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Sensitivity and Specificity of Anthropometric and Life-Style Variables for the Prediction of Pre-Hypertension and Hypertension in Three Generations Cohort Among Indian Punjabi Population

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Abstract: The present study has attempted to evaluate comparative three anthropometric indicators (BMI, waist circumference and WHR) and five socio-economic lifestyle factors (food habits, physical activity, exercise, smoking and alcohol) to identify the most distinctive indicators for pre-hypertension and hypertension for a specific community in Punjab. No such study has been performed in this region based on sensitivity, specificity and likelihood ratio with three generations. Among male parental generation the waist circumference and WHR for pre-hypertension; WHR and exercise for hypertension and waist circumference and BMI for pre-hypertension and hypertension among female parental generation were better indicators to assess CVD risk factors. High sensitivity suggested that waist circumference and BMI performed well in female parental generations. The results of the analysis of present data suggested waist circumference for almost all the generations with average high sensitivity upto 97% and 99% for female parental generation in the prediction of pre-hypertension and hypertension. BMI and WHR may be considered with respect to sensitivity in the second level of best predictor for both pre-hypertension and hypertension. If we compare positive likelihood ratio of the three generations with respect to all the indicators then it was observed that LR+ value of BMI has been consistently higher among all the generations as compared to waist circumference and WHR. Therefore, it is suggested that combination of waist circumference and BMI would be the better predictors to assess CVD risk.

Key words: Sensitivity · Specificity · Pre-Hypertension · Hypertension · Anthropometric and Life Style Factors · Punjab · India

INTRODUCTION

Cardiovascular disease in developing countries is spreading epidemically, related to aging population, changing lifestyle (due to industrialization, urbanization and demographic transition) and nutrition transition [1-5]. There have been transitions in social structure, economics, education and familial environments in most of the countries over the last few decades. These social and economic transitions have resulted in major changes in population demography, industrial structure, income levels, expenditure pattern, education level, family structure, eating habits and physical activity. These changes have substantially increased cardiovascular risk factors and disease rate, with majority burden occurring in developing countries [6, 7, 8, 9].

Obesity leads to adverse effect and metabolic changes of 2-6 fold rise in blood pressure. An increase in weight by 10 kg leading to an increase in 2-3 mm Hg SBP and 1-3 mm Hg DBP has been documented in the western population [10, 11].

A number of anthropometric measures were used as proxy measures of obesity for the evaluation of fat tissue accumulation. Waist-to-hip ratio, body mass index and waist circumference fat are the important indicators of obesity, cardiovascular disease and hypertension. This relationship is documented from many studies [12-18]. However, the question regarding the best obesity measures associated with blood pressures and hypertension remain unsolved. It might be difficult to determine a universally-applicable best obesity measure associated with blood pressures and hypertension, due to

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the existence of biological and cultural variation among different ethnic groups. Previously, non-vegetarian diet was thought to be superior over the vegetarian diet, as it was believed to contain more energetic ingredients, but, this concept has changed over time. With advancements in medical sciences vegetarian diet has been found to be more scientific for human body. Non-vegetarian diet contains cholesterol and fatty acids which are important cause of CHD, stroke and hypertension. Besides unhealthy food habit, the sedentary lifestyle is also of major concern. A negative association between the amount of physical activity and CVD, leading to mortality in the both developed and developing countries, has been well established [19, 20]. Physical activity should be considered as an important measure for the prevention and treatment of hypertension in adulthood. Even though for adults the effect of physical activity on blood pressure is well established, but the literature data are still limited regarding young adolescents. Physical activity is a key component of the therapeutic life style changes recommended for preventing and treating hypertension in children and in youth [7]. Exercise helps by reducing weight and lowering blood pressure. It also reduces the LDL (bad cholesterol) levels and total cholesterol and raises the HDL (good cholesterol) levels in blood. Researchers found that death rates reduced by 20-25% in heart attack patients who participated in formal exercise programs [21, 22].

Another life style factors is cigarette smoking. Cigarette smoking is a primary cause of preventable death in western society and is associated with both CVD and cancer [23, 24, 25]. Mortality from CHD is 60% higher in smokers [26]. Regular exposure to passive smoking increases CHD risk by 25% [27, 28]. In India, tobacco consumption is found among 27.5% of men and 11.6% of women [23]. Smoking is more common in rural population as compared to urban. World Health Organization (WHO) research estimates that over 20% of CVD is due to smoking [29]. However, moderate alcohol consumption in apparently healthy individuals is associated with lower CVD [30- 34]. The World Health Report in 2002 estimated that 2% of CHD in men in developed countries is due to excessive alcohol consumption [29]. Men should drink no more than 3 to 4 units on any one day and women no more than 2 to 3 units. If heavy alcohol intake is considered to be one of the risk factor for hypertension then one should easily realize that it is so reversible [35]. Therefore, the present study was undertaken to determine the sensitivity, specificity and likelihood ratio of different anthropometric and lifestyle factors for prediction of pre-hypertension and hypertension among three generations in Ramadasia community, a scheduled caste population of North-West Punjab in India.

