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Association of healthy lifestyle and the incidence of atrial fibrillation in senior adults: a prospective cohort study

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Abstract

Background Limited evidence was available on the association of the integrated effect of multidimensional lifestyle factors with AF incidence among Chinese old adults. This cohort study was to examine the effect of combined lifestyle factors on AF risk among Chinese older adults.

Methods A total of 3,253 adults aged 60 years or more from the Guangzhou Heart Study were successfully followed up. The healthy lifestyle score (HLS) was established using a weighted approach from seven dimensions of lifestyles, including diet quality, leisure-time physical activity, sleep quality, alcohol drinking, smoking, mental status, and waist-to-hip ratio. Hazard ratios (HRs) and 95% confidence intervals (95% CIs) were estimated using the Cox proportional hazard regression model.

Results During a median of 31.13 months of follow-up, 76 (2.34%) new-onset of AF were observed. After adjustment for confounders, HLS was associated with a 46% (HR: 0.54, 95% CI: 0.32–0.93) reduced AF risk when comparing the high with low tertiles of weight HLS, with an exposure-response trend. Every 0.1-unit increment of HLS was associated with 49% reduced AF risk. The protective effect of HLS on AF incidence was remarkable in the young-old (HR: 0.47, 95% CI: 0.29–0.79) but not in the old-old (HR: 0.85, 95% CI: 0.29–2.48), when comparing the high with low tertiles.

Conclusion The results suggest that higher HLS was associated with lower AF incidence among Chinese old adults, and the findings highlight the need to consider multi-dimensional lifestyles when developing health promotion strategies to lower the risk of new-onset AF the risk of new-onset AF.

Keywords Healthy lifestyle, Atrial fibrillation, Cohort study, Geriatric study

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Introduction

Atrial fibrillation (AF) is the most common arrhythmia in adults and can lead to stroke [1], thrombogenesis [2], and premature death, seriously increasing the cost of healthcare [3] and affecting the quality of life [4]. Worldwide, the AF incidence is increasing with age and its prevalence has doubled over the past three decades [5–8]. The prevalence was about 2.8–15.8% in Asia [9] and 0.9–2.4% in China [6], but considering the burden of AF disease, China ranked first over the world [10].

Recent studies underlined modifiable factors, especially lifestyle changes, in managing AF and reducing the risk and/or symptom burden of AF [11–13]. Each element of daily life behavior is interrelated, and exploring the overall effect of these elements is more helpful in making and taking reasonable prevention measures. Three cohort studies in the USA [14], Sweden [15], and Korea [16] found that the higher the healthy lifestyle score (HLS), the lower the incidence of AF; nonetheless, no relevant longitudinal study was observed in China. Lifestyle patterns, social culture, and racial and religious distinctions could remarkably influence the occurrence and development of cardiovascular diseases [17]. China is the country with the most serious AF burden, and it is necessary to longitudinally clarify the holistic effect of modifiable lifestyle factors on AF occurrence.

Moreover, the combined lifestyle scores in three studies [14–16] were calculated as the sum of the non-weighted healthy behaviors with the assumption of all lifestyle factors having the same magnitude of effect; however, this potentially might lead to a misclassification bias. The combined lifestyle scores generated with a weighted approach reflect the actual situation and have important clinical implications in AF prevention, but there is lacking evidence on this aspect. Therefore, we constructed this population-based cohort study to explore the effect of HLS defined with a weighted approach on the incidence of AF among old adults in Southern China.

Method

Subjects

The subjects in this study were selected from the Guangzhou Heart Study, an ongoing population-based prospective cohort study in Guangzhou, southern China. The profile of the Guangzhou Heart Study has been displayed elsewhere [18–22] and the surveys for all participants will be conducted every two to three years. Briefly, GZHS recruited permanent residents aged 35 years or above from the Yuexiu and Panyu districts in Guangzhou, China by randomized multistage cluster sampling method. Then, two streets (Dadong Street and Baiyun Street) were randomly selected from Yuexiu District to stand for urban areas while one street and two towns (Xiaoguwei Street, Xinzao Town, and Nancun Town) from Panyu District were chosen as rural areas. Participants were strictly identified in their local community health centers. Subjects with mental or cognitive disorders, mobility difficulties, pregnant or lactating status, malignant tumors under treatments, or no response during the 3-round mobilization were not eligible for this cohort. From July 2015 to August 2017, 12,013 individuals were enrolled and completed the baseline survey. The subjects aged 60 years or older were successfully followed up from March 2018 to September 2019. Besides, the outcome of AF occurrence for the participants was checked annually, which was done through project of regular health examination of the old adults, one of the core components of National Basic Public Health Services Programmed in China [23].

