REVIEW

Cardiovascular risk models for South Asian populations: a systematic review

Dipesh P. Gopal · Juliet A. Usher-Smith

Abstract

Objectives To review existing cardiovascular risk models applicable to South Asian populations.

Methods A systematic review of the literature using a combination of search terms for "South Asian", "cardiovascular", "risk"/"score" and existing risk models for inclusion. South Asian was defined as those residing in or with ancestry belonging to the Indian subcontinent.

Results The literature search including MEDLINE and EMBASE identified 7560 papers. After full-text review, 4 papers met the inclusion criteria. Only 1 reported formal measures of model performance. In that study, both a modified Framingham model and QRISK2 showed similar good discrimination with AUROCs of 0.73–0.77 with calibration also reasonable in men (0.71–0.93) but poor in women (0.43–0.52).

Conclusions Considering the number of South Asians and prevalence of cardiovascular disease, very few studies have reported performance of risk scores in South Asian populations. Furthermore, it was difficult to make comparisons, as many did not provide measures of discrimination, accuracy and calibration. There is a need for further research to evaluate risk models in South Asians, and ideally derive and validate cardiovascular risk models within South Asian populations.

Keywords Cardiovascular · Risk · South Asian · Systematic review

D. P. Gopal
West Suffolk Hospital, Hardwick Lane, Bury St Edmunds, Suffolk IP33 2QZ, UK

J. A. Usher-Smith (✉)
The Primary Care Unit, University of Cambridge, Strangeways Research Laboratory, 2 Wort's Causeway, Cambridge CB1 8RN, UK
e-mail: jau20@medschl.cam.ac.uk

Introduction

Despite advances in diagnosis, treatment and prevention of cardiovascular disease (CVD) in recent decades, CVD still remains the single largest cause of non-communicable disease death worldwide (WHO 2014). Individuals who are of South Asian descent make up one in five of the world's population and are at particular risk of CVD (Turin et al. 2013). Compared to Caucasian populations, South Asians have an increased prevalence of established risk factors, such as hyperlipidaemia, smoking and limited physical activity, at younger ages (Joshi et al. 2007; Misra and Khurana 2011; Prasad et al. 2011); are younger on admission with ischaemic stroke and have poorer 30-day survival (Gunarathne et al. 2008); have an increased risk of 30-day mortality from re-infarction or heart failure; and those with type-2 diabetes mellitus are affected by cardiovascular events 7.4 years before their Caucasian counterparts (Bellary et al. 2010).

The incidence and prevalence of CVD are also continuing to increase in South Asian populations. Over the last 20 years, the prevalence of coronary heart disease has increased twofold in India alone (Turin et al. 2013) and the associated global CVD adult burden in developing countries and increasing costs of hospitalisation on local workforces (Srivastava and Mohanty 2013) are reasons for concern (Prasad et al. 2011).

Attempts to reduce this excess morbidity and mortality include collective approaches targeting the wider underlying risk factors in an attempt to shift the entire population distribution of CVD risk, and approaches that focus on identification of individuals at high risk. A key part of the latter approach is the use of risk models that enable estimation of an individual's risk of developing CVD. These have the potential to help clinicians with decisions regarding treatment, facilitate an informed discussion between clinician and patient, and may also motivate individuals to improve their health-related behaviours. They also provide an opportunity to prioritise individuals with the highest CVD risk and so allocate resources more efficiently.

A number of risk models capable of identifying those at high risk of CVD exist, however most have been developed in Caucasian populations and, given the role of population ethnicity and region in modifying cardiovascular risk (Beswick and Brindle 2006), it is not clear which is currently the most appropriate for people of South Asian descent. The aim of this research was to systematically review and compare existing cardiovascular risk models validated in adult South Asian populations to inform the choice of risk model in these populations.

Methods

Search strategy

An electronic literature search of MEDLINE, EMBASE (Excerpta Medica dataBASE), HMIC (Health Management Information Consortium), AMED (Allied and Complementary Medicine Database) and PsychINFO from January 2000 to April 2014 was performed using a combination of medical subject heading (MESH) terms and free text incorporating "South Asian", "cardiovascular", "risk"/ "score" and specific risk models for inclusion (see Supplementary material for complete search strategy). The search was restricted to human studies. Duplicates were removed and the references of each included paper were screened manually for additional studies.

Study selection

Studies were included if they fulfilled all the following criteria: (1) a primary research paper published in a peer-reviewed journal; (2) contain details of a cardiovascular risk model; (3) apply a cardiovascular risk model to one or more subgroups of a South Asian population where South Asian is defined as originating from the Indian subcontinent—India, Pakistan, Bangladesh, Nepal, Bhutan, Sri Lanka; (4) include persons greater than and including the age of 18; (5) include a defined end-point such as 5-year all-cause mortality or overall lifetime cardiovascular risk. Studies focussing on sole ethnic groups that did not fall under the bracket of "South Asian" and studies with participants with a history of CVD or using cardiovascular risks models to estimate disease prevalence or incidence were excluded. Abstracts presented at conferences were also excluded.