MATERIALS AND METHODS

Sampling Design: This study used a stratified multistage cluster random sampling design. The world health organization (WHO) also recommended this kind of method of sampling to estimate the health conditions in a community [36]. The present sample is supposed to represent Ramadasia, a scheduled caste population of ages 7 years and above including three generation i.e. offspring, parental and grand-parental generations. The present survey had special emphasis on parental and offspring generation. The survey was oversampled to produce reliable estimates for these generations especially parental and offspring generations.

Inhabitant patterns of Ramadasia community are very peculiar. They have a tendency to build their houses as a cluster in different pockets and points in the districts due to socio-economic factors. In the several stages, the clusters with aggregation of Ramadasias households have been identified. However, these clusters were also heterogeneous with respect to caste grouping which helps to increase the size of the sample and thus the precision without a corresponding increase in the cost, labor and time.

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 questionnaire was in English language. Before the data collection the entire questionnaire was explained in local Punjabi language to the subjects along with the aims and objectives of the study and the procedure for the data collection. An informed consent was duly signed by the subject taken. In case of the offspring (=18) the entire procedure was explained to their parents or any elder person in the family and his/her signature was taken on offspring’s questionnaire. The present data was cross-sectional descriptive study and interview method was adopted as it provides an opportunity to the interviewer to extract the appropriate information by having a face to face contact with the subject in his/her residence.

Physiometric measurements included systolic blood pressure (SBP) and diastolic blood pressure (DBP). The anthropometric measurements comprised of the height, weight, waist circumference, hip circumference, waist to hip ratio (WHR) and body mass index (BMI).

Lifestyle included variables such as food habit, exercise, stress, smoking and drinking behavior. In the present study, food habits were classified into two groups vegetarian and non-vegetarian. The scoring pattern is as follows: vegetarian=1 and non- vegetarian= 2. Inactive or sedentary lifestyle refers to no or irregular physical activity. Sedentary activities included sitting, reading, watching television and computer use for much of the day with little or no vigorous physical exercise. The physical activity was classified as sedentary or active. The scoring pattern was: sedentary=1 and active=2 (Adapted and modified from Rastogi *et al.* [37] and Deb and Dasgupta [38]). The exercise is any bodily activity that enhances or maintains physical fitness and overall health and wellness. Subjects were categorized with respect to the regularity of exercise performed by them into three groups, never exercise, occasional exercise and regular exercise. The scoring pattern was as follows: never exercise=1; occasional exercise=2; regular exercise =3 (adapted and modified from Rastogi *et al.* [37]). A smoker is defined as a person who had ever smoked at least 100 cigarettes in his life time and currently smokes every day or some days [39]. The present respondents were broadly classified into three categories: never smoked (they did not smoke at any time), former smoker (quit during at least past two years) and current smoker which are further divided into three categories like light smoker (<5cigarette/day), medium smoker (5-10 cigarette/day) and heavy smoker (>10/day). The scoring pattern is as follows: never smoked=1; former smoker=2; current light smoker = 3; current medium smoker=4 and current heavy smoker = 5 (Adapted and modified from Nilsen *et al.* [40]). The present respondents with respect to alcohol consumption were broadly classified into three categories: never taken (they did not drink at any time), former drinker (quit during at least past two years) and current drinker which are further divided into three categories like light drinker (<50 ml/day), medium drinker (50-100 ml/day) and heavy drinker (>100/day). The scoring pattern is as follows never taken =1; former drinker=2; current light drinker=3; current medium drinker =4; current heavy drinker =5 (adapted and modified from Nilsen *et al.* [40]).

All the anthropometric measurements were taken on each individual using standard anthropometric measurement techniques [41, 42]. The BMI was calculated by dividing weight of the subject in kilogram by square of his height in meter. The WHR is calculated by dividing waist circumference in cm by hip circumference in cm.

The measurements of blood pressure were taken as recommended by American Heart Association [43]. At least two readings of blood pressure were taken, however, when the difference between the two readings was found to be more than 5 mmHg, then the third reading was taken and the average of the three measurements was used as the estimate of SBP and DBP in this study. All the efforts were made to minimize the factors like anxiety, fear, stress, laughter and recent activity which might affect blood pressure. The units of measurement taken were mmHg [43].

Data Collection and Field Operation: A cross-sectional survey was done in the four districts of Punjab namely, Gurdaspur, Jalandhar, Amritsar and Hoshiarpur. Houses were selected randomly from the particular locality. Mostly houses are situated in linear row fashion, one after another. Each house was visited twice during collection of data. During first visit all the information was gathered about subject’s personal and social information (age, gender, number of individuals in family including number of children in case of the parents and grandparents), anthropometric measurements (height, weight, waist circumference, hip circumference) and blood pressure measurements. Only those subjects were included in the study those were healthy and had not taken medicine prior two weeks. A second visit was made after two weeks and measurements were taken only from those subjects who were previously included in the first visit but absent for any reason and no new enrollments of subjects were made this time. Inclusion criteria: Healthy individuals were selected from four districts of Punjab (Gurdaspur, Jalandhar, Amritsar and Hoshiarpur) and only those individuals who had not taken any medication 2 weeks prior to study were chosen. Exclusion criteria: Unwillingness, unavailability in the first and second visits, illness, taken medicine in the prior two weeks and pregnancy.The study is ethically approved by the ethical research committee of Guru Nanak Dev University.

