DISCUSSION

The major purpose of the study was three folds; (i) to examine the prevalence of pre-hypertension and hypertension and to provide overall essential baseline data for CVD among the study population (ii) to analyze the trend of blood pressure variations with respect to different anthropometric and socio-economic lifestyle variables to track the cardiovascular risk factors in different adolescent age groups in the urban section of 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.

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). The response rate was greater in comparison to some other investigations (Brontons et al., 1989; Rosenthal et al., 1992; Fukushige et al., 1995; Vlajinac et al., 2003). In regard to these objectives, many interesting results have emerged from the study and will be discussed one by one.

5.1. Comparison of Descriptive Statistics and Distribution

Punjabi population is unique in India with respect to prosperity, culture, urbanized western lifestyle and rich food intake habits. Therefore, this population has a great importance for study of complex disorders related to origin of cardiovascular diseases
which are deeply influenced with lifestyle factors. Hence, current study is focused on adolescent Punjabi population group to dissect the anthropometric, physiometric and some socio-economic lifestyle variables underlying cardiovascular disease’s risks.

The average levels of SBP/DBP (mmHg), 117.18/77.38, 118.21/79.00, 119.18/79.24, 121.09/79.82, 123.30/81.59, 124.53/84.00, 128.12/85.65, 130.06/86.15 and 132.68/87.29 among boys and 119.06/79.27, 118.15/77.85, 119.65/78.74, 120.18/79.59, 122.06/82.09, 122.06/83.59, 124.53/83.21, 126.12/84.71 and 127.09/85.65 among girls of 10, 11, 12, 13, 14, 15, 16, 17 and 18 years, respectively, found in the present study were higher than the average blood pressure values in adolescents of the same age groups among other Indian studies (Mohan et al., 2004; Kumar et al., 2012; Sundar et al., 2013). The levels of SBP and DBP in every age group were also higher than those recorded in Japan, Singapore and USA (Fukushige et al., 1995; Daniels et al., 1996; 1998; Schmidt et al., 1997; Freedman et al., 1999b; Vlajinac et al., 2003).

The main findings of descriptive studies were, prevalence of higher blood pressure as well as, that of overweight and obesity which was relatively high, both at the baseline, among boys and girls. Therefore, blood pressure is tracked at moderate levels for boys as compared to the girls. However, these results should be interpreted with caution, since the diagnosis of pre-hypertension and hypertension was based on blood pressure measurements which were obtained on single occasion in the present study. Hence, the prevalence of elevated blood pressure was probably slightly over-estimated in the study. It may be because many adolescents might have felt uncomfortable being subjected to repeated anthropometric and blood pressure measurements. However, the guidelines on diagnosis and clinical significance of children and adolescents for obesity and hypertension have been followed very carefully during the study period and multi-layered approach for recruitment of the subjects including frequent contact and cooperation with school authorities and parents have been done (NHBPEP, 2004; Kollias et al., 2011).

In comparison to the results from ‘know your body’ study (Martin, 1992; 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. These observations have important public health and clinical implications and emphasize the importance of targeting elevated blood pressure among youngsters, especially interventions that may be successful at increasing physical activity levels among young boys and girls with slight modifications of food habits and reduction of screen time.

BMI, waist circumference, food habits, exercise, time spent on exercise, screen time, sleeping time, family status and parents’ education were chosen in present study for evaluation of pre-hypertension and hypertension in three age groups (10 to 12, 13 to 15 and 16 to 18 years). These indicators were also widely used by many researchers in adolescents, as well as, adults, to track hypertension (Ghosh et al., 2000; Hu et al., 2000; Sorof and Daniels, 2002; Shang et al., 2004; Abolfotouh et al., 2011; Chaudhary et al., 2011). Waist circumference and BMI have been validated in adolescents as useful predictors for cardiovascular diseases (Cole et al., 2000; Virani, 2011). However, BMI and waist circumference are the simple measurements that most of the investigators can precisely measure while the same does not apply to WHR and skinfold measurements for adolescents. 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. Therefore, individually
normal BMI had significantly higher risk of hypertension in adolescent boys and girls as compared to overweight and obese. However, overweight and obese boys and girls have also significantly developed hypertension in 10 to 12 years and subsequent age groups. The association between obesity and hypertension in adolescents in different studies among variety of ethnic and racial groups has been observed as the all studies have reported high blood pressure or higher prevalence of hypertension in overweight and obese adolescents (Guillaume et al., 1996; Mancedo et al., 1997; Freedman et al., 1999a,b; Morrison et al., 1999; Sorof and Daniels, 2002; Sorof et al., 2002).

