SUMMARY

Introduction

Prevalence of sustained hypertension is on the rise in urban area in adult as well as younger age groups (Mohan et al., 2004; Bansal et al., 2009; Sharma et al., 2010; Mitra et al., 2011). There are very few systematic and population based studies related to blood pressure and anthropometric measurements available in adolescent population. There is an evidence for early manifestation of the arteriosclerotic process present in adolescence (Lauer et al., 1984). However, hypertension is predictive for development of cardiovascular disease in adults, it is uncertain whether elevated blood pressure, in early adolescent period has the same predictive values. The degree to which blood pressure level is maintained during early adolescence has been described by many investigators to determine whether children with high levels of blood pressure are likely to become adults with hypertension (Lauer et al., 1984; Sun et al., 2007; Chen and Wang, 2008; Soudarssanane et al., 2008). Blood pressure is frequently elevated in obese children as compared to lean subjects. This is possibly related to their sedentary lifestyle, altered eating habits, increased fat content of diet and decreased physical activities (Mohan et al., 2004).

Risk factors for hypertension have been exhaustively investigated and it has been found that most hypertension risk factors are non-modifiable such as advanced age, gender, ethnicity and family history of disease. Other risk factors are subjected to intervention like obesity, diabetes mellitus, dyslipidemia, socio-economic and lifestyle factors, mainly lack of physical activity. It has been realized that early management of these risk factors of lifestyle by modifications and/or pharmacological interventions can result in a significant drop in cardiovascular morbidity and mortality. This increases the importance of early detection with reversible and treatable risk factors.

Hypertension is an increasing world health problem. In view of the substantial tracking of its risk factors from adolescents to adulthood, there is an urgent need to intervene early with efficacious strategies to identify and treat the youth with cardiovascular risk factors.
factors. It is clear that many traditional risk factors such as higher blood pressure, obesity and related metabolic determinants are significantly prevalent among adolescent age group. It is assumed that high risk adolescents are likely to become high risk adult (Dietz, 1998a,b). Therefore, the study of the present project related to identify the trends of blood pressure in adolescence which is the marker of future population burden of cardiovascular disease among Punjabi adolescent population. Hence, the present study enables the complete understanding of the dynamics of blood pressure with respect to many quantitative traits.

Aims and Objectives

The major objectives of the present study are as follows:

(i) to examine the prevalence of pre-hypertension and hypertension and to provide overall essential base-line data for cardiovascular disease among the study population

(ii) to analyze the trend of blood pressure variations with respect to different anthropometric, physiometric and socio-economic lifestyle risk factors to track the cardiovascular diseases in different adolescent age groups in the urban population in Punjab

(iii) to clarify that which of the anthropometric and socio-economic lifestyle variables are the best predictors for cardiovascular diseases and also to determine the magnitude of association with gender in adolescent population in Punjab.

Hypothesis to be tested (H₀)

(i) No association of rich battery of relevant anthropometric and socio-economic lifestyle variables with SBP and DBP in a multivariate system in adolescent population.

(ii) None of the anthropometric and socio-economic lifestyle risk factors are the best predictor for cardiovascular diseases among adolescent population.

Alternative hypothesis (H₁)

(i) Rejection of first hypothesis confirms impact of complex mode of anthropometric and socio-economic lifestyle variables on variation of SBP and DBP.
(ii) Rejection of second hypothesis implies any one or combined anthropometric and socio-economic lifestyle risk factors would be the best predictor of cardiovascular diseases in adolescent population.

**Material and Methods**

**Target Population:** There are very few systematic and population based studies related to blood pressure and anthropometric measurements available in adolescent population. However, it is reported that development of cardiovascular diseases has their origin in adolescence time (Soudarssanane *et al*., 2008). Traditionally, Punjabi identity was primarily linguistic, regardless of religious affiliation or heritage, referring to those for whom the Punjabi language(s), was the first language and who resided in the Punjab region. As such, they more or less shared the same cultural background. Therefore, in the present study, Punjabi language was fixed to define the ethnicity and adolescents speaking Punjabi language easily were chosen the target subjects.

**Sampling Design:** The present study used a stratified multistage cluster random sampling design. The World Health Organization (WHO) also recommended this method of sampling to estimate the health conditions in the community (Indrayan, 2008). The present sample is supposed to represent urban Punjabi adolescents aged 10 to 18 years. Therefore, sampling has been done from all available city areas (headquarters of the district) among 17 districts in Punjab. In several stages, two schools such as one private and one government or public school from the representative city of each district have been stratified among many schools.