One reviewer (DG) performed the search and screened the articles to exclude those that were clearly not relevant to assessment of cardiovascular risk at title and abstract level, whilst a second reviewer (JUS) independently assessed 5 % of articles excluded at this stage. Both reviewers independently examined all full texts where an article could not be rejected purely at title and abstract level. Those articles that did not fulfil inclusion criteria by both reviewers were excluded. Any discrepancies around whether articles fulfilled inclusion criteria were discussed at consensus meetings.
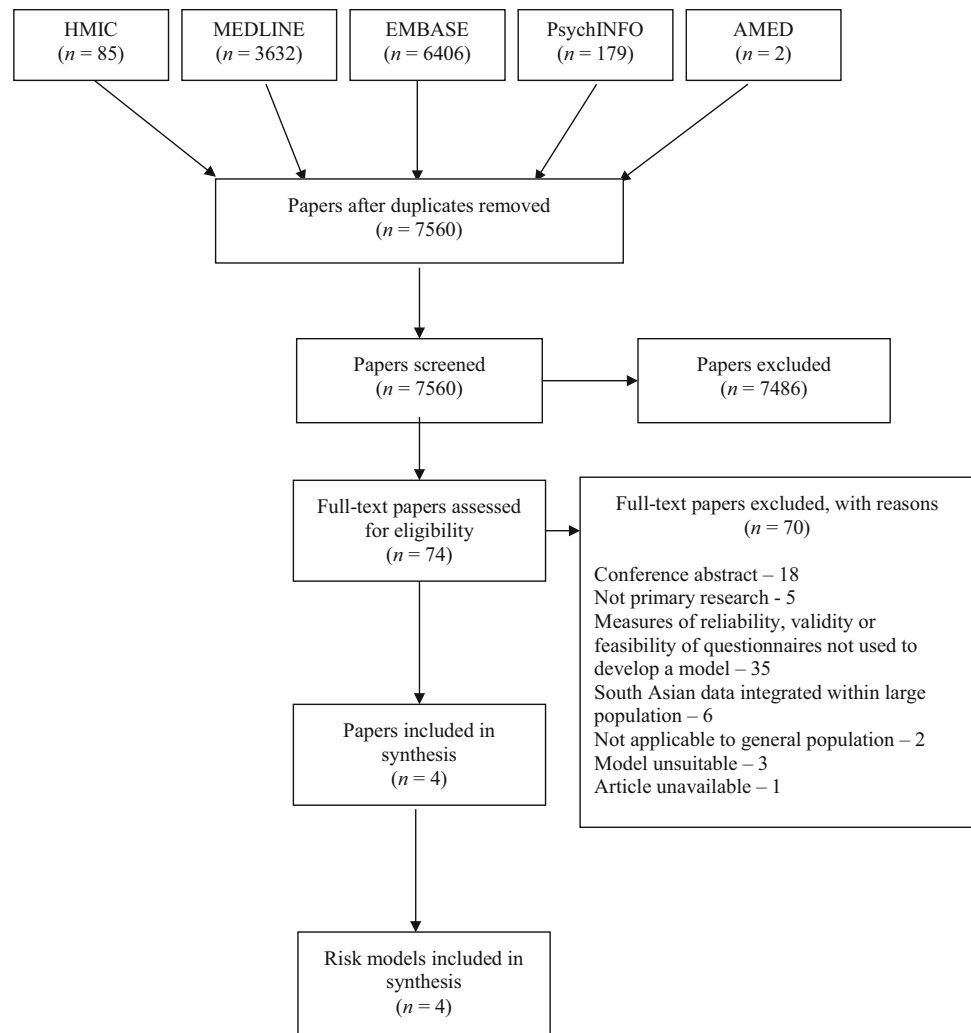
Data extraction and synthesis

Data were extracted independently by both researchers using a standardised form to decrease recording bias. The form included details on: (1) the risk model itself, including availability on the internet and risk model variables included; (2) model development, including study location, study years, study design, model development method, variables included in the model and model performance in the study population such as discrimination, calibration, accuracy where applicable; (3) external validation of the model on a study population, including study location, study years, study design, and model performance in the study population such as discrimination, calibration, accuracy where applicable.

Results

After removing duplicate records, the search isolated 7560 articles. 7486 were excluded at title and abstract level with a further 70 records excluded after full-text assessment (Fig. 1). Full concordance was reached between researchers during screening and a large proportion of articles were excluded because they had used risk scores only to estimate prevalence or incidence of CVD or were conference abstracts. A small number were also excluded because they were specific to patients with thyroid carcinoma or renal transplantation and so not applicable to the general population, the model was used to predict in-hospital mortality or the article was not available online or from the British Library. Further reference list searching and wider reading did not identify any extra papers that warranted inclusion in

Fig. 1 PRISMA diagram for Cardiovascular Risk Scores for South Asian populations: a systematic review with studies published in English between January 2000 and April 2014. *EMBASE* Excerpta Medica dataBASE, *HMIC* Health Management Information Consortium, *AMED* Allied and Complementary Medicine Database

HMIC (*n* = 85) | MEDLINE (*n* = 3632) | EMBASE (*n* = 6406) | PsychINFO (*n* = 179) | AMED (*n* = 2)

Papers after duplicates removed (*n* = 7560)

Papers screened (*n* = 7560) → Papers excluded (*n* = 7486)

Full-text papers assessed for eligibility (*n* = 74) → Full-text papers excluded, with reasons (*n* = 70)

