

## Observational Study

## Correlation between hypertension and hyperglycemia among young adults in India

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### Abstract

**AIM:** To assess the correlation between blood pressure levels and fasting plasma glucose levels among young adults attending Chatrapati Shahuji Maharaj University, Kanpur, India.

**METHODS:** The present study was cross-sectional in nature, conducted among students in the Institute of Paramedical Sciences, Chatrapati Shahuji Maharaj University, Kanpur. Study subjects included 185 young adults. Among them, 94 were males and 91 were females, in the age group 17 to 19 years.

**RESULTS:** Mean age among males was  $18.5 \pm 1.5$  years and among females was  $17.9 \pm 1.8$  years. Of the total 185 study subjects, 61 (32.9%) were classified as pre-diabetic and 20 (10.8%) as pre-hypertensive. Mean waist circumference, systolic blood pressure and serum high density lipoprotein did not vary significantly between normoglycemic and pre-diabetic subjects. However, the mean diastolic blood pressure of pre-diabetics ( $82 \pm 5$  mmHg) was significantly higher than normoglycemics ( $79 \pm 6$  mmHg). Mean

serum cholesterol, serum triglycerides, serum low density lipoprotein (LDL) and serum very low density lipoprotein was also higher among pre-diabetic subjects in comparison to normoglycemic subjects and the difference was statistically significant. Upon multiple linear regression analysis, it was observed that body mass index (BMI) ( $\beta = 0.149$ ), diastolic blood pressure ( $\beta = 0.375$ ) and serum LDL ( $\beta = 0.483$ ) were significantly associated with fasting plasma glucose. Multiple linear regression with diastolic blood pressure as the outcome variable showed that BMI ( $\beta = 0.219$ ), fasting blood glucose ( $\beta = 0.247$ ) and systolic blood pressure ( $\beta = 0.510$ ) were significantly associated.

**CONCLUSION:** A significant prevalence of pre-diabetes and pre-hypertension in young adults is a matter of concern therefore all young adults need to be targeted for screening of diabetes and hypertension and lifestyle modification.

**Key words:** Adolescent; Hypertension; Diabetes; Co-prevalence; India

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**Core tip:** In the present study, 32.9% young adults were pre-diabetic whereas 10.8% were pre-hypertensive. Around 2.7% young adults had both pre-diabetes and pre-hypertension. Among the pre-hypertensives, 25% also had pre-diabetes. However among the pre-diabetics, 8.2% had pre-hypertension. The correlation between systolic blood pressure and fasting plasma glucose was not statistically significant. However, the correlation between diastolic blood pressure and fasting plasma glucose was significant. The mean diastolic blood pressure of pre-diabetics ( $82 \pm 5$  mmHg) was significantly higher than normoglycemics ( $79 \pm 6$  mmHg). Upon multiple linear regression analysis, it was observed that body mass index ( $\beta = 0.149$ ), diastolic blood pressure ( $\beta = 0.375$ ) and serum LDL ( $\beta = 0.483$ ) were significantly associated with fasting plasma glucose.

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## INTRODUCTION

Diabetes and hypertension is the twin epidemic, rapidly on the rise in the developing countries<sup>[1]</sup>. Diabetes mellitus or chronic hyperglycemia is a metabolic disorder which results from defects in carbohydrate, fat and protein metabolism that occur

as a consequence of deranged insulin secretion or action. Long term hyperglycemia is associated with the development of cardiovascular disease, renal disease, neuropathy, retinopathy, peripheral vasculopathy, and stroke<sup>[2]</sup>. World Health Organization (WHO) has estimated that globally the number of adults with diabetes will increase from 171 million in 2000 to 366 million in the year 2030<sup>[3]</sup>. In 2004, worldwide, around 3.4 million people died as a result of hyperglycemia<sup>[4]</sup>. Of the total deaths among diabetics, around 80% occur in developing countries<sup>[5]</sup>. According to WHO, diabetes will be the 7<sup>th</sup> leading cause of global mortality in 2030<sup>[6]</sup>. India has been declared as the capital of diabetes because approximately 41 million Indians have diabetes to date and every fifth diabetic in the world is an Indian<sup>[7]</sup>.