The inclusion criteria for the subjects in this study were as follows: aged 60 years or more, capable of daily self-management, completed the baseline survey, without cognitive dysfunction at baseline survey, and has lived in Guangzhou more than 6 months before the baseline survey. Among 3,445 eligible participants, 299 people were excluded for the reason of incomplete information (1 subject), history of AF (60 subjects), stroke (88 subjects), and outlier data of leisure-time physical activity (LTPA). The outlier data means that the LTPA is more than 150 MET-h/week ($n = 43$ subjects). Finally, a total of 3,253 subjects were selected for further analysis. This study was approved by the Guangzhou Medical Ethics Committee of the Chinese Medical Association and by the Ethical Review Committee for Biomedical Research, School of Public Health, Sun Yat-sen University. The study was performed in line with the Declaration of Helsinki and all participants provided informed consent.

AF ascertainment

The outcome was the new onset of AF (ICD-11: BC81.3) which was checked every year as mentioned above and was diagnosed according to the latest guidelines [24]. All participants underwent 12-lead electrocardiograms (MAC5500; GE Healthcare, Little Chalfont, Buckinghamshire, UK), 24-hour single-lead Holter (DL-194, Good Friend, Guangzhou, China), and clinical examination by the cardiovascular specialist at the baseline survey and during each follow-up. Each electrocardiogram from both 12-lead electrocardiogram and 24-hour Holter was read by two cardiologists independently. If the results of the two experts were the same, the report was signed and issued; If the results of the two experts were different, the experts needed to check again or seek the help of a superior doctor until the results were consistent. The health records of all subjects were also retrieved, and AF was considered to have occurred if new-onset AF was recorded between the baseline and follow-up surveys.

The time of AF onset was defined as the time of first diagnosis.

Assessment of lifestyle factors

Structured questionnaires were conducted with a face-to-face approach by the strictly trained investigators and physical examinations were conducted [21]. Smoking status was assessed by asking participants about their current or prior smoking behavior. The response to smoking behavior was defined as active smokers and the response to contacting smokers in their life or during work was defined as passive smokers. Both active smoking and passive smoking are defined as smoking, while other behaviors are defined as non-smoking. Alcohol drinking was assessed by the information reported by participants; the responses of "frequent drinking" or "occasional drinking" were considered as drinking, and the responses of "do not drink or abstain from alcohol" were considered non-drinking. Then both smoking and drinking were considered as unhealthy behavior and non-smoking and non-drinking were considered as healthy behavior.

A 22-item food frequency questionnaire (FFQ) was used to collect dietary information including food type and eating frequency [20]. Each participant was required to report the intake frequency of each food item over the past year (< once per month, 1–3 times per month, 1–3 times per week, 4–6 times per week, once per week). All foods were then grouped into fourteen categories, including cereals, fruits, legumes, eggs, dairy, nuts, vegetables, poultry, aquatic products, red meat, animal viscera, fried foods, high-salt foods, and sugary beverages in light of Chinese Dietary Guidelines [25]. After that, we assigned a score to each response (supplementary Table S1). For cereals, fruits, legumes, eggs, dairy, nuts, vegetables, poultry, and aquatic product, 0, 1, 2, 3, 4 were assigned to < once per month, 1–3 times per month, 1–3 times per week, 4–6 times per week, once per week, respectively; while, for animal viscera, fried foods, high-salt foods, sugary beverage, 4, 3, 2, 1, 0 were assigned to < once per month, 1–3 times per month, 1–3 times per week, 4–6 times per week, once per week, respectively. The diet quality score was calculated by the sum of each category, which ranged from 0 (lowest) to 56 (highest). We defined diet quality score at or above 35 points (the median diet-quality score for all participants) as healthy, otherwise as unhealthy.

