189.
6. Lemogoum D, van Bortel L, Leeman M, Degaute JP, van de Borne P. Ethnic differences in arterial stiffness and wave reflections after cigarette smoking. J Hypertens 2006; 24: 683–689.
7. Steyn K, Fourie J, Temple N. Chronic diseases of lifestyle in South Africa: 1995–2005. Medical Research Council technical report, South African Medical Research Council, Cape Town, 2006: 48–57.
8. Sitas F, Urban M, Bradshaw D, Kielkowskis D, Bah S, Peto R. Tobacco attributable deaths in South Africa. Tob Control 2004; 13: 396–399.
9. Van Walbeek C. Recent trends in smoking prevalence in South Africa – some evidence from AMPs data. S Afr Med J 2002; 92: 468–472.
10. Schutte AE, van Rooyen JM, Huisman HW, Kruger HS, de Ridder JH. Factor analysis of possible risks for hypertension in a black South African population. J Hum Hypertens 2003; 17: 339–348.
11. Schutte AE, Kruger HS, Underhay C, Vorster HH. The emergence of the metabolic syndrome in urban obese African women: the POWIRS study. S Afr J Sci 2005; 101: 61–67.
12. Schutte AE, Ockers A. Metabolic syndrome risk in black South African women compared to Caucasian women. Horm Metab Res 2007; 39: 651–657.
13. Kelley-Hedgepeth A, Lloyd-Jones DM, Colvin A, Matthews KA, Johnston J, Sowers MR, Sternfeld B, Pasternak RC, Chae CU. Ethnic differences in C-reactive protein (CRP) concentrations. Clin Chem 2008; 54: 1027–1037.
14. Zevin S, Saunders S, Gourlay SG, Jacob III P, Benowitz NL. Cardiovascular effects of carbon monoxide and cigarette smoking. J Am Coll Cardiol 2001; 38: 1633–1638.
15. McMahan CA, Gidding SS, McGill HC. Coronary heart disease risk factors and atherosclerosis in young people. J Clin Lipidol 2008; 2: 118–126.
16. Azmauradis KA, Stefanadis CI. Inflammation and arterial function. Artery Res 2007; 1: 32–38.
17. Benowitz NL, Pomerleau OF, Pomerleau CS, Jacob P 3rd. Nicotine metabolite ratio as a predictor of cigarette consumption. Nicotinic Tob Res 2003; 5: 621–624.
18. Benowitz NL. Cotinine as a biomarker of environmental tobacco smoke exposure. Epidemiol Rev 1996; 18: 188–204.
19. Ntoumanis K, Oda T. Anthropometry. A Textbook of Body Measurement for Sport and Health Courses. Sydney: University of New South Wales Press, 1996.
20. Pieters M, Vorster HH. Nutrition and homeostasis: a focus on urbanization in South Africa. Mol Nutr Food Res 2008; 52: 164–172.
21. Stein L, Urban ML, Weber M, Ruff P, Hale M, Donde B, Patel M, Sitas F. Effects of tobacco smoking on cancer and cardiovascular disease in urban black South Africans. Br J Cardiol 2008; 98: 1586–1592.
22. Steyn K, Bradshaw D, Norman R, Laubscher R, Salooje Y. Tobacco use in South Africa during 1998: the first demographic and health survey. J Cardiovasc Risk 2002; 9: 161–170.
23. Back SE, Waldrop AE, Saladin ME, Yeatts SD, Simpson A, McAree AL, et al. Effects of gender and cigarette smoking on reactivity to psychological and pharmacological stress provocation. Psychoneuroendocrinology 2006; 33: 560–568.
24. Cho H, Kiang Y, Jun H, Kawachi J. Marital status and smoking in Korea: The influence of gender and age. Soc Sci Med 2008; 66: 609–619.
25. South Africa Demographic and Health Survey 2003. Preliminary report. Department of Health, Pretoria, South Africa, 2003: 22.
26. McGill HC, McMahan A, Malcom GT, Oalmann MC, Strong JP. Effects of serum lipoproteins and smoking on atherosclerosis in young men and women. Arterioscler Thromb Vasc Biol 1997; 17: 95–106.
27. Salooje Y. Tobacco control in South Africa. In: Steyn K, Fourie J, Temple N (eds), Chronic diseases of lifestyle in South Africa: 1995–2005. Medical Research Council technical report. Canada, 2006: 55–57.
28. Alberts M, Urdaal P, Steyn K, Stensvold I, Tverdal A, Nel JH, Steyn NP. Prevalence of cardiovascular disease and associated risk factors in a rural black population of South Africa. Eur J Cardiovasc Prev Rehabil 2005; 12: 347–354.
29. Vorster HH. The emergence of cardiovascular disease during urbanization of Africans. Publ Hlth Nutr 2002; 5: 239–243.
30. Barnoya J, Glantz, SA. Cardiovascular effects of secondhand smoke. Circulation 2005; 111: 2684–2698.
31. Asplund K. Smokeless tobacco and cardiovascular disease. Prog Cardiovasc Dis 2003; 45: 383–394.
32. Benowitz NL, Porchet H, Sheiner L, Jacob III P. Nicotine absorption and cardiovascular effects with smokeless tobacco use: comparison with cigarette and nicotine gum. Clin Pharmacol Ther 1988; 44: 23–28.
33. Perez-Blazevic J, Martin G, Marin BV, Venowtiz NL. Misclassification of smoking status by self-reported cigarette consumption. Am Rev Respir Dis 1992; 145: 43–57.
34. Burns DM. Epidemiology of smoking-induced cardiovascular disease. Prog Cardiovasc Dis 2003; 46: 11–29.
35. Yasue H, Hirai N, Mizuo Y, Harada E, Lich T, Yoshimura M, et al. Low-grade inflammation, thrombogenicity, and atherogenic lipid profile in cigarette smokers. Circulation 2006; 70: 8–13.
36. Heilbronn LK, Clifton PM. C-reactive protein and coronary artery disease: influence of obesity, caloric restriction and weight loss. J Nutr Biochem 2002; 13: 316–321.
37. Meighen GE, Lemay L, Morgan D, Cohn JN. Effects of long-term cigarette smoking on endothelial-dependent responses in humans. Am J Cardiol 1996; 78: 668–672.
38. Kusner I, Rzewnicki D, Samols D. What does minor elevation of CRP protein signify? Am J Med 2006; 119: e17–e28.
39. Vorster HH, Wissing MP, Venter CS, Kruger HS, Kruger A, Malan NT, et al. The impact of urbanization on physical, physiological and mental health of Africans in the North West Province of South Africa, the THUSA study. S Afr J Sci 2000; 96: 505–514.