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Cohort profile: The Tayside Screening For Cardiac Events (TASCFORCE) Study: A Prospective Cardiovascular Risk Screening Study.

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Abstract

Purpose: Risk factor based models struggle to accurately predict development of cardiovascular disease (CVD) at the level of the individual. Ways of identifying people with low predicted risk who will develop CVD would allow stratified advice/treatment, and this is the aim of this study.

Participants: The Tayside Screening for Cardiac Events (TASCFORCE) study recruited men and women aged ≥40yrs, free from known CVD, with a predicted 10-year risk of coronary heart disease (CHD) <20%. If BNP was greater than their gender-median, participants were offered a whole-body contrast enhanced magnetic resonance (WBCE-MRI) scan (cardiac imaging, whole-body angiography to determine left ventricular parameters, delayed gadolinium enhancement, atheroma burden). Blood, including DNA, was stored for future biomarker assays. Participants are being followed up using electronic record-linkage cardiovascular outcomes.

Findings to date: 4423 (1740, 39.3% male) were recruited. Mean age 52.3 years. Median BNP 7.50ng/L and 15.30ng/L for men and women respectively. 602 have a predicted 10-year risk of 10-19.9%, with the remainder <10%. Age, female sex, ex-smoking status, lower heart rate, higher high-density lipoprotein and lower total cholesterol were independently associated with higher log10 BNP levels. Mean left ventricular mass was 129.2g and 87.0g in men and women respectively.

Future plans: The TASCFORCE study is investigating the ability of a screening programme, using BNP and WBCE-MRI, to evaluate prediction of CVD in a population at low/intermediate risk at the time of enrolment. Blood stored for future biomarker analyses will allow testing/development of novel biomarkers. We believe this could be a new UK Framingham study allowing study for many years to come.

Clinical Trial Registration: ISRCTN38976321 https://doi.org/10.1186/ISRCTN38976321 registered 4th April 2007

Key words: Cardiovascular risk; Clinical Trial; magnetic resonance imaging; natriuretic peptide; Cardiovascular Biomarkers

Strengths and weaknesses

1. This study is one of the largest MRI/Cardiovascular risk studies to be published. It could be a UK Framingham

2. The MRI Scanning is a novel element to a cardiovascular risk trial, particularly as it is whole body and contrast enhanced

3. As many of the participants have also signed up to SHARE, it will be possible to link all subsequent blood tests from SHARE with our cohort details to study novel biomarkers as they are discovered

4. As these were 'healthy' volunteers it will take some time for cardiovascular events to occur

5. Not all participants underwent MRI scanning due to cost, only those above the BNP cut off, however numbers (n=1528) are sufficient to allow evaluations, and all (n=4423) had the demographic, and blood screening.

List of abbreviations

TASCFORCE -The Tayside Screening for Cardiac Events

CVD – Cardiovascular disease

WBCE-MRI -whole-body contrast enhanced magnetic resonance scan

BNP - B-type natriuretic peptide

CHD – Coronary Heart Disease

GP – General Practice

ECG – electrocardiogram

BP – Blood pressure

SAS - standardised atheroma score

SD - standard deviation

IQR -inter-quartile range

CT – Computerised Tomography

Introduction

Currently statins and other drugs for cardiovascular disease (CVD) primary prevention is targeted at those at increased risk by using risk estimation tools, but these have poor external validity.[1] A significant number of CVD occurs in people with “low” or “intermediate” cardiovascular risk [2] and many in these groups have evidence of atherosclerosis.[3,4] Offering statins to a wider range of the population has been suggested.[5] However, offering statins more widely raises a number of economic and ethical questions and concerns,[6,7] so improved targeting therapy may be more acceptable. Risk factor-based models struggle to predict development of disease at an individual person level, and an alternative approach could be the detection of preclinical disease - an approach successful employed in cancer. A similar strategy for CVD could facilitate individualised risk assessment and aid decisions about treatment.

The **Ta**yside **Sc**reening for **C**ardiac **E**vents (TASCFORCE) study is investigating the ability of a screening programme using B-type natriuretic peptide (BNP) and whole-body contrast enhanced magnetic resonance imaging (WBCE-MRI) incorporating cardiac imaging and whole-body angiography to detect preclinical disease, and predict future clinical CVD in a large population at low or intermediate risk. Blood stored for future analyses will allow validation of future proposed biomarkers. The study is novel in using a relatively cheap biomarker (BNP) to decide who proceeds to a relatively expensive test (MRI scan). In this paper we describe the aims and design of the study, and the baseline characteristics of participants including demographics, cardiovascular risk factors, BNP and imaging results.

Cohort description

1.1. Study design

TASCFORCE is a prospective normal volunteer cardiovascular risk screening study (ISRCTN number: ISRCTN38976321).

The aim of this study is to provide baseline data on both imaging and blood biomarkers, to understand which, if any, may predict future Cardiovascular events. The comprehensive collection of baseline cardiovascular risk and demographic data in combination with the blood and imaging biomarkers and robust follow up via electronic record linkage will allow further investigation of the development of CVD in this population, which we hope may become the Scottish 'Framingham'.

Men and women aged 40 years or older living in Tayside or Fife, Scotland, who were free from CVD and had a predicted 10-year risk of coronary heart disease (CHD) <20% were recruited. Participants were excluded if they were pregnant, breast-feeding, of child-bearing potential not using adequate contraception, unable to give consent, or had another accepted indication for statin therapy. To produce a cohort able to participate in a potential future statin intervention study those with contraindications to a statin were excluded, including known alcohol abuse or participation in a clinical trial other than observational trials or registries concurrently or within 30 days prior to screening, were excluded.

Participants were recruited from General Practice (GP) surgeries, local employers, publicity campaigns, via press and radio coverage of the project, direct mailing and using ethically approved leaflets. We aimed to obtain a locally representative population, so recruitment was targeted at socioeconomic and ethnic groups often under-represented in studies. Participants were recruited between November 2007 and February 2013.

1.2 *Patient and Public Involvement*

The Souter Foundation trustees ('lay' people) were involved in the design of the study. Volunteers who were recruited to the study were involved in the design, regarding the scheduling and timing of testing, to improve convenience to participants. Many volunteers were involved in further recruitment, by passing on information via word of mouth. Results of the final analysis using linked data will be disseminated to the participants via postal address.

1.3 *Screening visit and risk estimation*

Following written informed consent for the study, and for data-linkage for 20 years, the following information was obtained: medical history, lifestyle risk factors (diet/exercise/smoking status), risk perception question, family history of premature CVD, and concomitant medication. Subjects were examined to obtain their height, weight, waist circumference and blood pressure (BP) and a 12-lead electrocardiogram (ECG) was recorded. Plasma BNP, random lipid profile and random plasma glucose levels were determined using near patient testing equipment (Alere Triage BNP assay with Alere Triage MeterPro for BNP, and Alere Cholestech LDX analyser for lipids and glucose).

Each participant's predicted CHD event rate was calculated by using the National Cholesterol Education Program Adult Treatment Panel III (ATP III) guidelines.[8] Participants who had a predicted risk ≥20% or a BP >145/90 mmHg were excluded but were asked for consent to be followed up. Ineligible subjects were informed of their risk factors, given a copy of their results and asked to attend their GP for formal review. All participants received counselling on modifiable risk factors by study staff aided by British Heart Foundation leaflets.

1.4 Magnetic resonance imaging

Those with a BNP greater than the median (determined after 200 participants) were invited to attend for a WBCE-MRI scan. At a prespecified review after 1000 subjects it was observed that the median BNP was higher for women than men. The trial steering committee (comprising of the authors) decided to invite for a scan based on gender specific median BNP and the protocol was amended accordingly. Those recruited earlier who would be eligible based on their gender specific median were recalled. If the delay was greater than three months, they had their BNP, cholesterol and CHD risk score rechecked to ensure continued eligibility.

Combined cardiac and whole-body angiography MRI scans were performed on a 32-channel 3T Magnetom Trio scanner (Siemens, Erlangen, Germany) and used gadoteric acid contrast agent (Dotarem; Guerbet Laboratories, France). The scan protocol development and validation has been described in detail elsewhere.[9,10]

Details of the image acquisition, analysis and validation of the technique have been described and validated in earlier publications.[9,10,11] Cardiac magnetic resonance (CMR) images were analysed offline by four blinded observers using commercial software ('Argus', Siemens Multi-modality Work

Platform, version VB15). Electronic region of interest contours were placed around endocardial and epicardial left ventricular borders at end-diastole and end-systole on all CMR image slices identified to contain ≥50% full-thickness myocardium. Quantitative measurement of left ventricular mass (LVM), ejection fraction, end-diastolic volume, end-systolic volume and stroke volume were derived. The presence of luminal stenosis was assessed in 30 arterial segments from the internal carotids to the distal anterior tibial arteries (the coeliac artery was not included due to marked anatomical variation resulting in poor inter-observer agreement). A categorical grading scale from 0-4 was applied to each arterial segment as follows: grade 0=healthy segment, grade 1=1-50% stenosis, grade 2=51-70% stenosis, grade 3=71-99% stenosis, and grade 4=vessel occlusion. An additional point was added for presence of aneurysm >50% of the native vessel diameter. If any arterial segment contained more than one luminal abnormality the more severe abnormality was scored. If a segment was uninterpretable because of poor image quality, it was not allocated a numeric score. A standardised atheroma score (SAS) to express atheroma burden severity across the body as a percentage was calculated using the following equation where n is the number of interpretable segments:

$SAS=[(\sum score/n)x1/4]x100$

1528 (74.8% of those invited) completed or partially completed an MRI scan. 34 were not safe to scan due to metal in situ. 373 did not consent to a scan, and 12 failed to attend. 101 participants abandoned their scan mainly due to claustrophobia (n=83), with others abandoned due to large body habitus, problems with IV access or other technical issues. 32 participants (2.1% participants scanned) had an incidental finding on their MRI scan (MI detected by delayed enhancement, structural cardiac abnormality, benign masses, malignant masses, peripheral vascular abnormality, anatomical variation).

1.5 Baseline characteristics

Participant flow is summarised in the CONSORT diagram (figure 1). 5015 people (n=2066, 41.2% male) were screened. 438 failed screening due to either hypertension (n=291, 137 (47.1%) male), a predicted 10-year CHD risk ≥20% (n=146, 142 (97.3%) male) or marked dyslipidaemia (n=1, female). (table 1). 4423 (1740, 39.3% male) participants were eligible for the study.

Table 1. Characteristics of subjects excluded due to presence of increased CHD risk or hypertension.

		Hypertensive (BP> 145/90 mmHg) (n=291)	10-year CHD risk >20% (n=146)
Median (IQR) age (years)		58.2 (12.24)	58.7 (15.23)
No (%) men		138 (47.4)	142 (97.3)
No (%) current smokers		34 (11.7)	85 (58.2)
No (%) former smokers		65 (22.3)	24 (16.4)
No (%) never smokers		151 (51.9) *[N/A41]*	37 (25.3)
Mean (SD) systolic BP(mmHg)		156.5 (9.75)	132.2 (10.91)
Mean (SD) diastolic BP(mmHg)		88.9 (9.68)	77.3 (9.46)
Medan (IQR) heart rate (beats per min)		72.0 (16) [*N/A215]*	68.0 (14) *[N/A11]*
Mean (SD) total cholesterol (mmol/L)		5.69 (1.03) *[N/A55]*	6.07 (1.02)
Mean (SD) high density lipoprotein (mmol/l)		1.42 (0.48) *[N/A58]*	0.89 (0.24)
Mean (SD) low density lipoprotein (mmol/l)		3.34 (0.92) *[N/A71]*	3.93 (0.93) *[N/A17]*
Median (IQR) triglycerides (mmol/l)		1.82 (1.38) *[N/A55]*	2.50 (1.93)
Median (IQR) Body mass index (kg/m^2)		27.5 (5.5) *[N/A202]*	28.3 (4.7) *[N/A6]*
Median (IQR) weight (kg)		82.0 (18.60) *[N/A202]*	83.6 (17.30) *[N/A6]*
Mean (SD) height (cm)		168.5 (8.16) *[N/A202]*	173.4 (7.51) *[N/A6]*
Mean (SD) waist circumference (cm)		91.1 (13.35) *[N/A216]*	97.0 (12.93) *[N/A10]*
Median (IQR) 10-year CHD event risk (%)		5.0 (9.0) *[N/A72]*	20.0 (5.0)
No (%) with family history of cardiovascular disease		49 (16.8) *[N/A96]*	35 (23.2) *[N/A9]*
Scottish Index of Multiple Deprivation decile, number (%)	1	12 (4.1)	8 (5.5)
	2	19 (6.5)	11 (7.5)
	3	29 (10.0)	20 (13.7)
	4	19 (6.5)	10 (6.8)
	5	14 (4.8)	10 (6.8)
	6	21 (7.2)	14 (9.6)
	7	45 (15.5)	22 (15.1)
	8	51 (17.5)	22 (15.1)
	9	61 (21.0)	24 (16.4)
	10	18 (6.2)	4 (2.7)
	N/A	*2 (0.7)*	1 (0.7)

BP, blood pressure, CHD, coronary heart disease, IQR, inter-quartile range, SD, standard deviation. Full data were not collected for all screen failed participants: the number of participants with missing data is indicated in italics.