The most comprehensive study by Rosner et al. (2000) in pooled data from 8 large US epidemiological studies involving over 47,000 children to describe the relation of blood pressure with body size, the study, had found that irrespective of race, gender and age, the risk of elevated blood pressure was significantly higher in the upper compared to the lower deciles of BMI. Sorof et al. (2002) have reported a three times greater prevalence of hypertension in obese compared to non-obese adolescents in a school based hypertension and obesity screening test. A previous study (Rosner et al., 2000) reported a linear increase in the prevalence of hypertension in adolescents of all race, gender and age combinations as BMI increased across the normal race. Among all demographic and clinical factors analyzed in previous studies (Hu et al., 2000; Sorof and Daniels, 2002; Choudhary et al., 2011; Sundar et al., 2013), BMI was identified as the most strongly associated risk factors for hypertension.

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). However, the present study is not in accordance with the hypothesis that pre-hypertension and hypertension are the antecedents for cardiovascular diseases, which were associated with increasing measurements of BMI, because maximum prevalence and frequencies were found for adolescents within the normal range of BMI. Nevertheless, study agreed with the findings of other previous investigations (Vlajinac et al., 2003; Graf et al., 2005; Freedman et al., 2007; Kelishadi et al., 2007a; Burgos et
al., 2012) that have showed that risk of hypertension increased with increasing BMI especially in older age groups.

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 prevalence of pre-hypertension and hypertension in overweight subjects have been found maximum in 10 to 12 years age group of adolescents (2.75% and 5.29% for pre-hypertension and hypertension, respectively) among boys and 16 to 18 years age group (4.31% for pre-hypertension) and 13 to 15 years age group (5.88% for hypertension) among girls, whereas the prevalence of pre-hypertension and hypertension in obese adolescents had been found maximum in 16 to 18 years age group for both boys (4.9% and 9.8% for pre-hypertension and hypertension, respectively) and girls (4.71% and 10.78% for pre-hypertension and hypertension, respectively). Furthermore, adolescent girls with normal waist circumference range had maximum prevalence of pre-hypertension and hypertension in 10 to 12 years of age group (10.59% and 28.04%, respectively). However, in boys the maximum prevalence of pre-hypertension has been found in 16 to 18 years age group (20.59%) and of hypertension in 10 to 12 years age group (31.96%). 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, 2013a). 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. Although, BMI is widely used in epidemiological studies because this index is highly correlated with body fat. Some investigators (Lean et al., 1995; Ghosh et al., 2000; Neovius et al., 2005; Abolfotouh et al., 2011; Brar and Badaruddoza, 2013a,b; Moraes and Falcao, 2013) reported that waist circumference is the stronger predictor than BMI for prediction of
cardiovascular diseases. As waist circumference is the measurement of abdominal fat-mass, it is considered a simple, clinical alternative to BMI to detect the possible health risk due to cardiovascular diseases and obesity among adolescents. The present results also support this suggestion for screening the central obesity with elevated blood pressure among adolescents of 10 to 18 years age group.

In the present study, based on BMI, it can be 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 (Sarkar et al., 2009; Abolfotouh et al., 2011; Badaruddoza et al., 2011; Moraes and Falcao, 2013). However, the cross-sectional study does not provide information on the sequence of risk factors development that cause and effect relation cannot be inferred (Latiffah and Hanachi, 2008). Hence, to establish the prevalence of pre-hypertension and hypertension with respect to BMI and waist circumference in general adolescent population, more research should be carried out. These types of studies on adolescent population are lacking in India, as well as, abroad.