Total Samples: Total number of samples taken at first visit was 1923, which included 971 males and 952 females. The exclusion of subjects after second visit reduced the total samples studied in three generations to 1827, including 911 males (378 for offspring; 439 for parental and 94 for grand-parental) and 916 females (261 for offspring; 515 for parental and 140 for grand-parental).

Statistical Analysis: All the statistical analyses were done by using SPSS (Version 17.0, Chicago, IL, USA).

A valid diagnostic indicator could correctly detect the presence as well as absence of the disease. Some indicators are more valid than others. Sensitivity and specificity are the two components of the validity of the test that measures its inherent goodness. In the present study sensitivity, specificity and likelihood ratios for different anthropometric and lifestyle indicators such as BMI, waist circumference, WHR, food habits, exercise, smoking and alcohol to detect pre-hypertension and hypertension have been calculated to determine the best indicator among them in different generations. Both sensitivity and specificity can be converted to percentage by multiplying with 100 for best illustration. A diagnostic test is done based on a continuous measurements, a range of different decisions thresholds or cut-off values may be investigated in order to decide which cutoff points should be used to discriminate between patients according to the outcome. In practice the sensitivity and the specificity may not be regarded as equally important. It is desirable to choose the test that has high values for both sensitivity and specificity. However, if no judgement is made between the two then Youden's index (J) may be chosen as an appropriate cut-off. The Youden's index has been calculated through following formula: J=[sensitivity+specificity]-1. The maximum value of J is 1 when the test is perfect and the minimum value is usually zero when the test has no diagnostic value.

The classification of blood pressures has been used as such: normal <120/<80 mmHg (SBP/DBP), Pre-hypertension 120-139/80-89 mmHg, hypertension $\geq$140/ $\geq$ 90 mmHg [44]. The classification of blood pressure for children (age <18 years) has used as such: <90th percentile mmHg SBP/DBP), Pre-hypertension 90th-95th percentile or 120/80 mm Hg, hypertension 95th-99th percentile + 5 mm Hg. The classification of BMI [44, 45] has been used as such: underweight <18.5 (Kg/m^2), normal 18.5-24.9 (Kg/m^2), overweight 25.0 – 29.9 (Kg/m^2), obese $\geq$30 (Kg/m^2). The Classification of waist circumference [47] has been used as such: no risk <94 cm (male), <80 cm (female); medium risk 94-101 cm (male), 80-87 (female); high risk >101 cm (male), > 87 cm (female). The Classification of waist to hip ratio [44] has been used as such: no risk <0.90 (male), <0.80 (female); medium risk 0.90-1.0 (male), 0.80-0.85 (female); high risk >1.0 (male), >0. 85 (female).

RESULTS

Table 1 presented sensitivity, specificity and likelihood ratio of different anthropometric and socio-economic lifestyle indicators for pre-hypertension and hypertension among male offspring generation. The BMI (92.5%) and alcohol (91.8%) for pre-hypertension, BMI (92.5%) and waist circumference (82.9%) for hypertension among all indicators have high specificity. The higher sensitivity has been found with physical activity (87.6% for pre-hypertension and hypertension) and WHR (76.3% for pre-hypertension; 66.6% for hypertension). However, positive LR has been found maximum in BMI (1.74) and WHR (1.13) for pre-hypertension and in BMI (6.103) and waist circumference (2.67)) for hypertension. The maximum negative LR has been found for food habits (1.28) and smoking (1.07) for pre-hypertension and exercise (1.463) and alcohol (1.378) for hypertension. However, Youden's index has been found to be highest for food habits (11.3%) and WHR (9%) for pre-hypertension and BMI (38%) and waist circumference (28.4%) for hypertension.

Among female offspring (Table 2), BMI (97.2% for pre-hypertension; 85% for hypertension) and food habits (96.4% for pre-hypertension; 83.3% for hypertension) among all indicators have high specificity. High sensitivity has been found with physical activity (69.2%) and WHR (50%) for pre-hypertension; waist circumference (80%) and physical activity (69.2%) for hypertension. However, positive LR has been found higher in food habits (7.98) and BMI (5.4) for pre-hypertension and in waist circumference (2.72) and BMI (2.667) for hypertension. The largest negative LR has been found for physical activity (3.59) and WHR (3.5) for pre-hypertension and in WHR (5.25) and exercise (1.037) for hypertension. However, Youden's index has been found to be greater for WHR (35.7% for pre-hypertension; 60.7% for hypertension), food habits (24.9% for pre-hypertension) and waist circumference (50.6% for hypertension).