LTPA was evaluated by a modified Global Physical Activity Questionnaire [21]. The total score of LTPA was calculated as the sum of eight categories of main physical activities including strolls, Tai chi/Qigong, Brisk walking/health exercises/Yangko, long-distance running/aerobics dancing, swimming, ball games (basketball, table tennis badminton etc.), bicycling and housework. The score for each LTPA was calculated by the product of duration, frequency, and intensity (quantified by the value of metabolic equivalent, MET) of each activity, and the details could be seen in our previous study [18]. Adults were supported by the World Health Organization (WHO) to do at least 150–300 min of moderate-intensity aerobic physical activity or at least 75–150 min of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity activity throughout the week [26]. This indicated that at least 10.0 MET-hours/week was required to meet the recommended standard minimum. If the LTPA meets this standard, it is considered as healthy, otherwise is unhealthy.

Mental statements were assessed for depression and anxiety using the Center for Epidemiologic Studies Depression Scale (CES-D) and Zung's self-rating anxiety scale (SAS) respectively, and then assessed jointly [27, 28]. The range for the score of CES-D and SAS was 0–60 and 25–100 respectively. We considered depression as the CES-D score attaching 16 and above, and considered anxiety as the SAS index score attaching 50 and above. The participants who had either depression or anxiety were considered to have an unhealthy mental state, otherwise a healthy mental status.

Sleep quality was assessed by two questions from the structured questionnaire [22]. The one was "Whether fatigue after waking up in the morning", and the other was "Whether feeling tired during the day". If the answer to either question was "Yes", the subjects were considered to have an unhealthy sleep quality, otherwise a healthy sleep quality.

The waist-to-hip ratio (WHR) was calculated by the ratio of waist circumference to hip circumference to reflect adiposity. Waist circumference was the minimum circumference of the natural waistline between the lower costal margin and the iliac crest, and hip circumference was the maximum circumference between the iliac crest and the crotch. Abdominal obesity was defined as a WHR greater than or equal to 0.90 for men and 0.85 for women according to WHO standards [29]. If participants achieved this standard of abdominal obesity, it was considered unhealthy, otherwise healthy.

Healthy lifestyle score establishment

The healthy lifestyle score (HLS) was established based on seven modifiable lifestyle factors mentioned above, and the details were shown in supplementary Table S2. The correlation and collinearity between any two healthy life factors were examined before generating HLS; the Pearson's coefficient and variance inflation factor suggested that the likelihood of correlation and collinearity between healthy life factors was small (Figure S1 and Table S3). Each lifestyle factor was classified as healthy or unhealthy, and then unhealthy and healthy scored 0 and 1, respectively. The HLS was then calculated by using the weight approach [30], as the ratio of the sum of the product of β coefficients of each lifestyle factor and the score of each lifestyle factor to the sum of the β coefficients of each lifestyle factor. The calculation formula for weighted HLS was as follows:

$$\text{Weighted HLS} = \frac{\begin{array}{c}\beta 1 \times \text{diet quality} + \beta 2 \times \text{LTPA} \\ +\beta 3 \times \text{sleep quality} + \beta 4 \times \text{smoking} \\ +\beta 5 \times \text{alcohol drinking} \\ +\beta 6 \times \text{ mental status} + \beta 7 \times \text{abdomina obesity}\end{array}}{\beta 1 + \beta 2 + \beta 3 + \beta 4 + \beta 5 + \beta 6 + \beta 7}$$

Where β1, β2, β3, β4, β5, β6, β7 represented the coefficients of dietary quality, LTPA, sleep quality, smoking, alcohol drinking, mental status, and abdominal obesity, respectively, derived from the Cox proportional hazard regression model. The weighted HLS ranged from − 0.87 to 1.87. Then, the HLS was then transformed into a categorical variable by using tertiles: low (< 0.90), middle (0.90–1.19), and high (> 1.19).

Potential confounding factors

Social demographics and medical history were also collected by the structured questionnaire and face-to-face interview. Social demographics included age (years), sex (male, female), marital status (married, others), education (primary school or lower, junior high school, senior high school, college or above), and resident address. The average $PM_{2.5}$ concentration and average greenness around the resident address were then calculated with the approach shown in our latest report [31], and the greenness was quantified using the average normalized vegetation index [31]. The medical history included hypertension (yes, no), diabetes (yes, no), dyslipidemia (yes, no), myocardial infarction (yes, no), heart failure (yes, no), and obstructive sleep apnea (yes, no).