In the present study, two dietary patterns such as vegetarian and non-vegetarian have emerged and were observed to have varied association with cardiovascular risk factor. In cross sectional study for demographic and lifestyle variables diet across all parts of Punjab characterized by dairy products, fried, snacks and sweets have appeared to be positively associated with abdominal obesity and hypertension. Subsequently, dietary pattern in many parts of India, like Kerala, Mumbai, Bangalore characterized by intake of vegetables and pulses were inversely related to hypertension and obesity (Daniel et al., 2011). Very negligible studies have been conducted to examine the relationship of food pattern and cardiovascular risk factors in Indian adolescent population (Beilin et al., 1988; Dwyer, 1988; Radhika et al., 2008, 2010; Howe et al., 2013). High fat intake in the form of milk and its products like ghee, butter, cheese, especially in Punjab was one of major indicator to produce cardiovascular diseases and adverse health profile.
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 fruits, 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 relationship between diet and chronic diseases like hypertension and type 2 diabetes are certainly complex and likely to encounter unfamiliar challenges in Indian diet. As it was found in the present study vegetarians have also significant impact to raise the higher blood pressure, especially, in Punjabi adolescent girls. It is due to the fact that cooking of vegetables in traditional Indian mix vegetable dishes might alter the preventive property of the foods and also contribute substantially to added fats which enhance the risk of cardiovascular diseases.

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. The association between physical exercise and hypertension is an established fact as studied by many authors (Marti and Vartiainene, 1989; Kelley et al., 2003; Brage et al., 2004; Bouziotas et al., 2004; Anderson et al., 2006; Ness et al., 2007; Leary et al.,
2008; Godard et al., 2012). Relationship of physical exercise and BMI to the risk of hypertension has proved the protective effect of physical exercise in both sexes. Therefore, the present study also provides a valuable insight into patterns and correlates of physical exercise among all adolescent age groups. 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 (Devyer and Blizzara, 1996; Andersen et al., 1998; Berkey et al., 2003; Biddle et al., 2004; Kerner et al., 2004; Omar and Rager, 2005; Kelishadi et al., 2007b; 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.

To the best of knowledge, this is the first study in North Indian Punjabi adolescent population which has separately analyzed the relationship between different forms of daily physical exercise and time spent on exercise for boys and girls with cardiovascular risk factors (pre-hypertension and hypertension). The results showed that moderate to high levels of time spent on exercise were associated with a reduced risk of pre-hypertension and hypertension among both sexes. It seemed that time spent on physical exercise is inversely associated with pre-hypertension and hypertension among adolescent 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
Discussion

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 (Lowry et al., 1996; Pais et al., 1996; Mendez et al., 2003; Rastogi et al., 2004a; Xavier et al., 2008; Jeemon and Reddy, 2010; 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 as secondary/high school had maximum prevalence of pre-hypertension and hypertension. This showed parent education has relation with the prevalence of pre-hypertension and hypertension among adolescents. The present results with respect to education and prevalence status of pre-hypertension and hypertension were inconsistent with other studies. However, education has been proposed as the preferable characteristic as compared to other socio-economic lifestyle indicators for desirable outcome. Many studies from different countries (Winkleby et al., 1992; Smith et al., 1998; Howe et al., 2010; Jeemon and Reddy, 2010; Braig et al., 2011; van den Berg., et al., 2013) showed that the education level, occupation and socio-economic status have strong association with prevalence of pre-hypertension and hypertension.

5.2. 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. 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, parents’ education, exercise and time spent on exercise were 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 (Daniels et al., 2000; Gaskin and Walker, 2003; Raitakari et al., 2003; Hardy et al., 2004; Yalcin et al., 2005; Nur et al., 2008; Gupta et al., 2009; Affuso et al., 2011). Many investigators (Stallones et al., 1982; Byard et al., 1989; Sharma et al., 1991; Kaziel et al., 2001; Al-sendti et al., 2003; Frontini et al., 2003; Freedman et al., 2002; 2003; Remsberg et al., 2005; Bovet et al., 2012; Dagan et al., 2013) advocated that waist circumference, as well as BMI, have significant correlation with elevated blood pressure, especially, in adolescent girls, although, menarcheal age has some effect on cardiovascular parameters. 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. In conclusion, the strength of correlation of significant anthropometric predictors increases with increasing age, with a more rapid rise in the middle of adolescence. Therefore, it is recommended that routine blood pressure measurement should be encouraged in children and adolescents with in school and pre-college systems for early detection of hypertension. This screening method should be adapted in all schools within the region using group reference level to determine elevated blood pressure. Hence, the study also suggested that, especially, BMI and waist circumference would be the simple and significant indicators for the management of moderate and high risk of cardiovascular diseases and regular health care system in present Punjabi adolescent population.