Median (IQR) BNP levels for men and women were 7.50 (8.90) and 15.30 (17.63) ng/L respectively. The cut-off BNP values for being offered an MRI scan were 8.2 and 16.4 ng/L respectively. The characteristics of those invited for an MRI scan (MRI/BNP group), and those not invited (BNP group) are summarised in table 2.

Table 2. Baseline characteristics of participants.

	BNP group (n=2376)	MRI/BNP group (n=2047)	Difference between BNP and MRI/BNP groups*
Median (IQR) age (years)	49.5 (10.6)	53.4 (12.5)	p<0.001
No (%) men	937 (39.4)	803 (39.3)	p=0.94
No (%) current smokers	351 (14.8)	221 (10.8)	p<0.001
No (%) former smokers	663 (27.9)	563 (27.5)	p=0.81
No (%) never smokers	1361 (57.3)	1256 (61.4)	p=0.004
Mean (SD) systolic BP(mmHg)	122.1 (11.74)	122.9 (11.97)	p=0.027
Mean (SD) diastolic BP (mmHg)	73.6 (9.40)	73.1 (9.23)	p=0.06
Median (IQR) heart rate (beats per min)	67.0 (14)	63.0 (12)	p<0.001
Mean (SD) total cholesterol (mmol/L)	5.47 (1.02)	5.48 (0.99)	p=0.79
Mean (SD) high density lipoprotein (mmol/l)	1.34 (0.44)	1.43 (0.42)	p<0.001
Mean (SD) low density lipoprotein (mmol/l)	3.41 (0.92)	3.40 (0.42)	p=0.84
Median (IQR) triglycerides (mmol/l)	1.38 (1.18)	1.29 (1.02)	p<0.001
Median (IQR) body mass index (kg/m^2)	26.7 (5.80)	26.2 (5.35)	p<0.001
Median (IQR) weight (kg)	75.0 (21.23)	74.1 (19.95)	p=0.08
Mean (SD) height (cm)	167.10 (9.09)	167.67 (9.29)	p=0.041
Mean (SD) waist circumference (cm)	88.0 (13.56)	86.9 (12.95)	p=0.006
Median (IQR) 10-year CHD event risk estimation (%)	2.0 (5.0)	2.0 (5.0)	p<0.001
No (%) with 10-year CHD risk 10-19.9%	286 (12.0)	316 (15.4)	p=0.001

No (%) with family history of cardiovascular disease		561 (23.6)	514 (25.1)	p=0.25
Scottish Index of Multiple Deprivation decile, number (%)	1	132 (5.6)	85 (4.2)	p=0.054
	2	145 (6.1)	106 (5.2)	
	3	208 (8.8)	149 (7.3)	
	4	134 (5.6)	116 (5.7)	
	5	143 (6.0)	126 (6.2)	
	6	218 (9.2)	206 (10.1)	
	7	349 (14.7)	334 (16.3)	
	8	442 (18.6)	401 (19.6)	
	9	428 (18.0)	371 (18.1)	
	10	169 (7.1)	150 (7.3)	
	N/A	8 (0.3)	3 (0.1)	-

BNP, B-type natriuretic peptide, MRI, magnetic resonance imaging, IQR, inter-quartile range, SD, standard deviation, CHD, coronary artery disease. *Comparisons for variables with normal distributions are independent samples t-tests and for skewed distribution the Mann-Whitney-Wilcoxon test.

1.6 Follow up

Electronic anonymised data linkage by the Health Informatics Centre at the University of Dundee will provide follow up data on hospital admissions (including diagnoses and procedures) and GP prescriptions at regular intervals for up to 20 years. This uses data from the Scottish Office's Information Services Division which collects data on all hospital and GP encounters including prescriptions, diagnoses and procedures and from the General Registrar's office which collects data on all deaths in Scotland. Endpoints of interest are myocardial infarction, hospitalisation for angina, requirement for any endovascular procedure, stroke, critical limb ischemia, amputation, sudden death, cardiac and all-cause mortality. Underlying cause of death recorded on death certificates is supplemented by information from hospital records, including post-mortem examinations, if performed.

1.7 Statistical analysis

Analysis was performed using R (v.3.1) and SPSS (v.21). Continuous variables were expressed as mean and standard deviation (SD) for those with a normal distribution or median and inter-quartile range (IQR) for those with a skewed distribution, and categorical variables were expressed as numbers and percentages. When comparing characteristics between participant groups independent samples t-tests were used for variables with a normal distribution and Wilcoxon Mann-Whitney tests were used for those with a skewed distribution. To reduce skewness BNP levels were log10 transformed before regression analyses. Multivariable linear regression analysis was used to determine independent predictors of log10 BNP level. Analysis of correlations used Pearson correlation coefficients for variables with a normal distribution and Spearman Rank correlation for those with a skewed distribution.

Findings to date

Increasing age, female sex, ex-smoking status (but not current smoking status), lower heart rate, higher HDL and lower total cholesterol were significantly associated with higher log10 BNP levels (table 3). The following variables were initially included in the model: age, gender, smoking status, systolic BP, diastolic BP, heart rate, total cholesterol, HDL cholesterol, LDL cholesterol, triglycerides, glucose, BMI, waist circumference, family history of CVD and Scottish index of multiple deprivation (SIMD) decile.

Table 3. Predictors of log10 BNP: multivariable regression analysis.

	Unstandardised Coefficient (95% confidence intervals)	p value
Age (years)	0.010 (0.009, 0.011)	<0.001
Male sex	-0.211 (-0.230, -0.192)	<0.001
Ex-smoker	-0.026 (-0.045, -0.006)	0.01
Heart rate (bpm)	-0.006 (-0.007, -0.005)	<0.001
Total cholesterol (mmol/l)	-0.020 (-0.028, -0.011)	<0.001
High density lipoprotein (mmol/l)	0.055 (0.033, 0.076)	<0.001

The left ventricular characteristics are shown in table 4. A total of 10 patients (0.67%) displayed LGE, indicating the presence of an unidentified myocardial infarct (UMI) [12].

Table 4. Left ventricular characteristics by gender

	Men		Women		
	Mean	SD	Mean	SD	p value*
LVM (g)	129.2	24.4	87.0	16.7	<0.001
LVEDV (ml)	155.0	27.7	119.6	21.1	<0.001
LVESV (ml)	50.2	14.8	37.1	12.0	<0.001
LVM/LVEDV (g/ml)	0.85	0.16	0.74	0.13	<0.001
Ejection fraction (%)	67.9	6.2	69.3	6.6	<0.001
Stroke volume (ml)	104.8	19.0	82.5	14.2	<0.001
Cardiac output (l/min)	6.46	1.20	5.47	1.13	<0.001
LVM/height	73.2	13.1	53.5	9.8	<0.001
LVM/height$^{1.7}$	49.3	8.7	38.1	7.0	<0.001
LVM/height$^{2.7}$	28.0	5.0	23.5	4.4	<0.001
LVM/BSA	64.3	10.6	49.5	8.0	<0.001

SD, standard deviation, LVM, left ventricular mass, LVEDV, left ventricular end-diastolic volume, LVESV, left ventricular end systolic volume, BSA, body surface area. *Comparison between men and women using independent samples t-test.

Three cases (0.2%) were consistent with UMI, and 7 were considered non-specific and located in the mid-myocardium (n=4), epicardium (n=1), or right ventricular insertion points (n=2). Spearman rank correlations of left ventricular measurements with predicted CHD risk score are shown in table 5.

Table 5: Correlations of left ventricular measures with predicted 10-year coronary heart disease risk

	LVM	LVM/height (g/m)	LVM/height$^{1.7}$ (g/m$^{1.7}$)	LVM/height$^{2.7}$ (g/m$^{2.7}$)	LVMI/BSA (g/m^2)	LVM/LVEDV (g/ml)
Men	-0.07 (0.12)	-0.04 (0.31)	-0.02 (0.67)	-0.01 (0.73)	-0.05 (0.24)	0.17 (<0.001)
Women	0.08 (0.018)	0.11 (0.001)	0.13 (<0.001)	0.16 (<0.001)	0.10 (0.002)	0.30 (<0.001)

LVM, left ventricular mass, BSA, body surface area, LVEDV, left ventricular end diastolic volume. Correlations are Spearman rank correlations (ρ and (p) values are given) with predicted 10 year coronary heart disease risk using the ATPIII algorithm.

For WB-MRA 2468 segment locations (5%) demonstrated stenoses, of which 1649 (3.5%) showed stenosis <50% and 484 (1.0%) showed stenosis ≥50% [13]. The median, 80th percentile and 90th percentiles of SASs were 0.00, 1.67 and 3.33 respectively for men, and 0.83, 2.50, and 4.17 for women. There was no significant difference between SASs for men and women (p=0.08). The predicted CHD scores for those with a SAS above and below 80th centile and with and without the presence of any stenosis are shown in table 6.

Table 6: Predicted CHD risk in those with standardised atheroma scores above and below 80th percentile and in those with and without any stenosis.

	Men			Women		
	≤80th centile SAS (n=464)	>80th centile SAS (n=113)	p value*	≤80th centile SAS (n=786)	>80th centile SAS (n=150)	p value*
Median (IQR) predicted CHD risk score (%/10 years)	6 (6)	10 (5)	<0.001	1 (2)	2 (3)	<0.001
	No stenosis (n=308)	Any stenosis (n=269)	p value*	No stenosis (n=457)	Any stenosis (n=479)	p value*
Median (IQR) predicted CHD risk score (%/10 years)	6 (6)	8 (7)	**<0.001**	1 (2)	1 (2)	**<0.001**

*Mann-Whitney test used to compare groups. SAS, standardised atheroma score. 80th centile 1.67 for men and 2.50 for women.

The TASCFORCE study assesses the ability of a novel screening programme combining "traditional" clinical cardiovascular risk estimation with BNP and WBCE-MRI to predict future cardiovascular events. No other studies have investigated screening using this combination of blood and imaging biomarkers of preclinical disease as a potential method to predict future CVD in people free from and at "low" or "intermediate" predicted risk of future disease. The cohort is large and well characterised in terms of cardiovascular risk factors, with an Index of Multiple Deprivation similar to the community from which it was drawn. 602 of those recruited have a predicted 10-year risk of 10-19.9% (classified as intermediate risk); a group that is often debated as to what approach should be taken in terms of primary prevention.

During recruitment a significant number of people had a previously unknown predicted risk ≥20% over 10 years. 97% were men, and were from areas with increased deprivation compared to those who were lower risk and entered the main study. These findings also highlight the problem of currently undetected cardiovascular risk, particularly amongst men and those from areas of deprivation, illustrating the need for improved identification and engagement of those at risk. This could bring greater public health benefits than giving statins to more people at lower risk.

As expected, the BNP levels in the TASCFORCE population were within a "normal" clinical range and were significantly higher in women compared to men, justifying our use of gender specific medians for

invitation for MRI scan.[12,13] Age was independently associated with BNP levels. This is well recognised,[14,15,16] although the exact mechanism for the association remains unclear. Age related alterations in production, secretion, biological effect or degradation of BNP may be responsible.[17,18] The effect of age is independent of renal function, atrial volume, left ventricular dimension and LV mass.[14] Increasing levels with age may suggest that age specific reference ranges of BNP should be used. However, because age is an important risk factor for CVD, BNP may be reflecting this increased risk. Thus correcting for age when using BNP as a screening tool is inadvisable.

MRI is a safe, relatively non-invasive imaging modality, free from ionising radiation making it more acceptable for use as a screening tool compared to coronary artery calcification scoring using CT. By combining cardiac imaging with whole body angiography, it is conceivable that the sensitivity to detect subclinical disease may be improved as more target organs are imaged. The images also provide a reference for normal values within a low/intermediate risk population. The MRI protocol was kept simple, with the main constituents being WBCE-MRI together with CMR for quantification of LV structure and function – all completed within 45 minutes. The CMR acquisition was undertaken at the midpoint of the protocol (commencing after the first Gd contrast injection) to optimise the protocol in terms of time usage and to enable an assessment of late gadolinium enhancement (LGE) at this stage. The acquisition of other measures such as T1, extracellular volume (ECV), T2 mapping or myocardial strain would have been desirable, but the study was limited by the time available and the technological capabilities of the scanner.

The mean LVM values in our cohort are similar to those reported by other studies that have used steady state free precision imaging sequence MRI to determine LVM in a healthy population without CVD and free from hypertension, high cholesterol or treatment.[19] Mean LVM was also higher in men than women similar to other studies. Increased LVM-to-volume ratio (a marker of left ventricular remodelling) was more strongly correlated with predicted CHD risk than LVM or LVM index in both men and women. This measure has been shown to be independently associated with incident CHD [20] and stroke,[20,21] and suggests this may be a better measure of risk than LVM or LVM index which may not be able to differentiate between physiologically increased LVM due to, for example, exercise.