Conference abstract – 18
Not primary research - 5
Measures of reliability, validity or feasibility of questionnaires not used to develop a model – 35
South Asian data integrated within large population – 6
Not applicable to general population – 2
Model unsuitable – 3
Article unavailable – 1

Papers included in synthesis (*n* = 4)

Risk models included in synthesis (*n* = 4)

addition to the wider search results. Only 4 papers (Guha et al. 2004; Jaquet et al. 2008; Bellary et al. 2010; Tillin et al. 2014) fulfilled the inclusion criteria. Details of the design and methods of these four studies are shown in Table 1. Two are based in the UK, one in Guadeloupe and one in India. Two included only patients with diabetes (Bellary et al. 2010; Jaquet et al. 2008) and all used different outcome measures: Guha et al. included only acute coronary syndrome; Tillin et al. included angina, stroke and TIA in addition to myocardial infection and coronary heart disease; Bellary et al. and Jaquet et al. included all fatal and non-fatal cardiovascular events. Whilst the aim in all 4 was to assess the performance of CVD risk models in South Asian populations, the design of the studies also differed with Guha et al. using a case–control design with patients recruited in secondary care and the other three using a cohort design with follow-up of between 2 and 10 years.

Between them, the four studies included details on the performance of four cardiovascular risk models in adult South Asian populations. These are summarised in Table 2 along with the main results from each study. They include the Framingham model developed from 5573 participants in the USA between 1968 and 1975 (Anderson et al. 1991), a modified version of the Framingham model (NICE 2008), the UKPDS developed in the UK between 1977 and 1991 in patients with known type 2 diabetes (Stevens et al. 2001) and QRISK2 developed from the electronic primary health care records of 2,290,000 patients registered with GPs in the UK (Hippisley-Cox et al. 2008). All 4 include a set of 4 common risk factors (age, gender, smoking history, systolic blood pressure). The Framingham model includes an additional 5 risk factors (diastolic blood pressure, total cholesterol, HDL cholesterol, left ventricular hypertrophy, diabetes), the UKPDS an additional 3 (total: HDL cholesterol ratio, HbA1C and ethnicity) and QRISK2 11 extra factors, including both variables related to biological disease development and others, such as social deprivation, that may be markers of other determinants of disease in general (total: HDL cholesterol ratio, antihypertensive use,

Table 1 Summary of external validation studies published in English between January 2000 and April 2014

Author and date	Risk scores applied	Country	Period of study	Study design	Data collection method	Outcome	Definition of South Asian
Bellary et al. (2010)	Framingham 10-year and UKPDS 10-year	Coventry and Birmingham, England	2004–2007	Prospective cohort (2-year follow-up)	Examination and blood tests for baseline risk; CVD events and mortality extracted from GP records and cause of death from GP/hospital records or register of births and deaths	Fatal and non-fatal cardiovascular events	South Asian
Jaquet et al. (2008)	Framingham 10-year	St. Francois, Guadeloupe	1997–2006	Longitudinal, retrospective cohort (9-year follow-up)	Questionnaire/interview and investigation and hospital records for baseline risk; hospital medical records and questionnaires for outcome	Fatal and non-fatal cardiovascular events requiring hospitalisation—coronary heart disease, ischaemic/haemorrhagic stroke, peripheral vascular disease	Indian
Tillin et al. (2014)	Modified Framingham 10-year (×1.4 for men) (NICE 2008) and QRISK2 10-year	West London, UK	1988–2011	Cohort study (10-year follow-up)	Baseline questionnaire, examination and investigation. Outcome from official cause of death, primary care records, patient report, hospital episode statistics or physician report	First myocardial infarction, angina, CHD, stroke, TIA	South Asian–Indian, Pakistani
Guha et al. (2004)	Framingham 10-year	India	Not given	Case control	Medical records	Acute coronary syndrome	Not given specifically but in India

Table 1 continued

Author and date	Study population	Exclusion criteria	Total n	Number of South Asian cases	Gender of South Asian cases (male, %)	Age of South Asian cases
Bellary et al. (2010)	Aged 30–74 with type 2 diabetes from UK Asian Diabetes Study records (South Asians) and 21 GP Practices (white European)	Type 1 diabetes mellitus, impaired fasting glucose, impaired glucose tolerance, ages <30, ages >74, no previous history of CVD including CHD, stroke, peripheral vascular disease	1978	1486	Not reported. 52.2 for entire cohort	Not reported. 57.0 ± 11.9 for entire cohort
Jaquet et al. (2008)	Indian (by family name, self-stated or physical appearance) with impaired glucose tolerance or type 2 diabetes mellitus	None specified	148	148	43.9	M 57.3 ± 11.3, F 52.0 ± 12.7
Tillin et al. (2014)	Aged 40–69 years at baseline (1988–1991) randomly selected from primary care physician lists and workplaces	Previous CVD	3674	1317	81.7	M 50.8 ± 6.9; F 50.3 ± 6.5
Guha et al. (2004)	Patients presenting with ACS: STEMI, non-STEMI and unstable angina with troponinaemia	Not specified	464	464	78.6	57.6

CVD cardiovascular disease, GP general practice, CHD coronary heart disease, NICE National Institute for Health and Clinical Excellence, TIA transient ischaemic attack, ACS acute coronary syndrome, STEMI ST elevation myocardial infarction, NSTEMI Non-ST elevation myocardial infarction, M males, F females

