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Use of Risk Scores for Prediction of Type 2 Diabetes Mellitus: A Systematic Review.

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ABSTRACT

The prevalence of noncommunicable diseases, particularly diabetes mellitus, is rapidly increasing worldwide, and India is no exception. In the era of epidemiological transition, the need for prognostic models like the diabetes risk score is noteworthy. The various risk scores available at present include the Indian Diabetes Risk Score (IDRS), the American Diabetes Association (ADA) Risk Score, the Finish Diabetes Risk Score, and the Chinese Diabetes Risk Score. The present study was conducted with the primary objective of reviewing and evaluating the literature available on diabetic scores and models. In the present research work, published original articles based on diabetes risk scores and models were collected. The collected articles were scrutinized, and the relevant articles were included in the study. Maximum articles on development of risk score on diabetes mellitus were published in China and USA. The most common used risk parameters in the development of risk score are Age, parental history of diabetes, body mass index, waist circumference, gender, history of hypertension and physical activity etc. Much work has been done to develop a diabetes risk score, whereas all the risk factors were not considered by the majority of risk scores, such as stress level, smoking, cardiovascular disease, diet, waist hip ratio, neck circumference, tobacco and alcohol consumption etc. More extensive score development can be done by considering local multiple risk factors depending upon genotype, phenotype and ethnic variations.

Keywords: Diabetes, Risk Score, Prognostic Models.

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INTRODUCTION

Diabetes is heterogenous group of metabolic disease characterized by hyperglycemia and altered metabolism of carbohydrates, lipids and proteins. It occurs due to total or subtotal deficiency of insulin along with components of insulin resistance. The prevalence of diabetes mellitus is rising rapidly throughout the world, and India is no exception. The International Diabetes Federation reported that 537 million adults (20–79 years old) are living with diabetes, or 1 in 10. This number is predicted to rise to 643 million by 2030 and 783 million by 2045 [1]. This represents approximately 8.8% of the world's adult population living with T2DM. Diabetes is responsible for 6.7 million deaths in 2021—1 in every 5 seconds[1]. The prevalence of diabetes has significantly risen in recent decades in India, which varies in rural and urban parts of the country. Type 2 diabetes is the most common type of diabetes in India. The burden of diabetes is rising rapidly in India and throughout the world. The prevalence of diabetes in India has risen from 7.1% in 2009 to 8.9% in 2019 [2]. India is referred to as the "Diabetes Capital of the World" due to its increased prevalence of diabetes [3]. Undiagnosed diabetes is the major cause of chronic conditions. Some studies have reported that the prevalence of undiagnosed diabetes is more than 50% in India, whereas more than 75% of people around the world live with undiagnosed diabetes [2, 4]. In India, an estimated 77 million people above the age of 18 are suffering from diabetes (type 2), and nearly 25 million are prediabetics (at a higher risk of developing diabetes in the near future). Indian Council for Medical Research ICMR-INDIAB study reported that more than 50% of people in India are unaware of their diabetic status [5].

Diabetes risk scores and models identify the risk factors as well as the risk population for diabetes mellitus. The accuracy of risk scores and models depends on the completeness of the demographic and clinical data of the target population. The Diabetes Risk Score is a simple, fast, inexpensive, noninvasive, and reliable tool to identify individuals at high risk for type 2 diabetes. Most of the risk scores consider age, diabetes history in the family, physical activity, BMI, abdominal obesity, diet pattern, etc. as risk parameters for the development of a diabetes risk score. Smoking, stress level, use of steroids, and hypertension were not commonly used risk parameters for the derivation of the diabetes risk score. The very first diabetes risk score was published in 1993 in the USA, and the latest diabetes risk score was published in 2021.