Worldwide, hypertension or high blood pressure has caused around 7.5 million deaths, which accounts for 12.8% of the global mortality. Around 57 million disability adjusted life years (DALYs) or 3.7% of total DALYs have been attributed to hypertension<sup>[8]</sup>. The global prevalence of hypertension in adults more than 25 years of age, averaged around 40% in 2008<sup>[8]</sup>. The WHO has estimated that hypertension is directly responsible for about 62% of stroke and 49% of coronary artery disease, worldwide<sup>[9]</sup>. In a meta-analysis of prevalence studies on hypertension in India, from January 2000 to June 2012, it was observed that the prevalence of hypertension in the urban population was 40.8% whereas that in the rural population was 17.9%<sup>[10]</sup>. Hypertension leads to cardiovascular disease, peripheral vasculopathy, cerebrovascular disease, and nephropathy<sup>[11]</sup>.

It has been observed that diabetes and hypertension often exist together in the population. The risk of developing hypertension is 1.5-2.0 times higher in diabetics as compared to non-diabetics, whereas around one-third of the hypertensives develop diabetes<sup>[12]</sup>. These co-morbidities hasten the progress of vascular complications<sup>[13-15]</sup>.

Diabetes and hypertension both can be prevented and managed by lifestyle modification and medical intervention. Moreover, screening and early management of diabetes and hypertension, through periodic surveillance, will slow down the progress of the disease and prevent complications<sup>[16]</sup>. American Diabetic Association has described a new entity of impaired glucose metabolism as prediabetes in which two categories are included-Impaired Fasting Glucose, when fasting plasma glucose is between 100 and 125 mg/dL and Impaired Glucose Tolerance, when 2-h result following oral glucose tolerance test is between 140 and 199 mg/dL<sup>[17]</sup>. Persons with prediabetes, are at greater risk for the future development of diabetes as well as cardiovascular disease<sup>[18]</sup>. According to JNC-7,

systolic blood pressure 120-139 mmHg and/or diastolic blood pressure 80-89 mmHg was classified as pre-hypertension<sup>[19]</sup>. Similarly, individuals with pre-hypertension are pre-disposed to developing hypertension in the later years of life.

Though the manifestation of cardiovascular disease occurs in middle age and later, it has now been proved that the initiation of cardiovascular disease occurs in childhood and adolescence<sup>[20]</sup>. The known risk factors of cardiovascular disease such as hypertension, raised blood glucose, raised serum cholesterol, tobacco consumption, high fat diet and obesity start early in childhood and adolescence and then continue into adulthood<sup>[20]</sup>. Screening and early identification of these risk factors and their progenitors like pre-diabetes and pre-hypertension may go a long way to prevent cardiovascular morbidity and mortality in adults.

The overall prevalence of glucose intolerance among adolescents in South India was reported to be 3.7%<sup>[21]</sup>. Prevalence of hypertension among children and adolescents in north India was observed to be 9.4%<sup>[22]</sup>.

The rising prevalence of diabetes and hypertension in India, their beginning in the adolescent age group, and the co-occurrence of the two disease entities, is a cause of concern, therefore this study was planned to study the association between hypertension and hyperglycemia in Indian young adults.

## MATERIALS AND METHODS

### Study design and sample size

It was a cross-sectional study. The minimum sample size required ( $n = 89$ ) was calculated taking a prevalence of glucose intolerance of 3.7%, as reported in the ORANGE-2 study, with a precision of 4% and a confidence level of 95%<sup>[21]</sup>. The formula used was,  $n = Z_{(1-\alpha/2)}^2 pq/d^2$  (where  $Z_{(1-\alpha/2)}$  was taken at 95%CI;  $P$  = prevalence of obesity,  $q = 100-p$ ;  $d$  = absolute precision). For this study,  $P = 3.7\%$ ;  $q = 96.3\%$ ;  $d = 4\%$ . Adding a 10% for incomplete answers, the total number came out to be 98. A design effect of 2 was included to minimize any error due to inherent variation in the population. The calculated sample size was multiplied by 2 to obtain the sample size of 196.