The majority of participants had no evidence of atheroma, however, a higher SAS was associated with a higher predicted CHD risk. A WBCE-MRI angiography derived atheroma score similar to ours was associated with traditional cardiovascular risk factors [22], and with the combined end point of cardiac death, MI, stroke or coronary revascularisation when adjusted for multiple risk factors in a study of 70 year olds, some of whom had a history of CVD.[23] The score improved discrimination and reclassification when added to the Framingham risk score. In our study, the median SAS of 0.83% for females indicates that at least half the female group did have detectable arterial narrowing. This median approached statistical significance (p=0.08) relative to the equivalent for males, although we do not believe this has clinical implications since the overwhelming number of segments assessed (over 40000, 94.7%) were classified as normal.

We report a sex-differential regarding LVM and 10y-CHD risk, where LVM and indexed LVM were not correlated among men, but significantly correlated among women. Three large observational studies (n=1715-4988) reported raised LVM and LVMI, which was associated with higher incident CVD events, but did not report any sex difference.[24-26] Our finding that the LVM and LVMI was significantly associated with predicted 10-year CHD risk in females, but not in males, appears novel.

Healthcare in Scotland is delivered within the public sector National Health Service, and all healthcare contacts, diagnoses and procedures are systematically recorded. Further, all prescribing information from GPs is available in an anonymised form. Follow up is via electronic record linkage, which will reduce the number lost to follow up as direct contact is not required. This will allow analysis of whether the combination of BNP with cardiac MRI markers are able to improve prediction of future CVD. Stored serum, plasma and DNA will allow future novel biomarkers to be discovered or validated.

There is potential bias in the imaged population as those imaged are at the upper end of the BNP range. The MRI results therefore may not represent the low risk population and will prevent comparison of imaging biomarkers between those with high and low BNP levels. However, clinical outcomes between the two groups will be analysed to determine if lower BNP levels can exclude future events.

Given the cost of MRI, the economic viability of this program will need to be assessed. This will be done through a comprehensive follow up which will involve collecting data on hospital admissions and prescriptions, facilitating future economic evaluations of this screening programme.

In conclusion, the TASCFORCE study is investigating the ability of a novel screening programme incorporating BNP and WBCE-MRI to predict future cardiovascular events in a population at low or intermediate predicted risk of CHD. The comprehensive collection of baseline cardiovascular risk and demographic data in combination with blood and imaging biomarkers, and robust follow up via electronic record linkage, will allow further investigation of the development of CVD in this population, which we hope may become the Scottish 'Framingham'.

Collaboration

All data and materials are available stored in the University of Dundee, patient identifiable data is stored in the University of Dundee and NHS Tayside Health Informatics Centre, a Safe Haven. The datasets generated and/or analysed during the current study are not publicly available due to ongoing 10-year analyses but are available from the corresponding author on reasonable request.

Further details

Ethics approval and consent to participate

The protocol was approved by the Tayside Committee of Medical Research Ethics B (reference number: 07/S1402/42) and is available at http://www.controlled-trials.com/ISRCTN38976321/TASCFORCE.

Consent for publication

All authors give consent for this data to be published

Availability of data and materials

All data and materials are available stored in the University of Dundee; patient identifiable data is stored in the Safe Haven. The datasets generated and/or analysed during the current study are not publicly available due to ongoing 10-year analyses but are available from the corresponding author on reasonable request.

Competing interests

There are no competing interests

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Authors' contributions

JJFB and GH wrote the protocol, obtained the funding and contributed to writing the paper

MAL analysed the data to date and contributed to writing the paper

RL was the study coordinator and contributed to writing the paper

AS and FS were on the Trial Steering committee and contributed to writing the paper

CAF contributed to writing the paper and will be analysing future data

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The TASCFORCE Consortium

Prof Jill JF Belch (Principal Investigator), Prof J Graeme Houston, Dr Matthew A Lambert, Prof Allan Struthers, Prof Frank Sullivan (Co-investigators); Dr Roberta Littleford (Trial Manager); Anita Hutcheon, Janice Rowland (Trial Nurses); Dr Jonathan Weir McCall (Imaging methods); Daniel Levin, (statistical analysis); and Prof Colin Palmer (genetics lead).

Table legends

Figure 1: Consort diagram showing TASCFORCE study recruitment

Table 1. Characteristics of subjects excluded due to presence of increased CHD risk or hypertension.

Table 2. Baseline characteristics of participants.

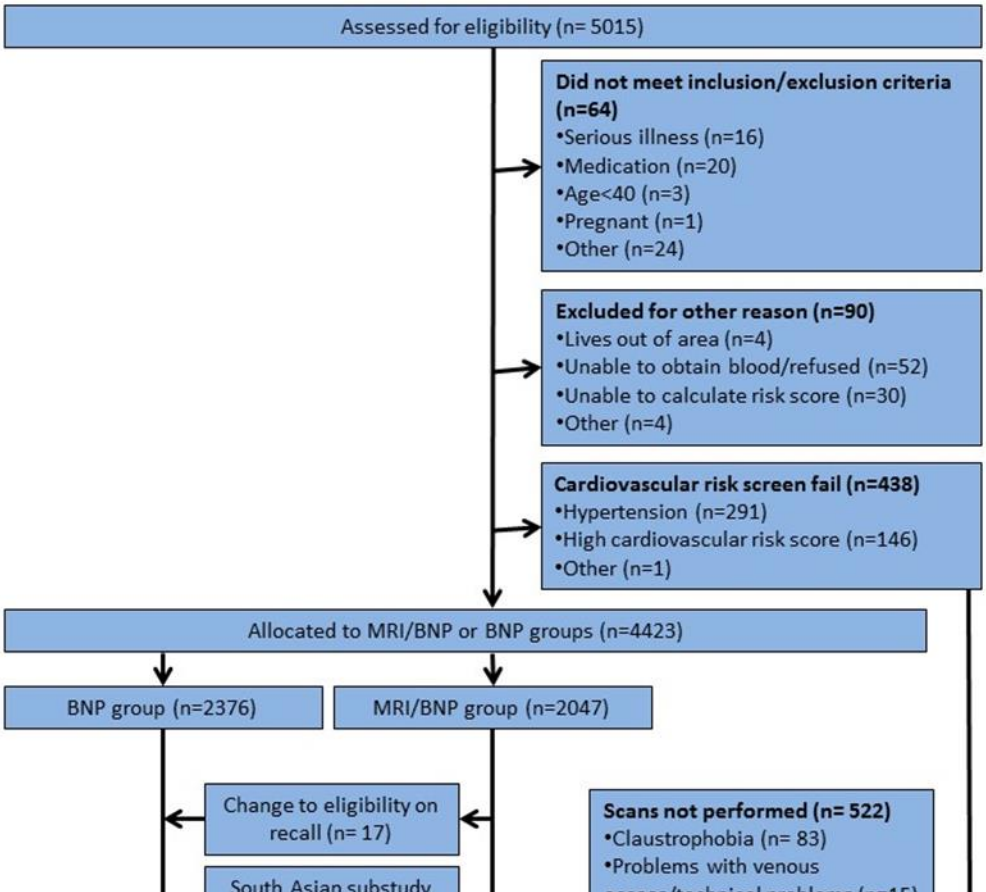
Table 3. Predictors of log10 BNP: multivariable regression analysis.

Table 4. Left ventricular characteristics by gender

Table 5: Correlations of left ventricular measures with predicted 10-year coronary heart disease risk

Table 6: Predicted CHD risk in those with standardised atheroma scores above and below 80th percentile and in those with and without any stenosis.

Figure 1: Consort diagram showing TASCFORCE study recruitment



STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	6
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6/7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	13
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	

Continued on next page

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8-12
		(b) Give reasons for non-participation at each stage	8-12
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8-12
		(b) Indicate number of participants with missing data for each variable of interest	N/A
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	*N/A*
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	*N/A*
		Cross-sectional study—Report numbers of outcome events or summary measures	14-18
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	14-18
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	14-18
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	19/20
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	20/21
Generalisability	21	Discuss the generalisability (external validity) of the study results	19/20
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	4

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Cohort profile: The Tayside Screening For Cardiac Events (TASCFORCE) Study:A Prospective Cardiovascular Risk Screening Study.

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Keywords:	Magnetic resonance imaging < RADIOLOGY & IMAGING, CARDIOLOGY, Cardiovascular imaging < RADIOLOGY & IMAGING

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Cohort profile: The Tayside Screening For Cardiac Events (TASCFORCE) Study:

A Prospective Cardiovascular Risk Screening Study.

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Abstract

Purpose: Risk factor based models struggle to accurately predict development of cardiovascular disease (CVD) at the level of the individual. Ways of identifying people with low predicted risk who will develop CVD would allow stratified advice and support informed treatment decisions about the initiation or adjustment of preventive medication, and this is the aim of this prospective cohort study.

Participants: The Tayside Screening for Cardiac Events (TASCFORCE) study recruited male and females aged ≥40yrs, free from known CVD, with a predicted 10-year risk of coronary heart disease (CHD) <20%. If B-type natriuretic peptide (BNP) was greater than their gender-median, participants were offered a whole-body contrast enhanced magnetic resonance (WBCE-MRI) scan (cardiac imaging, whole-body angiography to determine left ventricular parameters, delayed gadolinium enhancement, atheroma burden). Blood, including DNA, was stored for future biomarker assays. Participants are being followed up using electronic record-linkage cardiovascular outcomes.

Findings to date: 4423 (1740, 39.3% male) were recruited. Mean age 52.3 years. Median BNP 7.50ng/L and 15.30ng/L for male and females respectively. 602 had a predicted 10-year risk of 10-19.9%, with the remainder <10%. Age, female sex, ex-smoking status, lower heart rate, higher high-density lipoprotein and lower total cholesterol were independently associated with higher log10 BNP levels. Mean left ventricular mass was 129.2g and 87.0g in males and females respectively.

Future plans: The TASCFORCE study is investigating the ability of a screening programme, using BNP and WBCE-MRI, at the time of enrolment, to evaluate prediction of CVD in a population at low/intermediate risk.. Blood stored for future biomarker analyses will allow testing/development of novel biomarkers. We believe this could be a new UK Framingham study allowing study for many years to come.

Clinical Trial Registration: ISRCTN38976321 https://doi.org/10.1186/ISRCTN38976321 registered 4th April 2007

Key words: Cardiovascular risk; Clinical Trial; magnetic resonance imaging; B-type natriuretic peptide; Cardiovascular Biomarkers

Strengths and weaknesses

1. This study is one of the largest MRI/Cardiovascular risk studies to be published. It could be a UK Framingham

2. The MRI Scanning is a novel element to a cardiovascular risk trial, particularly as it is whole body and contrast enhanced

3. As many of the participants have also signed up to SHARE, it will be possible to link all subsequent blood tests from SHARE with our cohort details to study novel biomarkers as they are discovered

4. As these were 'healthy' volunteers it will take some time for cardiovascular events to occur

5. Not all participants underwent MRI scanning due to cost, only those above the BNP cut off, however numbers (n=1528) are sufficient to allow evaluations, and all (n=4423) had the demographic, and blood screening.

List of abbreviations

TASCFORCE -The Tayside Screening for Cardiac Events

CVD – Cardiovascular disease

WBCE-MRI -whole-body contrast enhanced magnetic resonance scan

BNP - B-type natriuretic peptide

CHD – Coronary Heart Disease

GP – General Practice

ECG – electrocardiogram

BP – Blood pressure

ATPIII – Adult Treatment Panel III

CMR - Cardiac magnetic resonance

LVM - left ventricular mass

SAS - standardised atheroma score

SD - standard deviation

IQR -inter-quartile range

CT – Computerised Tomography

MRI – Magnetic Resonance Imaging

HDL – High Density Lipoprotein

LDL – Low Density Lipoprotein

MI – Myocardial Infarction

SIMD - Scottish index of multiple deprivation

LGE – late gadolinium enhancement

UMI – unidentified myocardial infarct

ECV - extracellular volume

BMI – Body Mass Index

Introduction

Currently statins and other drugs for cardiovascular disease (CVD) primary prevention is targeted at those at increased risk by using risk estimation tools, but these have poor external validity.[1] A significant number of CVD occurs in people with “low” or “intermediate” cardiovascular risk [2] and many in these groups have evidence of atherosclerosis.[3,4] Offering statins to a wider range of the population has been suggested.[5] However, offering statins more widely raises a number of economic and ethical questions and concerns,[6,7] so improved targeted therapy may be more acceptable. Risk factor-based models struggle to predict development of disease at an individual person level, and an alternative approach could be the detection of preclinical disease - an approach successfully employed in cancer. A similar strategy for CVD could facilitate individualised risk assessment and aid decisions about treatment.

The **Ta**yside **Sc**reening for **C**ardiac **E**vents (TASCFORCE) study is investigating the ability of a screening programme using B-type natriuretic peptide (BNP) and whole-body contrast enhanced magnetic resonance imaging (WBCE-MRI) incorporating cardiac imaging and whole-body angiography to detect preclinical disease and predict future clinical CVD in a large population at low or intermediate risk. Blood stored will allow validation of future proposed biomarkers. The study is novel in using a relatively cheap biomarker (BNP) to decide who proceeds to a relatively expensive test (MRI scan).

The aim of this study is to provide baseline data on both imaging and blood biomarkers, to understand which, if any, may predict future Cardiovascular events. The comprehensive collection of baseline cardiovascular risk and demographic data in combination with the blood and imaging biomarkers and robust follow up via electronic health record linkage will allow further investigation of the development of CVD in this population, which we hope may become the Scottish ‘Framingham.’