Statistical analyses

The continuous variables with normal distribution were represented by mean and standard deviation (SD), while with non-normal distribution were represented by median and inter-quartile range (IQR); the distribution differences between the groups of AF and non-AF were tested by t-test or Mann-Whitney U Test. The categorical variables were expressed by frequency and percentage, and compared by chi-square test, Fisher's exact test, or chi-square test for trend.

The Cox proportional hazard regression model was performed to assess the hazard ratio (HR) and their 95% confidence interval (CI) to demonstrate the single and overall effects of lifestyle factors on AF risk. The proportional hazard assumption was examined using the Schoenfeld residual method, and no violation was observed. The linear exposure-response relationship was examined by putting the median of each tertile of exposure as a continuous variable into the model. The potential nonlinear relationship was examined using the restricted cubic spline regression model (knots on the 5th, 25th, 75th, and 95th), with HR and 95% CI being calculated based on the Cox proportional hazard regression model. The restricted cubic spline regression was performed with the "rms" package.

Sensitivity analysis was done by excluding the subjects with myocardial infarction or heart failure at baseline survey. We also considered the death event (all-cause death) before AF occurrence as a competing event and used a competing risk model to assess the relationship between HLS and AF risk. To check the stability of the HLS, each of the seven lifestyle factors was excluded in turn from HLS and repeated analyses were conducted. We also calculated the E-value to assess the potential degree of uncontrolled confounding effects. The E-value quantifies the minimum magnitude of association, expressed on the risk ratio scale, that an unmeasured confounder would need to have with both the treatment and the outcome to completely account for the observed association, given the measured covariates [32]. Stratified analysis was done by age (young-old: ≤ 75 years vs. old-old: >75 years); the multiplicative interaction of HLS with age, gender, and education was examined by using the likelihood ratio test, with a comparison of the likelihood scores of the two models with and without the interaction terms.

Stata 16.0 was used for all analyses except for restricted cubic splines and forest plots, which were analyzed using R software (version 4.2.2). All tests were two-sided, and $P < 0.05$ was considered as statistical significance.

Results

During a median of 31.13 months of follow-up, a total of 76 cases of new-onset AF (2.34%) was observed (Table 1). The mean age of all subjects was 69.73 (6.16) years, and the mean age in the AF group was larger than that in the non-AF group (71.54 vs. 68.69 years, $P = 0.042$). Compared with the non-AF group, the AF group was more likely to be older, male, with education in primary school or lower, with lower LTPA, and with more greenness in the living area ($P < 0.05$). Other characteristics, such as marital status, BMI, and medical history, were not significantly different between the two groups ($P > 0.05$).

The association of each single lifestyle factor and AF risk is shown in Table 2. After adjusting for possible confounders and the other six lifestyle factors, only healthy LTPA was observed to be remarkably related to a reduced risk of AF (HR: 0.45, 95% CI: 0.25–0.82), other factors did not find such significant association with AF.

For the overall effect of seven healthy lifestyle factors, HLS was negatively associated with AF incidence (Table 3). After adjustment for potential confounders, participants in the high tertile of HLS exhibited a 46%