There are several risk scores available in the literature that consider different risk parameters. The accuracy of these risk scores depends on demographic, anthropometric, and clinical data, which vary for different populations. The popular risk scores available at present include Indian Diabetes Risk Score (IDRS), American Diabetes Association (ADA) Risk Score, Finish Diabetes Risk Score, Canadian Risk Score, and Chinese Diabetes Risk Score. This study was conducted with the primary goal of reviewing and evaluating the literature available on the use of risk scores and models for the prediction of diabetes mellitus.

METHODS

In the present research work, published original articles based on Diabetic risk scores and models were collected. Articles were systematically searched on PubMed, Medline, Scopus and EMBASE databases. We search keywords used on these databases as “Diabetes Risk Score”, “Derivation of a Risk score for T2DM", "Risk Models for T2DM", "Diagnostic tool for Diabetes", “Algorithm for Diabetes” and “Prediction model for Diabetes”. The collected articles were reviewed, and only relevant articles were included in the study. The collected articles were scrutinized and the relevant articles were included in the study.

Inclusion Criteria

The articles which satisfy the following criteria were included in the study: 1) articles published in peer-reviewed journals. 2) Participants over the age of 18 years or older, regardless of gender 3) data collection was based on a questionnaire or secondary data, 4) development or derivation of a risk score to identify the risk of Diabetes Mellitus, 5) reported sensitivity, specificity and Area Under the Receiver Operating Characteristics (AUROC).

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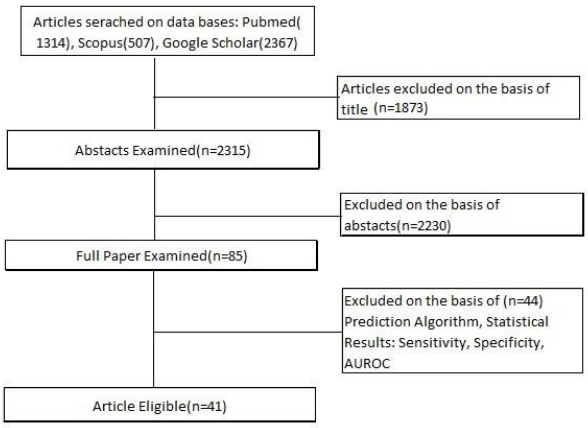
Article selection

articles which consider derivation/development and validation of risk score and models as per criterion were included in the study around the world. The summarized findings from the included articles were tabulated and presented. A total of 2315 abstracts and original articles were scanned, with 41 articles included in the final study.

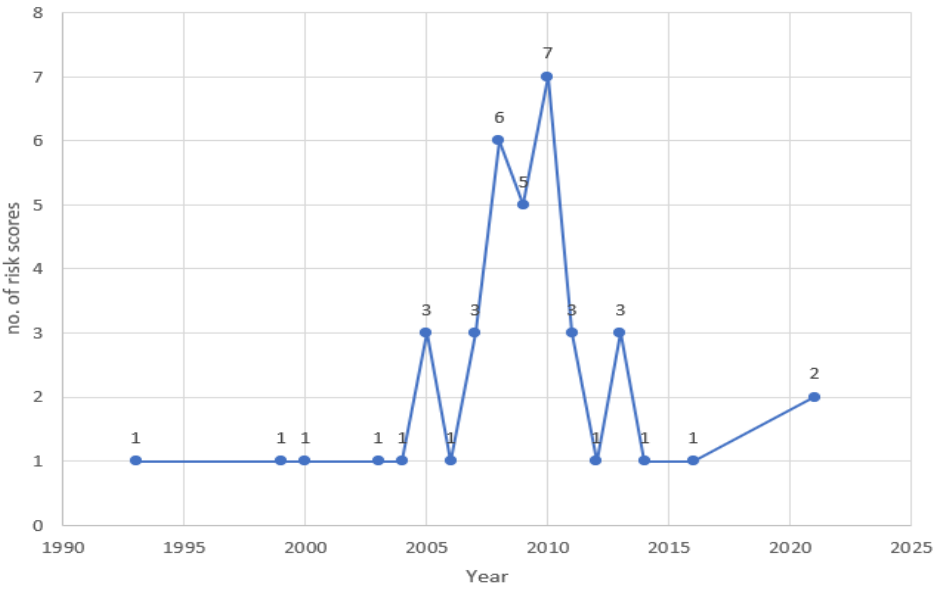
Figure 1: Article selection.