### Sampling

The study was conducted among students in the Institute of Paramedical Sciences, affiliated to Chatrapati Shahuji Maharaj University, Kanpur. The Institute of Paramedical Sciences provides a course of 4 years in Paramedical Sciences and enrolls around 100 students annually. A list of all the students enrolled in the Institute in the first, second and third year was obtained. Systematic random sampling technique was applied to identify

the required number of study subjects. Written informed consent was taken from the students and their parents/guardians. In case a student refused to participate in the study, the next consecutive student was included. The data was analyzed for 185 subjects only whose laboratory test results were available. Among the study subjects thus selected, 94 were males and 91 were females, in the age group 17 to 19 years.

### Methodology

A standard mercury sphygmomanometer, Diamond Co., Industrial electronics and Allied Products, Pune, Maharashtra, India, was used for recording blood pressure. Blood pressure (BP) was measured on the left arm, in the sitting position, using appropriate size cuffs. Before the measurement was taken, the subject was seated for at least 5 min. Care was taken that the arm muscles were relaxed and the arm was placed at heart level. The cuff was applied to the left upper arm and was inflated until the manometer reading was 30 mmHg above the level at which the radial pulse disappeared, and thereafter the cuff was slowly deflated. The Korotkoff sounds were monitored using a stethoscope applied over the brachial artery. The first (appearance) and the fifth (disappearance) Korotkoff sounds were noted as the systolic and diastolic blood pressure, respectively. Blood pressures were measured twice and their mean was recorded. Subjects were categorized into normotensive, pre-hypertensive and Stage I and Stage II hypertensive based on the blood pressure classification for adolescents for subjects of age 17 years and according to JNC-7 for subjects  $\geq 18$  years<sup>[19,23]</sup>. JNC-7 has classified systolic blood pressure (SBP)  $< 120$  mmHg and a diastolic blood pressure (DBP)  $< 80$  mmHg as normal blood pressure; SBP 120-139 mmHg and/or DBP 80-89 mmHg as pre-hypertension; SBP 140-159 mmHg and/or DBP 90-99 mmHg as Stage I hypertension and SBP  $\geq 160$  mmHg and/or DBP  $\geq 100$  mmHg as stage II hypertension<sup>[19]</sup>. For adolescents upto 17 years of age, normal BP was defined as systolic and diastolic blood pressure  $< 90^{\text{th}}$  percentile, Prehypertension as systolic or diastolic blood pressure  $90^{\text{th}}$  percentile to  $< 95^{\text{th}}$  percentile or blood pressure  $> 120/80$  mmHg to  $< 95^{\text{th}}$  percentile, Stage 1 Hypertension (HTN) as systolic and/or diastolic blood pressure  $95^{\text{th}}$  percentile to  $99^{\text{th}}$  percentile plus 5 mmHg and Stage 2 HTN as systolic and/or diastolic blood pressure  $> 99^{\text{th}}$  percentile plus 5 mmHg<sup>[23]</sup>.

According to American Diabetic Association, subjects were classified as normoglycemic when fasting plasma glucose was less than 100 mg/dL after 8 h fasting, prediabetic when fasting plasma glucose was between 100 and 125 mg/dL and diabetic when fasting plasma glucose was more than

**Table 1** Bio-social characteristics of study subjects

Determinant	Total	Male ( <i>n</i> = 94)		Female ( <i>n</i> = 91)		<i>P</i> value <sup>1</sup>
		<i>n</i>	%	<i>n</i>	%	
Place of residence						
Urban	119	56	47.1	63	53.9	0.17
Rural	66	38	57.6	28	42.4	
Religion						
Hindu	164	84	51.2	80	48.8	0.084
Muslim	15	6	40	9	60	
Sikh	4	4	100	0	0	
Christian	2	0	0	2	100	
Type of family						
Nuclear	100	36	36	64	64	< 0.001 <sup>2</sup>
Joint	85	58	68.2	27	31.8	
Physical activity						
Sedentary	69	28	40.6	41	59.4	0.056
Moderate	92	50	54.3	42	45.7	
Heavy	24	16	66.7	8	33.3	
Smoking habit						
Non-smoker	173	82	47.3	91	52.7	0.001 <sup>2</sup>
Smoker	12	12	100	0	0	
Alcohol intake						
Non-alcoholic	183	92	50.3	91	49.7	0.162
Alcoholic	2	2	100	0	0	
Eating habit						
Vegetarian	110	52	47.3	58	52.7	0.013 <sup>2</sup>
Mixed	75	42	56	33	44	
Diabetic status						
Normoglycemic	124	60	48.4	64	51.6	0.347
Pre-diabetic	61	34	55.7	27	44.3	
Hypertensive status						
Normotensive	165	86	52.1	79	47.9	0.306
Pre-hypertensive	20	8	40	12	60	

