ORIGINAL ARTICLE

Screening for atrial fibrillation in 13 122 Hong Kong citizens with smartphone electrocardiogram

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ABSTRACT

Objective The purpose of this study was to assess the feasibility of community screening for atrial fibrillation (AF) using a smartphone-based wireless single-lead ECG (SL-ECG) and to generate epidemiological data on the prevalence and risk factors of AF in Hong Kong.

Methods In the period between 1 May 2014 to 30 April 2015, 13 122 Hong Kong citizens consented and voluntarily participated in a territory-wide community-based AF screening programme.

Results 56 (0.4%) out of 13 122 SL-ECG were uninterpretable. 101 (0.8%) participants had newly diagnosed AF, with 66 (65.3%) being asymptomatic. The congestive heart failure, hypertension, age>75 (doubled), diabetes, stroke(doubled), vascular disease, age 65–74, sex(female) score (CHA_2DS_2VASc score) of participants with newly diagnosed AF was 3.1±1.3. The prevalence rates for AF detected by SL-ECG was 1.8% and for AF detected by SL-ECG or self-reported by participants was 8.5%. Using multivariable logistic regression analysis, independent predictors of AF include age, sex, height, weight, body mass index, history of heart failure, valvular heart disease, stroke, hyperlipidaemia, coronary artery disease, peripheral artery disease and cardiothoracic surgery.

Conclusion Community screening for AF with SL-ECG was feasible and it identified a significant proportion of citizens with newly diagnosed AF. The prevalence of AF in a Chinese population in Hong Kong was comparable with that of contemporary Western counterparts. Apart from age and sex, different anthropometric parameters and cardiovascular comorbid conditions were identified as independent predictors of AF.

INTRODUCTION

Atrial fibrillation (AF) is the most common sustained cardiac arrhythmia.[1] AF is associated with an increased risk of stroke, heart failure and cardiovascular mortality.[2] Although oral anticoagulation treatment can effectively reduce the risk of AF-related ischaemic stroke by 64%–70%,[3] around a quarter of patients have silent or asymptomatic AF, which can still cause this complication.[4] Opportunistic screening for AF is currently recommended.[3] However, whether systematic screening for AF can reduce the burden of ischaemic stroke remains controversial.[5] On the other hand, the experience and data on the use of smartphone-based wireless single-lead ECG (SL-ECG) in community screening for AF have been scarce and based on a relatively small number of subjects.[6 7]

There are only a few epidemiological studies on the prevalence and risk factors of AF in the Chinese population and none of them were performed in Hong Kong.[8–11] Thus, the purpose of this study was to assess the feasibility of community screening for AF using SL-ECG and to generate epidemiological data on the prevalence and risk factors of AF in Hong Kong.

METHODS

Study population

In the period between 1 May 2014 to 30 April 2015, 13 122 Hong Kong citizens voluntarily participated in a territory-wide community-based systematic AF screening programme. Informed consent was obtained. The screening programme was publicised via different channels including media promotion and placement of posters in community centres by non-governmental organisations in Hong Kong and all citizens aged 18 or above were eligible for participation. The population in Hong Kong in mid-2014 was estimated to be 7.24 million. The Princess Margaret Hospital Ethics Committee approved the study protocol. Information on history and symptom of AF and medical conditions were assessed by an interview questionnaire. For symptoms of AF, participants were asked whether they had ever experienced palpitations. Anthropometric measurements, including body weight, height and waist circumference, were taken. A SL-ECG was performed with the AliveCor device (AliveCor, San Francisco, California, USA).

ECG acquisition and analysis

SL-ECG was performed by a group of trained non-medical volunteers using the AliveCor device (AliveCor, San Francisco, California, USA). The device consists of a smartphone software application and a small handheld hardware component attached to or in close proximity to the phone.[6] The participant was instructed to place fingers of both hands on the two electrodes of the hardware component and a 30 s lead I ECG would be recorded. All recorded ECGs were reviewed by the first author of this manuscript within 1 month of the performance of SL-ECG. The ECGs were classified into three groups, namely sinus rhythm, AF and uninterpretable. Participants with uninterpretable SL-ECG were referred for conventional 12-lead ECGs, which were reviewed by the first author of this manuscript.

Categories of AF

AF was reported if it was observed in the entire 30 s recording of the SL-ECG. AF detected by SL-ECG likely represented non-paroxysmal AF.