A total of 4188 articles were found on different databases i.e., Pub Med (1314), Scopus (507), Google Scholar (2367). Then 1873 articles were excluded from the study based on the title of the research. A total of 2315 abstracts were reviewed, and 2230 articles were excluded based on abstracts. A total of 85 full articles were examined and 44 articles were excluded based on methodology and results and 41 articles were reviewed in the present research work.

RESULTS

Figure 2: Year-wise publication on Diabetes risk score or models.



Around the Globe, risk scores and models were used in the prediction of type 2 diabetes mellitus. The very first publication on diabetes risk score or model was seen in the year 1993 and was published by Michael P. Stern, from the United States of America. They consider secondary data from a population-based study from 1979 to 1982 within 25-64 years of age. In the year 2008, 6 articles were published on diabetes risk score whereas the maximum number of articles were published in the year 2010 i.e., 7 articles. The latest articles for diabetes risk scores were published in 2021 from USA and Qatar.

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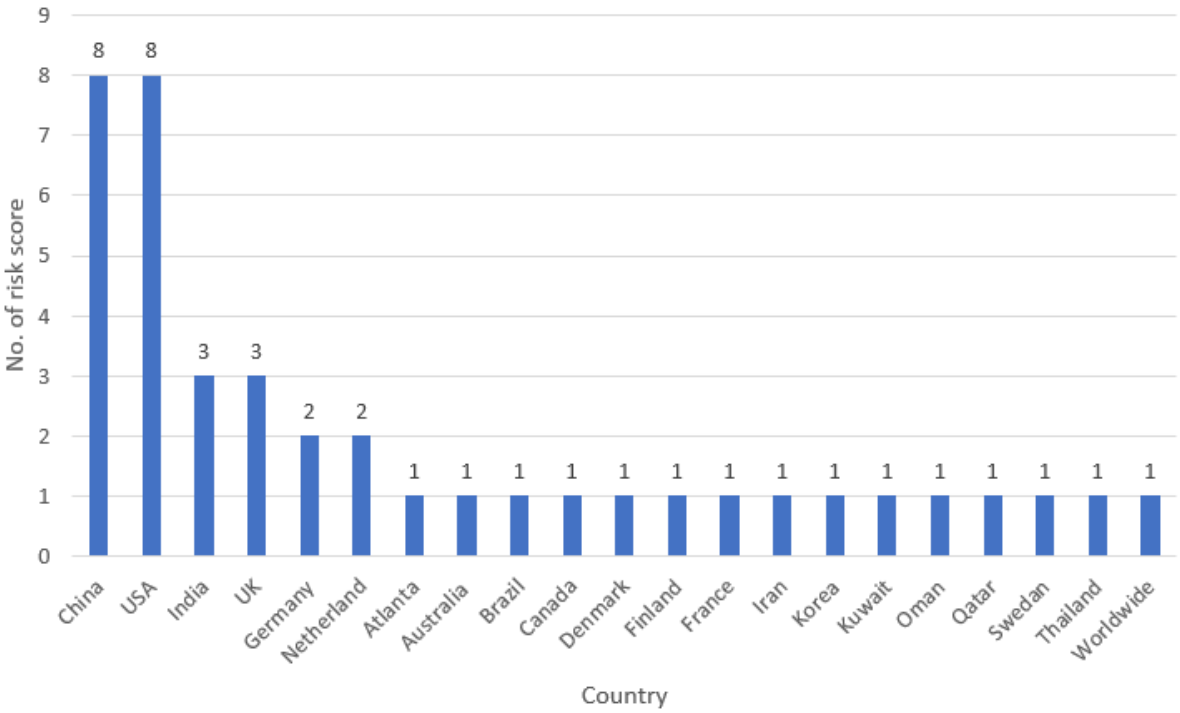
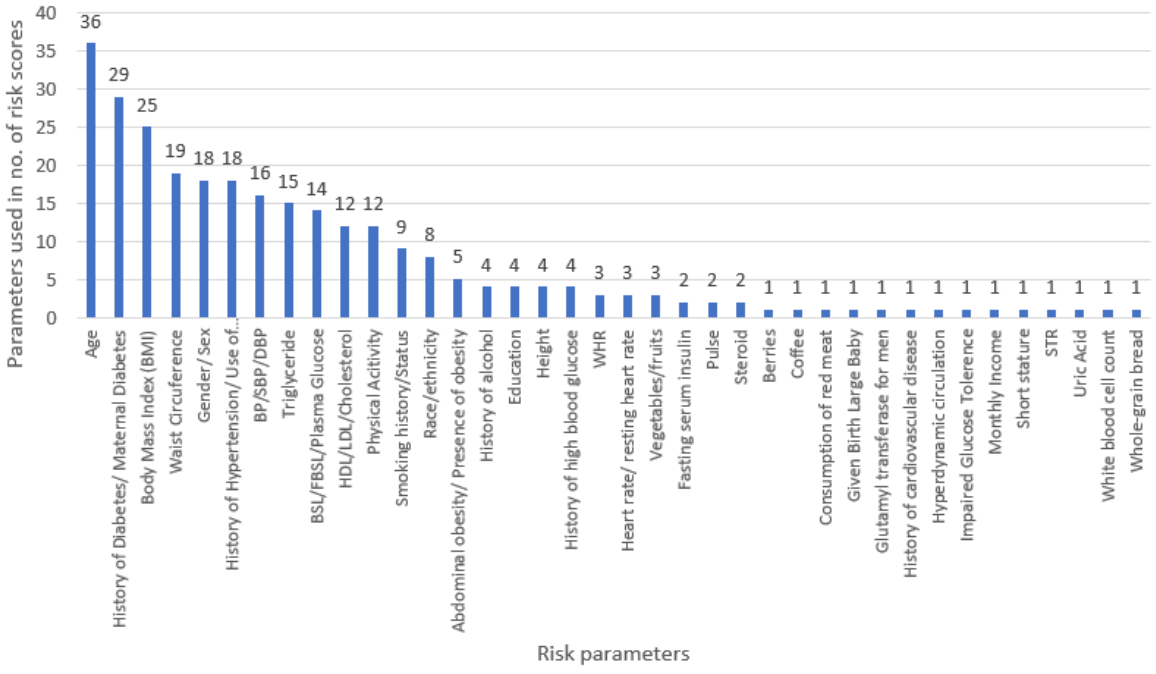
Figure 3: Country-wise diabetes risk score or models.



Worldwide various countries developed their risk scores and models for Diabetes mellitus. As comparing country-wise diabetes risk and model development, China and the United States of America has developed and derived maximum models and risk score for type 2 diabetes mellitus i.e., each country developed an 8-risk score for diabetes whereas India and the United Kingdom has developed 3 diabetes risk scores. A. Ramachandran (2005), V Mohan (2005), and V Chaturvedi (2008) published articles, which show the development of diabetes risk scores in the Indian population. We found one global risk score was developed and derived, published by D. Vistisen et al. in the year 2011 in which data from the DETECT-2 study were used, including 102,058 participants from 38 studies covering 8 geographical regions worldwide.

Figure 4: Risk parameters used in the development of risk score.