Among male parents (Table 3), waist circumference (57.1% for pre-hypertension and hypertension), exercise (82.3 % for pre-hypertension and 72.5% for hypertension) and smoking (58.7% for pre-hypertension and 74.7% for hypertension) among all indicators have high specificity. High sensitivity has been found with WHR (92% for pre-hypertension; 96.3% for hypertension); waist circumference (63.4%) for pre-hypertension and exercise (82.3%) for hypertension. However, positive LR has been found maximum in waist circumference (1.477 for pre-hypertension; 1.544 for hypertension) and exercise (1.350 for pre-hypertension; 2.992 for hypertension). The higher negative LR has been found for BMI (1.283 for pre-hypertension; 1.948 for hypertension); food habits (1.201) for pre-hypertension and alcohol (1.529)

Table 1: Sensitivity, specificity and likelihood ratio of different anthropometric and socio-economic lifestyle indicators for pre-hypertension and hypertension among male offspring

	Male Offspring (n= 378)									
	Pre-hypertension					Hypertension				
Variables	Sensitivity (95% CI)	Specificity (95% CI)	LR +(95% CI)	LR - (95% CI)	J	Sensitivity (95% CI)	Specificity (95% CI)	LR +(95% CI)	LR -(95% CI)	J
BMI (kg/m^2)	0.130 (0.070-0.224)	0.925 (0.887 -0.952)	1.740 (0.873-3.458)	0.941 (0.866-1.021)	0.055	0.455 (0.181-0.754)	0.925 (0.887-0.952)	6.103 (2.835-13.144)	0.589 (0.343-1.011)	0.380
Waist circumference (cm)	0.176 (0.105-0.277)	0.830 (0.780-0.871)	1.037 (0.612-1.755)	0.992 (0.898-1.097)	0.006	0.455 (0.181-0.754)	0.829 (0.779-0.871)	2.670 (1.330-5.360)	0.657 (0.383-1.129)	0.284
WHR	0.763 (0.594-0.878)	0.327 (0.256-0.406)	1.134 (0.921-1.396)	0.724 (0.399-1.314)	0.090	0.666 (0.310-0.909)	0.327 (0.256-0.406)	0.991 (0.616-1.592)	1.019 (0.394-2.633)	-0.007
Food habits	0.487 (0.421-0.554)	0.400 (0.297-0.512)	0.811 (0.652-1.010)	1.283 (1.092-1.507)	-0.113	0.487 (0.421-0.554)	0.727 (0.393-0.927)	1.785 (0.674-4.729)	0.706 (0.582-0.856)	0.214
Physical activity	0.876 (0.830-0.911)	0.141 (0.078-0.238)	1.020 (0.926-1.123)	0.879 (0.560-1.379)	0.017	0.876 (0.830-0.911)	0.182 (0.032-0.522)	1.071 (0.807-1.419)	0.683 (0.225-2.075)	0.058
Exercise	0.202 (0.158-0.255)	0.765 (0.658-0.847)	0.859 (0.549-1.344)	1.043 (0.977-1.114)	-0.033	0.202 (0.158-0.255)	0.545 (0.246-0.819)	0.445 (0.224-0.884)	1.463 (1.189-1.800)	-0.253
Smoking	0.078 (0.051-0.117)	0.859 (0.762-0.922)	0.553 (0.286-1.069)	1.074 (1.034-1.115)	-0.063	0.078 (0.051-0.117)	0.818 (0.478-0.968)	0.429 (0.115-1.600)	1.127 (1.047-1.213)	-0.104
Alcohol	0.036 (0.018-0.067)	0.918 (0.832-0.963)	0.432 (0.170-1.101)	1.051 (1.025-1.077)	-0.046	0.036 (0.018-0.066)	0.700 (0.354-0.919)	0.119 (0.038-0.366)	1.378 (1.239-1.532)	-0.264

LR+: positive likelihood ratio, LR-: negative likelihood ratio, J: Youden's index [(Sensitivity+Specificity)-1]

Table 2: Sensitivity, specificity and likelihood ratio of different anthropometric and socio-economic lifestyle indicators for pre-hypertension and hypertension among female offspring