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Participants who reported history of AF but did not have AF detected by SL-ECG likely had paroxysmal AF. Participants who did not report history of AF but had AF detected by SL-ECG were regarded to have newly diagnosed AF. The total burden of AF, both paroxysmal and non-paroxysmal, in the study population can be represented by AF detected by SL-ECG or self-reported by participants. All participants who had AF detected by SL-ECG were referred for medical consultation.

Statistical analysis

Continuous variables were presented as mean±SD and categorical variables as numbers and proportions. Continuous variables were compared using the Student's t-test. Categorical variables were compared using the Fisher's exact test or χ^2 test. The independent predictors of AF detected by SL-ECG, newly diagnosed AF and AF detected by SL-ECG or self-reported by participants were modelled by multivariable logistic regression. A univariate analysis was performed and variables with a p value of <0.2 were included for multivariable analysis. Receiver operating characteristic (ROC) curves were constructed and areas under the curve (AUCs) were calculated for the discriminative ability of different independent predictors identified for newly diagnosed AF. Statistics were performed with the Statistical Package for Social Science (IBM SPSS (V.19), Chicago, Illinois, USA). A p value of <0.05 was considered as statistically significant.

RESULTS

Baseline characteristics and predictors of AF

The baseline characteristics of 13 122 Hong Kong citizens who participated in the AF community screening programme are summarised in tables 1 and 2. In Table 1, comparison is made between participants who had AF detected by SL-ECG and those who had not. In table 2, comparison is made between participants who had AF detected by SL-ECG or who self-reported AF and those who had no AF. Among all participants, 3377 reported 'don't know' for a history of AF, of which, 62 had AF detected by SL-ECG. Therefore, 3315 (3377−62) participants were excluded from this analysis and 8696 (13122 minus 1111 minus 3315) participants with no AF formed the comparison group. Using multivariable logistic regression, independent predictors of AF detected by SL-ECG include age, weight, body mass index (BMI), history of heart failure, stroke, valvular heart disease and cardiothoracic surgery (table 3). On the other hand, independent predictors of AF detected by SL-ECG or self-reported by participants include age, height, history of hyperlipidaemia, heart failure, stroke, coronary artery disease, valvular heart disease, peripheral artery disease and cardiothoracic surgery (table 4).

Prevalence of AF

The overall prevalence of AF detected by SL-ECG, which likely represented non-paroxysmal AF, was 1.8% (239/13 122; 95% CI 1.6% to 2%) with a higher prevalence in men (2.8%, 105/3738; 95% CI 2.3% to 3.3%) than women (1.4%, 134/9384; 95% CI 1.2% to 1.6%). The overall prevalence of AF detected by SL-ECG or self-reported by participants was 8.5% (1111/13 122; 95% CI 8% to 9%) with similarly a higher prevalence in men (10.6%, 395/3738; 95% CI 9.6% to 11.6%) than women (7.6%, 716/9384; 95% CI 7.1% to 8.1%). Thus, the number and proportion of participants who likely had paroxysmal AF was 872 (1111 minus 239) and 78% (872/1111) respectively. For both AF categories, the prevalence increased with age (tables 5 and 6).

Ability to detect newly diagnosed AF by community screening and its feasibility using SL-ECG

Of the 13 122 SL-ECG, 56 (0.4%) were uninterpretable. A total of 101 (42.2% of AF detected by SL-ECG or 0.8% of all participants) participants had newly diagnosed AF with this screening programme. The number of participants with previously known AF was 1010 and there was a 10% (101/1010) increase in the prevalence rate of AF with this screening programme. Among the participants with newly diagnosed AF, 66 participants (65.3%) were asymptomatic. There was no significant

Table 1 Baseline characteristics of participants with AF detected versus those not detected by SL-ECG