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There are various modifiable and non-modifiable risk factors associated with the development of diabetes. In consideration of risk factors, the most commonly used risk parameters were age, history of diabetes, BMI, Waist circumference, Gender, use of antihypertensive drug/history of hypertension, and physical activity in the development and derivation of diabetes risk score and models whereas consumption of red meat, glutamyl transferase for men, monthly income, short stature, uric acid, white blood cell counts, etc. were least used as risk parameters for the derivation of diabetes risk score. Some researchers used smoking history, race/ethnicity, abdominal obesity, history of alcohol, history of high blood glucose, waist-hip ratio, pulse rate, fasting serum insulin, steroid, etc. were used for diabetes risk score development.

Table 1: Published articles on diabetes risk score development in Asian countries.

Sr. No.	Author Details	Study Design and Sampling Frame	Sample Size	Duration	Age of participant: Mean, SD, or range
1	A. Ramachandran, 2005, India [8]	Population-based cohort (C1, C2, C3, C4)	C1-4993, C2-5010, C3-2002, cohort 4-676	2000- C1, C2 National Urban Diabetes Survey, 1995 data for C3 Chennai survey, 1999 South Asian cohort Health Survey of UK	C1-40.3(14.2), C2-40.5(14.3), C3-39.5(12.2), C4-50.3(9.7
2	V Mohan, 2005, India [9]	Chennai Urban Rural Epidemiology Study	Phase 3 Validation =2350		<35, 35-49 and >50
3	Wichai Aekplakorn, 2006, Thailand [10]	Cohort	2677	1985	35–55
4	J.A. Al-Lawati, 2007, Oman [11]	National Diabetes Survey data, cohort	n = 4881	1991	≥ 20
5	Chaturvedi V, 2008, India [12]	Cross-sectional population survey, Independent multiple cross-sectional surveys for validation	nA-4044 for development of score, nB-10566 for validation of score	A-1991-1994, B-2001-2003	A-35-49, B-20-69
6	K. Chien, 2009, China [13]	Cohort	2960	1990	54(12.3)
7	W. G. Gao, 2009, China [14]	Population-based survey	1986, 4336	2001, 2006	20–74
8	Jing Xie, 2010, China [15]	A cross-sectional survey	15 540	2000 to 2001	35-74
9	M.M. Al Khalaf, 2010, Kuwait [16]	Cross-sectional survey	562	2007	36.2 (SD 8.9)
10	Mohammadreza Bozorgmanesh, 2010, Iran [17]	Population-based cohort	5018	1999–2001	≥ 20
11	Shao-Yuan Chuang, 2010, China [18]	MJ Health Screening Clinic based	24899	1994–1996	≥ 35
12	Jian-Jun Dong, 2011, China [19]	Survey	n_A =2985, n_B=2363	NM	55.23±7.49
13	D. Vistisen, 2011, Worldwide [20]	DETECT-2 population-based surveys	102058	1990 and onwards	25–74
14	Yong-Ho Lee, Md, 2012, Korea [21]	Nationwide, population-based, and cross-sectional health examination and survey	9602	2001 and 2005	≥ 20
15	Xianghai Zhou, 2013, China [22]	Cross sectional	41809	2007-08	≥ 20
16	Senlin Luo, 2014, China [23]	Cross sectional	16246	2001	≥ 20
17	Anxin Wang, 2016, China [24]	Cohort	73987	2006 to 2012	49.76 ± 12.04
18	Susanne F. Awad, 2021, Qatar [25]	2012 Qatar Stepwise Survey data	5000	2012	25-79

We found 18 diabetes risk scores developed and derived in the Asian population. The study design of these studies was a Cross-sectional survey, Cohort, and Population-based survey and some researchers used secondary data for the development of diabetes risk scores. The minimum sample size was 562 and the maximum sample size was 102058, used in the development of diabetes risk scores. Some researchers used two sample groups, the risk score was derived from the first group, and validation of the risk score was done in the second population. One Indian study was published by A. Ramachandran in 2005, they consider a population-based cohort and used four cohorts for the derivation and validation of diabetes risk scores. We include one worldwide diabetes risk score as they included the Asian population in their study. All researcher considers the age of the participant ≥ 20 years.