Table 2 Summary of cardiovascular risk models that have been externally validated in South Asian populations in studies published in English between January 2000 and April 2014

Risk model	Factors included in model	Outcome	Country	Period of follow-up	n	Method of model development	External validation Author and date	Key findings
Framingham 10-year	Age, gender, systolic BP, diastolic BP, total cholesterol, HDL, cigarette smoking, diabetes, left ventricular hypertrophy	10-year relative risk of CHD event (±stroke and CVD event)	USA	1968–1975	5573	Parametric regression	Bellary et al. (2010)	Trend for increased CVD events with increasing predicted risk. Despite similar predicted CVD risk in the South Asian and Caucasian groups, there were 35 % more CVD events in the South Asian group suggesting that the score underestimated risk in the South Asian group
							Guha et al. (2004)	Applying risk model prior to developing ACS would have underestimated CVD risk: only 20 % of those without diabetes and 14 % of those with diabetes would have been identified as high risk and 41 and 53 % of those with ACS would have been classified as low risk
							Jaquet et al. (2008)	Predicted risk scores at baseline were associated with CVD events at follow-up but this effect was greater for scores ≥10 % than ≥20 % (HR 4.78 (95 % CI 1.65–13.5) for a risk score ≥10 %, and 2.94 (95 % CI 1.42–6.06) for a risk score ≥20 %)
Modified Framingham 10-year × 1.4 for men (NICE 2008)	Age, gender, systolic BP, diastolic BP, total cholesterol, HDL, cigarette smoking, diabetes, left ventricular hypertrophy	10-year relative risk of CHD event	USA	1968–1975	5573	Parametric regression	Tillin et al. (2014)	AUROC M 0.73 (0.69–0.77), F 0.77 (0.69–0.86) D-stat M 1.23 (1.00–1.47), F 1.59 (0.96–2.21) R^2 M 26.6 (19.2–33.9), F 37.6 (18.1–53.9) Ratio of predicted to observed M 0.93 (0.88–0.96), F 0.43 (0.25–0.63) Brier M 0.14 (0.12–0.15), F 0.10 (0.073–0.13)
QRISK2 10-year	Age, gender, systolic BP, smoking status, TC/HDL ratio and presence of type 2 diabetes, BMI, family history, social deprivation, antihypertensive treatment, self-assigned ethnicity, hypertension, rheumatoid arthritis, CKD and AF	10-year risk of cardiovascular disease (no further description offered)	UK	1993–2008	2,290,000	Cox-regression	Tillin et al. (2014)	AUROC M 0.73 (0.69–0.77), F 0.75 (0.66–0.84) D-stat M 1.22 (0.99–1.45), F 1.55 (0.91–2.19) R^2 M 26.3 (19.0–33.5), F 36.4 (16.6–53.3). Ratio of predicted to observed M 0.71 (0.64–0.78), F 0.52 (0.34–0.72) Brier M 0.14 (0.12–0.15), F 0.10 (0.063–0.14)
UKPDS 10-year	Age, gender, ethnicity, systolic BP, total cholesterol/HDL ratio, HbA1C, cigarette smoking	10-year absolute risk of CHD event	UK	1977–1991	4540	Parametric risk modelling	Bellary et al. (2010)	Trend for increased CVD events with increasing predicted risk. Despite similar predicted CVD risk in the South Asian and Caucasian groups, there were 35 % more CVD events in the South Asian group suggesting that the score underestimated risk in the South Asian group

BP blood pressure; *HDL* high-density lipoprotein, *TC* total cholesterol, *CHD* coronary heart disease, *CVD* cardiovascular disease, *ACS* acute coronary syndrome, *BMI* body mass index, *CKD* chronic kidney disease, *AF* atrial fibrillation, *AUROC* area under receiver operator curve, *HR* hazard ratio, *M* males, *F* females

essential hypertension, chronic kidney disease, body mass index, social deprivation, family history of ischaemic heart disease in first-degree relative aged below 60 years, ethnicity, type 2 diabetes, rheumatoid arthritis, and atrial fibrillation). In total, 20 different factors were used across the 4 different risk models with the UKPDS using 7 factors and the modified Framingham and Framingham 10-year models were composed of 9 components, whilst the QRISK2 was made up using 15 factors. All are available online with the exception of the modified Framingham risk model which requires multiplication of the online Framingham score by a factor of 1.4 for men.

The Framingham 10-year risk model was used in 3 papers (Guha et al. 2004; Jaquet et al. 2008; Bellary et al. 2010). Guha et al. (2004) used a case–control design to compare the 10-year Framingham risk model in patients presenting with acute coronary syndrome (ACS) and controls with no history of CVD and a normal ECG. They then divided both cases and controls into those with and without diabetes and based on the calculated 10-year risk, grouped them into high risk (>20 %), moderately high risk (10–20 %) and low risk (<10 %). They found a statistically significant difference in the mean projected risk between cases and controls without diabetes (mean 10-year risk 14.15 for cases and 8.61 for controls, $p < 0.01$), but no difference amongst those with diabetes (mean 10-year risk 11.37 for cases and 10.41 for controls, $p =$ NS). Although the distribution of risk was higher in those who developed ACS, use of the Framingham 10-year risk score prior to developing ACS would have underestimated CVD risk: only 20 % of those without diabetes and 14 % of those with diabetes would have been identified as high risk and 41 and 53 % would have been classified as low risk, respectively.

