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ORIGINAL ARTICLE

Screening score for early detection of cardio-metabolic risk in Indian adults

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Abstract
Objectives To develop and to evaluate efficacy of screening score for early detection of cardio-metabolic risk (CMR) in adults.
Methods Cross-sectional data on anthropometry, lipids, sugar levels, diet, and physical activity were collected on 720 adults (361 men, 35–50 year) using standardized techniques. Screening score was developed using regression analysis—cluster of risk conditions (blood pressure, lipids, and sugar levels) was dependent variable against age, sex, waist, diet, and physical activity as independent variables. Odd ratios were added to obtain final score and receiver-operating characteristic (ROC) curves were constructed to identify cut-off value of CMR score.
Results Mean age and BMI were 42.7 ± 9.4 years and 25.7 ± 5.0 kg/m^2. Analysis showed age, male sex, waist, lack of fruits, green leafy vegetables, and lack of physical activity were independent predictors for increased CMR ($p < 0.05$). Total score ranged from 0 to 20. Area under the curve for ROC was 0.728 [95% (CI) 0.67–0.78]. Criterion value >8 had sensitivity (76%) and specificity (56%) for screening cases with CMR.
Conclusions Screening score is a pragmatic way of identifying individuals with CMR without performing biochemical tests. Cost-effective community screening programs may be planned.

Keywords Screening · Cardio-metabolic risk · Adults · Early detection · India

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Introduction

Cardiovascular disease (CVD) is the leading cause of death and disability worldwide (Murray and Lopez 1997). According to recent statistics, incidences of CVD-related death and disability in low-income countries have grown at an alarming pace. In India, there has been a drastic increase in the prevalence of CVD over the past two decades so much, so that CVD accounts for 24% of all deaths among adults aged 25–69 years (SRS 2007). Studies have reported India to be alone burdened with approximately 25% of CVD-related deaths and would serve as a home to more than 50% of the patients with heart ailments worldwide within the next 15 years (Gupta et al. 2008). Higher predisposition to metabolic syndrome characterized by insulin resistance, hyperinsulinemia, type 2 diabetes, impaired glucose tolerance, central obesity, hypertension, and dyslipidemia is another important reason for increase incidence of CVD in Indian population (Forouhi and Sattar 2006). Furthermore, high prevalence of excess body fat, dyslipidemia, and hypertension beginning at a young age have consistently been recorded in Asian Indians irrespective of their geographic locations (Misra et al. 2004; Yajnik et al. 2002; Repas 2007). These data warrant urgent screening of risk factors to plan primary prevention strategies. A well-established primary prevention strategy is to use prediction rules or risk scores to identify those at higher risk to target specific behavioral or drug interventions.

Evidence shows that the current screening procedures using blood estimations are regarded as invasive, relatively expensive, and time-consuming, and thus not appropriate for large population screening programs (Diabetes Research group 2003). A simple, non-invasive tool, such as a risk scoring system based on a questionnaire and simple measurement of anthropometric indices or blood pressure, would be practical for use by primary healthcare workers in identification of those at risk.

Several risk scores have been developed worldwide (Ramachandran et al. 2005; Gray et al. 2010; Riaz et al. 2012). Most of these risk scores have included age, sex, hypertension, smoking status, diabetes mellitus, lipid values, or family history (Wilson et al. 1998 and Ferrario et al. 2005), and are largely based on blood estimations (Carroll et al. 2014). Unfortunately, less attention has been directed at developing risk scores that would be easier to use in clinical practice/community settings without loss of predictive discrimination. Thus, there is need for scores that could comprise of combination of questions and measurements such as waist circumference, weight, height, diet, etc.

Researchers from the Framingham Heart Study created several algorithms to facilitate the assessment of risk in individual patients using biological and lifestyle factors (Wilson et al. 1998). The Framingham risk score has been utilised effectively to portend major coronary heart disease CHD events across ethnic groups and races. However, despite the applicability of this tool, it is inefficient to evaluate some key factors, which are influenced by dietary and metabolic patterns modification (D'Agostino et al. 2001). Caucasians studies have proposed questionnaire-based screening scores using anthropometric, demographic, and behavioral factors; however, most of these scores are largely for the assessment of risk of diabetes (Lindstrom and Tuomilehto 2003) and do not address other cardio-metabolic risk factors such as elevated lipid concentration, hypertension, diet, physical activity, etc. Increasing prevalence of cardiovascular risk factors further necessitates need for a cardio-metabolic risk score.