5.3. 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. In linear regression analysis, it has been noticed that main independent contributory risk factors of anthropometric variables to total variation of SBP and DBP in adolescent boys were pulse pressure (25.6%, 36.5% and 42.9% among 10 to 12, 13 to 15 and 16 to 18 years, respectively) for SBP and pulse rate (12.8%) for 10 to 12 years and weight for 13 to 15 years (20.3%) and for 16 to 18 years (14.8%) age groups, respectively for DBP. The main independent contributors in adolescent girls were pulse pressure (34.3%, 45.4% and 43.1% for three age groups, respectively) for SBP and pulse rate (22.4%), hip circumference (13.7%) and arm circumference (7.5%) for respective age groups in DBP. All socio-economic lifestyle factors have shown almost negligible contribution to total variation of SBP and DBP in all age groups among both boys and girls.

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 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) among girls. Some other variables of anthropometric and socio-economic lifestyle did not remain significant in strict sense of multivariate context and might be considered as secondary correlates for all age groups among both sexes. 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 results were 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 5.36%, 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.

In the present multivariate analysis, large sample size with 25 parameters is large enough to provide sufficient power of testing of any hypothesis, therefore, it may be hypothesized that anthropometric risk factors have comparatively robust effects than socio-economic lifestyle factors on SBP and DBP among three age groups of adolescents. The results showed the minimum contribution of socio-economic lifestyle variables to total variation of blood pressure phenotypes (SBP and DBP) in three age groups of adolescent population. However, it has been confirmed that this studied population has different risk profile to socio-economic lifestyle factors. The differences with respect to cumulative contribution on the total variation between anthropometric, physiometric and socio-economic lifestyle risk factors, strengthened the hypothesis that
anthropometric indicators like BMI, waist circumference and skinfold adiposity, physiometric indicators such as pulse pressure and pulse rate and socio-economic lifestyle factors such as sleeping time and family status could be recognized as best predictors for estimating cardiovascular disease risks. The findings of the study corroborates the earlier observation that reported significant positive correlation of anthropometric, physiometric and socio-economic lifestyle factors with SBP and DBP (Savva et al., 2000; Yarnell et al., 2005; Kuschnir and Mendonca, 2007; Soudarssanane et al., 2008; Ansa et al., 2010; Satish et al., 2012; Sundar et al., 2013).

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 selection of predictor variables in the model have been chosen with respect to largest correlation criterion variables such as SBP and DBP. The first predictor variables were selected based on the highest partial correlation followed by second, third and other predictor variables based on the respective highest partial correlation in the forward selection. The final model contains all of the independent variables that met inclusion criteria. 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. The R is the measure of correlation between observed values and predicted value (SBP and DBP), whereas, R square ($R^2$) is the square of measure of correlation and indicates the portion of variation in the criterion value (SBP and DBP), which is accounted by respective model. Overall statistical significance of regression model is checked by F-statistics. The significance indicates only that the model is not useless, it may or may not be a good fit. The complement of “goodness of fitness” is denoted also by R square ($R^2$). The larger $R^2$ is the better fit. $R^2$ is also used to compare one model with other. Using stepwise multiple regression analysis, the present study has shown that all anthropometric models (model 1 to 7) and socio-economic lifestyle models (model 3 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 (Morton et al., 1980; Stallones et al., 1982; Sangi and Mueller, 1991; Freedman et al., 1999a,b; Hara et al., 2002; 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. To evaluate the effect of anthropometric and socio-economic lifestyle variables, one may compare $R^2$, although the results of $R^2$ may, at first seem, not very large enough in socio-economic lifestyle variables for both SBP and DBP. With respect to F- statistics, all models of anthropometric indicators for
SBP and DBP have been found significant predictors for cardiovascular diseases. 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.