All the informations such as personal, socio-demographic, medical history, family history of CVD, physiometric, anthropometric and life style variables of subjects were collected through pre-tested self-designed questionnaire. The survey combines face to face interview and physical examination method for eliciting data. The interview includes demographic, socio-economic, dietary and health related questions. The examination comprises physiological measurements such as SBP, DBP and pulse rate and battery of anthropometric measurements such as height, weight, sitting height, waist circumference, hip circumference, arm circumference, calf circumference, biceps skinfold, triceps skinfold and subscapular skinfold. The questionnaire was in English.
language. Before data collection, the entire questionnaire was explained in local Punjabi language along with the aims and objectives of the study and the procedure for the data collection to the subjects and their parents in the parent-teacher meeting organized by the school administrative. With their parents’ permission an informed consent was duly signed by the subject. The subjects were provided complete transcripts of the examination results. However, all information has been kept fully confidential and privacy was maintained and protected.

Total number of samples taken at first visit was 3490, which included 1789 boys and 1701 girls. The exclusion of subjects after second visit reduced the total samples studied to 3060, including 1530 from each sex. The age of present study group has been recorded 10 to 18 years, but, it may have to be categorized into three age groups with the interval of three years, such as 10-12 years, 13-15 years and 16-18 years.

**Measurements:** All the measurements of anthropometric, physiometric and informations of socio-economic life style variables have been done on each subject through standard technique and protocol. The details have been given in the thesis.

**Analysis:** All the data were analyzed through different statistical methods such as descriptive, correlation, linear regression, multiple regressions, $R^2$ (coefficient of determination), stepwise regression, logistic regression, wald chi square statistics, student’s t-test, odds ratio, sensitivity, specificity, Youden’s index, principal component factor analysis have been done using Statistical Package for Social Sciences (SPSS v.17.0).

**Results and Discussions**

The total subjects were examined in urban Punjab based adolescents of 10 to 18 years age group. The present study represented a multivariate model which included the data with respect to anthropometric measurements (height, weight, BMI, sitting height, waist circumference, hip circumference, WHR, arm circumference, calf circumference, biceps skinfold, triceps skinfold and subscapular skinfold), physiometric phenotypes (systolic blood pressure, diastolic blood pressure, mean arterial blood pressure, pulse pressure and pulse rate) and socio-economic lifestyle variables (food habits, exercise, time spent on exercise, screen time, sleeping time, family status, father education and mother
education). Therefore, the study can be used to derive basic biological relationship between cardiovascular diseases and other studied variables. The overall response rate in this study was 95%, however, it was observed that the response rate was highest (97%) in older age group of adolescents (16 to 18 years).

**Descriptive statistics and distribution**

The average levels of SBP and DBP among boys and girls of 10-18 years found in the present study were higher than the average blood pressure values in adolescents of the same age groups among other Indian studies and also than those recorded in Japan, Singapore and USA (Freedman *et al.*, 1999; Vlajinac *et al.*, 2003).

In comparison to the results from ‘know your body’ study (Williams, 1992; Vlajinac *et al.*, 2003) comprising adolescent children from 15 countries, SBP and DBP levels in present study are slightly higher. At the same time, changes in SBP and DBP level with age and BMI have been observed in the present study. The pattern of changes in blood pressure levels with age and BMI was clearly non-linear among both sexes with the maximum reached at age of 18 years. In the present study, the differences of socio-economic lifestyle risk factors such as food habits, exercise, time spent on exercise, screen time, sleeping time, family status and parents education related to cardiovascular diseases have not been significantly different between boys and girls of lower age groups, however, these differences were significantly prominent in older age groups, 14 years and onwards. All these parameters have higher mean values among boys as compared to girls.