	Female Offspring (n=261)									
	Pre-hypertension					Hypertension				
Variables	Sensitivity (95% CI)	Specificity (95% CI)	LR +(95% CI)	LR - (95% CI)	J	Sensitivity (95% CI)	Specificity (95% CI)	LR +(95% CI)	LR -(95% CI)	J
BMI (kg/m^2)	0.15 (0.107-0.206)	0.972 (0.838-0.999)	5.4 (0.762-38.259)	0.874 (0.826-0.926)	0.122	0.4 (0.073-0.830)	0.85 (0.794-0.893)	2.667 (0.871-8.162)	0.706 (0.345-1.446)	0.25
Waist circumference (cm)	0.485 (0.312-0.661)	0.706 (0.630-0.772)	1.648 (1.081-2.513)	0.73 (0.522-1.021)	0.191	0.8 (0.299-0.989)	0.706 (0.630-0.772)	2.72 (1.656-4.468)	0.283 (0.049-1.643)	0.506
WHR	0.5 (0.027-0.973)	0.143 (0.083-0.231)	0.583 (0.146-2.338)	3.5 (0.776-15.779)	-0.357	0.25 (0.013-0.780)	0.143 (0.083-0.231)	0.292 (0.053-1.596)	5.25 (2.644-10.423)	-0.607
Food habits	0.285 (0.228-0.350)	0.964 (0.798-0.998)	7.982 (1.152-55.319)	0.741 (0.680-0.808)	0.249	0.285 (0.228-0.350)	0.833 (0.365-0.991)	1.71 (0.282-10.361)	0.858 (0.739-0.995)	0.118
Physical activity	0.692 (0.626-0.752)	0.086 (0.022-0.242)	0.757 (0.662-0.866)	3.59 (1.621-7.950)	-0.222	0.692 (0.626-0.752)	0.4 (0.073-0.830)	1.154 (0.561-2.373)	0.769 (0.351-1.688)	0.092
Exercise	0.136 (0.095-0.190)	0.857 (0.690-0.946)	0.95 (0.395-2.284)	1.008 (0.948-1.072)	-0.007	0.136 (0.095-0.190)	0.833 (0.365-0.991)	0.814 (0.132-5.026)	1.037 (0.922-1.167)	-0.031

LR+: positive likelihood ratio, LR-: negative likelihood ratio, J: Youden's index [(Sensitivity+Specificity)-1]

Table 3: Sensitivity, specificity and likelihood ratio of different anthropometric and socio-economic lifestyle indicators for pre-hypertension and hypertension among male parents

	Male Parent (n= 439)									
	Pre-hypertension					Hypertension				
Variables	Sensitivity (95% CI)	Specificity (95% CI)	LR +(95% CI)	LR - (95% CI)	J	Sensitivity (95% CI)	Specificity (95% CI)	LR +(95% CI)	LR -(95% CI)	J
BMI (kg/m^2)	0.391 (0.321-0.466)	0.474 (0.399-0.550)	0.744 (0.592-0.936)	1.283 (1.129-1.459)	-0.135	0.391 (0.321-0.466)	0.313 (0.216-0.427)	0.569 (0.451-0.719)	1.948 (1.644-2.308)	-0.296
Waist circumference (cm)	0.634 (0.558-0.705)	0.571 (0.496-0.643)	1.477 (1.208-1.806)	0.64 (0.523-0.785)	0.205	0.663 (0.552-0.759)	0.571 (0.496-0.643)	1.544 (1.233-1.933)	0.59 (0.436-0.801)	0.234
WHR	0.92 (0.867-0.954)	0.158 (0.110-0.220)	1.092 (1.012-1.179)	0.508 (0.290-0.888)	0.078	0.963 (0.887-0.990)	0.158 (0.110-0.220)	1.143 (1.059-1.232)	0.238 (0.074-0.764)	0.121
Food habits	0.609 (0.534-0.679)	0.326 (0.258-0.401)	0.903 (0.773-1.054)	1.201 (0.980-1.472)	-0.065	0.609 (0.534-0.679)	0.275 (0.184-0.388)	0.84 (0.703-1.003)	1.423 (1.114-1.818)	-0.116
Physical activity	0.62 (0.545-0.689)	0.32 (0.253-0.395)	0.911 (0.783-1.061)	1.189 (0.965-1.464)	-0.06	0.62 (0.545-0.689)	0.288 (0.195-0.401)	0.87 (0.727-1.040)	1.323 (1.036-1.691)	-0.092
Exercise	0.239 (0.181-0.309)	0.823 (0.756-0.875)	1.35 (0.896-2.035)	0.925 (0.851-1.005)	0.062	0.823 (0.756-0.875)	0.725 (0.612-0.816)	2.992 (2.082-4.299)	0.244 (0.176-0.339)	0.548
Smoking	0.302 (0.237-0.375)	0.587 (0.510-0.661)	0.731 (0.549-0.972)	1.189 (1.071-1.320)	-0.111	0.302 (0.237-0.375)	0.747 (0.634-0.835)	1.191 (0.768-1.849)	0.935 (0.842-1.038)	0.049
Alcohol	0.335 (0.265-0.414)	0.558 (0.476-0.636)	0.758 (0.574-1.001)	1.192 (1.058-1.026)	-0.107	0.335 (0.265-0.414)	0.435 (0.318-0.559)	0.593 (0.440-0.800)	1.529 (1.321-1.768)	-0.23

LR+: positive likelihood ratio, LR-: negative likelihood ratio, J: Youden's index [(Sensitivity+Specificity)-1]

Table 4: Sensitivity, specificity and likelihood ratio of different anthropometric and socio-economic lifestyle indicators for pre-hypertension and hypertension among female parents