Since many risk factors are common for cardiovascular disease and diabetes mellitus a score encompassing both would be of great value in screening for CVD. Therefore, there is a need to design a simplistic cost-effective questionnaire-based screening score for the early identification of cardio-metabolic risk in Indian adults. Thus, the objectives of the study were to develop a screening score for early detection of cardio-metabolic risk in Indian adults and to evaluate efficacy of the scoring system in identifying cases with or without cardio-metabolic risk.

Methods

In a cross-sectional study, a sample of apparently healthy adults (total 720; 361 men and 359 women) of age between 35 and 50 years was selected from routine health checks from hospitals and housing societies and residential areas using random sample method in Pune city, India during 2014–2015. Inclusion criteria: participant with age between 35 and 50 years is non-diabetic and not suffering from any established cardiovascular disease. From the study regions, approximately 15–20 sites comprising of housing societies, residential areas, schools (for enrolling teachers), and corporate offices were approached. From these sites, randomly, a total of 2500 adults were approached. Eighteen hundred provided consent for blood analysis and taken part in the study. Thus, a total of 1000 apparently healthy adults with age between 35 and 50 years satisfied inclusion criteria. Out of these, 720 adults were selected by computerized random number generation. With the sample size of 700, overall power was 80% at 5% level of significance to detect difference of more than 10% between the groups (presence and absence of risk factors) based on SD of the score observed from the previous studies (Saaristo et al. 2005). A written informed consent was obtained from all the participants prior to commencement of the study. The research protocol was approved by the institutional ethics committee.

In addition, set of 60 independent adults from routine health checks and tertiary care hospitals were enrolled randomly, so that the individuals were distributed over the whole range of risk categories (with or without CVD risk complications) at the end of the study for validation of the score. Efficacy of the score was validated using data regarding cardio-metabolic risk factors like biochemical estimations (lipid profile and blood glucose), anthropometry (weight, height, waist, and hip), and other clinical findings (blood pressure and history of ailments if any) on these 60 adults. All the cases were compared for their cardio-metabolic profile across derived scores and laboratory and clinical findings. A written informed consent was obtained from participants prior to commencement of the study. The research protocol was approved by the institutional ethics committee.

Height was measured to the nearest 0.1 cm. (Leicester height meter, UK, range 60–207 cm). Weight was measured on an electronic digital scale to the nearest 0.1 kg. Waist circumference was measured with an inelastic tape to the nearest 0.1 cm measuring at the end of normal expiration from the narrowest point between the lower borders of the rib cage and the iliac crest. Hip circumference was measured as maximal circumference at the level of the trochanters. Body mass index [BMI] was computed using the following formula: BMI = Weight (kg)/Height $(m)^2$. Using Asian Indian cutoffs, subjects were classified as overweight and obese (Misra 2003). Biochemical estimations for total lipid profile and glucose concentration were performed using kit method at the Biochemistry Unit of the hospital. All tests were performed on a fasting sample. Blood pressure was measured in the left arm after 10 min of rest with the subject lying down quietly using a mercury-column sphygmomanometer.

Daily food habits were assessed through administering a standardized semi-quantitative Food Frequency Questionnaire (FFQ) by interview method (Chiplonkar et al. 2001). Test–retest reliability of these measures was estimated on a sample of 30 adults prior to data collection (intra-class correlation coefficient, $r = 0.93$, $p < 0.05$). Daily physical activity was assessed using a validated structured questionnaire (reliability coefficient = 0.89) (Chiplonkar et al. 2004). Type of exercise and total time spent in daily exercise were recorded for all participants.

Family history of blood pressure, cardiovascular diseases, diabetes mellitus, and lifestyle factors like smoking and consumption of alcohol were recorded using a questionnaire.