Waist circumference and BMI have been validated in adolescents as useful predictors for cardiovascular diseases (Cole *et al.*, 2000; Virani, 2011). The results of present study indicated the prevalence of hypertension with normal BMI was maximum (33.72% in boys and 33.92% in girls) in 10 to 12 years of age group, which was followed by the subsequent age groups, 13 to 15 years group (24.51% in boys and 28.43% in girls) and 16 to 18 years group (24.9% in boys and 27.84% in girls). The similar trend has also been found for prevalence of pre-hypertension for boys and girls among three age groups. The highest prevalence of pre-hypertension with normal BMI was found in girls (13.33%) of 10 to 12 years of age group and in boys (26.08%) of 16
to 18 years of age group. The present findings were also consistent with other cross-sectional studies with respect to prevalence of overweight and obesity i.e. consistently increasing with the increase of age among both boys and girls (10.20%, 11.96%, 11.76% for overweight and 2.55%, 3.14%, 3.33% for obesity among boys; 9.41%, 9.22%, 9.61% for overweight and 1.76%, 2.55%, 3.73% for obesity among girls of three age groups, respectively).

When the adolescents were classified in normal, overweight and obese categories with criteria based on waist circumference (adopted from Virani, 2011), then different picture was observed. The prevalence of pre-hypertension and hypertension with overweight and obese subjects have been found maximum among all age groups in both sexes as compared to BMI classification. The waist circumference has been observed to be most important anthropometric indicator in adolescent boys and girls for prediction of cardiovascular diseases (Brar and Badaruddoza, 2013b). The present study has also observed a progressive increase in the prevalence of elevated blood pressure with increasing overweight and obesity based on waist circumference criteria.

The results of present study revealed that waist circumference is better predictor as compared to BMI to understand the relationship between obesity and cardiovascular risk developed especially in adolescent age group of girls. In the present study, based on BMI, it can concluded that general obesity is quite prevalent among adolescent boys, however, the prevalence of central obesity observed by waist circumference criteria was higher than general obesity especially in adolescent girls. This might be partly related to nature of diet and sedentary lifestyle. This has been reported in many other studies (Abolfotouh et al., 2011; Badaruddoza et al., 2011; Moraes and Falcao, 2013).

The results obtained from the present study with respect to food habit was that vegetarians exhibit higher blood pressure (pre-hypertension and hypertension) among adolescent girls in all three age groups (9.22% versus 5.49% for pre-hypertension, 22.51% versus 17.84% for hypertension among 10 to 12 years; 3.33% versus 2.16% for pre-hypertension, 18.43% versus 18.43% for hypertension among 13 to 15 years; 7.84% versus 6.27% for pre-hypertension, 20.78% versus 15.29% for hypertension among 16 to 18 years, respectively for vegetarians and non-vegetarians). Non-vegetarian exhibit
higher blood pressure among adolescent boys in all age groups (6.08% versus 7.06% for pre-hypertension, 18.24% versus 24.12% for hypertension among 10 to 12 years; 4.71% versus 6.47% for pre-hypertension, 13.92% versus 21.18% for hypertension among 13 to 15 years; 10.20% versus 19.41% for pre-hypertension, 13.14% versus 21.37% for hypertension among 16 to 18 years, respectively for vegetarians and non-vegetarians). It is interesting to note that boys were non-vegetarian and they preferred red meat, soft beverages and processed and fast food with high fat, but, most of the adolescent girls with pre-hypertension and hypertension were vegetarian. However, many previous studies reported that cardiovascular disease risks in India is likely to be inversely related to consumption of fruit, vegetables, mustered oil and positively associated with intake of refined carbohydrates and unhealthy fats (Misra et al., 2009; Mohan et al., 2010; Badaruddoza et al., 2011).

The present analysis addressed the association of physical activity and cardiovascular disease risk factors among three adolescent age groups. Spending more time in physical exercise played an important role in preventing and delaying the onset of hypertension. In general, the studied adolescent population groups were physically active with 55.29%, 62.55% and 59.41% among boys of 10 to 12, 13 to 15 and 16 to 18 years age groups, respectively and 55.86%, 50.78% and 37.65% for girls among all three age groups, respectively. However, 37.25%, 26.86% and 29.22% among boys and 35.29%, 38.24% and 53.73% among girls of 10 to 12, 13 to 15 and 16 to 18 years age groups were not interested in any kind of physical exercise. Therefore, the promotion of physical exercise at younger age might be an effective approach to reduce the cardiovascular disease mortality in the population. Most of the results from the present study regarding the correlates of sedentary/active lifestyles and physical exercise with hypertension are similar to other previous studies in many countries among adolescent population (Omar and Rager, 2005; Kelishadi et al., 2007; te Velde et al., 2007). The present analysis also addressed the association of time spent on physical exercise and cardiovascular disease risk factors among the three adolescent age groups. The apparent protective effect with moderate time spent on exercise (30-60 minutes) on cardiovascular diseases has been observed in all age groups among boys and girls.
In the middle income developing country, like India, blood pressure and hypertension levels were elevated in low as well as high income groups. High blood pressure was also significantly associated with income. In contrast to these general perceptions the present study observed that percentage of pre-hypertension and hypertension among adolescents were higher in middle income group. The possible explanation of this difference is that the maximum samples were from middle income group. Many Indian studies (Rastogi et al., 2004; Zaman et al., 2012; van den Berg. et al., 2013) showed significantly higher prevalence among low socio-economic group compared to high socio-economic group.