	Female Offspring (n=261)									
	Pre-hypertension					Hypertension				
Variables	Sensitivity (95% CI)	Specificity (95% CI)	LR +(95% CI)	LR - (95% CI)	J	Sensitivity (95% CI)	Specificity (95% CI)	LR +(95% CI)	LR -(95% CI)	J
BMI (kg/m²)	0.72	0.459	1.331	0.609	0.179	0.877	0.459	1.62	0.269	0.336
	(0.629-0.797)	(0.403-0.516)	(1.144-1.549)	(0.453-0.820)		(0.780-0.936)	(0.403-0.516)	(1.422-1.845)	(0.150-0.484)	
Waist circumference (cm)	0.974	0.16	1.159	0.164	0.134	0.988	0.16	1.176	0.077	0.148
	(0.919-0.993)	(0.122-0.207)	(1.095-1.228)	(0.052-0.519)		(0.924-0.999)	(0.122-0.207)	(1.113-1.242)	(0.011-0.559)	
WHR	0.5	0.039	0.52	12.75	-0.461	0.667	0.039	0.694	8.5	-0.294
	(0.027-0.973)	(0.021-0.069)	(0.130-2.081)	(2.726-59.642)		(0.125-0.982)	(0.021-0.069)	(0.312-1.545)	(1.466-49.269)	
Food habits	0.259	0.695	0.851	1.066	-0.046	0.259	0.864	1.911	0.857	0.123
	(0.213-0.312)	(0.602-0.775)	(0.612-1.183)	(0.991-1.146)		(0.213-0.312)	(0.766-0.927)	(1.070-3.413)	(0.800-0.918)	
Physical activity	0.085	0.831	0.504	1.101	-0.084	0.085	0.963	2.307	0.95	0.048
	(0.058-0.123)	(0.748-0.891)	(0.294-0.863)	(1.061-1.143)		(0.058-0.123)	(0.888-0.990)	(0.718-7.415)	(0.917-0.983)	
Exercise	0.177	0.898	1.743	0.916	0.075	0.177	0.84	1.104	0.98	0.017
	(0.138-0.225)	(0.826-0.944)	(0.969-3.132)	(0.869-0.966)		(0.138-0.225)	(0.738-0.908)	(0.636-1.917)	(0.927-1.036)	

LR+: positive likelihood ratio, LR-: negative likelihood ratio, J: Youden's index [(Sensitivity+Specificity)-1]

Table 5: Sensitivity, specificity and likelihood ratio of different anthropometric and socio-economic lifestyle indicators for pre-hypertension and hypertension among male grandparents

	Male Grandparent (n=94)									
	Pre-hypertension					Hypertension				
Variables	Sensitivity (95% CI)	Specificity (95% CI)	LR +(95% CI)	LR - (95% CI)	J	Sensitivity (95% CI)	Specificity (95% CI)	LR +(95% CI)	LR -(95% CI)	J
BMI (kg/m²)	0.417	0.853	2.833	0.684	0.27	0.356	0.853	2.418	0.756	0.209
	(0.165-0.714)	(0.682-0.945)	(0.991-8.100)	(0.420-1.114)		(0.223-0.513)	(0.682-0.945)	(0.983-5.947)	(0.602-0.948)	
Waist circumference (cm)	0.667	0.706	2.267	0.472	0.373	0.417	0.706	1.417	0.826	0.123
	(0.354-0.887)	(0.523-0.843)	(1.175-4.371)	(0.207-1.077)		(0.279-0.567)	(0.523-0.843)	(0.763-2.631)	(0.635-1.075)	
WHR	0.923	0.206	1.162	0.374	0.129	0.917	0.206	1.154	0.405	0.123
	(0.621-0.996)	(0.093-0.384)	(0.922-1.466)	(0.046-3.068)		(0.791-0.973)	(0.093-0.384)	(0.953-1.398)	(0.127-1.292)	
Food habits	0.382	0.417	0.655	1.482	-0.201	0.382	0.375	0.612	1.647	-0.243
	(0.227-0.564)	(0.165-0.714)	(0.345-1.245)	(0.905-2.427)		(0.227-0.564)	(0.243-0.527)	(0.378-0.989)	(1.181-2.297)	
Physical activity	0.324	0.75	1.294	0.902	0.074	0.324	0.646	0.913	1.047	-0.03
	(0.180-0.506)	(0.428-0.933)	(0.433-3.864)	(0.677-1.202)		(0.180-0.506)	(0.494-0.774)	(0.492-1.695)	(0.812-1.351)	
Exercise	0.441	0.667	1.324	0.838	0.108	0.441	0.5	0.882	1.118	-0.059
	(0.276-0.619)	(0.354-0.887)	(0.546-3.207)	(0.573-1.226)		(0.276-0.619)	(0.354-0.646)	(0.550-1.415)	(0.796-1.569)	
Smoking	0.571	0.9	5.714	0.476	0.471	0.571	0.543	1.251	0.789	0.114
	(0.374-0.750)	(0.541-0.995)	(0.866-37.706)	(0.304-0.746)		(0.374-0.750)	(0.392-0.688)	(0.798-1.962)	(0.496-1.254)	
Alcohol	0.259	0.5	0.519	1.481	-0.241	0.259	0.568	0.6	1.305	-0.173
	(0.119-0.466)	(0.174-0.826)	(0.202-1.330)	(0.928-2.366)		(0.119-0.466)	(0.396-0.725)	(0.287-1.252)	(1.003-1.699)	