Cohort description

1.1. Study design

TASCFORCE is a prospective normal volunteer cardiovascular risk screening study (ISRCTN number: ISRCTN38976321). The East of Scotland Research Ethics Committee approved the protocols (07/S1402/42). The study was conducted at Ninewells Hospital and Medical School, Dundee, UK, in accordance with the Good Clinical Practice Declaration of Helsinki. The volunteers gave written informed consent to participate in this study.

The study is registered on http://www.controlled-trials.com/ISRCTN38976321/TASCFORCE.

Males and females aged 40 years or older living in Tayside or Fife, Scotland, who were free from CVD and had a predicted 10-year risk of coronary heart disease (CHD) <20% were recruited. Participants were excluded if they were pregnant, breast-feeding, of child-bearing potential not using adequate contraception, unable to give consent, or had another accepted indication for statin therapy. To produce a cohort able to participate in a potential future statin intervention study those with contraindications to a statin were excluded, including known alcohol abuse or participation in a clinical trial other than observational trials or registries concurrently or within 30 days prior to screening, were excluded.

Participants were recruited from General Practice (GP) surgeries, local employers, publicity campaigns, via press and radio coverage of the project, direct mailing and using Human Research Ethics Committee approved leaflets. We aimed to obtain a locally representative population, so recruitment was targeted at socioeconomic and ethnic groups often under-represented in studies. Participants were recruited between November 2007 and February 2013.

1.2 *Patient and Public Involvement*

The Souter Foundation trustees ('lay' people) were involved in the design of the study. Volunteers who were recruited to the study were involved in the design, regarding the scheduling and timing of testing, to improve convenience for participants. Many volunteers were involved in further recruitment, by passing on information via word of mouth. Results of the final analysis using linked data will be disseminated to the participants via postal address.

1.3 *Screening visit and risk estimation*

Following written informed consent for the study, and for data-linkage for up to 20 years, the following information was obtained: medical history, lifestyle risk factors (diet/exercise/smoking status), risk perception question, family history of premature CVD, and concomitant medication. Risk perception included questions regarding family history, exercise frequency, cigarette smoking and added salt to food. Subjects were examined to obtain their height, weight, waist circumference and blood pressure (BP) and a 12-lead electrocardiogram (ECG) was recorded. Plasma BNP, random lipid profile and random plasma glucose levels were determined using point of care testing equipment (Alere Triage BNP assay with Alere Triage MeterPro for BNP, and Alere Cholestech LDX analyser for lipids and glucose).

Each participant's predicted CHD event rate was calculated by using the National Cholesterol Education Program Adult Treatment Panel III (ATP III) guidelines.[8] Participants who had a predicted risk ≥20% or a BP >145/90 mmHg were excluded but were asked for consent to be followed up. Ineligible subjects were informed of their risk factors, given a copy of their results, and asked to attend their GP for formal review. All participants received counselling on modifiable risk factors by study staff aided by British Heart Foundation leaflets.

1.4 Magnetic resonance imaging

Those with a BNP greater than the median (determined after 200 participants) were invited to attend for a WBCE-MRI scan. At a prespecified review after 1000 subjects it was observed that the median BNP was higher for females than males. The trial steering committee (comprising of the authors) decided to invite for a scan based on gender specific median BNP and the protocol was amended accordingly. Those recruited earlier who would be eligible based on the amended gender specific median were recalled. If the delay was greater than three months, they had their BNP, cholesterol and CHD risk score reassessed to ensure continued eligibility.

Combined cardiac and whole-body angiography MRI scans were performed on a 32-channel 3T Magnetom Trio scanner (Siemens, Erlangen, Germany) and used gadoteric acid contrast agent (Dotarem; Guerbet Laboratories, France). The scan protocol development and validation has been described in detail elsewhere.[9,10]

Details of the image acquisition, analysis and validation of the technique have been described and validated in earlier publications.[9,10,11] Cardiac magnetic resonance (CMR) images were analysed offline by four blinded observers using commercial software ('Argus', Siemens Multi-modality Work

Platform, version VB15). Electronic region of interest contours were placed around endocardial and epicardial left ventricular borders at end-diastole and end-systole on all CMR image slices identified to contain ≥50% full-thickness myocardium. Quantitative measurement of left ventricular mass (LVM), ejection fraction, end-diastolic volume, end-systolic volume, and stroke volume were derived. The presence of luminal stenosis was assessed in 30 arterial segments from the internal carotids to the distal anterior tibial arteries (the coeliac artery was not included due to marked anatomical variation resulting in poor inter-observer agreement). A categorical grading scale from 0-4 was applied to each arterial segment as follows: grade 0=healthy segment, grade 1=1-50% stenosis, grade 2=51-70% stenosis, grade 3=71-99% stenosis, and grade 4=vessel occlusion. An additional point was added for presence of aneurysm >50% of the native vessel diameter. If any arterial segment contained more than one luminal abnormality the more severe abnormality was scored. If a segment was uninterpretable because of poor image quality, it was not allocated a numeric score. A standardised atheroma score (SAS) to express atheroma burden severity across the body as a percentage was calculated using the following equation where n is the number of interpretable segments:

$SAS=[(\sum score/n)x1/4]x100$

Of those invited, 1528 (74.8%) completed or partially completed an MRI scan. Thirty-four were not safe to scan due to metal in situ, 373 did not agree to proceed to have a scan, and 12 failed to attend. One hundred and one participants abandoned their scan mainly due to claustrophobia (n=83), with others abandoned due to large body habitus, problems with IV access or other technical issues. Thirty-two participants (2.1% participants scanned) had an incidental finding on their MRI scan (MI detected by delayed enhancement, structural cardiac abnormality, benign masses, malignant masses, peripheral vascular abnormality, anatomical variation). These subjects were removed from the key study group.

1.5 Baseline characteristics

Participant flow is summarised in the CONSORT diagram (figure 1); 5015 people (n=2066, 41.2% male) were screened. In total, 438 failed screening due to either hypertension (n=291, 137 (47.1%) male), a predicted 10-year CHD risk ≥20% (n=146, 142 (97.3%) male) or marked dyslipidaemia (n=1, female). The enrolled population was determined to be at low or intermediate risk of CVD. (Supplemental Table 1). We have a specific ethnic group of South Asian people (n=19) deliberately

enrolled to attempt to cater for ethnic diversity. These subjects were recruited with the help of a local Mosque. The remainder are white British. These two ethnic groups are dominant in Tayside and the relative proportions enrolled reflects the distribution in the population. Further we have documented the Scottish Index of Multiple Deprivation (SIMD) for all subjects i.e., the area of deprivation in which they lived at time of enrolment. As the Scottish population is not very mobile, we believe this can be used in our 10y analyses. We also have other risk factors which relate to socioeconomic status such as obesity (BMI, waist Circumference), cigarette smoking and sex. These social determinants will all be evaluated in our 10y analysis. A total of 4423 (1740, 39.3% male) participants were eligible for the study.

Median (IQR) BNP levels for men and women were 7.50 (8.90) and 15.30 (17.63) ng/L respectively. The cut-off BNP values for being offered an MRI scan were 8.2 and 16.4 ng/L respectively; all South Asian participants were invited for MRI irrespective of BNP level. The characteristics of those invited for an MRI scan (MRI/BNP group), and those not invited (BNP group) are summarised in table 1.

Table 1. Baseline characteristics of participants.

	BNP group (n=2376)	MRI/BNP group (n=2047)	Difference between BNP and MRI/BNP groups*
Median (IQR) age (years)	49.5 (10.6)	53.4 (12.5)	p<0.001
No (%) men	937 (39.4)	803 (39.3)	p=0.94
No (%) current smokers	351 (14.8)	221 (10.8)	p<0.001
No (%) former smokers	663 (27.9)	563 (27.5)	p=0.81
No (%) never smokers	1361 (57.3)	1256 (61.4)	p=0.004
Mean (SD) systolic BP (mmHg)	122.1 (11.74)	122.9 (11.97)	p=0.027
Mean (SD) diastolic BP (mmHg)	73.6 (9.40)	73.1 (9.23)	p=0.06
Median (IQR) heart rate (beats per min)	67.0 (14)	63.0 (12)	p<0.001
Mean (SD) total cholesterol (mmol/L)	5.47 (1.02)	5.48 (0.99)	p=0.79
Mean (SD) high density lipoprotein (mmol/l)	1.34 (0.44)	1.43 (0.42)	p<0.001
Mean (SD) low density lipoprotein (mmol/l)	3.41 (0.92)	3.40 (0.42)	p=0.84
Median (IQR) triglycerides (mmol/l)	1.38 (1.18)	1.29 (1.02)	p<0.001
Median (IQR) body mass index (kg/m^2)	26.7 (5.80)	26.2 (5.35)	p<0.001
Median (IQR) weight (kg)	75.0 (21.23)	74.1 (19.95)	p=0.08
Mean (SD) height (cm)	167.10 (9.09)	167.67 (9.29)	p=0.041
Mean (SD) waist circumference (cm)	88.0 (13.56)	86.9 (12.95)	p=0.006
Median (IQR) 10-year CHD event risk estimation (%)	2.0 (5.0)	2.0 (5.0)	p<0.001
No (%) with 10-year CHD risk 10-19.9%	286 (12.0)	316 (15.4)	p=0.001

No (%) with family history of cardiovascular disease		561 (23.6)	514 (25.1)	p=0.25
Scottish Index of Multiple Deprivation decile, number (%)	1	132 (5.6)	85 (4.2)	p=0.054
	2	145 (6.1)	106 (5.2)	
	3	208 (8.8)	149 (7.3)	
	4	134 (5.6)	116 (5.7)	
	5	143 (6.0)	126 (6.2)	
	6	218 (9.2)	206 (10.1)	
	7	349 (14.7)	334 (16.3)	
	8	442 (18.6)	401 (19.6)	
	9	428 (18.0)	371 (18.1)	
	10	169 (7.1)	150 (7.3)	
	N/A	8 (0.3)	3 (0.1)	-

BNP, B-type natriuretic peptide, MRI, magnetic resonance imaging, IQR, inter-quartile range, SD, standard deviation, CHD, coronary artery disease. *Comparisons for variables with normal distributions are independent samples t-tests and for skewed distribution the Mann-Whitney-Wilcoxon test.

1.6 Follow up

Electronic anonymised data linkage by the Health Informatics Centre at the University of Dundee will provide follow up data on hospital admissions (including diagnoses and procedures) and GP prescriptions at regular intervals for up to 20 years (10, 15 and 20 years planned). This uses data from the Scottish Office's Information Services Division which collects data on all hospital and GP encounters including prescriptions, diagnoses, and procedures and from the General Registrar's office which collects data on all deaths in Scotland. Endpoints of interest are myocardial infarction, hospitalisation for angina, requirement for any endovascular procedure, stroke, critical limb ischemia, amputation, sudden death, cardiac and all-cause mortality. Underlying cause of death recorded on death certificates is supplemented by information from hospital records, including post-mortem examinations, if performed.

1.7 Statistical analysis

Analysis was performed using R (v.3.1) and SPSS (v.21). Continuous variables were expressed as mean and standard deviation (SD) for those with a normal distribution or median and inter-quartile range (IQR) for those with a skewed distribution, and categorical variables were expressed as numbers and percentages. When comparing characteristics between participant groups independent samples t-tests were used for variables with a normal distribution and Wilcoxon Mann-Whitney tests were used for those with a skewed distribution. To reduce skewness BNP levels were log10 transformed before regression analyses. Multivariable linear regression analysis was used to determine independent predictors of log10 BNP level. The following variables were initially included in the model: age, sex, smoking status, systolic BP, diastolic BP, heart rate, total cholesterol, HDL cholesterol, LDL cholesterol, triglycerides, glucose, BMI, waist circumference, family history of CVD and Scottish index of multiple deprivation (SIMD) decile. Analysis of correlations used Pearson correlation coefficients for variables with a normal distribution and Spearman Rank correlation for those with a skewed distribution.

Findings to date

Increasing age, female sex, ex-smoking status (but not current smoking status), lower heart rate, higher HDL and lower total cholesterol were significantly associated with higher log10 BNP levels (table 2).

Table 2. Predictors of log10 BNP: multivariable regression analysis.

	Unstandardised Coefficient (95% confidence intervals)	p value
Age (years)	0.010 (0.009, 0.011)	<0.001
Male sex	-0.211 (-0.230, -0.192)	<0.001
Ex-smoker	-0.026 (-0.045, -0.006)	0.01
Heart rate (bpm)	-0.006 (-0.007, -0.005)	<0.001
Total cholesterol (mmol/l)	-0.020 (-0.028, -0.011)	<0.001
High density lipoprotein (mmol/l)	0.055 (0.033, 0.076)	<0.001

The left ventricular characteristics are shown in table 3. A total of 10 patients (0.67%) displayed LGE, indicating the presence of an unidentified myocardial infarct (UMI) [12].