The present study also used parents’ education (father and mother) levels as the risk factor of cardiovascular diseases. It is noticed that parents’ education levels with maximum frequencies laid on secondary/ high school category for all age groups among both the sexes. However, the subjects with parents education level secondary/ high school had maximum prevalence of pre-hypertension and hypertension. This showed parents’ education has relation with the prevalence of pre-hypertension and hypertension among adolescents. Many studies from different countries (Winkleby et al., 1992; Smith et al., 1998; Howe et al., 2013; Jeemon and Reddy, 2010; Braig et al., 2011; van den Berg., et al., 2013) showed that the education level, occupation and socio-economic status has strong association with prevalence of pre-hypertension and hypertension.

**Correlation**

The simple Karl Pearson’s product moment correlation of anthropometric and socio-economic lifestyle variables with SBP, DBP and MBP among three age groups (10 to 12, 13 to 15 and 16 to 18 years) of adolescent boys and girls have shown significant independent relationship of these variables. Data clearly showed that almost all the anthropometric traits (except WHR for girls) among both boys and girls were significantly correlated with SBP, DBP and MBP. However, among lifestyle variables, family status, parent’s education, exercise and time spent on exercise are the significant correlates for SBP and DBP for both sexes. However, the strength of correlation has been different for different anthropometric and socio-economic lifestyle variables. In
general, the results of present study supports the hypothesis that BMI, waist and hip circumference, thickness of skinfolds, pulse rate, pulse pressure, parents’ education and sleeping time have some significant independent correlation with risk of elevated blood pressure among adolescents. Almost similar type of observations have been documented from other studies (Raitakari et al., 2003; Yalcin et al., 2005; Gupta et al., 2009; Affuso et al., 2011). The present study has also indicated that waist and hip circumference and thickness of skinfolds have strongest relationship in every age group of adolescent boys and girls. Therefore, the elevation of blood pressure among adolescent girls can be correlated with waist and hip circumference which are also important variables for obesity.

**Regression Analysis**

With respect to blood pressure indices, many interesting results from regression analysis have emerged. Across all age groups for three blood pressure phenotypes (SBP, DBP and MBP), almost all anthropometric variables were significantly related to blood pressure on the basis of univariate regression analysis. However, no such consistent pattern has been observed for socio-economic lifestyle variables. The study showed that different predictors have different contribution in different age groups. It is difficult to find out a single significant contributory predictor in all age groups. Therefore, such type of study would generate valuable information on nature-nurture interaction involved in cardiovascular diseases. Hence, considering the present linear regression, it may be assumed that mostly BMI, waist and hip circumference, thickness of skinfolds, pulse pressure, pulse rate, family status and parents education were found to be most consistent in explaining the risk factors of cardiovascular disease among adolescents. However, very negligible contribution of food habit and exercise has been observed to the total variation of elevated blood pressure among adolescents.