Jaquet et al. (2008) used data from a Guadeloupian retrospective cohort study to compare the Framingham 10-year risk model and metabolic syndrome as potential predictors of fatal or non-fatal coronary heart disease, ischaemic or haemorrhagic stroke or peripheral vascular disease in 148 Indian patients with impaired glucose tolerance or type-2 diabetes. Using Cox proportional hazards modelling, they found that higher Framingham risk scores at baseline were associated with cardiovascular events at 9-year follow-up but this effect was greater for scores ≥10 % than ≥20 % (hazard ratio 4.78 (95 % CI 1.65–13.5) for a risk score ≥10 %, and 2.94 (95 % CI 1.42–6.06) for a risk score ≥20 %).

The third study to use the Framingham risk model was Bellary et al. (2010) who used data from the United Kingdom Asian Diabetes Study (UKADS) cohort (Bellary et al. 2008) to compare the Framingham 10-year risk and UKPDS 10-year risk in 1140 British South Asians and 317 Caucasians with established type-2 diabetes over a 2-year period. For both Framingham and UKPDS risk models they observed a trend for increased CVD events with increasing risk score in the South Asian group. However, despite similar predicted CVD risk in the South Asian and Caucasian groups (Framingham 10-year females: 7.3 vs 6.5, males: 11.7 vs 11.7; UKPDS 10-year females: 10.8 vs 10.1, males 21.9 vs 22.6), over the 2-year period there were substantially more cardiovascular events in the South Asian group (26.10 per 1000 person-years for South Asians vs 19.29 for Caucasians) suggesting that both models underestimated risk in the South Asian group.

The fourth study by Tillin et al. (2014) compared the performance of a modified Framingham 10-year model (derived by multiplying the Framingham risk by 1.4 for South Asian men and recommended by the NICE guidelines in 2008 (NICE 2008)) and QRISK2 10-year score in a tri-ethnic cohort including 1317 South Asians with 10-year CVD event follow-up. They chose the same end-points as for QRISK2 (first myocardial infarction, angina, CHD, stroke, transient ischaemic attack) for assessment of both QRISK2 and the modified Framingham 10-year model which was initially developed with only CHD as an end-point which would be expected to favour performance of the QRISK2. They also did not have data on presence or absence of rheumatoid arthritis, chronic kidney disease or atrial fibrillation at baseline and only had data on family history of CHD for survivors at 20-year follow-up and left ventricular hypertrophy in a subset and so assumed null values for these variables when calculating the risk scores. Despite these limitations, it is the only study to provide statistical measures of model performance. For South Asians, there was little difference in the discriminatory performance of the two models with both having moderate discrimination and better in females than males: the modified Framingham model had an area under receiver operator curve (AUROC) of 0.73 for males and 0.77 for females and QRISK2 an AUROC of 0.73 for males, 0.75 for females; and the R^2 statistic was also similar for the modified Framingham score (males 26.6 %, females 37.6 %) and QRISK2 model (males 26.3 %, females 36.4 %). Both under-predicted risk with the modified Framingham model better calibrated in men compared to the QRISK2 (predicted: observed (95 % CI) modified Framingham 0.93 (0.88–0.96) vs QRISK2 0.71 (0.64–0.78)) and QRISK 2 better in women (predicted: observed QRISK2 0.52 (0.32–0.72) vs modified Framingham 0.43 (0.25–0.63)). Overall performance, as measured by the Brier M statistic, was moderate and almost identical for both models with values of 0.14 and 0.10 for South Asian males and females, respectively.

Discussion

Despite the increasing use of cardiovascular risk models and recognition of the impact of ethnicity on CVD risk, this systematic review identified only 4 studies that assessed the performance of risk models in South Asian populations. All showed that an increased risk score was associated with increased CVD events, and 3 of the 4 risk models underestimated risk in South Asian populations. Only 1 reported formal measures of model performance. In that study (Tillin et al. 2014), both a modified Framingham model and QRISK2 showed similar good discrimination with AUROCs of 0.73–0.77 with calibration also reasonable in men (0.71–0.93) but poor in women (0.43–0.52).

Strengths and limitations

The main strength of this study is the systematic approach and use of different search engines, including EMBASE and MEDLINE, as well as manual screening of the reference lists of included articles. However, there is an element of publication bias that is intrinsic to the literature limiting available analysable data sets, so we cannot exclude the possibility that there are other studies that we did not identify.

The main weaknesses relate to the volume and quality of the published data. The results of the widespread search found only 4 studies using 4 risk models. All used different outcome measures, only 1 reported statistical measures for performance, and only the Framingham model was assessed in more than one study so the conclusions that can be drawn from the extracted data are limited. Additionally, the populations included in the studies are of limited generalisability: two included only participants with type 2 diabetes and one only those presenting to one secondary care hospital. Although unlikely to have a large effect, the only study to include performance measures (Tillin et al. 2014) also had missing data for several of the component risk factors for each model. Furthermore, of the studies included, only two specified the subgroups of South Asians within their study (Jaquet et al. 2008; Tillin et al. 2014), whilst the other two described the included population as only 'South Asian' (Bellary et al. 2010) or 'Indian' (Guha et al. 2004). This makes interpreting and applying the results to specific subgroups more difficult. Finally, there was a lack of reporting of consistent measures of discrimination, calibration and accuracy making a comparison between risk models difficult.