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Table 2: Statistical results of diabetes risk score development in Asian countries.

Sr. No.	Autor details	Component of risk score	Sensitivity	Specificity	AUROC
1	A. Ramachandran, 2005, India [8]	Age, Gender, Family History, BMI, Waist Circumference, Physical Activity, Monthly Income	C1-76.6%, C2-72.4%, C3-73.7%	C1-59.9%, C2-59%, C3-61.0%	C1-0.732(0.702-0.761), C2- 0.696(0.668,0.731), C3-0.734(0.698-0.771), C4-0.665(0.610-0.720)
2	V Mohan, 2005, India [9]	Age, abdominal obesity, family history of diabetes, and physical activity	72.5%	60.1%	0.698
3	Wichai Aekplakorn, 2006, Thailand [10]	Age, BMI, WC, hypertension, and history of diabetes	77%	60%	0.74
4	J.A. Al-Lawati, 2007, Oman [11]	Age, WC, BMI, family history of diabetes, and hypertension status	78.6%	73.4%	0.83 (95% 0.82–0.84)
5	Chaturvedi V, 2008, India [12]	Age, Blood pressure, WC, Family History of Diabetes, BMI, smoking status, education, cholesterol level, triglyceride.	A-66%, B-79%	A-67%, B-56%	A-0.72(95% CI:0.68-0.75), B- 0.69(95% CI: 0.66-0.71)
6	K. Chien, 2009, China [13]	Age, elevated fasting glucose, body mass index, triglyceride, white blood cell count, and higher HDL-cholesterol	54%	78%	0.702
7	W. G. Gao, 2009, China [14]	Age, WC, BMI, Family history of diabetes, Triglyceride, Fasting glucose, Systolic blood pressure	84.2%	39.8%	0.673
8	Jing Xie, 2010, China [15]	Age, body mass index, waist-hip ratio, and WC.	61% Women, 59% Men	71%Women, 63% men.	NM
9	M.M. Al Khalaf, 2010, Kuwait [16]	Age, WC, use of blood pressure medication, family history of diabetes in a sibling.	87%	64%	0.82
10	Mohammadreza Bozorgmanesh, 2010, Iran [17]	SBP, family history of diabetes, Waist hip ratio, TG/HDL-C, and FPG	75%	77%	0.83
11	Shao-Yuan Chuang, 2010, China [18]	Age, education level, alcohol use, abdominal obesity, elevated BMI, blood pressure, triglycerides, and impaired fasting glucose	79%	65%	0.713 to 0.835
12	Jian-Jun Dong, 2011, China [19]	Age, sex, smoking, physical activity, BMI, WHR, systolic blood pressure, diastolic blood pressure, pulse, family history of diabetes mellitus, history of high glucose	A- 82.1%, B-83.3%	A-65.6%, B-66.5%	A-0.477, B-0.498
13	D. Vistisen, 2011, Worldwide [20]	Age, height, body mass index, WC, and systolic- and diastolic blood pressure	72% to 80%	41% to 63%	0.71 (95% CI: 0.70–0.72)
14	Yong-Ho Lee, Md, 2012, Korea [21]	Age, Family history of diabetes, Hypertension, WC, Smoking status, Alcohol intake (drinks/day)	81%	54%	0.73(95% CI 0.720–0.739)
15	Xianghai Zhou, 2013, China [22]	Age, sex, waist circumference, BMI, systolic blood pressure, and family history of diabetes	92.3%	35.5%	0.748
16	Senlin Luo, 2014, China [23]	Age, diastolic blood pressure (DBP), high-density lipoprotein (HDL), waist, sex, cholesterol (CHOL), parental or sibling history, body mass index (BMI), and triglyceride	79.4%	67.9%	0.808
17	Anxin Wang, 2016, China [24]	Age, gender, BMI, family history of diabetes, education, BP, resting heart rate, FPG, and TG or using lipid-lowering drugs	C-72%, A-70%	C-52%, A-70%	C-0.77, A-0.67
18	Susanne F. Awad, 2021, Qatar [25]	Age, sex, obesity, smoking, and physical inactivity	79%	66.8%	0.79