<sup>1</sup>Pearson's  $\chi^2$  test; <sup>2</sup>*P* value < 0.05 is significant.126 mg/dL<sup>[17]</sup>.

Body weight was estimated, using Krup's weighing machine, with a least count of 0.5 kg. The subject was made to stand on the weighing scale, feet around 15 cm apart, and weight distributed on both the legs. Zero setting was done before each measurement. Height was estimated, with the subject standing upright against the wall such that the roof of the external auditory meatus was in line with the lower margin of the orbit. A hard board was placed on the wall, just over the head and height was marked on the wall and measured with a measuring tape with a least count of 0.5 cm. Waist circumference was measured, at the level of the umbilicus, with the subject in the erect position, breathing silently.

Fasting blood samples were drawn on the day subsequent to the interview. A total of 10 mL blood was collected from each subject: 4 mL in EDTA tube and 6 mL in plain tube. The samples were immediately sent to the laboratory in the Department of Biochemistry, Chatrapati Shahuji Maharaj University, Kanpur. The samples were centrifuged without any delay. The samples were analyzed for glucose on the same day. Remaining plasma and serum was aliquoted and stored at -70 deg C. Lipid

**Table 2** Co-prevalence of diabetes and hypertension

	Prediabetes		Normoglycemia		Total
	<i>n</i>	%	<i>n</i>	%	
Pre-hypertension	5	25	15	75	20
Normotension	56	33.9	109	66.1	165

estimations were done in batches in serum samples. Standard internal quality control procedures for laboratory were followed. Fasting plasma glucose was estimated using the Enzymatic colorimetric GOD-PAP method, Serum Cholesterol using Enzymatic Colorimetric High Performance CHOD-PAP method, Serum HDL using Enzymatic Colorimetric High Performance CHOD-PAP method, and Serum triglycerides using colorimetric method<sup>[24]</sup>.

Data was compiled using Microsoft Excel and analysed using SPSS 17.0. Pearson's Chi square test was applied to study the difference between categorical variables. Student's *t*-test was used to analyse the difference between continuous variables. Two-tailed *P*-value less than 0.05 was considered significant. Pearson's correlation coefficient was applied to determine the association between fasting plasma glucose and systolic and diastolic blood pressure. Multiple linear regression analysis was done to analyse the association of various determinants with fasting plasma glucose.

### Statistical analysis

The statistical methods are adequately and appropriately applied to the best of the authors' knowledge.

## RESULTS

Data was analyzed for 185 subjects, 94 males and 91 females. Mean age among males was  $18.5 \pm 1.5$  years and among females was  $17.9 \pm 1.8$  years. Among the subjects living in urban area, 47.1% were males whereas among those living in rural areas 57.6% were males (Table 1). Subjects predominantly belonged to Hindu religion. Among those who were sedentary, 40.6% were males, whereas among heavy workers, 66.7% were males. However, there was no statistically significant association between physical activity and gender. Of all the study subjects, 12 (6.4%) were smokers and all were male (100%). The association between smoking and gender was statistically significant.

Among the total study subjects, 61 (32.9%) were pre-diabetic whereas 20 (10.8%) were pre-hypertensive. Five (2.7%) subjects had both pre-diabetes and pre-hypertension. Among the pre-hypertensives, 25% also had pre-diabetes (Table 2). However among the pre-diabetics, 8.2% had pre-hypertension.