	Total (n=13 122)	AF detected by SL-ECG (n=239)	AF not detected by SL-ECG (n=12 883)	p Value
Age (years)	64.7±13.4	75.1±9.5	64.6±13.4	<0.001
Sex (F), n (%)	9384 (71.5)	134 (56.1)	9250 (71.8)	<0.001
Weight (kg)	58.9±10.5	61.2±11.4	58.9±10.5	<0.001
Height (cm)	157.5±8.6	158.5±8.9	157.5±8.6	0.09
BMI (kg/m^2)	23.7±3.6	24.3±3.7	23.7±3.6	<0.001
Waist circumference (cm)	83.2±9.8	86.8±10.3	83.2±9.8	<0.001
Comorbid conditions				
Hypertension, n (%)	5012 (38.2)	92 (38.5)	4920 (38.2)	0.948
Diabetes, n (%)	1944 (14.8)	61 (25.5)	1883 (14.6)	<0.001
Hyperlipidaemia, n (%)	2613 (19.9)	58 (24.3)	2555(19.8)	0.099
Heart failure, n (%)	97 (0.7)	13 (5.4)	84 (0.7)	<0.001
Stroke, n (%)	367 (2.8)	24 (10)	343 (2.7)	<0.001
Coronary artery disease, n (%)	295 (2.2)	15 (6.3)	280 (2.2)	<0.001
Valvular heart disease, n (%)	114 (0.9)	18 (7.5)	96 (0.7)	<0.001
Peripheral vascular disease, n (%)	66 (0.5)	3 (1.3)	63 (0.5)	0.119
Obstructive sleep apnoea, n (%)	146 (1.1)	2 (0.8)	144 (1.1)	1.000
Thyroid disease, n (%)	517 (3.9)	5 (2.1)	512 (4.0)	0.177
COPD, n (%)	56 (0.4)	0	56 (0.4)	0.628
Cardiothoracic surgery, n (%)	354 (2.7)	25 (10.5)	329 (2.6)	<0.001

AF, atrial fibrillation; BMI, body mass index; COPD, chronic obstructive pulmonary disease; F, female; SL-ECG, wireless single-lead ECG.

Table 2 Baseline characteristics of participants with AF detected by SL-ECG or self-reported AF versus those with no AF

	Total (n=9807)	AF detected by SL-ECG or self-reported by participants (n=1111)	No AF (n=8696*)	p Value
Age (years)	65.5±13.3	70.5±11	64.8±13.4	<0.001
Sex (F), n (%)	7058 (72)	716 (64.4)	6342 (72.9)	<0.001
Weight (kg)	59±10.4	59.9±10.4	58.8±10.4	0.001
Height (cm)	157.3±8.6	158±9	157.2±8.6	0.009
BMI (kg/m^2)	23.8±3.6	24±3.5	23.8±3.6	0.076
Waist circumference (cm)	83.5±9.8	85±9.6	83.3±9.8	<0.001
Comorbid conditions				
Hypertension, n (%)	3720 (37.9)	421 (37.9)	3299 (37.9)	1.0
Diabetes, n (%)	1515 (15.4)	232 (20.9)	1283 (14.8)	<0.001
Hyperlipidaemia, n (%)	1934 (19.7)	332 (29.9)	1602 (18.4)	<0.001
Heart failure, n (%)	85 (0.9)	56 (5)	29 (0.3)	<0.001
Stroke, n (%)	284 (2.9)	70 (6.3)	214 (2.5)	<0.001
Coronary artery disease, n (%)	206 (2.1)	89 (8)	117 (1.3)	<0.001
Valvular heart disease, n (%)	84 (0.9)	47 (4.2)	37 (0.4)	<0.001
Peripheral vascular disease, n (%)	48 (0.5)	22 (2)	26 (0.3)	<0.001
Obstructive sleep apnoea, n (%)	88 (0.9)	17 (1.5)	71 (0.8)	0.026
Thyroid disease, n (%)	366 (3.7)	40 (3.6)	326 (3.7)	0.867
COPD, n (%)	37 (0.4)	10 (0.9)	27 (0.3)	0.007
Cardiothoracic surgery, n (%)	266 (2.7)	107 (9.6)	159 (1.8)	<0.001

*Participants who reported 'don't know' for a history of AF together with AF not detected by SL-ECG were excluded.
AF, atrial fibrillation; BMI, body mass index; COPD, chronic obstructive pulmonary disease; F, female; SL-ECG, wireless single-lead ECG.

Table 3 Univariate and multivariable logistic regression model to predict AF detected by SL-ECG