Development of cardio-metabolic risk score:

1. The presence of cardio-metabolic risk was decided based upon manifestation of any three or more metabolic abnormalities; such as high triglycerides (>150 mg/dl), low HDL (<40 mg/dl), high glucose (>110 g/dl), and high blood pressure (>130/85). This cluster of conditions was treated as the dependent variable.
2. Lifestyle and demographic factors, namely, age, sex, waist circumference, daily physical activity, consumption of unhealthy foods (fried/junk foods), and intake of fruits and vegetables were used as independent variables for identifying cardio-metabolic risk.
3. Univariate models were used to test the significance for each independent factor.
4. Independent variables that emerged with significance levels below 0.1 were analyzed. Logistic regression model was used to compute odds ratios for the significant independent variables considering the collinearity amongst the independent variables for cardio-metabolic risk.
5. Odds ratios of significant risk factors were then used to assign a score value for each significant variable, and finally, the composite cardio-metabolic risk score was calculated. A cutoff for total CMR was obtained using receiver-operating curve (ROC) analysis.

Analyses were performed using SPSS software for Windows (version 11.0, 2001, SPSS Inc, Chicago, IL). Prior to the statistical analyses, all the study parameters were tested for normality using one-sample Kolmogorov–Smirnov test. Descriptive statistics including mean and SD or SE for continuous variables were calculated. Differences in means of men and women were tested using Student‘s *t* test. Binary logistic regression model was fitted; adjusted odds ratio (OR) was calculated as the antilogarithm of the beta coefficient of the logistic regression of the outcome events. Receiver-operating characteristic (ROC) curve is a plot of the true positive rate (sensitivity) against the false positive rate (1 specificity), across a range of values from the diagnostic test. The decision threshold is the criterion value with the highest accuracy that maximizes the sum of the sensitivity and specificity. ROC analysis was utilised to determine cut-off values that minimize the total number of misclassification errors and to provide an evaluation of the global performance of the cardio-metabolic risk score to discriminate between those with or without risk factors. Statistical significance for differences was set at $p < 0.05$.

Results

Mean age of participants was 42.7 ± 9.4 years. Average age, weight, height, waist circumference, and systolic and diastolic pressure were significantly higher in men as compared to women, whereas body mass index and hip circumference were higher in women than in men ($p < 0.05$). Average body mass index (BMI) was higher than the Asian cutoff of 25 in 44.7% and higher than 28 in 29.8% both in men and women, respectively, indicating higher percentage of overweight and obesity (Table 1).

Thirty-two percent of the participants reported family history of hypertension followed by 23.2% with diabetes mellitus and only 10.7% reported family history of CVD in the present study. Small percentage of the study population reported habit of smoking, chewing tobacco, and alcohol consumption (5.4, 8, and 13.8%).

Mean lipid concentration (total cholesterol and triglycerides) and blood glucose were significantly higher and HDL cholesterol significantly lowers in men than women ($p < 0.05$). As per Asian cutoff of lipid levels, hypertriglyceridemia (>150 mg/dl) was observed in 13.4% low HDL cholesterol (<40 mg/dl) in 22.3% and high total cholesterol (>200 mg/dl) in 24.6% of the participants, respectively, indicating almost one-fourth of the participants with abnormal lipid concentrations. Daily physical activity was recorded using 24-h standardized activity questionnaire. Total exercise time included time spent in walking, jogging, playing sport, or in gym. Median time spent in daily physical activity was 30 min. As per the

Table 1 General characteristics of the study participants, India (2014–2015)

S. no.	Parameters	Men ($n = 361$)	Women ($n = 356$)	Total ($n = 717$)
1	Age (years)	44.2 ± 8.7*	40.9 ± 9.8	42.7 ± 9.4
2	Weight (kg)	66.9 ± 20.1*	59.8 ± 16.7	63.0 ± 19.3
3	Height (cm)	166.4 ± 9.0*	154.4 ± 8.1	160.4 ± 10.4
4	Body Mass Index (kg/m^2)	25.5 ± 4.8	26.1 ± 5.3*	25.8 ± 5.0
4	Waist (cm)	90.7 ± 11.9*	88.2 ± 10.8	89.4 ± 11.4
5	Hip (cm)	97.5 ± 10.4	99.4 ± 10.4*	98.5 ± 10.5
6	Systolic blood pressure (mmHg)	126.4 ± 13.6*	118.9 ± 14.2	122.5 ± 14.4
7	Diastolic blood pressure (mmHg)	83.8 ± 10.8*	79.4 ± 11.3	81.5 ± 11.3
8	Total cholesterol (mg/dl)	181.2 ± 36.8*	176.4 ± 37.1	178.9 ± 37.0
9	Triglycerides (mg/dl)	132.0 ± 83.9*	95.9 ± 59.9	117.9 ± 87.9
10	HDL cholesterol (mg/dl)	42.4 ± 10.0	48.7 ± 10.6*	45.4 ± 10.8
11	LDL cholesterol (mg/dl)	111.7 ± 33.5	107.5 ± 32.2	109.7 ± 32.9
12	Blood glucose level (g/dl)	103.6 ± 37.7*	97.7 ± 33.8	100.7 ± 35.9
13	Total physical activity (min)	30 (25)	30 (30)	30 (45)