The correlation of systolic blood pressure with fasting plasma glucose was not found to be stati-



**Table 3** Correlation between fasting plasma glucose and systolic and diastolic blood pressure among study subjects

Fasting plasma glucose	Pearson's correlation coefficient	P value <sup>1</sup>
Systolic blood pressure	0.045	0.546
Diastolic blood pressure	0.301	< 0.001 <sup>2</sup>

<sup>1</sup>Pearson's Correlation coefficient; <sup>2</sup>P value < 0.05 is significant.

stically significant. However, the correlation of diastolic blood pressure with fasting plasma glucose was significant ( $P < 0.001$ ) (Table 3).

Among the normoglycemic subjects, mean BMI was  $20.6 \pm 42.0$  kg/m<sup>2</sup> whereas among the pre-diabetic subjects the BMI was  $21.8 \pm 3.0$  kg/m<sup>2</sup> and the association was found to be significant (Table 4). There was no significant association between the waist circumference, systolic blood pressure and serum HDL of normoglycemic and pre-diabetic subjects. However, the mean diastolic blood pressure of pre-diabetics ( $82 \pm 5$  mmHg) was significantly higher than normoglycemics ( $79 \pm 6$  mmHg). Mean serum cholesterol, serum triglycerides, and serum VLDL was also higher among pre-diabetic subjects as compared to normoglycemic subjects and the association was found to be significant. Mean serum LDL was also significantly higher in prediabetics ( $104.1 \pm 22.7$  mg/dL) than in normoglycemics ( $92.7 \pm 23.6$  mg/dL).

Multiple linear regression analysis for the determinants of fasting plasma glucose was done and the adjusted  $R^2$  was 23.5% (Table 5). Waist circumference, systolic blood pressure, serum cholesterol, serum triglycerides, serum HDL, serum VLDL were not significantly associated with fasting plasma glucose. For every 1 mmHg increase in diastolic blood pressure, the fasting plasma glucose was expected to rise by 0.375 mg/dL ( $\beta = 0.375$ ) and this association was found to be significant ( $P < 0.05$ ). Similarly, BMI ( $\beta = 0.149$ ), and serum LDL ( $\beta = 0.483$ ) were also significantly associated with fasting plasma glucose.

Multiple linear regression analysis was done for systolic blood pressure as the outcome variable and the adjusted  $R^2$  was 43.7% (Table 6). Diastolic blood pressure and serum LDL were observed to be significantly associated. Multiple linear regression analysis for diastolic blood pressure as the outcome variable showed an adjusted  $R^2$  of 49.6% (Table 7). BMI ( $\beta = 0.219$ ), fasting plasma glucose ( $\beta = 0.247$ ) and systolic blood pressure ( $\beta = 0.510$ ) were found to be significantly associated.

## DISCUSSION

In this study, the overall prevalence of pre-diabetes was 32.9%. In another study from Dhaka, Bangladesh, around 20% subjects aged 11-18

years, with BMI  $\geq 95^{\text{th}}$  percentile for age and sex using CDC growth chart, were reported to have impaired glucose tolerance as detected after two hours oral glucose tolerance test<sup>[25]</sup>. A study from United States revealed that 21 percent of obese adolescents between 11 and 18 years had impaired glucose tolerance following two hours oral glucose tolerance test<sup>[26]</sup>. The difference from our study may be due to the criteria used for impaired glucose tolerance as we have considered fasting plasma glucose, whereas the other studies have considered the plasma glucose after a two hours oral glucose tolerance test which may have greater specificity in labelling impaired glucose tolerance. In a study from South India, the prevalence of impaired glucose tolerance was 3.7% in children and adolescents 6-19 years following oral glucose tolerance test<sup>[21]</sup>. The low prevalence as compared to our study may be due to the large age range of study subjects and the criteria used for impaired glucose tolerance.

In our study, the prevalence of pre-hypertension was 10.8%. The prevalence of pre-hypertension among adolescents from Wardha, in central India, was reported as 10.6%, which was very similar to our results<sup>[27]</sup>. This was also in concordance with the results of another study from Shimla, in north India wherein the prevalence of prehypertension was found to be 12.3%<sup>[28]</sup>.