However, in subsequent analysis when blood pressure was regressed on the different sets of variables (anthropometric and socio-economic lifestyle) using multiple regression analysis, then, fewer variables were found to be statistical significant at least at 5% level of significance in different age groups of Punjabi adolescent population. This suggested that some of the variables among anthropometric and socio-economic
lifestyle factors are primary in nature (significant multivariate correlates), while others are secondary (non-significant multivariate correlates) in different adolescent age groups. Pulse pressure and pulse rate in every age group for both boys and girls were common correlates for SBP and DBP. However, different significant multivariate predictors observed in different age groups, such as waist circumference, hip circumference, WHR, thickness of skinfolds and sleeping time for 10 to 12 years of age group; weight and family status for 13 to 15 years age group; sitting height, weight, thickness of skinfolds and family status for 16 to 18 years age group among boys and hip circumference, arm circumference and sleeping time for 10 to 12 years; thickness of skinfolds and family status for 13 to 15 years; waist circumference and arm circumference for 16 to 18 years age group among girls. However, socio-economic lifestyle did not enter in multivariate analysis in higher age group (16 to 18 years) in girls. It is also interesting to note that in multivariate system, cumulative contribution of maximum total variance ($R^2$) for anthropometric variables were 43.1%, 24.2% among boys and 54.7%, 31.1% among girls of 10 to 12 years of age group; 54.4%, 28.3% among boys and 61.1%, 28.8% among girls of 13 to 15 years of age group; 60.8%, 31.4% among boys and 52.7%, 17.2% among girls of 16 to 18 years of age group for SBP and DBP, respectively. For socio-economic lifestyle variables, the similar result was as follows; 2.77%, 3.61% among boys and 0.7%, 1.57% among girls of 10 to 12 years of age group; 4.08%, 1.29% among boys and 3.36%, 1.93% among girls of 13 to 15 years of age group; 2.16%, 1.87% among boys of 16 to 18 years of age group for SBP and DBP, respectively. The results suggested a stronger and greater impact of anthropometric variables on SBP as compared to DBP. However, socio-economic lifestyle factors did not have strong impact on SBP and DBP, respectively in all age groups.

There is a great difficulty in partitioning the contribution of independent variables that are highly correlated with each other. For this reason, the stepwise regression analysis was done separately with different models for the variables that appeared to be contributing most to the explanation of variance of blood pressure. This analysis was able to make the combined association of significant correlates of blood pressure. All alternative regression models such as 7 and 5 models for possible subsets among
anthropometric and socio-economic lifestyle factors have been used for greater explanatory power of association for cardiovascular diseases. The models used such as model 1: BMI; model 2: BMI + waist circumference; model 3: BMI + waist circumference + WHR; model 4: BMI + waist circumference + WHR + biceps skinfold; model 5: BMI + waist circumference + WHR + biceps skinfold + triceps skinfold; model 6: BMI + waist circumference + WHR + biceps skinfold + triceps skinfold + subscapular skinfold; model 7: BMI + waist circumference + WHR + biceps skinfold + triceps skinfold + subscapular skinfold + pulse rate for anthropometric predictors and for socio-economic lifestyle predictors, the models used were, model 1: food habits; model 2: food habits + time spent on exercise; model 3: food habits + time spent on exercise + family status; model 4: food habits + time spent on exercise + family status + father education; model 5: food habits + time spent on exercise + family status + father education + mother education. Using stepwise multiple regression analysis, the present study has shown that all anthropometric models (model 1 to 7) and socio-economic lifestyle models (model 1 to 5) have significant and pronounced influences on SBP and DBP. The regression coefficients of all models were significant at p<0.001. Hence, the increase of such measure of combined risk factors of anthropometric and socio-economic lifestyle also enhances the occurrence of pre-hypertension and hypertension in different age groups of adolescents. The results of present study were also consistent with many other similar studies of India and abroad (Freedman et al., 1999; Katzmarzyk et al., 2004; Sarkar et al., 2009). Furthermore, the maximum percent of variance ($R^2$) was explained by model: 7 (BMI + waist circumference + WHR + biceps skinfold + triceps skinfold + subscapular skinfold + pulse rate) for anthropometric predictors and model: 5 (food habits + time spent on exercise + family status + father education + mother education) for socio-economic lifestyle predictors. Model: 7 for anthropometric indicators contribute maximum 19.4%, 29.8%, 25.3% among boys and 29.3%, 25.0%, 19.0% among girls for SBP and 17.8%, 24.0%, 21.8% among boys and 27.6%, 26.4%, 13.2% among girls for DBP in 10 to 12, 13 to 15 and 16 to 18 years group, respectively, whereas, model 5 for socio-economic lifestyle indicators contribute maximum 1.3%, 4.1%, 2.0% among boys and 0.3%, 7.3%, 2.7% among girls for SBP and 2.5%, 1.5%, 1.8% among boys and 0.2%, 3.9%, 1.1% among girls for DBP in
respective three age groups. Therefore, results suggested that anthropometric models were better fit as compared to socio-economic lifestyle model to explain the total variation of blood pressure in all adolescent age groups. However, the socio-economic lifestyle variables have not produced high $R^2$ due to the fact that appropriate regression may not be found in this situation, especially, during adolescence. It is difficult to choose appropriate socio-economic lifestyle predictor on the basis of interpretability and convenience in obtaining the data in adolescent population.

