Is combined systolic blood pressure associated with smoking? A study on noninstitutionalized civilian resident population of the United States.

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onoptimal levels of blood pressure (BP) is the first most common cause of death in the world, and, this together with smoking, account for more than 20% of the global burden of premature death^{1,2} In particular, increased BP³⁻⁷ and smoking⁷⁻¹¹ are major risk factors for cardiovascular diseases (CVD), including coronary heart disease (CHD) and stroke.

Smoking causes an acute increase in blood pressure (BP) and heart rate and has been found to be associated with malignant hypertension. Nicotine acts as an adrenergic agonist, mediating local and systemic catecholamine release and possibly the release of vasopressin. Paradoxically, several epidemiological studies have found that BP levels among smokers were the same as or lower than those of nonsmokers.

Potential mechanisms linking systolic blood pressure and smoking may include age, gender, alcohol intake and body mass index (BMI). Relevant study has shown that any independent chronic effect of smoking on BP is small. Differences between men and women in this association are likely to be due to complex interrelations among smoking, alcohol intake, and BMI.

Currently, there have been lot of studies investigating the effect of blood pressure and smoking on cardiovascular diseases. However, studies related to the association between systolic blood pressure and smoking are limited.

The aim of the present study was to examine this issue using data from the National Center for Health Statistics (NCHS); Centre that has conducted a series of health and nutrition surveys since early 1960's.

METHODS

Study population

This analysis was conducted using data collected by The National Center for Health Statistics (NCHS). Every year, approximately 5,000 individuals of all ages are interviewed in their homes and complete the health examination component of the survey. The health examination is conducted in a mobile examination center (MEC); the MEC provides an ideal setting for the collection of high-quality data in a standardized environment.

In 2011-2012, 13,431 persons were selected for NHANES (National Health and Nutrition Examination Surveys) from 30 different study locations. Of those selected, 9,756(72.6%) completed the interview and 9,338(69.5%) were examined. Additionally, for analysis in this report, 400 random observations with people age > 17 were selected and only 17 out of 76 variables from the original dataset were considered.

Measures of interest

Systolic Blood Pressure

The primary exposure of interest in this study was to obtain combined systolic blood pressure reading for every individual.

Three and sometimes 4 BP determinations (systolic and diastolic) are taken in the mobile examination center (MEC) and during home examinations on all eligible individuals using a mercury sphygmomanometer.

Participants who are 50 years and older or less than one year of age who are unable to travel to the MEC are offered an abbreviated examination in their homes. Blood pressure measurements are taken by one of the MEC examiners.

Smoking Status

Current smoking status of the participants aged 20 years or older was recorded with response option of "Yes" and "No". participants were supposed to answer "Yes", if they smoked 100 or more cigarettes in their lifetime. All subjects who have not smoked 100 or more cigarettes were listed as NA.

Other Covariates

Demographic information, such as age, education (8thGrade, 9-11th Grade, High School, Some College, or College Grad), marital status (Married, Widowed, Divorced, Separated, Never Married, or LivePartner (living with partner)) and some other information related to health and lifestyle was also collected.

Data analysis

Data from a total of 382 participants were used in analyses after excluding 18 (4.5%) out of 400 participants since their blood pressure readings were outliers to the dataset and to improve linearity (Figure 1). The relationship between smoking and systolic blood pressure was assessed with linear regression after performing model diagnostics to check the assumptions of linear regression model. (Figure 2) shows that there was no evident pattern seen of non-linearity, hence there was no need for any transformation. Furthermore, Homoscedasticity assumption is also satisfied. The dependent variable in the linear regression was the continuous variable BPSysAve (Combined systolic blood pressure). There were 15 explanatory or independent variables used in the model. But the variable of interest was smoking status. These multivariable analyses were adjusted for the potential confounding effects of gender, and age. Further analyses where all exposures were included simultaneously in the model were conducted to determine whether each of the exposures of interest were independently associated with the outcomes. Variance inflation factor of the model was checked to see if multicollinearity exists. Model selection methods (Stepwise selection, Lasso selection) were used to obtain best suitable model. Cross validation was also used to assess the prediction accuracy of the model.

The regression analyses were conducted in R (version 4.0.1).

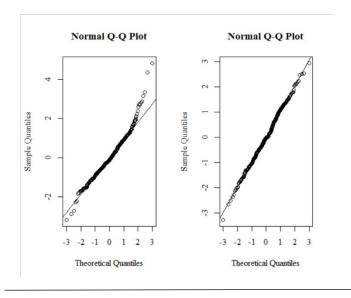


Figure 1. Normal QQ plot used as a part of model diagnostics showing plots before and after removal of outliers.