Therefore, to understand etiology of cardiovascular disease with respect to different combination of anthropometric, physiometric and socio-economic lifestyle factors, future investigation should be undertaken on the other Indian adolescent population keeping in mind that different ethnic and cultural heterogeneity in India have to determine the relative role of these anthropometric, physiometric and socio-economic lifestyle factors especially food habits, physical activity and parents’ income status in explaining occurrence risk of pre-hypertension and hypertension. Longitudinal studies to show the interaction between anthropometric, physiometric and socio-economic lifestyle factors for understanding the etiology of cardiovascular diseases in different adolescent group in India are also needed in future. The wide cultural heterogeneity and differences in food consumption habits among different communities across the Indian subcontinent have a potential risk for cardiovascular diseases.

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. Logistic regression is useful for present situation in which the study is able to classify the subjects based on values of a set of predictor variables like anthropometric and socio-economic lifestyle factors. 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,
Discussion

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 (Hanley et al., 2000; Yu et al., 2000; Nirmala, 2001; Sande et al., 2001; Janssen et al., 2005; Manios et al., 2004; Reis et al., 2006; Rodriguez et al., 2006; Soudarssanane et al., 2006; Amin et al., 2008; Monyeki and Kemper, 2008; Cobayashi et al., 2010; Simonetti et al., 2011; Vasan et al., 2011; Kumar et al., 2012; Park et al., 2013). Although, girls had higher awareness than boys related to their body structure, however, this difference was no longer significant. The present findings showed that 13 to 15 years age group of adolescent girls have higher blood pressure with respect to waist circumference, BMI, sleeping time and family status as compared to male counterpart. It may be suggested that sex hormone may contribute to some extent to gender differences. In the present study, risk of having pre-hypertension and hypertension in late adolescence were higher as compared to early adolescence. Many studies reported that the prevalence of hypertension increased with age (Singh et al., 2006; Taksande et al., 2008; Sharma et al., 2010; Kumar et al., 2012). Therefore multivariate regression analysis confirmed that significant correlates of pre-hypertension and hypertension were BMI, waist circumference, sleeping time, food habits and family income status among Punjabi adolescents.

The relation of hypertension and obesity related traits have been well established for many decades. In the present study and several other studies, it was observed that
obesity related traits such as BMI and waist circumference were strong risk factors for development of hypertension/ pre-hypertension among adolescent age groups. In this study, obesity has also an important risk factor for hypertension with wide range in all three age groups of adolescents. In addition to that all the present study subjects lived in urban areas and had regular job, business, etc. and cared for physical appearance and unwillingness to change their lifestyle and food habits which enhanced the risk of obesity and prevalence of hypertension.

The diagnostic ability of anthropometric measurements during adolescence has demonstrated a varied predictability. In this study, logistic regression models have shown that BMI and waist circumference were significantly associated with clustering of obesity and elevated blood pressure. The present results are consistent with previous published literature on BMI and waist circumference. Waist circumference was the only strongest modifiable predictor with highest predicting power to all anthropometric and vascular predictors among adolescence (Freedman et al., 1999a,b; Franks et al., 2007; Burns and Arslanian, 2009; Vassan et al., 2011).

5.4. 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 factor accounted for largest portion of variations was strongly loaded with factors related to obesity (BMI, waist circumference, hip circumference, WHR and thickness of skinfolds) among all age groups of adolescents, which has been known to be an independent predictor for
cardiovascular morbidity and mortality. The second largest components, factor 2 and 3 for all age groups of adolescents reflected traits of blood pressure phenotypes. Therefore, in the present study factor analysis has been applied to investigate the clustering of variables that are thought to be important component to cardiovascular diseases. Hence, 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 (Maffeis et al., 2001; Rose et al., 2004; Gupta et al., 2007; Adeyemo et al., 2009; Badaruddoza et al., 2010; Badaruddoza et al., 2011a; Kaur et al., 2012; Howe et al., 2013; 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. Furthermore, all the loaded risk factors (anthropometric and physiometric) are modifiable in nature. Therefore, it seems to argue early prevention and proper intervention strategies to promote healthy lifestyle to reduce the burden of cardiovascular diseases in subsequent adult life. It seems that PCA is an attraction and better predictor for quantitative trait analysis to identify the cluster of risk factors for cardiovascular diseases among adolescent population. Therefore, 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 component), time spent on exercise, sleeping time and food habits (which are recognized as factor 2 and 3 components).