In binary logistic regression analysis, the magnitude and nature of significant association between pre-hypertension and hypertension with anthropometric and socio-economic lifestyle variables were different in different age groups of adolescent boys and girls. In the present study, the risk of developing pre-hypertension was significant for 10 to 12 years age group with respect to waist circumference (1.07 times) in boys and thickness of skinfolds (1.04 times) in girls; for 13 to 15 years age group with respect to thickness of skinfolds (1.02 times) and sleeping time (2.05 times) in boys; for 16 to 18 years age group with respect to waist circumference (1.06 times) and BMI (1.21 times) in boys and BMI (1.22 times) in girls, respectively. Similarly, the risk of developing hypertension was maximum in 10 to 12 years age group with respect to BMI (1.29 time) in girls; for 13 to 15 years age group with respect to BMI (1.23 times) and family status (1.85 times) in boys and waist circumference (1.05 times), BMI (1.14 times), sleeping time (1.65 times) and family status (1.97 times) in girls; for 16 to 18 years with respect to waist circumference (1.04 times) and BMI (1.17 times) in boys and BMI (1.38 times) in girls. Therefore, overall, it was observed that BMI, waist circumference, sleeping time and family income status have almost equal association with development of pre-hypertension and hypertension among boys and girls of all age groups. It was also observed that adolescent boys and girls in all age groups almost equally tended to have pre-hypertension and hypertension. The present findings did not differ from previous reports showing gender differences in elevated blood pressure with respect to waist circumference, BMI and socio-economic lifestyle risk factors among adolescents of different age groups (Nirmala, 2001; Rodriguez et al., 2006; Soudarssanane et al., 2006; Cobayashi et al., 2010; Vasan et al., 2011; Kumar et al., 2012; Park et al., 2013).
Principal Component Analysis

The current study focused on one of the major objectives to determine significant cardiovascular risk factors through principal component analysis (PCA) among three age groups of Punjabi adolescents. The study performed PCA with orthogonal rotation to reduce 20 inter-correlated variables (12 anthropometric and physiometric variables and 8 socio-economic lifestyle variables) into groups of independent factors among three age groups of adolescents. The factors have been identified as three for anthropometric risk factors in boys among the three age groups and four for girls of 10 to 12, 16 to 18 years and three for 13 to 15 years of age group. This data reduction method identified these factors and explained 77.87%, 76.33% and 76.92% for boys and 86.44%, 77.11% and 83.59% for girls among 10 to 12, 13 to 15 and 16 to 18 years age groups, respectively of the variation in original quantitative traits. The present analysis yielded, only two clusters of factors such as obesity and elevated blood pressure with pulse rate and pulse pressure to be considered as third component. This result is not unusual in the literature, majority of studies have reported these factors (Gupta et al., 2007; Adeyemo et al., 2009; Badaruddoza et al., 2010; Badaruddoza et al., 2011; Kaur et al., 2012; Shin et al., 2013; Sungwacha et al., 2013). The present model suggested that clustering of variables in obesity and blood pressure was a result of multiple factors in which centripetal fat and blood pressure (SBP and DBP) played key roles. The present findings have three major contribution to the literature: (i) obesity risk components such as BMI, WHR, waist circumference, hip circumference and thickness of skinfolds are core predictors for cardiovascular diseases and these core factors are equally distributed among all age groups of adolescents in both boys and girls, (ii) physiometric risk components (SBP and DBP, pulse rate and pulse pressure) for cardiovascular diseases have been identified as second important core factors among different adolescent age groups and (iii) socio-economic lifestyle risk components such as family income status, parents education (which are recognized as factor 1), time spent on exercise, sleeping time and food habits (which are recognized as factors 2 and 3).

It is interesting to observe that the pattern of clustering of variables of BMI, waist circumference, hip circumference, WHR and sum of skinfolds seems to load more than
blood pressure. Therefore, it may be concluded that BMI, waist circumference, hip circumference, WHR and sum of skinfolds have played more important role in the occurrence of cardiovascular diseases.