LR+: positive likelihood ratio, LR-: negative likelihood ratio, J: Youden's index [(Sensitivity+Specificity)-1]

Table 6: Sensitivity, specificity and likelihood ratio of different anthropometric and socio-economic life style indicators for pre-hypertension and hypertension among female grandparents

	Female Offspring (n=261)									
	Pre-hypertension					Hypertension				
Variables	Sensitivity (95% CI)	Specificity (95% CI)	LR +(95% CI)	LR - (95% CI)	J	Sensitivity (95% CI)	Specificity (95% CI)	LR +(95% CI)	LR -(95% CI)	J
BMI (kg/m²)	0.5	0.444	0.9	1.125	-0.056	0.628	0.444	1.131	0.837	0.072
	(0.304-0.696)	(0.283-0.617)	(0.555-1.459)	(0.716-1.769)		(0.511-0.694)	(0.283-0.617)	(0.806-1.586)	(0.586-1.195)	
Waist circumference (cm)	0.923	0.139	1.072	0.554	0.062	0.91	0.139	1.057	0.646	-0.051
	(0.734-0.987)	(0.052-0.303)	(0.903-1.273)	(0.104-2.939)		(0.818-0.960)	(0.052-0.303)	(0.911-1.226)	(0.227-1.836)	
WHR	0.037	0.026	0.038	36.592	-0.937	0.974	0.026	1.001	0.974	0
	(0.002-0.209)	(0.001-0.154)	(0.006-0.260)	(5.040-265.656)		(0.902-0.996)	(0.001-0.154)	(0.939-1.066)	(0.037-25.801)	
Food habits	0.167	0.923	2.167	0.903	0.09	0.167	0.833	1	1	0
	(0.070-0.335)	(0.734-0.987)	(0.474-9.894)	(0.775-1.051)		(0.070-0.335)	(0.728-0.905)	(0.414-2.418)	(0.860-1.163)	
Physical activity	0.028	0.963	0.75	1.01	-0.009	0.028	0.936	0.433	1.039	-0.036
	(0.001-0.162)	(0.791-0.998)	(0.049-11.460	(0.953-1.070)		(0.001-0.162)	(0.850-0.976)	(0.053-3.576)	(0.981-1.100)	
Exercise	0.222	0.769	0.963	1.011	-0.009	0.222	0.718	0.788	1.083	-0.06
	(0.107-0.396)	(0.559-0.902)	(0.380-2.442)	(0.830-1.232)		(0.107-0.396)	(0.603-0.811)	(0.389-1.596)	(0.901-1.303)	

LR+: positive likelihood ratio, LR-: negative likelihood ratio, J: Youden's index [(Sensitivity+Specificity)-1] for hypertension. However, Youden's index has been found to be conclusively high for waist circumference (20.5%) and BMI (13.5%) for pre-hypertension and exercise (54.8%) and BMI (54.8%) for hypertension.

Among female parents (Table 4), physical activity (83.1% for pre-hypertension and 96.3% for hypertension) and exercise (89.8%) for pre-hypertension and food habits (86.4%) for hypertension among all indicators have high specificity. High sensitivity has been found with waist circumference (97.4% for pre-hypertension; 98.8% for hypertension) and BMI (72% for pre-hypertension and 87.7% for hypertension). However, positive LR has been found maximum in exercise (1.743) and BMI (1.331) for pre-hypertension and physical activity (2.307) and food habits (1.911) for hypertension. The maximum negative LR has been found for WHR (12.75 for pre-hypertension; 8.5 for hypertension); physical activity (1.101) for pre-hypertension and exercise (0.98) for hypertension. However, Youden's index has been found to be highest for WHR (46.1%) and BMI (17.9%) for pre-hypertension and BMI (33.6%) and WHR (29.4%) for hypertension.

Among male grandparents (Table 5), BMI (85.3% for pre-hypertension and hypertension), smoking (90%) for pre-hypertension and waist circumference (70.6%) for hypertension among all indicators have high specificity. High sensitivity has been found with WHR (92.3% for pre-hypertension; 91.7% for hypertension), waist circumference (66.7% for pre-hypertension) and smoking (57.1% for pre-hypertension and hypertension). However positive LR has been found higher in BMI (2.833 for pre-hypertension; 2.418 for hypertension) and smoking (5.714 for pre-hypertension; 1.251 for hypertension) and waist circumference (1.417 for hypertension). The maximum negative LR have been found for food habits (1.482) and alcohol (1.481) for pre-hypertension and food habits (1.647) and alcohol (1.305) for hypertension. However, Youden's index has been found to be larger for smoking (47.1%) and waist circumference (37.3%) for pre-hypertension and food habits (24.3%) and BMI (20.9%) for hypertension.