Table 3. Left ventricular characteristics by gender

	Men		Women		
	Mean	SD	Mean	SD	p value*
LVM (g)	129.2	24.4	87.0	16.7	<0.001
LVEDV (ml)	155.0	27.7	119.6	21.1	<0.001
LVESV (ml)	50.2	14.8	37.1	12.0	<0.001
LVM/LVEDV (g/ml)	0.85	0.16	0.74	0.13	<0.001
Ejection fraction (%)	67.9	6.2	69.3	6.6	<0.001
Stroke volume (ml)	104.8	19.0	82.5	14.2	<0.001
Cardiac output (l/min)	6.46	1.20	5.47	1.13	<0.001
LVM/height	73.2	13.1	53.5	9.8	<0.001
LVM/height$^{1.7}$	49.3	8.7	38.1	7.0	<0.001
LVM/height$^{2.7}$	28.0	5.0	23.5	4.4	<0.001
LVM/BSA	64.3	10.6	49.5	8.0	<0.001

SD, standard deviation, LVM, left ventricular mass, LVEDV, left ventricular end-diastolic volume, LVESV, left ventricular end systolic volume, BSA, body surface area. *Comparison between men and women using independent samples t-test.

Three cases (0.2%) were consistent with UMI, and 7 were considered non-specific and located in the mid-myocardium (n=4), epicardium (n=1), or right ventricular insertion points (n=2). Spearman rank correlations of left ventricular measurements with predicted CHD risk score are shown in table 4.

Table 4: Correlations of left ventricular measures with predicted 10-year coronary heart disease risk

	LVM	LVM/height (g/m)	LVM/height$^{1.7}$ (g/m$^{1.7}$)	LVM/height$^{2.7}$ (g/m$^{2.7}$)	LVMI/BSA (g/m^2)	LVM/LVEDV (g/ml)
Men	-0.07 (0.12)	-0.04 (0.31)	-0.02 (0.67)	-0.01 (0.73)	-0.05 (0.24)	0.17 (<0.001)
Women	0.08 (0.018)	0.11 (0.001)	0.13 (<0.001)	0.16 (<0.001)	0.10 (0.002)	0.30 (<0.001)

LVM, left ventricular mass, BSA, body surface area, LVEDV, left ventricular end diastolic volume. Correlations are Spearman rank correlations (ρ and (p) values are given) with predicted 10-year coronary heart disease risk using the ATPIII algorithm.

For WB-MRA 2468 segment locations (5%) demonstrated stenoses, of which 1649 (3.5%) showed stenosis <50% and 484 (1.0%) showed stenosis ≥50% [13]. The median, 80th percentile and 90th percentiles of SASs were 0.00, 1.67 and 3.33 respectively for men, and 0.83, 2.50, and 4.17 for women. There was no significant difference between SASs for men and women (p=0.08). The predicted CHD scores for those with a SAS above and below 80th centile and with and without the presence of any stenosis are shown in table 5.

Table 5: Predicted CHD risk in those with standardised atheroma scores above and below 80th percentile and in those with and without any stenosis.

	Males			Females		
	≤80th centile SAS (n=464)	>80th centile SAS (n=113)	p value*	≤80th centile SAS (n=786)	>80th centile SAS (n=150)	p value*
Median (IQR) predicted CHD risk score (%/10 years)	6 (6)	10 (5)	<0.001	1 (2)	2 (3)	<0.001
	No stenosis (n=308)	Any stenosis (n=269)	p value*	No stenosis (n=457)	Any stenosis (n=479)	p value*
Median (IQR) predicted CHD risk score (%/10 years)	6 (6)	8 (7)	**<0.001**	1 (2)	1 (2)	**<0.001**

*Mann-Whitney test used to compare groups. SAS, standardised atheroma score. 80th centile 1.67 for men and 2.50 for women.

The TASCFORCE study assesses the ability of a novel screening programme combining "traditional" clinical cardiovascular risk estimation with BNP and WBCE-MRI to predict future cardiovascular events. No other studies have investigated screening using this combination of blood and imaging biomarkers of preclinical disease as a potential method to predict future CVD in people free from and at "low" or "intermediate" predicted risk of future disease. The cohort is large and well characterised in terms of cardiovascular risk factors, with an Index of Multiple Deprivation similar to the community from which it was drawn. Of those recruited, 602 have a predicted 10-year risk of 10-19.9% (classified as intermediate risk); a group that is often debated as to what approach should be taken in terms of primary prevention.

During recruitment, a significant number of people had a previously unknown predicted risk ≥20% over 10 years. A total of 97% were males, and from areas with increased deprivation compared to those who were lower risk and entered the main study. These findings also highlight the problem of currently undetected cardiovascular risk, particularly amongst males and those from areas of deprivation, illustrating the need for improved identification and engagement of those at risk. This could bring greater public health benefits than giving statins to more people at lower risk.

As expected, the BNP levels in the TASCFORCE population were within a "normal" clinical range and were significantly higher in females compared to males, justifying our use of gender specific medians

for invitation for MRI scan.[12,13] Age was independently associated with BNP levels. This is well recognised,[14,15,16] although the exact mechanism for the association remains unclear. Age related alterations in production, secretion, biological effect or degradation of BNP may be responsible.[17,18] The effect of age is independent of renal function, atrial volume, left ventricular dimension and LV mass.[14] Increasing levels with age may suggest that age specific reference ranges of BNP should be used. However, because age is an important risk factor for CVD, BNP may be reflecting this increased risk. Thus, correcting for age when using BNP as a screening tool is inadvisable.

MRI is a safe, relatively non-invasive imaging modality, free from ionising radiation making it more acceptable for use as a screening tool compared to coronary artery calcification scoring using CT. By combining cardiac imaging with whole body angiography, it is conceivable that the sensitivity to detect subclinical disease may be improved as more target organs are imaged. The images also provide a reference for normal values within a low/intermediate risk population. The MRI protocol was kept simple, with the main constituents being WBCE-MRI together with CMR for quantification of LV structure and function – all completed within 45 minutes. The CMR acquisition was undertaken at the midpoint of the protocol (commencing after the first Gd contrast injection) to optimise the protocol in terms of time usage and to enable an assessment of late gadolinium enhancement (LGE) at this stage. The acquisition of other measures such as T1, extracellular volume (ECV), T2 mapping or myocardial strain would have been desirable, but the study was limited by the time available and the technological capabilities of the scanner.

The mean LVM values in our cohort are similar to those reported by other studies that have used steady state free precision imaging sequence MRI to determine LVM in a healthy population without CVD and free from hypertension, high cholesterol or treatment.[19] Mean LVM was also higher in males than females similar to other studies. Increased LVM-to-volume ratio (a marker of left ventricular remodelling) was more strongly correlated with predicted CHD risk than LVM or LVM index in both males and females. This measure has been shown to be independently associated with incident CHD [20] and stroke,[20,21] and suggests this may be a better measure of risk than LVM or LVM index which may not be able to differentiate between physiologically increased LVM due to, for example, exercise.

The majority of participants had no evidence of atheroma; however, a higher SAS was associated with a higher predicted CHD risk. A WBCE-MRI angiography derived atheroma score similar to ours was associated with traditional cardiovascular risk factors [22], and with the combined end point of cardiac death, MI, stroke or coronary revascularisation when adjusted for multiple risk factors in a study of 70 year olds, some of whom had a history of CVD.[23] The score improved discrimination and reclassification when added to the Framingham risk score. In our study, the median SAS of 0.83% for females indicates that at least half the female group did have detectable arterial narrowing. This median approached statistical significance (p=0.08) relative to the equivalent for males, although we do not believe this has clinical implications since the overwhelming number of segments assessed (over 40000, 94.7%) were classified as normal.

We report a sex-differential regarding LVM and 10y-CHD risk, where LVM and indexed LVM were not correlated among males, but significantly correlated among females. Three large observational studies (n=1715-4988) reported raised LVM and LVMI, which was associated with higher incident CVD events, but did not report any sex difference.[24-26] Our finding that the LVM and LVMI was significantly associated with predicted 10-year CHD risk in females, but not in males, appears novel.

Healthcare in Scotland is delivered within the public sector National Health Service, and all healthcare contacts, diagnoses and procedures are systematically recorded. Further, all prescribing information from GPs is available in an anonymised form. Follow up is via electronic health record linkage, which will reduce the number lost to follow up as direct contact is not required. This will allow analysis of whether the combination of BNP with cardiac MRI markers are able to improve prediction of future CVD. Stored serum, plasma and DNA will allow future novel biomarkers to be discovered or validated.

There is potential bias in the imaged population as those imaged are at the upper end of the BNP range. The MRI results therefore may not represent the low-risk population and will prevent comparison of imaging biomarkers between those with high and low BNP levels. However, clinical outcomes between the two groups will be analysed to determine if lower BNP levels can exclude future events.

Given the cost of MRI, the economic viability of this program will need to be assessed. This will be done through a comprehensive follow up which will involve collecting data on hospital admissions and prescriptions, facilitating future economic evaluations of this screening programme.

In conclusion, the TASCFORCE study is investigating the ability of a novel screening programme incorporating BNP and WBCE-MRI to predict future cardiovascular events in a population at low or intermediate predicted risk of CHD. The comprehensive collection of baseline cardiovascular risk and demographic data in combination with blood and imaging biomarkers, and robust follow up via electronic record linkage, will allow further investigation of the development of CVD in this population, which we hope may become the Scottish 'Framingham.'

Collaboration

All data and materials are available stored in the University of Dundee, patient identifiable data is stored in the University of Dundee and NHS Tayside Health Informatics Centre, a Safe Haven. The datasets generated and/or analysed during the current study are not publicly available due to ongoing 10-year analyses but are available from the corresponding author on reasonable request.

Further details

Ethics approval and consent to participate

The protocol was approved by the Tayside Committee of Medical Research Ethics B (reference number: 07/S1402/42) and is available at http://www.controlled-trials.com/ISRCTN38976321/TASCFORCE.

Consent for publication

All authors give consent for this data to be published

Availability of data and materials

All data and materials are available stored in the University of Dundee; anonymised patient data is stored in the Safe Haven. The datasets generated and/or analysed during the current study are not publicly available due to ongoing 10-year analyses but are available from the corresponding author on reasonable request.

Competing interests

There are no competing interests

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Authors' contributions

JJFB and GH wrote the protocol, obtained the funding, and contributed to writing the paper

MAL analysed the data to date and contributed to writing the paper

RL was the study coordinator and contributed to study design and writing the paper

AS and FS were on the Trial Steering committee and contributed to writing the paper

SG obtained the MRI data and contributed to writing the paper

CAF contributed to writing the paper and will be analysing future data

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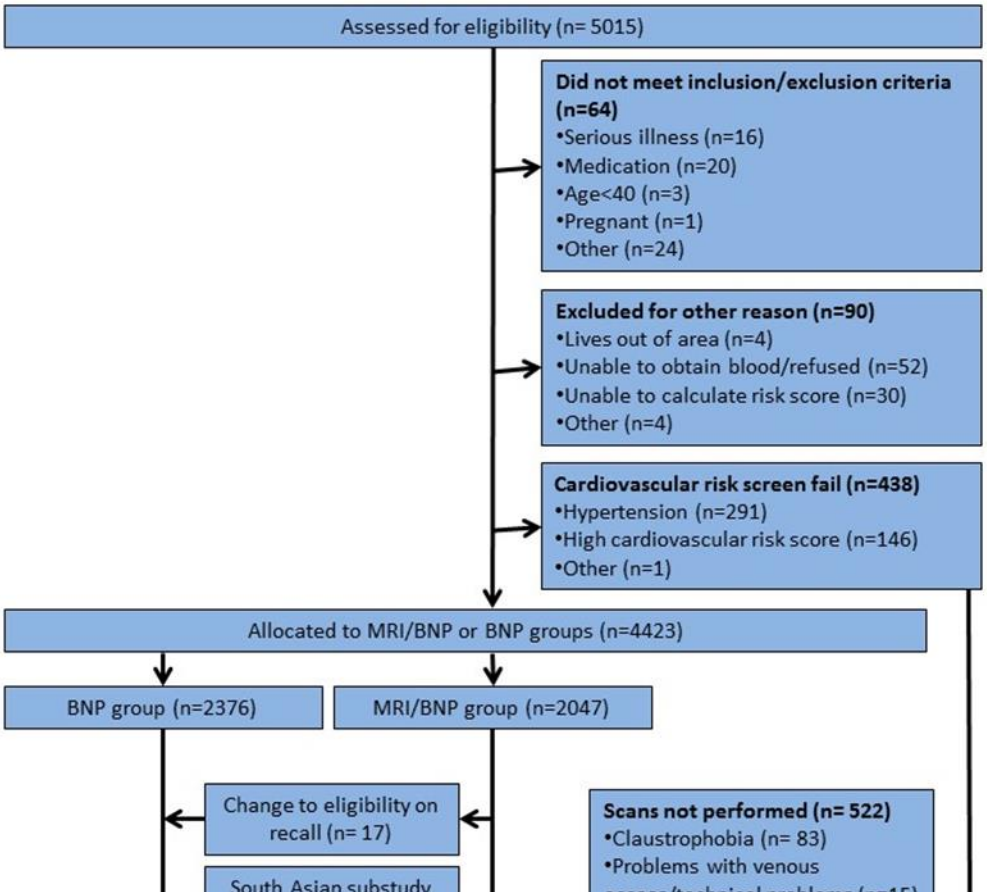
The TASCFORCE Consortium

Prof Jill JF Belch (Principal Investigator), Prof J Graeme Houston, Dr Matthew A Lambert, Prof Allan Struthers, Prof Frank Sullivan (Co-investigators); Dr Roberta Littleford (Trial Manager); Anita Hutcheon, Janice Rowland (Trial Nurses); Dr Jonathan Weir McCall (Imaging methods); Daniel Levin, (statistical analysis); and Prof Colin Palmer (genetics lead).