Implications for clinicians and policy makers

Despite these limitations, the findings from this review are of relevance to the large number of clinicians worldwide that use CVD risk information with South Asian patients regularly in their practice, and policy makers involved in designing and implementing strategies for the prevention of CVD. Given the widespread use of CVD risk models and the increasing South Asian population (UN 2014), it is surprising and concerning that there is such limited data on the performance of these models in South Asian populations. Only 4 risk models have been tested and performance data are only available for 2. Increased risk scores in all 4 models are associated with increased CVD events, but, where reported, all underestimate risk. This underestimation is perhaps not surprising for the Framingham risk model as it was developed in a cohort of white Caucasian individuals from the late 1960s onwards (Anderson et al. 1991) and, along with other risk models, is commonly believed to underestimate CVD risk when applied to 1990s and 2000s South Asian populations (Kanjilal et al. 2008; Bansal et al. 2009; Perumal et al. 2012; Khanna et al. 2013) and when compared to expected mortality rates amongst South Asians (Cappuccio et al. 2002; Quirke et al. 2003; Aarabi and Jackson 2005; Bhopal et al. 2005; Brindle et al. 2006; Wells et al. 2007; Kumar et al. 2009; Perumal et al. 2012). QRISK2, however, was derived using a large South Asian population ($n = 17{,}102$) (Hippisley-Cox et al. 2008) and so would be expected to take account of differences in intrinsic CVD risk amongst South Asians. Nevertheless, the performance of QRISK2 and the modified Framingham model in South Asian populations are not dissimilar from those in white Caucasians or other ethnic groups: in the study by Tillin et al. (2014), the AUROC and R^2 statistic for both risk models were higher in South Asians than Europeans or African Caribbeans or all ethnicities combined for both men and women. The notable difference is in South Asian females where both QRISK2 and the modified Framingham model underestimate risk substantially more than for other ethnic groups (predicted: observed 0.52 (95 % CI 0.34–0.72) for QRISK2 and 0.43 (95 % CI 0.25–0.63) for modified Framingham compared to 0.73 (0.57–0.88) and 0.74 (0.57–0.88), respectively, in Europeans), and the QRISK2 high-risk classification would miss approximately two-thirds of events. This may be explained by the absence of any incident cases in South Asian women in the Framingham model development population (compared to 241 in white Caucasian women) and the small number of incident cases in South Asian women in the QRISK2 derivation dataset relative to those in the White ethnic group (413 compared to 40,278). This underestimation is important though for clinicians to recognise as women often do not present with typical symptoms before or during a cardiovascular event (McSweeney et al. 2003, 2010) and alternative strategies may be required to identify high-risk South Asian women.

When choosing which model to use, clinicians should be aware that both QRISK2 and a modified Framingham model have been externally tested in South Asian populations and both have similar modest discrimination and overall performance but underestimate risk, particularly in South Asian women. The choice of which to use can therefore be guided by access, availability of risk factors, and local preferences. Both QRISK2 and the Framingham model are freely accessible on the internet but, whilst QRISK2 includes an option for 'South Asian', when using the Framingham model in South Asians clinicians would need to multiply the calculated risk by 1.4 for men before interpreting it. This is not difficult but adds a further step into risk calculation and limits the use of the Framingham model to screen electronic records. QRISK2 includes 15 variables compared to the 9 in the Framingham score. Age, gender, systolic BP, total cholesterol, HDL, smoking status and diabetes are risk factors common to both scores with the Framingham model additionally including left ventricular hypertrophy and QRISK2 body mass index, family history, social deprivation, antihypertensive treatment, ethnicity, hypertension, rheumatoid arthritis, chronic kidney disease and atrial fibrillation. Some of these additional variables in the QRISK2 model may not be readily known, however, in the validation study (Tillin et al. 2014), data were also not available for rheumatoid arthritis, chronic kidney disease, atrial fibrillation or left ventricular hypertrophy and family history data was missing for many participants so this may have limited consequences. Both are also recommended in current guidelines but these differ between countries with the UK National Institute for Health and Clinical Excellence (NICE) currently recommending QRISK2 (NICE 2015) and the American College of Cardiology suggesting the Framingham risk model or SCORE guidelines (Conroy et al. 2003) based on validation in Afro-Caribbeans (Goff et al. 2014).

Unanswered questions and future research

Whilst this review provides a summary of published studies reporting the performance of CVD risk models in South Asian populations, it also highlights the lack of evidence in this area. Given the increasing incidence of CVD and reliance on risk prediction tools for treatment decisions, there is the need for further research in this area. This includes both wider validation of existing risk models, such as ETHRISK which is another modified version of the Framingham risk model designed to take account of ethnicity (Brindle et al. 2006), and the development of new models incorporating ethnicity to reduce the intrinsic difficulties when applying a risk model developed in one ethnicity to a different ethnicity in a different location and point in time. This work will also need to address the difficulties involved in developing risk models for South Asians where the umbrella term 'South Asian' includes persons with different levels of acculturation, different migration patterns and different ethnic subgroups, both within and outside the Indian subcontinent.