All the values are presented as mean ± SD

* $p < 0.05$. Physical activity is expressed as median inter-quartile range

CDC guidelines, time spent in activity was further divided into categories as 30–60 min and more than or equal to 60 min. Almost half (43.4%) of the participants reported no physical activity in terms of exercise. Remaining 41.7% reported 30–60 min of exercise and in only 15%, exercise was recorded for 60 or more minutes.

Diet data on various food groups like milk and milk products, legumes and sprouts, fruits, green leafy vegetable and salads, junk food, and bakery items was recorded among the study participants using food frequency questionnaire. Figure 1 illustrates percentage of participants with frequency of different food groups. Furthermore, the frequency was divided into three groups namely, daily, more frequently (once or twice a week) and less frequently (once or twice a month). Almost half of the participants reported daily intake of healthy food groups like milk, GLVs and salads (44.8, 50.1, and 45.5%), whereas daily intake of fruits and sprouts was stated by only 15 and 26.6% of the participants. Among unhealthy food group, intake of bakery on daily basis was reported by only 20% of the participants, whereas 25% participants stated more frequent intake of fried and junk food (Fig. 1).

Cardio-metabolic risk score was developed using logistic regression analysis; cluster of risk conditions

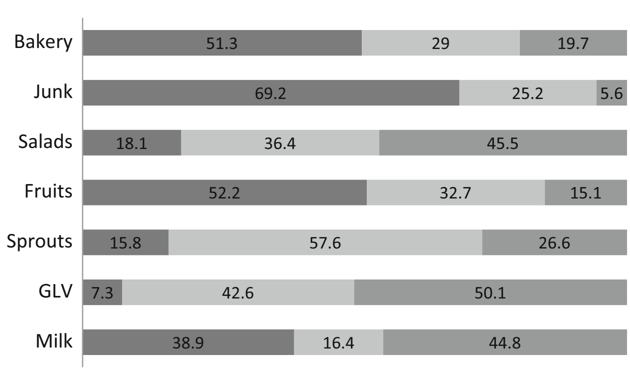

Fig. 1 Percentage of participants with intake of food groups, India (2014–2015). *Grey* daily, *light grey* less frequently, and *dark grey* more frequently

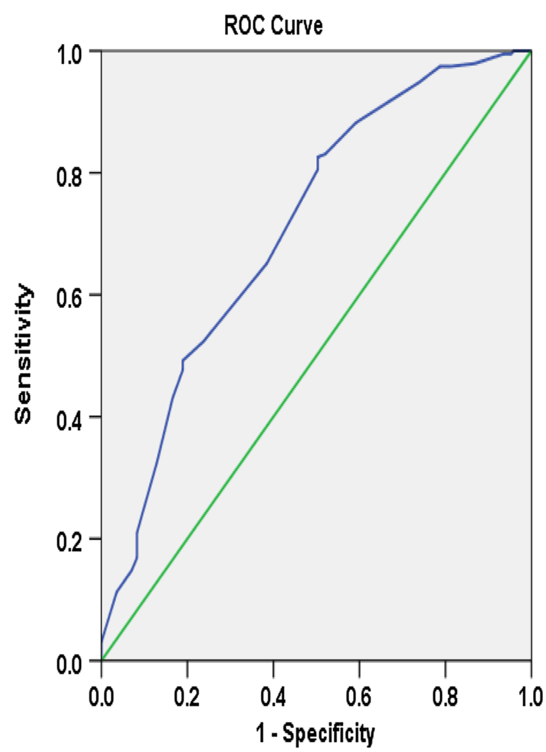

Fig. 2 Receiver-operating characteristic curve for identification of risk, India (2014–2015)