The factor analysis of this study demonstrated that obesity factors are the predominant and significant correlates of cardiovascular risks among the individuals of these age groups, regardless, the risk is defined in terms to individual physiological variables on a cumulative risk scales. BMI, waist circumference and obesity were associated with high risk of cardiovascular diseases. The magnitude of the loading of these obesity factors have been found maximum and consistent in all age groups of adolescents in both boys and girls. The similar pattern has also been observed in socio-economic lifestyle factors such as family status, parent’s education, food habits and screening time, etc. Thus, inter-relationship between these variables appeared to be established, may be early in the life course. Whether high factors score on any of these particular factors will predict development of cardiovascular disease in adulthood remains to be determined through longitudinal analysis.

Remark: This study not only confirmed, but, also extended prior work by developing a cumulative risk scores. Till date such a cumulative and extensive scale has not been used by any other Indian study among adolescent population. These findings and study highlights the importance of global approach assessing the risk and need for studies that elucidate how these different cardiovascular risk factors interact with each other over the time to create clinical disease. These findings also added depth to the negligible amount of literature of factor analysis of cardiovascular risks in any Indian adolescent population.

Receiver Operating Characteristics Curve (ROC)
(Sensitivity, Specificity, Likelihood Ratio and Youden’s Index)

The present study has an attempt to evaluate comparative four anthropometric indicators (waist circumference, WHR, sum of skinfolds and BMI) and five socio-economic lifestyle factors (food habits, exercise, family income status, father and mother education) to identify the most distinctive indicator for pre-hypertension and hypertension among Punjabi adolescent population. No such study has been performed
in this region based on sensitivity, specificity and likelihood ratio in different age groups of adolescent population. Therefore, with the lack of data on this subject, the present study was unable to compare with other studies, especially, in this region. It is desirable to choose a test that has high values for both sensitivity and specificity. The maximum value a Youden’s index can attain is 1 when the test is perfect and the minimum value is zero when the test has no diagnostic value.

The results of the present study indicated high sensitivity with respect to waist circumference among boys (30.5%), and girls (33.3%) for pre-hypertension in 16 to 18 years of age group, whereas, for hypertension, waist circumference (from anthropometric factors) showed higher sensitivity for boys (44.7%) in 13 to 15 years and for girls (40.8%) in 16 to 18 years of adolescent age group; parents education (father and mother) and food habits (socio-economic lifestyle risk factors) have shown higher sensitivity for adolescent boys and girls. The values of positive likelihood ratio (LR+) and Youden’s Index have been found to be maximum for BMI, waist circumference and sum of skinfolds from anthropometric variables and family income status, food habits and parents education among socio-economic lifestyle variables. This showed that these indicators have significant positive association with the occurrence of cardiovascular disease among adolescent population.

The present findings were consistent with many other studies in India and abroad (Delavari et al., 2009; Christofaro et al., 2011; Gupta and Kapoor, 2011; Bovet et al., 2012; Burgos et al., 2013). However, certain studies in adult population (Dobbelsteyn et al., 2001; Lee et al., 2008) suggested that measure of central obesity, such as waist circumference, is better predictor for cardiovascular disease risk factors compared to BMI. They also rejected the previous suggestion that combining BMI with waist circumference increased the cardiovascular risk prediction more than either measured alone (Zhu et al., 2004) and supported the use of WHR as a sole measure of obesity. However, the present analysis in adolescent population did not support this hypothesis and proposed that combined BMI and waist circumference would be better predictor for both the sexes, especially, in girls. BMI, which was most widely used indicator for total adiposity, cannot distinguish visceral fat from muscle mass and peripheral from the central fat and also its limitation were recognized by its change according to age and its
dependency on ethnic background (WHO, 1995; Hsieh et al., 2000). Therefore, waist circumference has shown to be highly correlated with the amount of visceral body fat and majority of current studies suggest that waist circumference is better predictor for cardiovascular diseases than BMI and WHR (Vasan et al., 2011; Gupta and Kapoor, 2011; Brar and Badaruddoza, 2013a). Furthermore WHO (1995) has suggested that waist circumference is the easiest and most effective anthropometric indicator to be used in population based study because it measures fatness and fat location. However, there is no global standard for measure of obesity in adolescent population. Some studies measure waist circumference at the level of umbilicus and some according to WHO standard definition which is half way between iliac crest and lower rib of ribcage. However waist circumference cut off values differ genders and ethnic groups, but, there is no gold standard cut off values in adolescents among population (Hsieh and Muto, 2006; Virani, 2011).