	Univariate			Multivariable		
	OR	95% CI	p Value	OR	95% CI	p Value
Female sex	0.501	0.387 to 0.649	<0.001	0.866	0.612 to 1.225	0.417
Age (per year)	1.083	1.069 to 1.097	<0.001	1.09	1.075 to 1.106	<0.001
Weight (per kg)	1.02	1.008 to 1.032	<0.001	1.061	1.041 to 1.082	<0.001
Height (per cm)	1.013	0.998 to 1.028	0.079	0.98	0.891 to 1.079	0.684
BMI (per kg/m^2)	1.044	1.01 to 1.08	0.012	0.911	0.859 to 0.966	0.002
Weight circumference (per cm)	1.037	1.024 to 1.05	<0.001	0.988	0.965 to 1.011	0.307
Comorbid conditions						
Hypertension	1.004	0.92 to 1.028	0.924			
Diabetes	1.189	1.105 to 1.28	<0.001	1.074	0.994 to 1.16	0.071
Hyperlipidaemia	1.053	0.992 to 1.118	0.09	0.975	0.914 to 1.041	0.452
Heart failure	1.436	1.3 to 1.587	<0.001	1.188	1.057 to 1.334	0.004
Stroke	1.192	1.129 to 1.259	<0.001	1.110	1.047 to 1.176	<0.001
Coronary artery disease	1.13	1.065 to 1.2	<0.001	1.013	0.947 to 1.085	0.701
Valvular heart disease	1.269	1.205 to 1.337	<0.001	1.229	1.156 to 1.307	<0.001
Peripheral artery disease	1.09	0.981 to 1.212	0.110	0.973	0.57 to 1.104	0.669
Thyroid disease	0.957	0.902 to 1.015	0.146	0.937	0.878 to 1	0.05
Obstructive sleep apnoea	0.982	0.9 to 1.072	0.683			
Cardiothoracic surgery	4.437	2.89 to 6.813	<0.001	2.141	1.34 to 3.422	0.001

AF, atrial fibrillation; BMI, body mass index; SL-ECG, wireless single-lead ECG.

difference in the mean heart rates between symptomatic and asymptomatic participants (84.5±23.9 vs 82.1±18.4/min; p=0.607). The congestive heart failure, hypertension, age >75 (doubled), diabetes, stroke (doubled), vascular disease, age 65–74, sex (female) (CHA_2DS_2VASc) scores of participants with AF detected by SL-ECG and newly diagnosed AF were 3.1±1.4 and 3.1±1.3, respectively. Table 7 shows a comparison between participants with newly diagnosed AF and those with no AF. Independent predictors of newly diagnosed AF include age, weight, stroke and valvular heart disease. Female sex predicted a lower risk for newly diagnosed AF (table 8). The ROC curves were constructed for the discriminative ability of age and weight for newly diagnosed AF. The AUCs for age and weight were 0.768 and 0.548, respectively. When a cut-off age threshold of 60 or above was used, there was a 98% sensitivity and 29.2% specificity in detecting newly diagnosed AF.

DISCUSSION

Main findings

According to the WHO criteria, a disease is suitable for screening when it is an important health problem with an accepted treatment, there are facilities for diagnosis and treatment, there

Table 4 Univariate and multivariable logistic regression model to predict AF detected by SL-ECG or self-reported by participants

	Univariate			Multivariable		
	OR	95% CI	p Value	OR	95% CI	p Value
Female sex	0.673	0.59 to 0.767	<0.001	0.929	0.775 to 1.113	0.425
Age (per year)	1.039	1.033 to 1.045	<0.001	1.038	1.031 to 1.044	<0.001
Weight (per kg)	1.010	1.004 to 1.016	0.001	1.004	0.996 to 1.012	0.297
Height (per cm)	1.010	1.002 to 1.017	0.009	1.018	1.009 to 1.027	<0.001
BMI (per kg/m^2)	1.015	0.998 to 1.033	0.083	0.996	0.843 to 1.178	0.966
Weight circumference (per cm)	1.017	1.011 to 1.024	<0.001	0.991	0.979 to 1.002	0.117
Comorbid conditions						
Hypertension	0.999	0.957 to 1.043	0.978			
Diabetes	1.111	1.069 to 1.156	<0.001	1.011	0.967 to 1.057	0.625
Hyperlipidaemia	1.135	1.104 to 1.168	<0.001	1.079	1.046 to 1.112	<0.001
Heart failure	1.585	1.47 to 1.709	<0.001	1.386	1.273 to 1.509	<0.001
Stroke	1.13	1.092 to 1.17	<0.001	1.063	1.022 to 1.105	0.002
Coronary artery disease	1.229	1.191 to 1.268	<0.001	1.131	1.09 to 1.172	<0.001
Valvular heart disease	1.263	1.209 to 1.319	<0.001	1.206	1.147 to 1.267	<0.001
Peripheral artery disease	1.189	1.129 to 1.253	<0.001	1.098	1.03 to 1.171	0.004
COPD	1.086	1.027 to 1.148	0.004	1.019	0.953 to 1.089	0.584
Thyroid disease	0.997	0.975 to 1.02	0.806			
Obstructive sleep apnoea	1.041	1.006 to 1.076	0.019	1.019	0.98 to 1.06	0.347
Cardiothoracic surgery	5.893	4.571 to 7.597	<0.001	3.065	2.29 to 4.1	<0.001