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. Studies across the population among adolescents demonstrated that these risk factors played an important role for development of cardiovascular diseases (Katzmarzk et al., 2004; Maffeis et al., 2006; Freedman et al., 2007; 2012; Kelishadi et al., 2007a; Beck et al., 2011; Leung et al., 2011; Kumar et al., 2012). Therefore, identification of the components of phenotypes of cardiovascular risk factors and how its phenotypic expression differs across the different age groups among adolescents could be helpful in understanding the etiology of cardiovascular diseases in adult life.

Different statistical techniques examined the association between risk factors and cardiovascular diseases. PCA is one such important approach to identify these associations. As far as Indian data among adolescent population is concerned negligible work so far has been undertaken to identify the underlying factors/components among different adolescent age groups. However, no such work at all has been undertaken in present adolescent population group of Punjab. Hence, the present work could be considered as a reference baseline data for further research work in adolescents. Further limitation of factor analysis is that investigator is forced to retain the number of factors with respect to eigen values (>1). However, it has been observed that some risk traits have low eigen values, but, act as important predictors.

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, parents’ education, food habits and screening time, etc. Thus, interrelationship 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.

5.5. Receiver Operating Characteristics Curve (ROC)

(Sensitivity, Specificity, Likelihood Ratio and Youden’s Index)

The cut off values for different significant anthropometric and socio-economic lifestyle indicators for cardiovascular diseases are different in different countries and these are highly race and ethnicity dependent. Therefore, there is no global standard for these indicators among adult/adolescents (Katzmarzyk et al., 2004; Kelishadi et al., 2007a,b; Rosa et al., 2007; Lee et al., 2008; Raj et al., 2009; Beck et al., 2011). Therefore, it is important to develop simple and effective anthropometric/socio-economic lifestyle indicators for screening the cardiovascular disease risk subjects in different adolescent population groups, until, reaching internationally accepted measures. 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. The sensitivity is the proportion of patients for whom outcome is positive that are correctly identified by the test. The specificity is the proportion of the patients for whom the outcome is negative that are correctly identified by the test. Generally, both the sensitivity and specificity of a test indicator need to be known in order to assess its usefulness for diagnosis of
discriminating test that would have sensitivity and specificity close to 100%. However, a test with high sensitivity may have low specificity and vice-versa. Sensitivity and specificity are usually combined in likelihood ratio (LR). The likelihood ratio of positive test result (LR+) is the ratio of a probability of a positive test result, if, the outcome is positive (true positive) to the probability of a positive test result, if, the outcome is negative (false positive). Therefore, LR+ represents the increase in odds favouring the outcome given a positive result. Similarly, LR- is the ratio of probability of a negative test result, if, the outcome is positive to the probability of a negative test result, if, the outcome is negative. Therefore, LR- represents the increase in odds favouring the outcome given negative test result. A high likelihood ratio for a positive result or a low likelihood ratio for a negative test which is close to zero indicates that the test is useful.

It is desirable to choose a test that has high values for both sensitivity and specificity. However, in practice the sensitivity and specificity may not be considered as equally important such as false negative finding may be more critical than a false positive one in which the cut-off with relatively high specificity will be chosen. However, if no judgement is made between the two then Youden’s index (J) may be used to choose appropriate cut-off. 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 risk factors among adolescent population.
The present findings were consistent with many other studies in India and abroad (Nawrot et al., 2002; Mirmiran et al., 2004; Ng et al., 2007; Delavari et al., 2009; Allamanda et al., 2010; Ferreira et al., 2010; Haun et al., 2009; Lu et al., 2010; Beck et al., 2011; Christofaro et al., 2011; Ejike, 2011; Gupta and Kapoor, 2011; Bovet et al., 2012; Burgos et al., 2013; Khashayar et al., 2013). However, certain studies in adult population (Dobbelsteyn et al., 2001; Zhu et al., 2005; 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; Grinker et al., 2000; 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 (Ledoux et al., 1997; Mellati et al., 2009; Vasan et al., 2011; Gupta and Kapoor, 2011; Zhang et al., 2012; 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 adolescent population (Molanus and Seidell, 1998; 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 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; Ng et al., 2007; Delavari et al., 2009; Allamanda et al., 2010; Ferreira et al., 2011; Chistofaro 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.