Table 1 Baseline characteristics of the participates

Characteristic	Total	Non-AF group (*N* = 3,177)	AF group (*N* = 76)	*P*
Age, years, mean (SD)	69.73 (6.16)	69.69 (6.12)	71.54 (7.41)	0.042*
PM2.5, median (INQ)	46.31 (0.69)	46.31 (0.69)	46.40 (0.55)	0.372*
Greenness, median (INQ)	0.34 (0.02)	0.33 (0.02)	0.35 (0.02)	< 0.001*
Waist-hip ratio, mean (SD)	0.91 (0.07)	0.91 (0.07)	0.91 (0.06)	0.894*
Dietary quality score, mean (SD)	35.41 (5.05)	35.40 (5.02)	35.93 (6.02)	0.215*
CES-D score, mean (SD)	2.45 (3.51)	2.44 (3.51)	2.99 (3.63)	0.182*
SAS index, mean (SD)	30.17 (2.53)	30.18 (2.53)	30.05 (2.22)	0.676*
LTPA, MET-h/week, median (INQ)	36.75 (38.38)	36.75 (38.78)	25.25 (36.13)	0.011*
Sex, N (%)				< 0.001†
Male	1199 (36.86)	1156 (36.39)	43 (56.58)	
Female	2054 (63.14)	2021 (63.61)	33 (43.42)	
Marital status, N (%)				0.212†
Married	2505 (77.01)	2451 (77.15)	54 (71.05)	
Others	748 (22.99)	726 (22.85)	22 (28.95)	
Education, N (%)				0.036‡
Primary school or lower	1929 (59.30)	1891 (59.52)	39 (50.00)	
Junior high school	518 (15.92)	508 (15.99)	10 (13.16)	
Senior high school	497 (15.28)	483 (15.20)	14 (18.42)	
College or above	309 (9.50)	295 (9.29)	14 (18.42)	
Active smoking, N (%)				0.170†
No	288(40.17)	277(39.74)	11(55.00)	
Yes	429(59.83)	420(60.26)	9(45.00)	
Passive smoking, N (%)				0.884†
No	2123(65.26)	2074(65.28)	49(64.47)	
Yes	1130(34.74)	1103(34.72)	27(35.53)	
Alcohol drinking, N (%)				0.923†
Never or former drinking	570(17.52)	557(17.53)	13(17.11)	
Occasional or frequent drinking	2683(82.48)	2620(82.47)	63(82.89)	
Hypertension, N (%)				0.551†
No	1817 (55.86)	1772 (55.78)	45 (59.21)	
Yes	1436 (44.14)	1405 (44.22)	31 (40.79)	
Diabetes, N (%)				0.413†
No	2801 (86.11)	2738 (86.18)	63 (82.89)	
Yes	452 (13.89)	439 (13.82)	13 (17.11)	
Dyslipidemia, N (%)				0.504†
No	2419 (74.36)	2365 (74.44)	54 (71.05)	
Yes	834 (25.64)	812 (25.56)	22 (28.95)	
Myocardial infarction, N (%)				0.185§
No	3142 (96.59)	3071 (96.66)	71 (93.42)	
Yes	111 (3.41)	106 (3.34)	5 (6.58)	
Heart failure, N (%)				0.214§
No	3216 (98.86)	3142 (98.90)	74 (97.37)	
Yes	37 (1.14)	35 (1.10)	2 (0.9)	
OSA, N (%)				0.217†
No	2552 (78.45)	2488 (78.31)	64 (84.21)	
Yes	701 (21.55)	689 (21.69)	12 (15.79)	

Abbreviation: LTPA, Leisure-time physical activity; OSA, Obstructive sleep apnea; PM2.5; INQ, interquartile

* *P* value for a t-test or Mann-Whitney U test

† *P* for chi-square test

‡ *P* for chi-square test for trend

§ *P* for Fisher's exact test

Table 2 Association between each lifestyle factor and atrial fibrillation risk

	*N**		HR (95% CI)		
	Non-AF group	**AF group**	**Unadjusted**	**Adjusted** †	**Adjusted** ‡
Diet quality					
Unhealthy	1670	37	1.00	1.00	1.00
Healthy	1507	39	0.72 (0.46, 1.15)	0.84 (0.51, 1.35)	0.84 (0.52, 1.37)
Leisure-time physical activity					
Unhealthy	363	15	1.00	1.00	1.00
Healthy	2814	61	0.38 (0.22, 0.68)	0.45 (0.25, 0.81)	0.45 (0.25, 0.82)
Sleep quality					
Unhealthy	535	19	1.00	1.00	1.00
Healthy	2643	57	0.75 (0.44, 1.27)	0.68 (0.40, 1.16)	0.70 (0.40, 1.20)
Mental status					
Unhealthy	112	4	1.00	1.00	1.00
Healthy	3065	72	0.92 (0.33, 2.51)	0.87 (0.31, 2.43)	1.03 (0.37, 2.91)
Alcohol drinking					
Drinking	557	13	1.00	1.00	1.00
Non-drinking	2620	63	1.07 (0.59, 1.94)	1.34 (0.72, 2.48)	1.26 (0.67, 2.36)
Cigarette smoking					
Smoking	1304	29	1.00	1.00	1.00
Non-smoking	1873	47	1.19 (0.75, 1.91)	1.33 (0.83, 2.14)	1.32(0.82, 2.15)
Waist-to-hip ratio					
Unhealthy	2261	49	1.00	1.00	1.00
Healthy	916	27	1.26 (0.79,2.01)	1.13 (0.69, 1.85)	1.19 (0.73, 1.96)