AF, atrial fibrillation; BMI, body mass index; COPD, chronic obstructive pulmonary disease; SL-ECG, wireless single-lead ECG.

is a latent and symptomatic stage, the natural history is understood, there is an agreed policy on whom to treat, the cost of finding is economically balanced with overall health and the case finding is a continuous process.[12] Last but not the least, the screening test should be suitable and acceptable to the population. Recent advances in smartphone and wireless technology has enabled ECG screening for cardiac arrhythmias without the use of 12-lead ECG machines.[7 13] In the current study, a smartphone-based wireless single-lead ECG was used as a screening tool for AF in a large population of 13 122 citizens in the community of Hong Kong. To the best of our knowledge, this is currently the largest study in mass screening for AF in the general population. Only 0.4% of ECGs, which were performed by trained non-medical volunteers were uninterpretable. This lends strong support to the technical ease and feasibility of SL-ECG in community screening for AF. Svennberg *et al*[5] performed a mass screening for AF in 7173 Swedish inhabitants aged 75–76 years. A single-lead ECG recorder (Zenicor, Zenicor Medical Systems, Stockholm, Sweden) was used for screening. Diagnosis was difficult in 3.5% of participants and 24-hour ECG monitoring was required. Compared with the 0.4% uninterpretable ECGs in our study, there was an apparently higher failure rate of ECG diagnosis in their study. The question whether there is a genuine performance difference between the two SL-ECG technologies or whether it was merely due to a difference in study methodology requires further study. In their study, newly diagnosed AF was found in 0.5% of the screened population on the first ECG and it was found in 3% of the screened population with repeated ECGs performed twice daily and on palpitations. In our study, only a single ECG was performed and we found that 42.2% of participants with AF detected by SL-ECG (0.8% of all participants) were previously undiagnosed and they had a mean CHA_2DS_2VASc score of 3.1 ±1.3. Most of them were therefore recommended oral anticoagulants for stroke prevention. As shown in other studies, asymptomatic AF was common. At least one-third of patients with AF were asymptomatic and only a fifth of the patients with symptomatic AF had symptoms temporally related to AF episodes.[14–16] More importantly, around a quarter of patients with ischaemic stroke had asymptomatic or silent AF.[4] In our participants with newly diagnosed AF, 65.3% were asymptomatic and this may explain why they remained undiagnosed before screening. We have shown that a population-based screening programme with a smartphone-based wireless single-lead ECG is feasible in identifying previously undiagnosed AF with low rate of uninterpretable ECGs. On the other hand, evidenced from our data, there was a high proportion of asymptomatic AF in participants who were not previously diagnosed of arrhythmia. Whether a systematic population-based ECG screening for AF, instead of an opportunistic approach as recommended by the current guidelines,[3] leads to a reduction in the incidence of stroke in a community requires a well-designed randomised controlled study. From our study, we found that age was a variable with good discriminative ability for newly diagnosed AF with an AUC of 0.768 in screening the general population. On the other hand, we observed a steep rise in the prevalence of AF from the age of 60 onwards with a sensitivity of 98% and specificity of 29.2% in detecting newly diagnosed AF. This may serve as an age cut-off criterion to improve the cost-effectiveness of AF screening in the community.

Prevalence and risk factors of AF

Interpretation of prevalence studies on AF has been difficult because of difference in methodology, especially in the definition of AF cases, the ethnic population under study and the time of data collection. A single ECG was performed to detect AF in some studies,[17 18] while, in others, history of AF was also taken into account in the counting of cases.[9 10 19] In general, a higher prevalence of AF has been observed in whites compared with Asians, blacks and Hispanics.[20 21] The time of data collection in different studies can also vary by a few decades. DeWilde *et al*[19] observed an increase in prevalence of AF from 0.78% to