5.6. 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, the path analysis of structural equation modeling using Analysis of Moments Structures (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 (de Faire et al., 1982; Kelishadi et al., 2007a,b; 2013; Chen et al., 2008; Gamborg et al., 2009; Akter et al., 2010; Chaix et al., 2010; Mehio Sibai et al., 2010; Shankaran 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 significantly 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 (H₀), 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.

Strengths of the Thesis

The strengths of the present study are as follows:

(i) This is one of the largest urban based adolescent study with respect to cardiovascular risk factors.

(ii) This study has covered all the sections of populations with respect to social, economic and education levels.

(iii) The prevalence of risk factors was age, group and gender specific.

(iv) It provides base line data which can be used for planning, intervention and tracking of elevated cardiovascular disease in the adolescents.

(v) The samples were collected from 17 districts of Punjab with 34 schools and 3060 samples which may be to some extent representative of general adolescent population in Punjab.

(vi) The present study findings identified many significant anthropometric, physiometric and socio-economic lifestyle factors for further study related to tracking of hypertension among Punjabi adolescents.

(vii) The present work is a comprehensive population based study investigating patterns and correlations of anthropometric, physiometric and socio-economic lifestyle factors with cardiovascular diseases among 10-18 years age group.
(viii) Very negligible previous studies reporting results of principal component analysis and path analysis have been reported among adolescents. Therefore, the findings also added depth to the negligible amount of literature of extended and deep analysis of cardiovascular risk factors in adolescent age group.

(ix) These findings of the study highlighted the importance of global approach for assessing the risk and need for studies, especially, in adolescent age group that elucidate how these different cardiovascular disease risk factors interact with each other over the time to create clinical disease in future in adult life.

(x) To support the present results and discussions, a wide range of references from 1929-2013 have been used.

(xi) The key strength of the present study included the use of representative study sample and age appropriate measure of elevated blood pressure for adolescents.

(xii) The study lies in the near absence of antihypertensive medication in this population, which makes it possible to ascertain individuals’ actual blood pressure.

(xiii) This study measured different sub-categories for different socio-economic lifestyle variables.

(xiv) The strength of the present study includes meticulous geocoding of participants with respect to large study territory like 17 districts and diverse composition of subjects.

Limitations of the Thesis

(i) Due to cross-sectional nature of the data, observed association of different risk factors such as anthropometric, physiometric and socio-economic life style risk factors with cardiovascular diseases cannot be determined as cause and effect relationship.

(ii) The study was based on minimum self report of respondent, especially regarding socio-economic lifestyle factors and it probably may have led to underestimation or overestimation of the true association between socio-economic lifestyle and morbidity, especially, in the adolescent age group.
(iii) No data is available on menarcheal age of the girls, however this may have some impact on elevated blood pressure in adolescents.

(iv) Longitudinal analysis in this and other adolescent populations will be required to validate the present hypothesis.

(v) The limitations of factor analysis is that the investigator is forced to retain the number of factors with respect to eigen values (>1), however, it has been observed that some risk traits have low-eigen values but act as important predictors.

(vi) As the present study is based on different age groups of adolescent population, it posed a difficulty in comparison of present results with previous investigations on relative risk of hypertension as because negligible studies have available with respect to adolescent population.

**Recommendations**

(i) Pre-hypertensive and hypertension screening should be included in the school and pre-college health programme follow-up and regular blood pressure measurement should be an important step especially in school health programme. Waist circumference and BMI should be measured in school clinics, both for boys and girls, which could be used in health promotion programme to identify adolescents at risk of developing pre-hypertension and hypertension.

(ii) Prevention of cardiovascular risk factors as early as childhood/adolescence may be an important strategy to prevent non-communicable diseases in future course perspective, especially, in those countries, like India, where limited health care capacity is available for common people.

(iii) The programmes and policies to limit sedentary lifestyle and promote physical activity among adolescents is recommended.

(iv) The results provided in the present study are first step toward better understanding of the association of different qualitative and quantitative predictors of pre-hypertension and hypertension among Indian Punjabi adolescents.