The results of the analysis of present data suggested that waist circumference have moderate to high sensitivity in prediction of pre-hypertension and hypertension for adolescent boys and girls. BMI and sum of skinfolds may be considered with respect to high specificity (>90%) in the second level of best of best predictor for both pre-hypertension and hypertension. When the results were compared for positive likelihood ratio of three age groups between boys and girls with respect to all indicators, than it was observed that LR+ values of BMI have been consistently higher in all age groups among boys and girls as compared to other indicators. Therefore, it has been suggested that combination of waist circumference and BMI would be better predictor to assess cardiovascular disease risks in adolescent population. Several studies analyzed the association between cardiovascular disease risk factors and other anthropometric variables based on sensitivity, specificity and likelihood ratio analysis. Most of studies (Katzmarzyk et al., 2004; Allamanda et al., 2010; Ferreira et al., 2011; Burgos et al., 2013) including present one supported the idea that waist circumference and BMI are best anthropometric index of cardiovascular disease risk factors. However, due to different reported cut off values across different ethnic population groups further research and study would be required, especially, in adolescent population until reaching an Internationally acceptable simple and appropriate measure, that could be easily and efficiently used in clinical and epidemiological research.
Of the four of anthropometric and five socio-economic lifestyle markers studied, BMI, waist circumference, family income status and parents education were found to have largest area under the curve in relation to pre-hypertension and hypertension among both adolescent boys and girls. Therefore, the result further confirm that the combination of BMI and waist circumference is a better predictor of cardiovascular risk factors as compared to other anthropometric markers whereas, in socio-economic lifestyle variables parents’ education and family status were found to be good predictors for cardiovascular diseases.

**Path Analysis and Structural Equation Modeling**

Keeping in mind, that the complex nature all studied anthropometric and socio-economic lifestyle variables to evaluate the determinants of pre-hypertension and hypertension, a path analysis of structural equation modeling using AMOS (AMOS 21.0) model fitting program has been applied in the study. The study first tested the adequacy of hypothesized path model which contain the inter-correlated variables (such as BMI, waist circumference, WHR, sum of skinfolds, food habits, exercise, screen time and family status). Next, the study tested the relative strength of association of independent variables with SBP and DBP on the basis of the magnitude of path coefficients of regression, covariances and variance. The study adopted maximum likelihood estimation, 95% confidence limit and critical ratio in generating the estimate of path coefficients and its significance. The whole analysis further confirmed that the waist circumference, BMI and family income status have significant contribution to increase blood pressure. The findings of the present study regarding effect of BMI, waist circumference, WHR, sum of skinfolds, food habits, exercise, screen time and family status on blood pressure are in an agreement with few other studies (Kelishadi et al., 2007; 2013; Gamborg et al., 2009; Akter et al., 2010; Kuriyan et al., 2012). However, very negligible studies have used path analysis to derive the significant predictors of cardiovascular diseases, especially, in Punjabi adolescent population. Therefore, it may be concluded that it is a powerful statistical technique that allows for more complicated and realistic models than multiple regression model with its single dependent variables. In the present study comparing four anthropometric (BMI, waist circumference, WHR and sum of skinfolds) and socio-economic lifestyle variables
(food habits, exercise, screen time and family status), only BMI, waist circumference and family status were independently related to SBP and DBP which is consistent with previous findings established at the individual level (Chaix et al., 2010). It is further established from estimates of covariances from path analysis that combination of BMI with waist circumference, waist circumference with sum of skinfolds, BMI with sum of skinfolds, exercise with family status and screen time with family status have significant association with elevated SBP and DBP. Whereas, impact of variances on SBP and DBP of all the studied variables have been found significant for path analysis model among both adolescent boys and girls.

**Conclusion**

In conclusion, the statistical evidences obtained from the entire hard core analysis of the present work would be sufficient to reject the first null hypothesis ($H_0$), however, confirming the evidence that the impact of complex mode of anthropometric and socio-economic lifestyle variables on SBP and DBP are consistent with major significant effect.

Rejection of second null hypothesis has confirmed specific anthropometric and socio-economic lifestyle risk factors for prediction of cardiovascular diseases in Punjabi adolescent population.