Figure legends

Figure 1: Consort diagram showing TASCFORCE study recruitment

Figure 1: Consort diagram showing TASCFORCE study recruitment



Supplemental Table 1. Characteristics of subjects excluded due to presence of increased CHD risk or hypertension.

		Hypertensive (BP> 145/90 mmHg) (n=291)	10-year CHD risk >20% (n=146)
Median (IQR) age (years)		58.2 (12.24)	58.7 (15.23)
No (%) men		138 (47.4)	142 (97.3)
No (%) current smokers		34 (11.7)	85 (58.2)
No (%) former smokers		65 (22.3)	24 (16.4)
No (%) never smokers		151 (51.9) *[N/A41]*	37 (25.3)
Mean (SD) systolic BP (mmHg)		156.5 (9.75)	132.2 (10.91)
Mean (SD) diastolic BP (mmHg)		88.9 (9.68)	77.3 (9.46)
Medan (IQR) heart rate (beats per min)		72.0 (16) [*N/A215]*	68.0 (14) *[N/A11]*
Mean (SD) total cholesterol (mmol/L)		5.69 (1.03) *[N/A55]*	6.07 (1.02)
Mean (SD) high density lipoprotein (mmol/l)		1.42 (0.48) *[N/A58]*	0.89 (0.24)
Mean (SD) low density lipoprotein (mmol/l)		3.34 (0.92) *[N/A71]*	3.93 (0.93) *[N/A17]*
Median (IQR) triglycerides (mmol/l)		1.82 (1.38) *[N/A55]*	2.50 (1.93)
Median (IQR) Body mass index (kg/m^2)		27.5 (5.5) *[N/A202]*	28.3 (4.7) *[N/A6]*
Median (IQR) weight (kg)		82.0 (18.60) *[N/A202]*	83.6 (17.30) *[N/A6]*
Mean (SD) height (cm)		168.5 (8.16) *[N/A202]*	173.4 (7.51) *[N/A6]*
Mean (SD) waist circumference (cm)		91.1 (13.35) *[N/A216]*	97.0 (12.93) *[N/A10]*
Median (IQR) 10-year CHD event risk (%)		5.0 (9.0) *[N/A72]*	20.0 (5.0)
No (%) with family history of cardiovascular disease		49 (16.8) *[N/A96]*	35 (23.2) *[N/A9]*
Scottish Index of Multiple Deprivation decile,	1	12 (4.1)	8 (5.5)
number (%)	2	19 (6.5)	11 (7.5)
	3	29 (10.0)	20 (13.7)
	4	19 (6.5)	10 (6.8)
	5	14 (4.8)	10 (6.8)
	6	21 (7.2)	14 (9.6)
	7	45 (15.5)	22 (15.1)
	8	51 (17.5)	22 (15.1)
	9	61 (21.0)	24 (16.4)
	10	18 (6.2)	4 (2.7)
	N/A	*2 (0.7)*	1 (0.7)

BP, blood pressure, CHD, coronary heart disease, IQR, inter-quartile range, SD, standard deviation. Full data were not collected for all screen failed participants: the number of participants with missing data is indicated in italics.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	6
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6/7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	13
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	

Continued on next page

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8-12
		(b) Give reasons for non-participation at each stage	8-12
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8-12
		(b) Indicate number of participants with missing data for each variable of interest	N/A
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	*N/A*
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	*N/A*
		Cross-sectional study—Report numbers of outcome events or summary measures	14-18
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	14-18
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	14-18
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	19/20
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	20/21
Generalisability	21	Discuss the generalisability (external validity) of the study results	19/20
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	4

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Cohort profile: The Tayside Screening For Cardiac Events (TASCFORCE) Study:A Prospective Cardiovascular Risk Screening Study.

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Cohort profile: The Tayside Screening For Cardiac Events (TASCFORCE) Study: A Prospective Cardiovascular Risk Screening Study.

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Abstract

Purpose: Risk factor based models struggle to accurately predict development of cardiovascular disease (CVD) at the level of the individual. Ways of identifying people with low predicted risk who will develop CVD would allow stratified advice and support informed treatment decisions about the initiation or adjustment of preventive medication, and this is the aim of this prospective cohort study.

Participants: The Tayside Screening for Cardiac Events (TASCFORCE) study recruited male and females aged ≥40yrs, free from known CVD, with a predicted 10-year risk of coronary heart disease (CHD) <20%. If B-type natriuretic peptide (BNP) was greater than their gender-median, participants were offered a whole-body contrast enhanced magnetic resonance (WBCE-MRI) scan (cardiac imaging, whole-body angiography to determine left ventricular parameters, delayed gadolinium enhancement, atheroma burden). Blood, including DNA, was stored for future biomarker assays. Participants are being followed up using electronic record-linkage cardiovascular outcomes.

Findings to date: 4423 (1740, 39.3% male) were recruited. Mean age was 52.3 years with a median BNP of 7.50ng/L and 15.30ng/L for male and females respectively. 602 had a predicted 10-year risk of 10-19.9%, with the remainder <10%. Age, female sex, ex-smoking status, lower heart rate, higher high-density lipoprotein and lower total cholesterol were independently associated with higher log10 BNP levels. Mean left ventricular mass was 129.2g and 87.0g in males and females respectively.

Future plans: The TASCFORCE study is investigating the ability of a screening programme, using BNP and WBCE-MRI, at the time of enrolment, to evaluate prediction of CVD in a population at low/intermediate risk. Blood stored for future biomarker analyses will allow testing/development of novel biomarkers. We believe this could be a new UK Framingham study allowing study for many years to come.

Clinical Trial Registration: ISRCTN38976321 https://doi.org/10.1186/ISRCTN38976321 registered 4th April 2007

Key words: Cardiovascular risk; Clinical Trial; magnetic resonance imaging; B-type natriuretic peptide; Cardiovascular Biomarkers

Strengths and weaknesses

1. This study is one of the largest MRI/Cardiovascular risk studies to be published. It could be a UK Framingham

2. The MRI Scanning is a novel element to a cardiovascular risk trial, particularly as it is whole body and contrast enhanced

3. As many of the participants have also signed up to SHARE, it will be possible to link all subsequent blood tests from SHARE with our cohort details to study novel biomarkers as they are discovered

4. As these were 'healthy' volunteers it will take some time for cardiovascular events to occur

5. Not all participants underwent MRI scanning due to cost, only those above the BNP cut off, however numbers (n=1528) are sufficient to allow evaluations, and all (n=4423) had the demographic, and blood screening.

List of abbreviations

TASCFORCE -The Tayside Screening for Cardiac Events

CVD – Cardiovascular disease

WBCE-MRI -whole-body contrast enhanced magnetic resonance scan

BNP - B-type natriuretic peptide

CHD – Coronary Heart Disease

GP – General Practice

ECG – electrocardiogram

BP – Blood pressure

ATPIII – Adult Treatment Panel III

CMR - Cardiac magnetic resonance

LVM - left ventricular mass

SAS - standardised atheroma score

SD - standard deviation

IQR -inter-quartile range

CT – Computerised Tomography

MRI – Magnetic Resonance Imaging

HDL – High Density Lipoprotein

LDL – Low Density Lipoprotein

MI – Myocardial Infarction

SIMD - Scottish index of multiple deprivation

LGE – late gadolinium enhancement

UMI – unidentified myocardial infarct

ECV - extracellular volume

BMI – Body Mass Index

WB-MRA – Whole Body – Magnetic Resonance Angiography

LVMI -Left Ventricular Mass Index

Introduction

Currently statins and other drugs for cardiovascular disease (CVD) primary prevention is targeted at those at increased risk by using risk estimation tools, but these have poor external validity.[1] A significant number of CVD occurs in people with “low” or “intermediate” cardiovascular risk [2] and many in these groups have evidence of atherosclerosis.[3,4] Offering statins to a wider range of the population has been suggested.[5] However, offering statins more widely raises a number of economic and ethical questions and concerns,[6,7] so improved targeted therapy may be more acceptable. Risk factor-based models struggle to predict development of disease at an individual person level, and an alternative approach could be the detection of preclinical disease - an approach successfully employed in cancer. A similar strategy for CVD could facilitate individualised risk assessment and aid decisions about treatment.

The **Ta**yside **Sc**reening for **C**ardiac **E**vents (TASCFORCE) study is investigating the ability of a screening programme using B-type natriuretic peptide (BNP) and whole-body contrast enhanced magnetic resonance imaging (WBCE-MRI) incorporating cardiac imaging and whole-body angiography to detect preclinical disease and predict future clinical CVD in a large population at low or intermediate risk. Blood stored will allow validation of future proposed biomarkers. The study is novel in using a relatively cheap biomarker (BNP) to decide who proceeds to a relatively expensive test (MRI scan).

The aim of this study is to provide baseline data on both imaging and blood biomarkers, to understand which, if any, may predict future Cardiovascular events. The comprehensive collection of baseline cardiovascular risk and demographic data in combination with the blood and imaging biomarkers and robust follow up via electronic health record linkage will allow further investigation of the development of CVD in this population, which we hope may become the Scottish ‘Framingham.’

Cohort description

1.1. Study design

TASCFORCE is a prospective normal volunteer cardiovascular risk screening study (ISRCTN number: ISRCTN38976321). The East of Scotland Research Ethics Committee approved the protocols (07/S1402/42). The study was conducted at Ninewells Hospital and Medical School, Dundee, UK, in accordance with the Good Clinical Practice Declaration of Helsinki. The volunteers gave written informed consent to participate in this study.

The study is registered on http://www.controlled-trials.com/ISRCTN38976321/TASCFORCE.

Males and females aged 40 years or older living in Tayside or Fife, Scotland, who were free from CVD and had a predicted 10-year risk of coronary heart disease (CHD) <20% were recruited. Participants were excluded if they were pregnant, breast-feeding, of child-bearing potential not using adequate contraception, unable to give consent, or had another accepted indication for statin therapy. To produce a cohort able to participate in a potential future statin intervention study those with contraindications to a statin were excluded, including known alcohol abuse or participation in a clinical trial other than observational trials or registries concurrently or within 30 days prior to screening, were excluded.

Participants were recruited from General Practice (GP) surgeries, local employers, publicity campaigns, via press and radio coverage of the project, direct mailing and using Human Research Ethics Committee approved leaflets. We aimed to obtain a locally representative population, so recruitment was targeted at socioeconomic and ethnic groups often under-represented in studies. Participants were recruited between November 2007 and February 2013.

1.2 *Patient and Public Involvement*

The Souter Foundation trustees ('lay' people) were involved in the design of the study. Volunteers who were recruited to the study were involved in the design, regarding the scheduling and timing of testing, to improve convenience for participants. Many volunteers were involved in further recruitment, by passing on information via word of mouth. Results of the final analysis using linked data will be disseminated to the participants via postal address.

1.3 *Screening visit and risk estimation*

Following written informed consent for the study, and for data-linkage for up to 20 years, the following information was obtained: medical history, lifestyle risk factors (diet/exercise/smoking status), risk perception question, family history of premature CVD, and concomitant medication. Risk perception included questions regarding family history, exercise frequency, cigarette smoking and added salt to food. Subjects were examined to obtain their height, weight, waist circumference and blood pressure (BP) and a 12-lead electrocardiogram (ECG) was recorded. Plasma BNP, random lipid profile and random plasma glucose levels were determined using point of care testing equipment (Alere Triage BNP assay with Alere Triage MeterPro for BNP, and Alere Cholestech LDX analyser for lipids and glucose).

Each participant's predicted CHD event rate was calculated by using the National Cholesterol Education Program Adult Treatment Panel III (ATP III) guidelines.[8] Participants who had a predicted risk ≥20% or a BP >145/90 mmHg were excluded but were asked for consent to be followed up. Ineligible subjects were informed of their risk factors, given a copy of their results, and asked to attend their GP for formal review. All participants received counselling on modifiable risk factors by study staff aided by British Heart Foundation leaflets.

1.4 Magnetic resonance imaging

Those with a BNP greater than the median (determined after 200 participants) were invited to attend for a WBCE-MRI scan. At a prespecified review after 1000 subjects it was observed that the median BNP was higher for females than males. The trial steering committee (comprising of the authors) decided to invite for a scan based on gender specific median BNP and the protocol was amended accordingly. Those recruited earlier who would be eligible based on the amended gender specific median were recalled. If the delay was greater than three months, they had their BNP, cholesterol and CHD risk score reassessed to ensure continued eligibility.