Age, gender/ sex, waist circumference, family history of diabetes, BMI, and physical activity are the common risk parameters used in the derivation of diabetes risk scores. Some researchers used smoking, cholesterol, Blood pressure, education, hypertension, history of high blood glucose, and waist-hip ratio in the derivation of diabetes risk score or model. The highest sensitivity of 87% was observed in the Kuwaiti study and the Lowest sensitivity of 54% was observed in one of the Chinese studies. The maximum AUROC was 83% observed in a study of Iran and Oman, minimum AUROC was 47.7% observed in one Chinese study.

In India, three diabetes risk scores were developed and derived which consider different risk variables and the range of their risk score varies. V Mohan developed a risk score (2005) for diabetes which is known as IDRS and commonly used in India to assess the risk of diabetes. In V Mohan's risk score- IDRS only four risk factors were included age, abdominal obesity, family history and waist

circumference and the risk score range between 0-100. IDRS risk score can assess the patients into high, moderate, and low risk of diabetes whereas Ramachandran and Chaturvedi V's risk score asses only the high-risk population. Chaturvedi V's diabetes risk score included smoking status, education, cholesterol, triglyceride as well as blood pressure in the derivation of risk score. In Ramachandran's diabetes risk score, BMI and monthly income is included as a risk predictor of diabetes.

DISCUSSION

There were 8 articles published on the development of diabetes risk scores in the United States of America that consider various risk predictors. Race or ethnicity is a common risk predictor used by most researchers for the American Population. The first article in the USA on diabetes risk score was published in the year 1993 which was on a population-based study. Various studies published on diabetes risk score in the USA was based on anthropometric, demographic, and behavioral factors. American Diabetes Association (ADA) risk score included Age sex gestational history of DM, Family history of diabetes, High blood pressure, Physical activity, and BMI in the risk predictor and the score ranges between 0-10. The risk categories of ADA risk score are Score ≥ 4- High risk of having prediabetes or diabetes, Score ≥ 5 High Risk of Having Diabetes. Alka M. Kanaya et al. developed a risk score that was based on sex, age, triglycerides, and Fasting glucose only with a sensitivity of 54% and specificity of 82%. Author Henry S. Kahn included HDL/LDL and triglyceride, uric acid for the development of risk score. Authors Michael P. Stern, Janice A. Kolberg, and Natalie V. Schwatkaid used clinical parameters in their diabetes risk score which may not be cost-effective.

In the Chinese population, 8 articles were published on diabetes risk scores. The diabetes risk score published by K. Chien in 2008 considers Age, elevated fasting glucose, body mass index, triacylglycerol, white blood cell count, and a higher HDL-cholesterol in the derivation of risk score. New Chinese diabetes risk score considers the risk predictor as Age, Sex, Waist circumference, BMI, Systolic blood pressure, and family history of diabetes and the score ranges between 0-51 if the risk score is < 25 low risks of diabetes and if the score ≥ 25 high risks of type diabetes. Some of these 8 studies included demographic, anthropometric, and behavioral risk factors whereas some researchers used clinical parameters for prediction. Some Chinese researchers consider waist-hip ratio, Fasting glucose level, Body mass index, systolic blood pressure, alcohol use, HDL, and triglyceride in the derivation of diabetes risk score.