Among female grandparents (Table 6), physical activity (96.3% for pre-hypertension and 93.6% for hypertension) and food habits (92.3% for pre-hypertension and 83.3% for hypertension) among all indicators have high specificity. High sensitivity has been found with waist circumference (92.3%) and BMI (50%) for pre-hypertension, WHR (97.4%) and waist circumference (91%) for hypertension. However, positive LR has been found maximum in food habits (2.16) and waist circumference (1.07) for pre-hypertension, BMI (1.131) and waist circumference (1.057) for hypertension. The maximum negative LR has been found for WHR (36.59) and BMI (1.125) for pre-hypertension and exercise (1.08) and physical activity (1.03) for hypertension. Youden's index has been found to be higher for WHR (93.7%) and food habits (9%) for pre-hypertension and BMI (7.2%) and exercise (6%) for hypertension.

DISCUSSION

The cut-off values for different anthropometric and socioeconomic lifestyle indicators for CVD differ in different countries and it is highly race and ethnic dependent. There is no global standard for these indicators [48-53]. Therefore, it is important to develop simple and effective anthropometric/socio-economic lifestyle indicators for the screening of CVD risk subjects in different populations until reaching internationally accepted measures. The present study has attempted to evaluate comparative three anthropometric indicators (BMI, waist circumference and WHR) and five socio-economic lifestyle factors (food habits, physical activity, exercise, smoking and alcohol) to identify the most distinctive indicators for pre-hypertension and hypertension for a specific community in Punjab. No such study has been performed in this region based on sensitivity, specificity and likelihood ratio with three generations. Therefore, with the lack of data on this subject unfortunately, the present study was unable to be compared with other studies.

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 which 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.

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 physical activity and WHR for pre-hypertension among male offspring and female offspring and for hypertension in male offspring; waist circumference and physical activity for female offspring were better indicators for CVD risk factors in comparison to other anthropometric and socioeconomic lifestlyle factors. The values of positive likelihood ratio (LR+) and Youden's index were also found to be maximum for BMI, WHR and food habits for these generations. This showed these indicators have significant positive association with the occurrence of CVD risk factors. Although, from the present results it was observed that BMI, waist circumference and WHR clearly have higher sensitivity but, food habit also has significant contribution for the occurrence of CVD in these generations.

Among male parental generation the waist circumference and WHR for pre-hypertension; WHR and exercise for hypertension and waist circumference and BMI for pre-hypertension and hypertension among female parental generation were better indicators to assess CVD risk factors. High sensitivity suggested that waist circumference and BMI performed well in female parental generations. The present analysis proposed combined BMI and waist circumference would be the better predictor for both males and females, especially in female generations. BMI, which was most widely used indicator for total adiposity, cannot distinguish visceral fat from muscle mass or peripheral from the central fat and also its limitations were recognized by its change according to age and its dependency on ethnic groups [54-57]. Therefore, waist circumference has shown to be highly correlated with the amount of visceral body fat measured by computer tomography [51, 58] and majority of the current studies suggested that waist circumference is the better indicator for CVD risk factors than BMI and WHR [52, 59]. Furthermore, it has been 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 this measurement. Some studies measured waist circumference at the level of umbilicus and some at WHO standard definition which is half way between iliac crest and lower rib. However, waist circumference cut-off values differ between genders and ethnic groups.

The results of the analysis of present data suggested waist circumference for almost all the generations with average high sensitivity upto 97% and 99% for female parental generation in the prediction of pre-hypertension and hypertension. BMI and WHR may be considered with respect to sensitivity in the second level of best predictor for both pre-hypertension and hypertension. If we compare positive likelihood ratio of the three generations with respect to all the indicators then it was observed that LR+ value of BMI have been consistently higher among all the generations as compared to waist circumference and WHR. Therefore, it is suggested that combination of waist circumference and BMI would be the better predictor to assess CVD risk. Several studies have analyzed the association between CVD risk factors and other anthropometric factors based upon sensitivity, specificity and likelihood ratio analysis. Most of the studies [52] including present one supported the idea that waist circumference and BMI are the best anthropometric indices of CVD risk factors compared to other indicators. However, due to different reported cut-off values across different ethnic population groups, future research and study would be required until reaching an internationally acceptable simple and appropriate measure that could be easily and efficiently used in the clinical and epidemiological research. It is because none of the three anthropometric indicators (BMI/waist-circumference/ WHR) and six socioeconomic lifestyle indicators (food habits/physical activity/exercise/smoking/alcohol) studied here consistently yielded a higher sensitivity or specificity to predict the pre-hypertension and hypertension. Therefore, the other criterion may need to be used to choose the criterion value. This was also supported by the result from the report of 'Workshop on Use of Anthropometry for Public Health and Primary Health Care' [60, 61] which emphasized that measurement's error may be compounded in a ratio such as WHR and BMI and the interpretation of these ratios in patho-physiologic terms is difficult. Sometimes, BMI is also criticized because it is calculated by the formula that may be difficult to explain to the patients and even to some clinicians. Despite these facts the reports of that workshop pointed out waist circumference alone could be the reasonable indicator to assess the CVD risk factors. However, the results presented here support the use of combined association of waist circumference and BMI for the prediction of CVD risk.

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