Table 2 Logistic regression model to develop cardio-metabolic risk score, India (2014–2015)

S. no.	Risk factors	Odds ratio (OR)	Score
1	Age groups		
	>45 years	3.2 (1.5–6.7)*	3
	35–45 years	2.2 (1.0–4.6)*	2
	<35 years		
2	Waist circumference		
	High adiposity	3.1 (1.7–5.8)*	3
	Normal		
3	Sex		
	Males	5.7 (3.2–9.4)*	6
	Females		
4	Physical activity		
	No activity	1.8 (0.8–3.9)*	2
	30–60 min	1.4 (0.6–2.8) NS	
	>60 min		
5	Fruits intake		
	Less frequently	1.9 (0.9–3.9)*	2
	More frequently	1.0 (0.5–2.0) NS	
	Daily		
6	Green leafy vegetables		
	Less frequently	1.9 (0.6–5.3)*	2
	More frequently	0.8 (0.4–1.4) NS	
	Daily		

NS not significant

* $p < 0.05$

(blood pressure, lipids, and sugar levels) was used as the dependent variable against age, sex, abdominal obesity (waist circumference), diet, and physical activity as independent risk factors. The multivariate binary logistic regression analysis results showed age, male sex, waist circumference, and less intake of fruits and green leafy vegetables and lack of physical activity as independent predictors for increased cardio-metabolic risk ($p < 0.05$) (Table 2).

Odds ratios were then added so as to obtain final score. The total cardio-metabolic score ranges from 0 to 20. CMR scores were computed for each individual using his/her data regarding age, waist, diet, activity, etc. Receiver-operating characteristic [ROC] curve was constructed to identify the optimum value of score for detecting cardio-metabolic risk. Area under the curve for the ROCs was 0.728 [95% confidence interval (CI) 0.67–0.78]. A criterion value >8 had the optimum sensitivity of 76% and specificity 56% for screening cases with cardio-metabolic risk (Fig. 2).

Furthermore, this score was validated on a subset of 60 independent adults, using the cutoff values of 8; positive predictive value (PPV) of the score was found to be 78% which shows true positive cases with risk. On the other hand, negative predictive value (NPV) was 60% which shows true negative cases. All the cases were matched for their derived scores and laboratory/clinical findings. The PPV gives correct classification of the cases with risk without biochemical tests thus, showing efficacy of the score.

Discussion

High prevalence of obesity and dyslipidemia was observed in the present study. Majority of the participants reported no physical activity and lesser intake of fruits, leafy vegetables, and sprouts indicating inadequate activity and dietary practices. Though the physical activity and dietary intake of fruits and leafy vegetables were self-reported, care was taken for the accuracy and reliability of the data through personal interview using validated questionnaires and use of standard measures for portion sizes. Age, male sex, abdominal adiposity, lack of physical activity, and lesser intakes of green leafy vegetables and fruits were independent predictors for increased cardio-metabolic risk. Screening score was developed and it ranged between 0 and 20 with optimum cutoff of 8 for predicting cardio-metabolic risk. Efficacy of the developed CMR score was demonstrated on an independent sample of 60 adults.

Recent reports have shown that CVD can be prevented in high-risk subjects by lifestyle intervention (Maruthur et al. 2009). Therefore, a strong argument exists in the favor of screening for subjects who are at increased risk of CVD. Various studies in the west have derived scores based on anthropometric, demographic, and behavioral factors, to detect undiagnosed diabetes (Glumer et al. 2004; Mohan et al. 2005). However, there are very few studies on cardio-metabolic risk score especially in adults (Raiko Juho et al. 2010; Carroll et al. 2014). The present study is, to the best of our knowledge, the first of its kind to derive a score for screening of CMR in Indian adults. As there are ethnic differences in risk factors, it becomes necessary to determine ethnic specific scores. The entire population in the present study belongs to the same ethnic and socioeconomic group; therefore, the data are representative and could be applicable to Indian population.