* N represents the sample size for the non-AF group or for the AF group

† Adjustment for age, sex, education, marital status, diabetes, hypertension, dyslipidemia, myocardial infarction, heart failure, obstructive sleep apnea, $PM_{2.5}$, and greenness

‡ Further adjustment for the other six lifestyle factors

Table 3 Association between the healthy lifestyle score and atrial fibrillation risk

Healthy lifestyle score	*N**		HR (95% CI)	
	Non-AF group	**AF group**	**Unadjusted**	**Adjusted**†
All subjects				
Low tertile (< 0.90)	809	27	1.00	1.00
Middle tertile (0.90 ~ 1.19)	1007	21	0.57 (0.32, 1.01)	0.63 (0.35, 1.12)
High tertile (> 1.19)	1361	28	0.48 (0.28, 0.81)	0.54 (0.32, 0.94)
P for trend			0.006	0.022
Every 0.1-unit increment			0.42 (0.27, 0.64)	0.51 (0.34, 0.76)
Young-old (Age ≤ 75 years)				
Low tertile (< 0.90)	625	18	1.00	1.00
Middle tertile (0.90 ~ 1.19)	801	13	0.49 (0.24, 1.01)	0.55 (0.26, 1.13)
High tertile (> 1.19)	1086	19	0.45 (0.23, 0.86)	0.50(0.25, 0.97)
P for trend			0.008	0.036
Every 0.1-unit increment			0.39 (0.22, 0.67)	0.47 (0.29, 0.79)
Old-old (Age > 75 years)				
Low tertile (< 0.90)	184	9	1.00	1.00
Middle tertile (0.90 ~ 1.19)	206	8	0.76 (0.29, 1.98)	0.66 (0.21, 2.09)
High tertile (> 1.19)	275	9	0.56 (0.22, 1.41)	0.85 (0.29, 2.48)
P for trend			0.291	0.396
Every 0.1-unit increment			0.49(0.24, 1.01)	0.56 (0.28, 1.13)

* N represents sample size for the non-AF group or for the AF group

† Adjustment for age, sex, education, marital status, body mass index, diabetes, hypertension, dyslipidemia, myocardial infarction, heart failure, obstructive sleep apnea, $PM_{2.5}$, and greenness

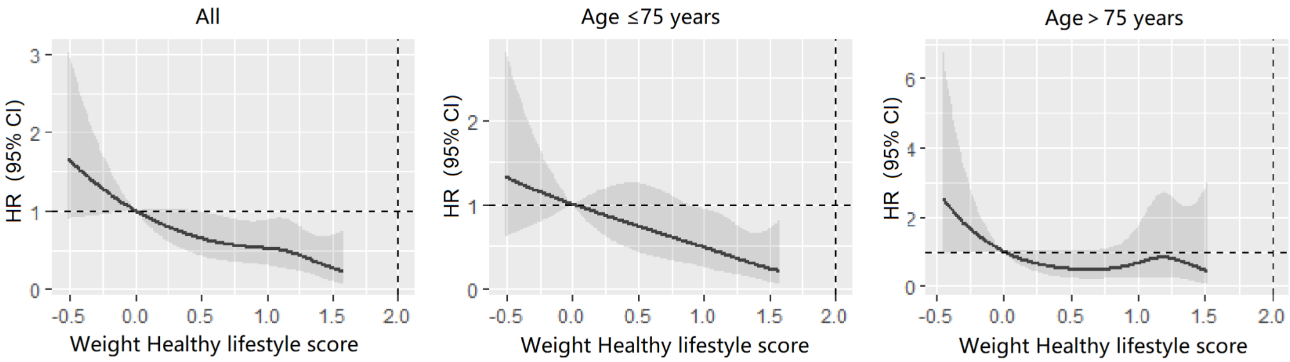

Fig. 1 Association between healthy lifestyle index score and atrial fibrillation risk. HR was adjusted for age, sex, education, $PM_{2.5}$, greenness, diabetes, hypertension, dyslipidemia, myocardial infarction, heart failure, obstructive sleep apnea. The potential non-linear association was examined using restricted cubic spline regression (knots on the 5th, 25th, 75th, and 95th percentiles), with OR and 95% CI being calculated based on the Cox model. The restricted cubic spline regression was performed with the "rms" package. *P for* linear trend was 0.012, 0.045, 0.324 in all subjects, subjects aged ≤ 75 years, and subjects aged > 75 years, respectively; and *P for* non-linear trend was 0.752, 0.905, 0.611 in all subjects, subjects aged ≤ 75 years, and subjects aged > 75 years, respectively