Table 5 Prevalence of AF detected by SL-ECG

	Age (years)							
	All (n=13 122) (3731 M; 9357 F)	<55 (n=2492) (670 M; 1822 F)	55–59 (n=1412) (311 M; 1101 F)	60–64 (n=1927) (460 M; 1467 F)	65–69 (n=2273) (690 M; 1583 F)	70–74 (n=1778) (574 M; 1204 F)	75–79 (n=1628) (538 M; 1090 F)	≥80 (n=1578) (488 M; 1090 F)
M								
No. of participants with AF	105	2	3	7	15	18	30	30
Prevalence rate (%)	2.8	0.3	1	1.5	2.2	3.1	5.5	6.1
95% CI (%)	2.3 to 3.3	0 to 0.7	0 to 2	0.4 to 2.6	1.1 to 3.3	1.7 to 4.5	3.6 to 7.4	4.0 to 8.2
F								
No. of participants with AF	134	2	3	11	17	23	29	49
Prevalence rate (%)	1.4	0.1	0.3	0.7	1.1	1.9	2.6	4.4
95% CI (%)	1.2 to 1.6	0 to 0.2	0 to 0.6	0.3 to 1.1	0.6 to 1.6	1.1 to 2.7	1.7 to 3.5	3.2 to 5.6
Total								
No. of participants with AF	239	4	6	18	32	41	59	79
Prevalence rate (%)	1.8	0.2	0.4	0.9	1.4	2.3	3.6	5
95% CI (%)	1.6 to 2.0	0 to 0.4	0.1 to 0.7	0.5 to 1.3	0.9 to 1.9	1.6 to 3.0	2.7 to 4.5	3.9 to 6.1

AF, atrial fibrillation; F, female; M, male; SL-ECG, wireless single-lead ECG.

Table 6 Prevalence of AF detected by SL-ECG or self-reported by participants

	Age (years)							
	All (n=13 122) (3731 M; 9357 F)	<55 (n=2492) (670 M; 1822 F)	55–59 (n=1412) (311 M; 1101 F)	60–64 (n=1927) (460 M; 1467 F)	65–69 (n=2273) (690 M; 1583 F)	70–74 (n=1778) (574 M; 1204 F)	75–79 (n=1628) (538 M; 1090 F)	≥80 (n=1578) (488 M; 1090 F)
M								
No. of participants with AF	395	24	15	38	71	70	95	82
Prevalence rate (%)	10.6	3.6	4.8	8.3	10.3	12.2	17.7	16.8
95% CI (%)	9.6 to 11.6	2.2 to 5.0	2.4 to 7.2	5.8 to 10.8	8.0 to 12.6	9.5 to 14.9	14.5 to 20.9	13.5 to 20.1
F								
No. of participants with AF	716	56	60	89	119	122	118	149
Prevalence rate (%)	7.6	3.1	5.4	6.1	7.5	10.1	10.8	13.7
95% CI (%)	7.1 to 8.1	2.3 to 3.9	4.1 to 6.7	4.9 to 7.3	6.2 to 8.8	9 to 11.8	9 to 12.6	11.7 to 15.7
Total								
No. of participants with AF	1111	80	75	127	190	192	213	231
Prevalence rate (%)	8.5	3.2	5.3	6.6	8.4	10.8	13.1	14.6
95% CI (%)	8 to 9	2.5 to 3.9	4.1 to 6.5	5.5 to 7.7	7.3 to 9.5	9.4 to 12.2	11.5 to 14.7	12.9 to 16.3

AF, atrial fibrillation; F, female; M, male; SL-ECG, wireless single-lead ECG.

Table 7 Baseline characteristics of participants with newly detected AF versus those with no AF

	Total (n=8797)	Newly detected AF (n=101)	No AF (n=8696*)	p Value
Age (years)	65±13.4	76.2±8.9	64.8±13.4	<0.001
Sex (F), n (%)	6399 (72.7)	57 (56.4)	6342 (72.9)	<0.001
Weight (kg)	58.9±10.4	60.6±11	58.8±10.4	0.101
Height (cm)	157±9	157.6±9.5	157.2±8.6	0.639
BMI (kg/m^2)	23.8±3.6	24.3±3.7	23.8±3.6	0.128
Waist circumference (cm)	83.4±9.8	87.5±10.7	83.3±9.8	<0.001
Comorbid conditions				
Hypertension, n (%)	3332 (37.9)	33 (32.7)	3299 (37.9)	0.303
Diabetes, n (%)	1312 (14.9)	29 (28.7)	1283 (14.8)	<0.001
Hyperlipidaemia, n (%)	1625 (18.5)	23 (22.8)	1602 (18.4)	0.248
Heart failure, n (%)	32 (0.4)	3 (3)	29 (0.3)	0.006
Stroke, n (%)	224 (2.5)	10 (9.9)	214 (2.5)	<0.001
Coronary artery disease, n (%)	121 (1.4)	4 (4)	117 (1.3)	0.05
Valvular heart disease, n (%)	41 (0.5)	4 (4)	37 (0.4)	0.001
Peripheral vascular disease, n (%)	26 (0.3)	0 (0)	26 (0.3)	1.0
Obstructive sleep apnoea, n (%)	72 (0.8)	1 (1)	71 (0.8)	0.566
Thyroid disease, n (%)	328 (3.7)	2 (2)	326 (3.7)	0.592
COPD, n (%)	27 (0.3)	0 (0)	27 (0.3)	1.0
Cardiothoracic surgery, n (%)	166 (1.9)	7 (6.9)	159 (1.8)	0.003