Periodic screening for risk factors allows health professionals early identification of high-risk individuals. Some previous studies have used comprehensive screening scores for cardiovascular risk factors in adults using validated algorithms such as Framingham score or Reynolds score (Raiko Juho et al. 2010). In recent study by Carroll et al. in Australian adults, authors have constructed two continuous clinical indices of cardio-metabolic risk for CVD and type 2 diabetes risk. Barden et al. (2013)

constructed cardio-metabolic risk score in pregnant women for assessment of type 2 diabetes. In a multi-centric follow-up study in young Finns, different risk scores such as PROCAM, SCORE (Systematic Coronary Risk Evaluation), etc. were used and have different algorithms for males and females (Raiko Juho et al. 2010).

One of the main advantages of our study lies in the fact that it includes non-invasive variables, whereas previously reported study scores (as mentioned above) required blood estimations for predicting cardio-metabolic risk. The significant predictors in the present study were age, male sex, waist circumference, lack of physical activity, and less intake of fruits and green leafy vegetables. There are studies which have used both body mass index and waist to hip ratio in the same model (Bhowmik et al. 2015), but since BMI and waist circumference were strongly correlated, we have used waist circumference over BMI. Physical activity (Lynch et al. 2005), the quality and quantity of dietary fat, and the intake of fiber (Hu et al. 2001) have been demonstrated to modify risk of CVD. We included in our prediction model, questions on physical activity, and consumption of fruits and leafy vegetables, and found them to be significant predictors. Some western studies have also used questions on fruit or vegetable consumption (Lindstrom and Tuomilehto 2003; Glumer et al. 2004; Spijkerman et al. 2004) for deriving risk scores. On the contrary, due to difficulties in standardization of food portions across different cultural and socioeconomic groups, some studies have decided not to use questions on diet (Mohan et al. 2005). Majority of these studies were on a diabetes score, so we could not compare our findings with them (Lindstrom and Tuomilehto 2003; Glumer et al. 2004; Bhowmik et al. 2015).

Despite of the fact that family history of diabetes and hypertension reflects the genetic predisposition for the disease and is known to be an important marker for increased risk of CVD (Kaur 2014), it was not a significant predictor in the present study. The underlying reason could be the fact that there may have been some underreporting of data on the same.

In the current study, CMR score values were derived from odds ratio of logistic model. Addition of odds ratios or their expansions is a precise method that has been used in present analysis. Studies have used different methods for development of the score. Authors have multiplied each coefficient by an arbitrary factor, and the score number was rounded to the nearest digit before the sum of odds ratio (Bhowmik et al. 2015). Mohan et al. have rounded off the risk score to the nearest 5 and then doubled the same to bring the maximum possible score to 100.

The usefulness of risk prediction tools is generally assessed based on their sensitivity, specificity and ROC curves. The risk model in the present study showed good sensitivity (76%) and moderate specificity (56%). Validation model also showed PPV of 76% and NPV of 60% for predicting individuals with CMRs with a cutoff of risk score >8. We have found that individuals with a risk score between 0 and 8 have low probability of cardio-metabolic risk. This way of selecting individuals will help to reduce the overall laboratory cost and thereby it could be cost-effective method for identifying individuals with CMR risk. Other cross-sectional and prospective studies have reported PPVs between 14 and 20% for diabetes risk scores. We have found a reasonable performance in predicting CMR with an area under the curve (AUC) of 0.72 which is consistent with Australian study (0.72), SCORE (0.72), PROCAM (0.71), and Reynolds score (0.72) for cardiovascular risk assessment in adults (Carroll et al. 2014; Raiko Juho et al. 2010).

In conclusion, we present here a risk score based on age, sex, abdominal adiposity, diet, and physical activity for identifying individuals at cardio-metabolic risk. This sure may be a practical way of identifying individuals at high risk of CVD without performing biochemical tests, thereby possibly minimizing cost of screening. Furthermore, use of such a risk score would be of great help in developing countries like India where there is a marked explosion of diabetes, hypertension, and high cholesterol. One of the limitations in the present study was that the findings are based on a cross-sectional data which needs further validation in prospective studies.

Finally, we propose that individual with score of 8 or above should be further investigated for definitive diagnosis of cardio-metabolic problems and also for appropriate management.

Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

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