The present study revealed that 5 (2.7%) subjects had both pre-diabetes and pre-hypertension. However, the multi-center Screening India's Twin Epidemic (SITE) survey revealed that 20.6% of the study subjects had co-existent diabetes and hypertension<sup>[16]</sup>. In our study, among the pre-hypertensives, 25% also had pre-diabetes whereas in the SITE study, among 7212 hypertensives, 3227 (44.7%) had diabetes. The present study showed that among the pre-diabetics, 8.2% had pre-hypertension whereas in the SITE study, among 5427 diabetics, 59.5% were hypertensive. These differences may be because only adult subjects more than 18 years were studied in the SITE survey whereas our study included subjects in the 17 to 19 years age group.

Hypertension is responsible for acceleration of the vascular complications of diabetes, including coronary artery disease, renal disease, and retinopathy<sup>[29]</sup>. The pathophysiology of hypertension occurs at the cellular level in the intima of the arteries, which involves the function of the endothelial cells. Hypertension and diabetes both alter the endothelial cell structure and function. In large and medium size vessels and in the kidney, endothelial dysfunction causes proliferation of vascular smooth muscle cells and vasoconstriction of mesangial cells<sup>[29]</sup>. These alterations in the smooth muscle cells lead to atherosclerosis and glomerulosclerosis. Similarly, proliferation of retinal capillary endothelial cells causes retinopathy. Therefore, endothelial

**Table 4** Determinants of impaired fasting plasma glucose

Determinant	Normoglycemic ( <i>n</i> = 124)		Impaired fasting glucose ( <i>n</i> = 61)		<i>P</i> value <sup>1</sup>
	Mean	SD	Mean	SD	
BMI	20.6	4.2	21.8	3	0.026 <sup>2</sup>
Waist circumference	76	9.3	76.7	20.1	0.794
SBP	121	12	122	8	0.238
DBP	79	6	82	5	0.003 <sup>2</sup>
S.Cholesterol	155.9	31.6	174.2	34.5	0.001 <sup>2</sup>
S.Triglycerides	128.1	55.9	154.7	55.6	0.002 <sup>2</sup>
S.HDL	39.3	8.6	41.4	7.3	0.095
S.LDL	92.7	23.6	104.1	22.7	0.002 <sup>2</sup>
S.VLDL	25.6	11.2	32.8	12.3	< 0.001 <sup>2</sup>

<sup>1</sup>Student's *t*-test; <sup>2</sup>*P* value < 0.05 is significant. BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; HDL: High density lipoprotein; LDL: Low density lipoprotein; VLDL: Very low density lipoprotein.

**Table 5** Multiple linear regression analysis of determinants of fasting plasma glucose

Determinant	Unstandardized coefficients		Standardized $\beta$	<i>P</i> value <sup>1</sup>
	$\beta$	SE		
(Constant)	24.067	17.964		0.182
Smoking	3.075	8.899	0.023	0.730
BMI	0.530	0.263	0.149	0.046 <sup>2</sup>
Waist circumference	0.049	0.070	0.050	0.483
SBP	0.121	0.113	0.094	0.285
DBP	0.844	0.200	0.375	< 0.001 <sup>2</sup>
Cholesterol	0.092	0.126	0.224	0.467
Triglycerides	0.008	0.038	0.033	0.830
HDL	0.060	0.154	0.036	0.696
LDL	0.279	0.141	0.483	0.040 <sup>2</sup>
VLDL	0.151	0.146	0.132	0.301

<sup>1</sup>Multiple linear regression analysis.  $R^2 = 48.5\%$ , adjusted  $R^2 = 23.5\%$ ; <sup>2</sup>*P* value < 0.05 is significant. BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; HDL: High density lipoprotein; LDL: Low density lipoprotein; VLDL: Very low density lipoprotein.