*Participants who reported 'don't know' for a history of AF together with AF not detected by SL-ECG were excluded.
AF, atrial fibrillation; BMI, body mass index; COPD, chronic obstructive pulmonary disease; F, female.

Table 8 Univariate and multivariable logistic regression model to predict newly detected AF

	Univariate			Multivariable			
	OR	95% CI	p Value	OR	95% CI	p Value	AUC
Female sex	0.481	0.324 to 0.715	<0.001	0.624	0.401 to 0.972	0.037	
Age (per year)	1.095	1.072 to 1.117	<0.001	1.10	1.073 to 1.122	<0.001	0.768
Weight (per kg)	1.015	0.997 to 1.033	0.101	1.026	1.005 to 1.048	0.016	0.548
Height (per cm)	1.005	0.983 to 1.028	0.639				
BMI (per kg/m^2)	1.041	0.988 to 1.097	0.128	0.911	0.859 to 0.966	0.002	
Weight circumference (per cm)	1.042	1.022 to 1.063	<0.001	1.007	0.972 to 1.043	0.697	
Comorbid conditions							
Hypertension	0.926	0.806 to 1.064	0.279				
Diabetes	1.235	1.108 to 1.377	<0.001	1.09	0.972 to 1.223	0.139	
Hyperlipidaemia	1.055	0.961 to 1.158	0.264				
Heart failure	1.446	1.183 to 1.768	<0.001	1.251	0.992 to 1.576	0.058	
Stroke	1.202	1.106 to 1.306	<0.001	1.118	1.025 to 1.219	0.012	
Coronary artery disease	1.131	1.010 to 1.266	0.033	0.992	0.866 to 1.136	0.909	
Valvular heart disease	1.129	1.129 to 1.393	<0.001	1.188	1.048 to 1.347	0.007	
Thyroid disease	0.957	0.872 to 1.051	0.360				
Obstructive sleep apnoea	1.012	0.894 to 1.146	0.848				
Cardiothoracic surgery	4.031	1.84 to 8.832	<0.001	2.187	0.946 to 5.095	0.067	

AF, atrial fibrillation; AUC, area under curve; BMI, body mass index; COPD, chronic obstructive pulmonary disease.

1.31% in men and 0.79% to 1.15% in women from 1994 to 2003. In our study, we observed an overall prevalence of AF detected by SL-ECG to be 1.8%, with 2.8% in men and 1.4% in women. The prevalence increased with age for both men and women. These prevalence rates are consistent with the data from Singapore[18] and Korea.[22] The overall prevalence of AF detected by SL-ECG or self-reported by participants was 8.5%, with 10.6% in men and 7.6% in women. This category of AF likely represents both non-paroxysmal and paroxysmal AF. Interestingly, these prevalence rates are comparable with those observed in some recent studies on the US and European populations but much higher than those reported in studies on the Chinese population. Shen *et al*[23] reported AF prevalence rates of 9.8% in men and 6.5% in women in the whites from the data of a large California health maintenance organisation. Similarly, Krijthe *et al*[24] reported AF prevalence rates of 8.6% in men and 7.1% in women in a Dutch population. In contrast, Zhou and Hu,[9] in a study performed in 2004, observed a much lower prevalence rate of AF in a Chinese population with 0.91% in men and 0.65% in women. The remarkable difference in prevalence rates observed in our study, which was also performed on a Chinese population, may be due to a real

epidemiological expansion over a decade, difference in environmental factors in Hong Kong compared with Mainland China or a selection bias in the current study. Interestingly, Guo *et al*[8] also recently reported an observation of epidemiological expansion in AF burden for the years 2001–2012 in the southwest of China.