In the past, this has been limited by the lack of studies including South Asian populations but with the development of large cohorts such as the Emerging Risk Factors Collaboration (Danesh et al. 2007; Thompson et al. 2010) and UK Biobank (Elliott and Peakman 2008; Kaptoge et al. 2012) and the increasing availability of electronic medical record databases, it should now be possible to validate existing models and develop new ones. Only once we have an accurate risk model for South Asian populations, will we be able to maximise the potential benefits of a calibrated CVD risk assessment and directed primary preventive strategies for this group who make up 1 in 5 of the ever-expanding world population.

References

Aarabi M, Jackson PR (2005) Predicting coronary risk in UK South Asians: an adjustment method for Framingham-based tools. Eur J Cardiovasc Prev Rehabil 12:46–51. doi:10.1097/01.hjr.0000159279.88814.aa

Anderson K, Odell P, Wilson P, Kannel W (1991) Cardiovascular disease risk profiles. Am Heart J 121:293–298. doi:10.1016/0002-8703(91)90861-B

Bansal M, Shrivastava S, Mehrotra R et al (2009) Low Framingham risk score despite high prevalence of metabolic syndrome in asymptomatic North-Indian population. J Assoc Physicians India 57:17–22

Bellary S, O'Hare JP, Raymond NT et al (2008) Enhanced diabetes care to patients of south Asian ethnic origin (the United Kingdom Asian Diabetes Study): a cluster randomised controlled trial. Lancet 371:1769–1776. doi:10.1016/S0140-6736cf(08)60764-3

Bellary S, O'Hare JP, Raymond NT et al (2010) Premature cardiovascular events and mortality in south Asians with type 2 diabetes in the United Kingdom Asian Diabetes Study—effect of ethnicity on risk. Curr Med Res Opin 26:1873–1879. doi:10.1185/03007995.2010.490468

Beswick A, Brindle P (2006) Risk scoring in the assessment of cardiovascular risk. Curr Opin Lipidol 17:375–386. doi:10.1097/01.mol.0000236362.56216.44

Bhopal R, Fischbacher C, Vartiainen E et al (2005) Predicted and observed cardiovascular disease in South Asians: application of FINRISK, Framingham and SCORE models to Newcastle Heart Project data. J Public Health (Oxf) 27:93–100. doi:10.1093/pubmed/fdh202

Brindle P, May M, Gill P et al (2006) Primary prevention of cardiovascular disease: a web-based risk score for seven British black and minority ethnic groups. Heart 92:1595–1602. doi:10.1136/hrt.2006.092346

Cappuccio FP, Oakeshott P, Strazzullo P, Kerry SM (2002) Application of Framingham risk estimates to ethnic minorities in United Kingdom and implications for primary prevention of heart disease in general practice: cross sectional population based study. BMJ 325:1271–1274. Erratum BMJ. 2003 327(7420):919. doi:10.1136/bmj.325.7375.1271

Conroy R, Pyörälä K, Fitzgerald A et al (2003) Estimation of ten-year risk of fatal cardiovascular disease in Europe: the SCORE project. Eur Heart J 24:987–1003. doi:10.1016/S0195-668X(03)00114-3

Danesh J, Erqou S, Walker M, Thompson SG (2007) The Emerging Risk Factors Collaboration: analysis of individual data on lipid, inflammatory and other markers in over 1.1 million participants in 104 prospective studies of cardiovascular diseases. Eur J Epidemiol 22:839–869. doi:10.1007/s10654-007-9165-7

Elliott P, Peakman TC (2008) The UK Biobank sample handling and storage protocol for the collection, processing and archiving of human blood and urine. Int J Epidemiol 37:234–244. doi:10.1093/ije/dym276

Goff DC, Lloyd-Jones DM, Bennett G et al (2014) 2013 AHA/ACC guideline on lifestyle management to reduce cardiovascular risk: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol 63:2960–2984. doi:10.1016/j.jacc.2013.11.005

Guha S, Basu A, Pal S, et al (2004) Predictive efficacy of Framingham's risk score in Indian scenario—a retrospective case-control study. J Indian Med Assoc 102:568, 570, 584 passim

Gunarathne A, Patel JV, Potluri R et al (2008) Secular trends in the cardiovascular risk profile and mortality of stroke admissions in an inner city, multiethnic population in the United Kingdom (1997–2005). J Hum Hypertens 22:18–23. doi:10.1038/sj.jhh.1002265

Hippisley-Cox J, Coupland C, Vinogradova Y et al (2008) Predicting cardiovascular risk in England and Wales: prospective derivation and validation of QRISK2. BMJ 336:1475–1482. doi:10.1136/bmj.39609.449676.25

Jaquet A, Deloumeaux J, Dumoulin M et al (2008) Metabolic syndrome and Framingham risk score for prediction of cardiovascular events in Caribbean Indian patients with blood glucose abnormalities. Diabetes Metab 34:177–181. doi:10.1016/j.diabet.2007.10.005

Joshi P, Islam S, Pais P et al (2007) Risk factors for early myocardial infarction in South Asians compared with individuals in other countries. JAMA 297:286–294. doi:10.1001/jama.297.3.286