Table 4 Sensitivity analysis on the association between healthy lifestyle index score and atrial fibrillation risk by using Fine-Gray competing multivariable regression analysis

Healthy lifestyle score	Unadjusted HR (95% CI)	Adjusted HR (95% CI) †
Low tertile (< 0.90)	1.00	1.00
Middle tertile (0.90 ~ 1.19)	0.57 (0.32, 1.00)	0.63 (0.36, 1.09)
High tertile (> 1.19)	0.48 (0.28, 0.82)	0.54 (0.31, 0.95)
P for trend	0.007	0.031
Every 0.1-unit increment	0.42 (0.27, 0.65)	0.51 (0.34, 0.76)

* N represents sample size for non-AF group or for AF group

† Adjustment for age, sex, education, marital status, diabetes, hypertension, dyslipidemia, myocardial infarction, heart failure, OSA, $PM_{2.5}$ and greenness

risk reduction (HR: 0.54, 95% CI: 0.32–0.93) in AF risk when compared with those in the low tertile, with a significant linear exposure-response trend ($P = 0.022$). Every 0.1-point increment of HLS was associated with a 49% (HR: 0.51, 95% CI: 0.34–0.76) reduced risk of AF. By using the restricted cubic spline regression (Fig. 1), a significant linear trend rather than an unilinear trend was observed ($P_{\text{line trend}} = 0.012$, $P_{\text{non-linear trend}} = 0.752$).

Similar protective effects were observed in sensitivity analysis with Fine-Gray competing multivariable regression analysis (Table 4). For unmeasured confounders, we obtained an E-value of 3.33 for the primary estimate and 1.96 for the lower confidence limit (Figure S2). Seven repeated analyses were conducted by excluding one factor from HLS in turn, and a consistent protective effect by HLS was consistently observed (Figure S3). Besides, after excluding participants with myocardial infarction or heart failure at baseline, every 0.1-unit increment of the HLS was associated with a 39% reduced risk of AF (Table S4). In stratified analysis by age, the protective effect of the HLS on AF incidence was remarkable in the young-old (HR: 0.47, 95% CI: 0.29–0.79) but not in the old-old (HR: 0.85, 95% CI: 0.29–2.48), when comparing the high with lower tertiles (Table 3). Multiplicative interaction of HLS with age, gender, or education was not observed ($P > 0.05$).

Discussion

To our knowledge, this is the first large-scale community-based prospective cohort study conducted among Chinese old adults to investigate the single and holistic effects of health lifestyle factors on the risk of AF. This study found that the HLS was negatively associated with AF incidence.

The HLS was developed by considering both physical and psychological aspects, which can better reflect the real state of life. Due to the existence of a combination of various factors, the comprehensive consideration of several lifestyles was of great significance for AF prevention and control. Alcohol drinking, smoking, LTPA, and diet quality were the common lifestyles that were widely used in most studies to generate the HLS [14–16, 30, 33–36]. Current international guidelines recommend normal weight, not smoking, no or moderate alcohol consumption, daily moderate exercise, and healthy nutrition as key health behaviors to prevent AF [37]. Unlike other studies [14–16], we used WHR instead of BMI because most Chinese were abdominal obese [38] and WHR was also an AF predictor [39]. In addition, we also considered sleep and mental status to generate the health lifestyle score, as they were important elements affecting the occurrence and prognosis of arrhythmia [40, 41]. The development of modern medicine pays more and more attention to mental and psychological factors and puts forward that positive psychology should be included in the scope of basic lifestyle and lifestyle medicine [42]. Therefore, it is necessary to take mental state into account when evaluating the overall effects of a healthy lifestyle. Current evidence suggested that depression was associated with AF risk

[41, 43], and anxiety was independently associated with AF risk [41, 44] and AF recurrence [45].