Combined cardiac and whole-body angiography MRI scans were performed on a 32-channel 3T Magnetom Trio scanner (Siemens, Erlangen, Germany) and used gadoteric acid contrast agent (Dotarem; Guerbet Laboratories, France). The scan protocol development and validation has been described in detail elsewhere.[9,10]

Details of the image acquisition, analysis and validation of the technique have been described and validated in earlier publications.[9,10,11] Cardiac magnetic resonance (CMR) images were analysed offline by four blinded observers using commercial software ('Argus', Siemens Multi-modality Work

Platform, version VB15). Electronic region of interest contours were placed around endocardial and epicardial left ventricular borders at end-diastole and end-systole on all CMR image slices identified to contain ≥50% full-thickness myocardium. Quantitative measurement of left ventricular mass (LVM), ejection fraction, end-diastolic volume, end-systolic volume, and stroke volume were derived. The presence of luminal stenosis was assessed in 30 arterial segments from the internal carotids to the distal anterior tibial arteries (the coeliac artery was not included due to marked anatomical variation resulting in poor inter-observer agreement). A categorical grading scale from 0-4 was applied to each arterial segment as follows: grade 0=healthy segment, grade 1=1-50% stenosis, grade 2=51-70% stenosis, grade 3=71-99% stenosis, and grade 4=vessel occlusion. An additional point was added for presence of aneurysm >50% of the native vessel diameter. If any arterial segment contained more than one luminal abnormality the more severe abnormality was scored. If a segment was uninterpretable because of poor image quality, it was not allocated a numeric score. A standardised atheroma score (SAS) to express atheroma burden severity across the body as a percentage was calculated using the following equation where n is the number of interpretable segments:

$SAS=[(\sum score/n)x1/4]x100$

Of those invited, 1528 (74.8%) completed or partially completed an MRI scan. Thirty-four were not safe to scan due to metal in situ, 373 did not agree to proceed to have a scan, and 12 failed to attend. One hundred and one participants abandoned their scan mainly due to claustrophobia (n=83), with others abandoned due to large body habitus, problems with IV access or other technical issues. Thirty-two participants (2.1% participants scanned) had an incidental finding on their MRI scan (MI detected by delayed enhancement, structural cardiac abnormality, benign masses, malignant masses, peripheral vascular abnormality, anatomical variation). These subjects were removed from the key study group.

1.5 Baseline characteristics

Participant flow is summarised in the CONSORT diagram (figure 1); 5015 people (n=2066, 41.2% male) were screened. In total, 438 failed screening due to either hypertension (n=291, 137 (47.1%) male), a predicted 10-year CHD risk ≥20% (n=146, 142 (97.3%) male) or marked dyslipidaemia (n=1, female). The enrolled population was determined to be at low or intermediate risk of CVD. (Supplemental Table 1). We have a specific ethnic group of South Asian people (n=20) deliberately

enrolled to attempt to cater for ethnic diversity. These subjects were recruited with the help of a local Mosque. The remainder are white British. These two ethnic groups are dominant in Tayside and the relative proportions enrolled reflects the distribution in the population. Further we have documented the Scottish Index of Multiple Deprivation (SIMD) for all subjects i.e., the area of deprivation in which they lived at time of enrolment. As the Scottish population is not very mobile, we believe this can be used in our 10y analyses. We also have other risk factors which relate to socioeconomic status such as obesity (BMI, waist Circumference), cigarette smoking and sex. These social determinants will all be evaluated in our 10y analysis. A total of 4423 (1740, 39.3% male) participants were eligible for the study.

Median (IQR) BNP levels for men and women were 7.50 (8.90) and 15.30 (17.63) ng/L respectively. The cut-off BNP values for being offered an MRI scan were 8.2 and 16.4 ng/L respectively; all South Asian participants were invited for MRI irrespective of BNP level. The characteristics of those invited for an MRI scan (MRI/BNP group), and those not invited (BNP group) are summarised in table 1.

Table 1. Baseline characteristics of participants.

	BNP group (n=2376)	MRI/BNP group (n=2047)	Difference between BNP and MRI/BNP groups*
Median (IQR) age (years)	49.5 (10.6)	53.4 (12.5)	p<0.001
No (%) men	937 (39.4)	803 (39.3)	p=0.94
No (%) current smokers	351 (14.8)	221 (10.8)	p<0.001
No (%) former smokers	663 (27.9)	563 (27.5)	p=0.81
No (%) never smokers	1361 (57.3)	1256 (61.4)	p=0.004
Mean (SD) systolic BP (mmHg)	122.1 (11.74)	122.9 (11.97)	p=0.027
Mean (SD) diastolic BP (mmHg)	73.6 (9.40)	73.1 (9.23)	p=0.06
Median (IQR) heart rate (beats per min)	67.0 (14)	63.0 (12)	p<0.001
Mean (SD) total cholesterol (mmol/L)	5.47 (1.02)	5.48 (0.99)	p=0.79
Mean (SD) high density lipoprotein (mmol/l)	1.34 (0.44)	1.43 (0.42)	p<0.001
Mean (SD) low density lipoprotein (mmol/l)	3.41 (0.92)	3.40 (0.42)	p=0.84
Median (IQR) triglycerides (mmol/l)	1.38 (1.18)	1.29 (1.02)	p<0.001
Median (IQR) body mass index (kg/m^2)	26.7 (5.80)	26.2 (5.35)	p<0.001
Median (IQR) weight (kg)	75.0 (21.23)	74.1 (19.95)	p=0.08
Mean (SD) height (cm)	167.10 (9.09)	167.67 (9.29)	p=0.041
Mean (SD) waist circumference (cm)	88.0 (13.56)	86.9 (12.95)	p=0.006
Median (IQR) 10-year CHD event risk estimation (%)	2.0 (5.0)	2.0 (5.0)	p<0.001
No (%) with 10-year CHD risk 10-19.9%	286 (12.0)	316 (15.4)	p=0.001

No (%) with family history of cardiovascular disease		561 (23.6)	514 (25.1)	p=0.25
Scottish Index of Multiple Deprivation decile, number (%)	1	132 (5.6)	85 (4.2)	p=0.054
	2	145 (6.1)	106 (5.2)	
	3	208 (8.8)	149 (7.3)	
	4	134 (5.6)	116 (5.7)	
	5	143 (6.0)	126 (6.2)	
	6	218 (9.2)	206 (10.1)	
	7	349 (14.7)	334 (16.3)	
	8	442 (18.6)	401 (19.6)	
	9	428 (18.0)	371 (18.1)	
	10	169 (7.1)	150 (7.3)	
	N/A	8 (0.3)	3 (0.1)	-

BNP, B-type natriuretic peptide, MRI, magnetic resonance imaging, IQR, inter-quartile range, SD, standard deviation, CHD, coronary artery disease. *Comparisons for variables with normal distributions are independent samples t-tests and for skewed distribution the Mann-Whitney-Wilcoxon test.

1.6 Follow up

Electronic anonymised data linkage by the Health Informatics Centre at the University of Dundee will provide follow up data on hospital admissions (including diagnoses and procedures) and GP prescriptions at regular intervals for up to 20 years (10, 15 and 20 years planned). This uses data from the Scottish Office's Information Services Division which collects data on all hospital and GP encounters including prescriptions, diagnoses, and procedures and from the General Registrar's office which collects data on all deaths in Scotland. Endpoints of interest are myocardial infarction, hospitalisation for angina, requirement for any endovascular procedure, stroke, critical limb ischemia, amputation, sudden death, cardiac and all-cause mortality. Underlying cause of death recorded on death certificates is supplemented by information from hospital records, including post-mortem examinations, if performed.

1.7 Statistical analysis

Analysis was performed using R (v.3.1) and SPSS (v.21). Continuous variables were expressed as mean and standard deviation (SD) for those with a normal distribution or median and inter-quartile range (IQR) for those with a skewed distribution, and categorical variables were expressed as numbers and percentages. When comparing characteristics between participant groups independent samples t-tests were used for variables with a normal distribution and Wilcoxon Mann-Whitney tests were used for those with a skewed distribution. To reduce skewness BNP levels were log10 transformed before regression analyses. Multivariable linear regression analysis was used to determine independent predictors of log10 BNP level. The following variables were initially included in the model: age, sex, smoking status, systolic BP, diastolic BP, heart rate, total cholesterol, HDL cholesterol, LDL cholesterol, triglycerides, glucose, BMI, waist circumference, family history of CVD and Scottish index of multiple deprivation (SIMD) decile. Analysis of correlations used Pearson correlation coefficients for variables with a normal distribution and Spearman Rank correlation for those with a skewed distribution.

Findings to date

Increasing age, female sex, ex-smoking status (but not current smoking status), lower heart rate, higher HDL and lower total cholesterol were significantly associated with higher log10 BNP levels (table 2).

Table 2. Predictors of log10 BNP: multivariable regression analysis.

	Unstandardised Coefficient (95% confidence intervals)	p value
Age (years)	0.010 (0.009, 0.011)	<0.001
Male sex	-0.211 (-0.230, -0.192)	<0.001
Ex-smoker	-0.026 (-0.045, -0.006)	0.01
Heart rate (bpm)	-0.006 (-0.007, -0.005)	<0.001
Total cholesterol (mmol/l)	-0.020 (-0.028, -0.011)	<0.001
High density lipoprotein (mmol/l)	0.055 (0.033, 0.076)	<0.001

The left ventricular characteristics are shown in table 3. A total of 10 patients (0.67%) displayed LGE, indicating the presence of an unidentified myocardial infarct (UMI) [12].

Table 3. Left ventricular characteristics by gender

	Men		Women		
	Mean	SD	Mean	SD	p value*
LVM (g)	129.2	24.4	87.0	16.7	<0.001
LVEDV (ml)	155.0	27.7	119.6	21.1	<0.001
LVESV (ml)	50.2	14.8	37.1	12.0	<0.001
LVM/LVEDV (g/ml)	0.85	0.16	0.74	0.13	<0.001
Ejection fraction (%)	67.9	6.2	69.3	6.6	<0.001
Stroke volume (ml)	104.8	19.0	82.5	14.2	<0.001
Cardiac output (l/min)	6.46	1.20	5.47	1.13	<0.001
LVM/height	73.2	13.1	53.5	9.8	<0.001
LVM/height$^{1.7}$	49.3	8.7	38.1	7.0	<0.001
LVM/height$^{2.7}$	28.0	5.0	23.5	4.4	<0.001
LVM/BSA	64.3	10.6	49.5	8.0	<0.001

SD, standard deviation, LVM, left ventricular mass, LVEDV, left ventricular end-diastolic volume, LVESV, left ventricular end systolic volume, BSA, body surface area. *Comparison between men and women using independent samples t-test.

Three cases (0.2%) were consistent with UMI, and 7 were considered non-specific and located in the mid-myocardium (n=4), epicardium (n=1), or right ventricular insertion points (n=2). Spearman rank correlations of left ventricular measurements with predicted CHD risk score are shown in table 4.

Table 4: Correlations of left ventricular measures with predicted 10-year coronary heart disease risk

	LVM	LVM/height (g/m)	LVM/height$^{1.7}$ (g/m$^{1.7}$)	LVM/height$^{2.7}$ (g/m$^{2.7}$)	LVMI/BSA (g/m^2)	LVM/LVEDV (g/ml)
Men	-0.07 (0.12)	-0.04 (0.31)	-0.02 (0.67)	-0.01 (0.73)	-0.05 (0.24)	0.17 (<0.001)
Women	0.08 (0.018)	0.11 (0.001)	0.13 (<0.001)	0.16 (<0.001)	0.10 (0.002)	0.30 (<0.001)

LVM, left ventricular mass, BSA, body surface area, LVEDV, left ventricular end diastolic volume. Correlations are Spearman rank correlations (ρ and (p) values are given) with predicted 10-year coronary heart disease risk using the ATPIII algorithm.

For WB-MRA 2468 segment locations (5%) demonstrated stenoses, of which 1649 (3.5%) showed stenosis <50% and 484 (1.0%) showed stenosis ≥50% [13]. The median, 80th percentile and 90th percentiles of SASs were 0.00, 1.67 and 3.33 respectively for men, and 0.83, 2.50, and 4.17 for women. There was no significant difference between SASs for men and women (p=0.08). The predicted CHD scores for those with a SAS above and below 80th centile and with and without the presence of any stenosis are shown in table 5.

Table 5: Predicted CHD risk in those with standardised atheroma scores above and below 80th percentile and in those with and without any stenosis.

	Males			Females		
	≤80th centile SAS (n=464)	>80th centile SAS (n=113)	p value*	≤80th centile SAS (n=786)	>80th centile SAS (n=150)	p value*
Median (IQR) predicted CHD risk score (%/10 years)	6 (6)	10 (5)	<0.001	1 (2)	2 (3)	<0.001
	No stenosis (n=308)	Any stenosis (n=269)	p value*	No stenosis (n=457)	Any stenosis (n=479)	p value*
Median (IQR) predicted CHD risk score (%/10 years)	6 (6)	8 (7)	**<0.001**	1 (2)	1 (2)	**<0.001**

*Mann-Whitney test used to compare groups. SAS, standardised atheroma score. 80th centile 1.67 for men and 2.50 for women.

The TASCFORCE study assesses the ability of a novel screening programme combining "traditional" clinical cardiovascular risk estimation with BNP and WBCE-MRI to predict future cardiovascular events. No other studies have investigated screening using this combination of blood and imaging biomarkers of preclinical disease as a potential method to predict future CVD in people free from and at "low" or "intermediate" predicted risk of future disease. The cohort is large and well characterised in terms of cardiovascular risk factors, with an Index of Multiple Deprivation similar to the community from which it was drawn. Of those recruited, 602 have a predicted 10-year risk of 10-19.9% (classified as intermediate risk); a group that is often debated as to what approach should be taken in terms of primary prevention.