**Table 6** Multiple linear regression analysis of determinants of systolic blood pressure

Determinant	Unstandardized coefficients		Standardized $\beta$	<i>P</i> value
	$\beta$	SE		
(Constant)	65.983	10.961		< 0.001
Smoking	1.276	5.939	0.012	0.830
BMI	0.241	0.177	0.087	0.174
Waist circumference	0.057	0.047	0.074	0.225
DBP	0.997	0.118	0.571	< 0.001 <sup>2</sup>
Cholesterol	0.018	0.084	0.056	0.831
Triglycerides	0.009	0.025	0.048	0.715
HDL	-0.135	0.103	-0.104	0.188
LDL	0.085	0.095	0.189	0.025 <sup>2</sup>
VLDL	0.218	0.096	0.245	0.053
FPG	0.054	0.050	0.069	0.285

<sup>1</sup>Multiple linear regression analysis.  $R^2 = 66.1\%$ , adjusted  $R^2 = 47.3\%$ ; <sup>2</sup>*P* value < 0.05 is significant. BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; HDL: High density lipoprotein; LDL: Low density lipoprotein; VLDL: Very low density lipoprotein; FPG: Fasting plasma glucose.

cell damage is responsible for the complications of diabetes and this damage is accelerated by co-existing hypertension<sup>[29]</sup>.

Co-occurrence of hypertension in diabetics increases the risk of development of macrovascular and microvascular complications<sup>[30,31]</sup>. Diabetic

**Table 7 Multiple linear regression analysis of determinants of diastolic blood pressure**

Determinant	Unstandardized coefficients		Standardized $\beta$	P value <sup>1</sup>
	$\beta$	SE		
(Constant)	21.387	6.314		0.001
Smoking	0.682	3.214	0.012	0.832
BMI	0.347	0.093	0.219	< 0.001 <sup>2</sup>
Waist circumference	0.013	0.025	0.030	0.602
Cholesterol	0.053	0.045	0.288	0.249
Triglycerides	0.014	0.014	0.125	0.311
HDL	-0.090	0.055	-0.121	0.105
LDL	0.064	0.051	0.250	0.212
VLDL	0.062	0.053	0.121	0.242
FPG	0.110	0.026	0.247	< 0.001 <sup>2</sup>
SBP	0.292	0.035	0.510	< 0.001 <sup>2</sup>

<sup>1</sup>Multiple linear regression analysis.  $R^2 = 70.4\%$ , adjusted  $R^2 = 49.6\%$ ; <sup>2</sup>P value < 0.05 is significant. BMI: Body mass index; SBP: Systolic blood pressure; HDL: High density lipoprotein; LDL: Low density lipoprotein; VLDL: Very low density lipoprotein; FPG: Fasting plasma glucose.

individuals with coexisting hypertension have a much higher occurrence of cerebrovascular accidents as compared to diabetics with normal blood pressure<sup>[30,32,33]</sup>. The risk of peripheral vasculopathy also increases in case of co-existence of hypertension in diabetics<sup>[33]</sup>. Both hypertension and diabetes lead to coronary artery disease<sup>[34]</sup>. It has been observed that in hypertensive diabetics, the risk of death due to cardiovascular disease is almost doubled<sup>[34]</sup>. Hypertension accelerates the progress of diabetic retinopathy and nephropathy<sup>[35,36]</sup>. Hypertension in diabetics hastens the occurrence of microalbuminuria and the progress of nephropathy after the development of proteinuria<sup>[36]</sup>.

In our study, mean waist circumference, systolic blood pressure and serum HDL did not vary significantly between normoglycemic and pre-diabetic subjects. However, the mean diastolic blood pressure of pre-diabetics ( $82 \pm 5$  mmHg) was significantly higher than normoglycemics ( $79 \pm 6$  mmHg). Correlation between systolic blood pressure and fasting plasma glucose was not statistically significant. However, the correlation of diastolic blood pressure with fasting plasma glucose was significant ( $P < 0.001$ ).

In the present study, upon multiple linear regression analysis for fasting plasma glucose, BMI ( $\beta = 0.149$ ) diastolic blood pressure ( $\beta = 0.375$ ) and serum LDL ( $\beta = 0.483$ ) were found to be significantly associated. However, in the study from South India, on multiple regression analysis, only family history of diabetes (OR 4.11) and HOMA-IR (insulin resistance assessed by homeostasis model assessment) (OR 11.22) were found to be significant in girls and only HOMA-IR (OR 5.19) was associated with glucose intolerance in boys<sup>[21]</sup>. Due to financial constraints, HOMA-IR assessment was not included in our study. Upon multiple linear regression for diastolic blood pressure, it was observed that BMI ( $\beta$

= 0.219), fasting plasma glucose ( $\beta = 0.247$ ) and systolic blood pressure ( $\beta = 0.510$ ) were significantly associated.