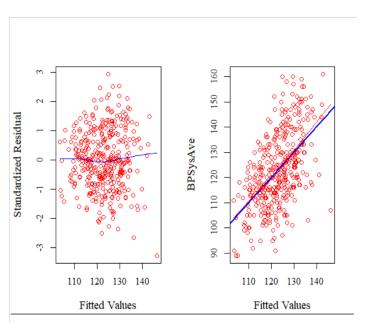


Figure 2. plots verifying the assumptions for linear model.

Results

The mean ages of male and female respondents were 50.84 years (range 21 to 80 years) and 51.09 years (range 21 to 80 years) respectively. Among men, current smokers were younger (mean age 45.4 years) than non-smokers (mean age 55.2). Current smokers also made up the youngest group of women (mean age 45.5 years), whereas current non-smokers made up the oldest group (mean age 55.4 years). Data below along with (Table 1) shows the number of smokers and non-smokers by gender.

	Male	Female	Total
Smoke	95	73	168
Do not Smoke	118	96	214
Total	213	169	382

Linear models were used to investigate relationship among smoking status and blood pressure, adjusting for potential confounding effects of age, and gender. "Age" variable was common among all the different model selection method used. (Figure 3) shows the cross-validation calibration of different model selection techniques used. AIC based selection mod el had the lowest mean absolute error. However, it h ad many predictors, and that caused the prediction e rror to go high.

In our final model, we kept age, and gender as our explanatory variables. Smoking variable was removed from the model as it was not significant, and confounding variables such as age and gender were more significant and gave better predictions. Recent studies using the technique of 24-hour ambulatory blood pressure monitoring have shown that blood pressure is higher in men than in women at similar ages. After menopause, however, blood pressure increases in women to levels even higher than in men. This is verified by (Figure 4). Increase in age was associated with increase in systolic blood pressure.

 $(\beta = 0.36, 95\% \text{ CI: } 0.28, 0.44). 18.25\%$ variation in systolic blood pressure is explained by the age and gender of the respondent. The lower value may have caused by the unavailability of extra information and there might be other factors which affect systolic blood pressure and were not considered.

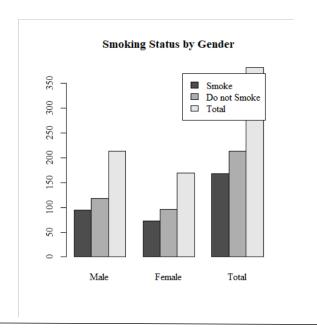


Table 1. Bar chart showing smoking status by categories

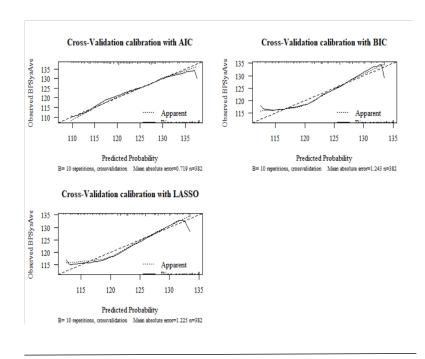


Figure 3. Calibration of cross-validation using three different techniques.

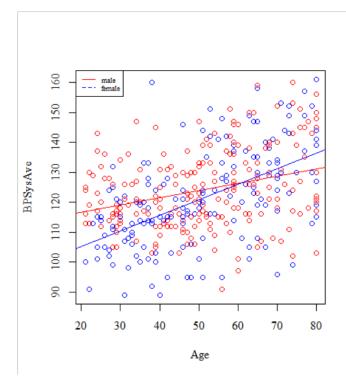


Figure 4. Scatter plot showing relation btw systolic blood pressure and Age categorized by gender.

The P-values for the t-tests appearing in the table of estimates suggest that the slope parameters for Age (P < 0.001) is significantly different from 0 at 99% CI and Gender (P < 0.05) are significantly different from 0 at 95% CI. The P-value for the analysis of variance F-test (P < 0.001) suggests that the model containing age and gender is more useful in predicting systolic blood pressure than not considering the two predictors.

Discussion

The results of the present study show that any independent chronic effect of smoking on systolic blood pressure is small. After adjustment for age, and gender, we saw association between systolic blood pressure and age for both the genders. Increasing systolic blood pressure was observed in men and women both with increasing age.

One of the possible limitations of the study is that NCHS collects information by means of a questionnaire, and therefore some of the risk factor data are self-reported, which may be inaccurate.

The BP differences associated with smoking that were observed in this study differed with age and between men and women and may well be explained at least in part by differential confounding

effects of BMI and alcohol intake (which were not much significant in our sample analysis). However, because smoking and BP have been shown to exert a synergistic adverse effect on the risk of coronary heart disease,³ it is critical that persons with raised BP are advised to stop

smoking. Furthermore, because BP levels in smokers are rarely recorded during or immediately after smoking when acute rises in BP occur, usual BP levels of smokers tend to be systematically underestimated.

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