In India, 3 articles were published on the development of diabetes risk score by R Ramachandran, V Mohan, and V Chaturvedi in the years 2005, 2005, and 2008 respectively. Author R Ramachandran used Age, Gender, Family History, Waist circumference, Physical activity as well as monthly income in the derivation of risk score while author V Mohan used Age, abdominal obesity, family history, and physical activity in the development of risk score. Researcher V Chaturvedi used Age, Blood pressure, Waist circumference, Family history of diabetes, BMI, Smoking status, education, cholesterol level, and triglyceride as risk predictors in the derivation of diabetes risk score. The risk score developed by V Mohan et al. is known as the Indian Diabetes Risk Score (IDRS) which ranges between 0-100 risk categories of IDRS are Score <30 -Low Risk, 30-60- Moderate Risk, and ≥ 60 High Risk of diabetes.

Three research articles were published on diabetes risk scores based on United Kingdom's population. One researcher considered coronary heart disease in the Diabetes risk score whereas all the researchers considered antihypertensive medication in the development of the diabetes risk score. In the Finish Diabetes risk score (FINRISK) daily consumption of fruits, berries, or vegetables was used as a risk predictor. FINRISK included Age, BMI, WC, history of antihypertensive drug treatment and high blood glucose, physical activity, and daily consumption of fruits, berries, or vegetables as risk predictors in their risk score. The FINRISK ranges between 0-25 and the risk categories are if the score < 7 Low, 7-11 Slightly Elevated,12-14- Moderate, 15-20-High, and >20 Very High risk of diabetes.

In the Canadian Diabetes Risk Score (CANDRISK), consumption of vegetables or fruits, High blood pressure, given birth to a large baby, High blood sugar, ethnicity and education level used as risk factors. CANDRISK lies between 0-93 and risk categories are, if score < 21- Low risk, 21-32- Moderate risk and, ≥ 21- High risk of type 2 diabetes mellitus.

In Australian Diabetes Risk Score (AUSRISK), birth continent, ethnicity, smoking history and vegetable consumption considered as risk factors for diabetes. AUSRISK ranges between 0-38 and risk categories are ≤ 5-Low Risk, 6-11- Intermediate Risk and ≥ 12- High risk of type 2 diabetes [26-58].

Most of the studies considered demographic and behavioral factors in development of diabetes risk while some researcher used clinical parameters as well in their risk score.

Strength and limitation

Diabetes risk score is cost effective, self-measurable screening tool for diagnosis of type 2 diabetes mellitus. These diabetes risk score access the patients with risk categories as low, moderate and high risk of type 2 diabetes which will be helpful in early detection and prevention of type 2 diabetes mellitus. Some diabetes risk score considers clinical parameters which is not self-measurable and required investigations, is limitation of diabetes risk score. All the risk parameters of type 2 diabetes were not considered in all the risk scores.

CONCLUSION

The most common risk parameters for type 2 diabetes mellitus are age, history of diabetes, BMI, Waist circumference, Gender, use of antihypertensive drug/history of hypertension, and physical activity and these risk predictors were used by most the researcher for derivation of risk score for diabetes. The consumption of red meat, glutamyl transferase for men, monthly income, short stature, uric acid, white blood cell counts, etc. were least used as risk parameters for the derivation of diabetes risk score.

China and the United States of America has developed and derived maximum models and risk score for type 2 diabetes mellitus i.e., each country developed an 8-risk score for diabetes whereas India and the United Kingdom has developed 3 diabetes risk scores. A. Ramachandran et al. (2005), V Mohan et al. (2005), and V Chaturvedi et al. (2008) published articles, which show the development of diabetes risk scores in the Indian population. The maximum number of articles were published in the year 2010 i.e., 7 articles on development of risk score for type 2 diabetes mellitus.

Much work has been done to develop diabetes risk score whereas all the risk factors were not considered by majority of risk scores such as stress level, smoking, cardio vascular disease, diet, waist hip ratio, neck circumference, tobacco and alcohol consumption etc. More extensive score development can be done by considering multiple risk factors depending upon genotype, phenotype and ethnic variables.

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