The present study reveals that prediabetes and pre-hypertension begin to occur in young adults. It is well known that the prevalence of cardiovascular disease is increasing among Indians, occurring especially at a younger age<sup>[12]</sup>. Therefore it is imperative that policies and programs be developed for identifying and successfully managing hypertension and diabetes at an early age.

Given the risk associated with co-prevalence of diabetes and hypertension, it is important to identify young adults with pre-diabetes and pre-hypertension who are prone to develop full blown disease as adults, and it is the need of the hour that guidelines be formulated under the National Program for Prevention and Control of Cancer, Diabetes, CVD and Stroke (NPCDCS) for primordial and primary prevention efforts through evidence-based screening and health education initiatives. Health education programs among young adults regarding lifestyle modification to curb diabetes and hypertension in their incipient stage may be considered as a cost-effective public health approach in dealing with the morbidity attributed to consequent cardiovascular diseases.

## COMMENTS

### Background

As per World Health Organization estimates, globally the number of adults with diabetes will rise from 171 million in 2000 to 366 million in the year 2030. India has been declared as the capital of diabetes because approximately 41 million Indians have diabetes till date and every fifth diabetic in world is an Indian. The global prevalence of raised blood pressure or hypertension in adults aged 25 and over was around 40% in 2008. A meta-analysis of prevalence studies on hypertension in India, from January 2000 to June 2012, revealed a high prevalence of hypertension in the urban (40.8%) as well as rural population (17.9%). The co-prevalence of diabetes and hypertension is strongly associated with cardiovascular disease. Prevalence of cardiovascular disease

is on the rise among Indians, especially at a younger age, therefore early detection and management of hypertension and diabetes may hold the key to reducing cardiovascular mortality in India. Prevalence of glucose intolerance among adolescents in South India was reported to be 3.7%. Prevalence of hypertension among children and adolescents in north India was observed to be 9.4%. The high prevalence of diabetes and hypertension in India with their beginning in the adolescent age group, and the co-occurrence of the two disease entities leading to cardiovascular diseases, is an area of concern. Screening and health education programs regarding lifestyle modification may be considered as a cost-effective public health approach in dealing with the morbidity attributed to cardiovascular diseases. Therefore, a precise estimate of the prevalence of diabetes and hypertension among Indian young adults is required to assess the magnitude of the problem that has to be addressed and to design programs and policies for prevention and control.

### Research frontiers

Pre-diabetes and pre-hypertension have a high degree of co-prevalence among Indian young adults and this knowledge will help in shaping primordial and primary level preventive programs for our country.

### Innovations and breakthroughs

In India, very few studies are available on the prevalence of diabetes and hypertension among young adults and none have analysed the association between the two co-morbidities. Given the risk associated with co-prevalence of diabetes and hypertension, it is important to estimate their prevalence among Indian young adults to provide evidence-based guidelines for preventive efforts through screening and health education initiatives.

### Applications

Very few studies on the prevalence of diabetes and hypertension among young adults are available in India; and this study reveals their co-prevalence in the indigenous population and emphasizes the need to develop a strategy for prevention of these co-morbidities to bring down the consequent cardiovascular morbidity and mortality in India.

### Terminology

Regression analysis is a statistical process for estimating the relationships among variables. It includes many techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables. More specifically, regression analysis helps one understand how the typical value of the dependent variable changes when any one of the independent variables is varied, while the other independent variables are held fixed. In statistics, linear regression is an approach for modeling the relationship between a scalar dependent variable  $y$  and one or more explanatory or independent variables denoted  $X$ . The case of one explanatory variable is called simple linear regression. For more than one explanatory variable, the process is called multiple linear regression. The beta ( $\beta$ ) regression coefficient is computed to assess the strength of the relationship between each predictor variable and the dependent variable.

### Peer review

This a well written report from a useful study.

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