Kanjilal S, Rao VS, Mukherjee M et al (2008) Application of cardiovascular disease risk prediction models and the relevance of novel biomarkers to risk stratification in Asian Indians. Vasc Health Risk Manag 4:199–211. doi:10.2147/vhrm.2008.04.01.199

Kaptoge S, Di Angelantonio E, Pennells L et al (2012) C-reactive protein, fibrinogen, and cardiovascular disease prediction. N Engl J Med 367:1310–1320. doi:10.1056/NEJMoa1107477

Khanna R, Kapoor A, Kumar S et al (2013) Metabolic syndrome and Framingham Risk Score: observations from a coronary angiographic study in Indian patients. Indian J Med Res 137:295–301

Kumar BN, Selmer R, Lindman AS et al (2009) Ethnic differences in SCORE cardiovascular risk in Oslo, Norway. Eur J Cardiovasc Prev Rehabil 16:229–234. doi:10.1097/HJR.0b013e3283294b07

McSweeney JC, Cody M, O'Sullivan P et al (2003) Women's early warning symptoms of acute myocardial infarction. Circulation 108:2619–2623. doi:10.1161/01.CIR.0000097116.29625.7C

McSweeney JC, O'Sullivan P, Cleves MA et al (2010) Racial differences in women's prodromal and acute myocardial

infarction symptoms jean. Am J Crit Care 19:63–73. doi:10.1016/j.biotechadv.2011.08.021.Secreted

Misra A, Khurana L (2011) Obesity-related non-communicable diseases: South Asians vs White Caucasians. Int J Obes (Lond) 35:167–187. doi:10.1038/ijo.2010.135

NICE (2008) Lipid modification: Cardiovascular risk assessment and the modification of blood lipids for the primary and secondary prevention of cardiovascular disease. In: Natl. Inst. Heal. Clin. Excell. http://www.nice.org.uk/guidance/cg67/resources/guidance-lipid-modification-cardiovascular-risk-assessment-and-the-modification-of-blood-lipids-for-the-primary-and-secondary-prevention-of-cardiovascular-disease-pdf. Accessed 1 May 2015

NICE (2015) Lipid modification: cardiovascular risk assessment and the modification of blood lipids for the primary and secondary prevention of cardiovascular disease. In: National Institute for Health and Clinical Excellence. http://www.nice.org.uk/guidance/cg181/resources/guidance-lipid-modification-cardiovascular-risk-assessment-and-the-modification-of-blood-lipids-for-the-primary-and-secondary-prevention-of-cardiovascular-disease-pdf. Accessed 1 May 2015

Perumal L, Wells S, Ameratunga S et al (2012) Markedly different clustering of CVD risk factors in New Zealand Indian and European people but similar risk scores (PREDICT-14). Aust N Z J Public Health 36:141–144. doi:10.1111/j.1753-6405.2011.00808.x

Prasad DS, Kabir Z, Dash AK, Das Bhagabati C (2011) Childhood cardiovascular risk factors in South Asians: a cause of concern for adult cardiovascular disease epidemic. Ann Pediatr Cardiol 4:166–171. doi:10.4103/0974-2069.84663

Quirke TP, Gill PS, Mant JW, Allan TF (2003) The applicability of the Framingham coronary heart disease prediction function to black and minority ethnic groups in the UK. Heart 89:785–786. doi:10.1136/heart.89.7.785

Srivastava A, Mohanty SK (2013) Age and sex pattern of cardiovascular mortality, hospitalisation and associated cost in India. PLoS One 8:1–13. doi:10.1371/journal.pone.0062134

Stevens RJ, Kothari V, Adler AI, Stratton IM (2001) The UKPDS risk engine: a model for the risk of coronary heart disease in Type II diabetes (UKPDS 56). Clin Sci (Lond) 101:671–679. doi:10.1042/CS20000335

Thompson S, Kaptoge S, White I et al (2010) Statistical methods for the time-to-event analysis of individual participant data from multiple epidemiological studies. Int J Epidemiol 39:1345–1359. doi:10.1093/ije/dyq063

Tillin T, Hughes AD, Whincup P et al (2014) Ethnicity and prediction of cardiovascular disease: performance of QRISK2 and Framingham scores in a UK tri-ethnic prospective cohort study (SABRE–Southall And Brent REvisited). Heart 100:60–67. doi:10.1136/heartjnl-2013-304474

Turin TC, Shahana N, Wangchuk LZ et al (2013) Burden of cardio- and cerebro-vascular diseases and the conventional risk factors in South Asian population. Glob Heart 8:121–130. doi:10.1016/j.gheart.2012.01.001

UN (2014) Concise report on the world population situation in 2014. In: United Nations. http://www.un.org/en/development/desa/population/publications/pdf/trends/Concise. Report on the World Population Situation 2014/en.pdf. Accessed 4 Aug 2015

Wells S, Kerr A, Broad J et al (2007) The impact of New Zealand CVD risk chart adjustments for family history and ethnicity on eligibility for treatment (PREDICT CVD-5). N Z Med J 120:U2712

WHO (2014) Global status report on noncommunicable diseases 2014. In: World Health Organisation. http://apps.who.int/iris/bitstream/10665/148114/1/9789241564854_eng.pdf?ua=1. Accessed 1 May 2015