During recruitment, a significant number of people had a previously unknown predicted risk ≥20% over 10 years. A total of 97% were males, and from areas with increased deprivation compared to those who were lower risk and entered the main study. These findings also highlight the problem of currently undetected cardiovascular risk, particularly amongst males and those from areas of deprivation, illustrating the need for improved identification and engagement of those at risk. This could bring greater public health benefits than giving statins to more people at lower risk.

As expected, the BNP levels in the TASCFORCE population were within a "normal" clinical range and were significantly higher in females compared to males, justifying our use of gender specific medians

for invitation for MRI scan.[12,13] Age was independently associated with BNP levels. This is well recognised,[14,15,16] although the exact mechanism for the association remains unclear. Age related alterations in production, secretion, biological effect or degradation of BNP may be responsible.[17,18] The effect of age is independent of renal function, atrial volume, left ventricular dimension and LV mass.[14] Increasing levels with age may suggest that age specific reference ranges of BNP should be used. However, because age is an important risk factor for CVD, BNP may be reflecting this increased risk. Thus, correcting for age when using BNP as a screening tool is inadvisable.

MRI is a safe, relatively non-invasive imaging modality, free from ionising radiation making it more acceptable for use as a screening tool compared to coronary artery calcification scoring using CT. By combining cardiac imaging with whole body angiography, it is conceivable that the sensitivity to detect subclinical disease may be improved as more target organs are imaged. The images also provide a reference for normal values within a low/intermediate risk population. The MRI protocol was kept simple, with the main constituents being WBCE-MRI together with CMR for quantification of LV structure and function – all completed within 45 minutes. The CMR acquisition was undertaken at the midpoint of the protocol (commencing after the first Gd contrast injection) to optimise the protocol in terms of time usage and to enable an assessment of late gadolinium enhancement (LGE) at this stage. The acquisition of other measures such as T1, extracellular volume (ECV), T2 mapping or myocardial strain would have been desirable, but the study was limited by the time available and the technological capabilities of the scanner.

The mean LVM values in our cohort are similar to those reported by other studies that have used steady state free precision imaging sequence MRI to determine LVM in a healthy population without CVD and free from hypertension, high cholesterol or treatment.[19] Mean LVM was also higher in males than females similar to other studies. Increased LVM-to-volume ratio (a marker of left ventricular remodelling) was more strongly correlated with predicted CHD risk than LVM or LVM index in both males and females. This measure has been shown to be independently associated with incident CHD [20] and stroke,[20,21] and suggests this may be a better measure of risk than LVM or LVM index which may not be able to differentiate between physiologically increased LVM due to, for example, exercise.

The majority of participants had no evidence of atheroma; however, a higher SAS was associated with a higher predicted CHD risk. A WBCE-MRI angiography derived atheroma score similar to ours was associated with traditional cardiovascular risk factors [22], and with the combined end point of cardiac death, MI, stroke or coronary revascularisation when adjusted for multiple risk factors in a study of 70 year olds, some of whom had a history of CVD.[23] The score improved discrimination and reclassification when added to the Framingham risk score. In our study, the median SAS of 0.83% for females indicates that at least half the female group did have detectable arterial narrowing. This median approached statistical significance (p=0.08) relative to the equivalent for males, although we do not believe this has clinical implications since the overwhelming number of segments assessed (over 40000, 94.7%) were classified as normal.

We report a sex-differential regarding LVM and 10y-CHD risk, where LVM and indexed LVM were not correlated among males, but significantly correlated among females. Three large observational studies (n=1715-4988) reported raised LVM and LVMI, which was associated with higher incident CVD events, but did not report any sex difference.[24-26] Our finding that the LVM and LVMI was significantly associated with predicted 10-year CHD risk in females, but not in males, appears novel.

Healthcare in Scotland is delivered within the public sector National Health Service, and all healthcare contacts, diagnoses and procedures are systematically recorded. Further, all prescribing information from GPs is available in an anonymised form. Follow up is via electronic health record linkage, which will reduce the number lost to follow up as direct contact is not required. This will allow analysis of whether the combination of BNP with cardiac MRI markers are able to improve prediction of future CVD. Stored serum, plasma and DNA will allow future novel biomarkers to be discovered or validated.

There is potential bias in the imaged population as those imaged are at the upper end of the BNP range. The MRI results therefore may not represent the low-risk population and will prevent comparison of imaging biomarkers between those with high and low BNP levels. However, clinical outcomes between the two groups will be analysed to determine if lower BNP levels can exclude future events.

Given the cost of MRI, the economic viability of this program will need to be assessed. This will be done through a comprehensive follow up which will involve collecting data on hospital admissions and prescriptions, facilitating future economic evaluations of this screening programme.

In conclusion, the TASCFORCE study is investigating the ability of a novel screening programme incorporating BNP and WBCE-MRI to predict future cardiovascular events in a population at low or intermediate predicted risk of CHD. The comprehensive collection of baseline cardiovascular risk and demographic data in combination with blood and imaging biomarkers, and robust follow up via electronic record linkage, will allow further investigation of the development of CVD in this population, which we hope may become the Scottish 'Framingham.'

Collaboration

All data and materials are available stored in the University of Dundee, patient identifiable data is stored in the University of Dundee and NHS Tayside Health Informatics Centre, a Safe Haven. The datasets generated and/or analysed during the current study are not publicly available due to ongoing 10-year analyses but are available from the corresponding author on reasonable request.

Further details

Ethics approval and consent to participate

The protocol was approved by the Tayside Committee of Medical Research Ethics B (reference number: 07/S1402/42) and is available at http://www.controlled-trials.com/ISRCTN38976321/TASCFORCE.

Consent for publication

All authors give consent for this data to be published

Availability of data and materials

All data and materials are available stored in the University of Dundee; anonymised patient data is stored in the Safe Haven. The datasets generated and/or analysed during the current study are not publicly available due to ongoing 10-year analyses but are available from the corresponding author on reasonable request.

Competing interests

There are no competing interests

Funding

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Authors' contributions

JJFB and GH wrote the protocol, obtained the funding, and contributed to writing the paper

MAL analysed the data to date and contributed to writing the paper

RL was the study coordinator and contributed to study design and writing the paper

AS and FS were on the Trial Steering committee and contributed to writing the paper

SG obtained the MRI data and contributed to writing the paper

CAF contributed to writing the paper and will be analysing future data

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The TASCFORCE Consortium

Prof Jill JF Belch (Principal Investigator), Prof J Graeme Houston, Dr Matthew A Lambert, Prof Allan Struthers, Prof Frank Sullivan (Co-investigators); Dr Roberta Littleford (Trial Manager); Anita Hutcheon, Janice Rowland (Trial Nurses); Dr Jonathan Weir McCall (Imaging methods); Daniel Levin, (statistical analysis); and Prof Colin Palmer (genetics lead).

Figure legends

Figure 1: Consort diagram showing TASCFORCE study recruitment

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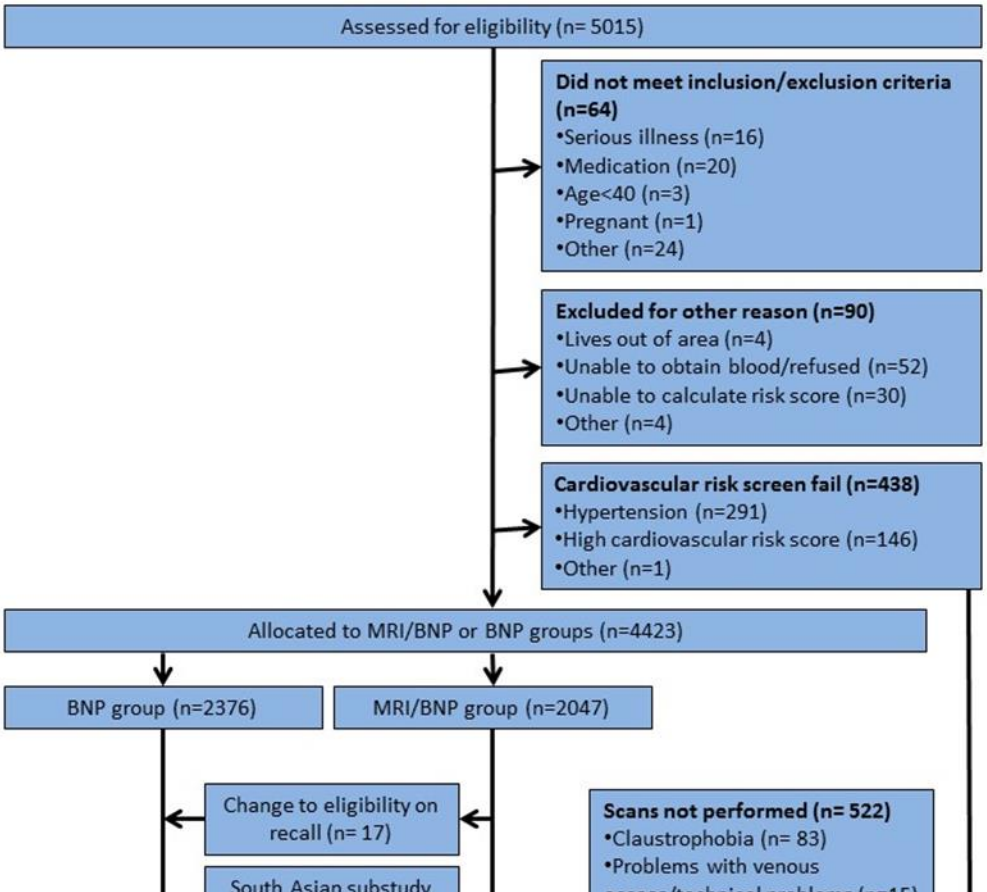

Supplemental Table 1. Characteristics of subjects excluded due to presence of increased CHD risk or hypertension.

		Hypertensive (BP> 145/90 mmHg) (n=291)	10-year CHD risk >20% (n=146)
Median (IQR) age (years)		58.2 (12.24)	58.7 (15.23)
No (%) men		138 (47.4)	142 (97.3)
No (%) current smokers		34 (11.7)	85 (58.2)
No (%) former smokers		65 (22.3)	24 (16.4)
No (%) never smokers		151 (51.9) *[N/A41]*	37 (25.3)
Mean (SD) systolic BP (mmHg)		156.5 (9.75)	132.2 (10.91)
Mean (SD) diastolic BP (mmHg)		88.9 (9.68)	77.3 (9.46)
Medan (IQR) heart rate (beats per min)		72.0 (16) [*N/A215]*	68.0 (14) *[N/A11]*
Mean (SD) total cholesterol (mmol/L)		5.69 (1.03) *[N/A55]*	6.07 (1.02)
Mean (SD) high density lipoprotein (mmol/l)		1.42 (0.48) *[N/A58]*	0.89 (0.24)
Mean (SD) low density lipoprotein (mmol/l)		3.34 (0.92) *[N/A71]*	3.93 (0.93) *[N/A17]*
Median (IQR) triglycerides (mmol/l)		1.82 (1.38) *[N/A55]*	2.50 (1.93)
Median (IQR) Body mass index (kg/m^2)		27.5 (5.5) *[N/A202]*	28.3 (4.7) *[N/A6]*
Median (IQR) weight (kg)		82.0 (18.60) *[N/A202]*	83.6 (17.30) *[N/A6]*
Mean (SD) height (cm)		168.5 (8.16) *[N/A202]*	173.4 (7.51) *[N/A6]*
Mean (SD) waist circumference (cm)		91.1 (13.35) *[N/A216]*	97.0 (12.93) *[N/A10]*
Median (IQR) 10-year CHD event risk (%)		5.0 (9.0) *[N/A72]*	20.0 (5.0)
No (%) with family history of cardiovascular disease		49 (16.8) *[N/A96]*	35 (23.2) *[N/A9]*
Scottish Index of Multiple Deprivation decile,	1	12 (4.1)	8 (5.5)
number (%)	2	19 (6.5)	11 (7.5)
	3	29 (10.0)	20 (13.7)
	4	19 (6.5)	10 (6.8)
	5	14 (4.8)	10 (6.8)
	6	21 (7.2)	14 (9.6)
	7	45 (15.5)	22 (15.1)
	8	51 (17.5)	22 (15.1)
	9	61 (21.0)	24 (16.4)
	10	18 (6.2)	4 (2.7)
	N/A	*2 (0.7)*	1 (0.7)

BP, blood pressure, CHD, coronary heart disease, IQR, inter-quartile range, SD, standard deviation. Full data were not collected for all screen failed participants: the number of participants with missing data is indicated in italics.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	6
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6/7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	13
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	

Continued on next page

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8-12
		(b) Give reasons for non-participation at each stage	8-12
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8-12
		(b) Indicate number of participants with missing data for each variable of interest	N/A
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	N/A
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	*N/A*
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	*N/A*
		Cross-sectional study—Report numbers of outcome events or summary measures	14-18
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	14-18
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	14-18
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	19/20
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	20/21
Generalisability	21	Discuss the generalisability (external validity) of the study results	19/20
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	4

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.