Epidemiological studies revealed a wide variety of risk factors for AF, which include age, male gender, hypertension, diabetes, coronary artery disease, valvular heart disease, congestive heart failure and hyperthyroidism.[1 25–27] In our study, we have identified age, heart failure, valvular heart disease, history of stroke and cardiothoracic surgery as independent predictors of AF detected by SL-ECG, which may represent persistent AF. In addition to these predictors, hyperlipidaemia, coronary artery disease and peripheral artery disease were found to be independent predictors of AF detected by SL-ECG or self-reported by participants, which likely include both paroxysmal and non-paroxysmal AF. With the growing worldwide epidemic of obesity,[28] it has been increasingly recognised as a risk factor for AF. On the other hand, individual anthropometric parameters like weight and height have also been shown to be risk factors of AF.[5] Interestingly, in our study, we also found weight as an independent predictor for AF detected by SL-ECG, while height was identified as an independent predictor for AF detected by SL-ECG or self-reported by participants. In contrast with some studies, male gender was not found to be an independent predictor for these two categories of AF in our study. The higher prevalence of these two categories of AF in men compared with women was likely a result of the former being on average taller and heavier. The finding that a higher BMI independently predicted a lower risk for AF detected by SL-ECG in our study is provocative and inconsistent with some studies.[29 30] However, if both higher weight and height independently predicted a higher risk of AF, as observed in our and other studies,[5] the predictability of AF with BMI becomes a function of both height and weight. The exact relationship between different anthropometric parameters, like weight, height and BMI, and AF requires further large-scale research to clarify.

LIMITATIONS

Since the recruitment of citizens to participate in the screening programme was non-randomised, selection bias might occur. The participants self-reported their medical history, including history of AF and other comorbid conditions. The information provided might not be accurate and a significant proportion of participants did not know whether they had a history of AF. SL-ECG with single-lead tracing was used in the diagnosis of AF. No conventional 12-lead ECG was performed as reference. However, all SL-ECGs were analysed by a cardiologist and there was only a very low proportion of ECGs being uninterpretable. On the other hand, since only SL-ECG with single-lead tracing was performed for each participant, arrhythmias other than AF might be missed. Although we have shown in our study that nearly half of the participants who had AF detected by SL-ECG were newly diagnosed with the help of a community-based screening programme, further studies are required to show that these participants will proceed to seek and comply with appropriate medical treatment and that a territory-wide community-based AF screening programme will lead to a reduction in the incidence of stroke. Last, this was a report on 13 122 citizens who participated in an AF screening programme in Hong Kong which is populated by over 7 million inhabitants. This study was not designed to assess the administrative feasibility, for example, uptake of the programme and efficiency of the recruitment procedure and cost-effectiveness of a community-based AF screening programme. Therefore, whether a similar screening programme can be recommended to other communities requires further study.

CONCLUSION

Community screening of AF with a smartphone-based wireless single-lead ECG was feasible and identified a significant proportion of citizens with newly diagnosed AF. The proportion of 'uninterpretable' ECGs with this screening tool was very low. The prevalence of AF in this large population sample in Hong Kong increased with age and rose steeply from age of 60 onwards which may serve as an age cut-off criterion in the future community-based AF screening programme. Apart from age and sex, height, weight, BMI, history of heart failure, valvular heart disease, stroke, hyperlipidaemia, coronary artery disease, peripheral artery disease and cardiothoracic surgery were identified as independent predictors of AF.

Key messages

What is already known on this subject?
The role of systematic screening for atrial fibrillation (AF) in reducing the burden of ischaemic stroke remains controversial. The data on the prevalence and risk factors of AF in the Chinese population especially in Hong Kong are limited.

What might this study add?
Community screening for AF with smartphone-based wireless single-lead ECG was feasible and it identified a significant proportion of citizens with newly diagnosed AF. The prevalence of AF in a Chinese population in Hong Kong was comparable with that of contemporary Western counterparts. Apart from age and sex, different anthropometric parameters and cardiovascular comorbid conditions were identified as independent predictors of AF.

How might this impact on clinical practice?
A systematic population-based ECG screening for AF, instead of an opportunistic approach as recommended by the current guidelines, may lead to a reduction in the incidence of stroke in a community, and a well-designed randomised controlled study is required.

Correction notice Since this paper was first published online edits have been made to table 5. Each figure in the row 'No of participants with AF' has moved to the right one space.

Competing interests None declared.

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