We found that the likelihood of correlation and collinearity between the seven selected lifestyle factors was low, indicating that the seven factors were independent of each other. Like many other studies [30, 33, 34], the HLS in this study, which was constructed using a weighted method, has an advantage in reflecting real-life conditions compared to the index created by the equal-weight method, because each factor contributes differently to health outcomes. Our study observed that the HLS generated with a weighted approach was negatively associated with the risk of AF, which was consistent with the findings of previous cohort studies [14–16], though they created HLS with an unweighted approach. Moreover, two sensitivity analyses yielded similar results, further demonstrating the robustness of our study.

The stratified analysis showed that the association of HLS with AF incidence was more significant in young-old (≤75 years) than in old-old (>75 years). This may be due to the natural aging issues in people over 75 years old [46]; in the very old, the effects of multiple age-related chronic diseases related to natural changes in body function/function outweigh the modulating role of lifestyle.

Numerous studies have analyzed the relationship of individual lifestyle factors with AF risk [40, 47–53]. Noteworthy, our study highlighted the importance of getting a workout meeting WHO criteria to reduce the risk of AF, which is consistent with the results from the latest meta-analysis [54]. The association of the other six lifestyles with the reduced risk of AF did not arrive at a significant level, which may be due to the relatively short follow-up.

There are several advantages. First, all participants underwent examination of both 12-lead electrocardiogram and 24-hour single-lead Holter, as well as assessment of medical records, which would increase the pick-up of subclinical/asymptomatic AF. Second, we used a community-based population cohort to investigate, for the first time, the single and overall impact of lifestyles on the AF risk in Chinese old adults. Our findings provided longitudinal evidence or clues for AF prevention based on lifestyle improvements. Third, the HLS was developed by considering both physical and psychological aspects, which can better reflect the real state of life. Fourth, our study adopted the multi-stage sampling method and the samples were representative. The fact that stratified analyses and sensitivity analyses yielded consistent results, indicates good internal consistency for the HLS evaluated.

Some limitations also exist. First, the follow-up period of our study was relatively short, and relatively few new cases were observed, especially in people older than 75 years ($n = 26$); this may lead to the non-significant association of LTPA with AF in adults aged more than 75 years, restricting the generality of the findings. Our ongoing research will extend the follow-up period for further evaluation. Besides, the study setting was located in a city in southern China, so the results need to be further verified by a multi-city, long-term prospective study. Second, most lifestyle factors including diet, sleep, LTPA, etc. were investigated based on questionnaires, monitoring data based on wearable devices may be more reflective of the real situation. Third, although our study included confounding factors as much as possible, we cannot avoid the possibility of residual confounders. However, the E-value test showed that the unmeasured confounding effect was relatively small. Fourth, this study only focused on old adults in the communities, whether it can be extrapolated to other study populations, such as athletes, young adults, or old people in nursing homes, needs to be treated with caution. In addition, mortality is higher in older adults than in young and middle-aged adults. Due to the death and loss of follow-up, this cohort study in only the old adults might result in selection bias. However, similar protective effect was observed by using Fine-Gray competing regression model, suggesting that the death after the baseline recruitment had limited influence on the results. Notwithstanding, the death before the baseline recruitment might also cause section bias. Fifth, the coefficients to establish the weighted HLS were calculated based on the same subjects as the main analysis, this might produce biased estimates due to overfitting the data and might influence the extrapolation of the results. Hence, more studies with rigorous design and large -samples, and with cross-validation analysis, are needed to shed light on the impact of lifestyle on the development of AF.

In conclusion, this prospective community-based cohort study among Chinese old adults showed that the higher the HLS, the lower the AF risk. The findings highlight the need to consider multi-dimensional lifestyles, rather than a single lifestyle, when developing health promotion strategies to lower the risk of new-onset AF.

Abbreviations

AF	Atrial fibrillation
BMI	Body mass index
CI	Confidence interval
CES-D	Center for Epidemiologic Studies Depression Scale
FFQ	Food frequency questionnaire
HLS	Healthy lifestyle score
HR	Hazard ratio
IQR	Inter-quartile range (IQR)
LTPA	Leisure-time physical activity
MET	Metabolic equivalent
SD	Standard deviation
SAS	Zung's self-rating anxiety scale
WHO	World Health Organization
WHR	Waist-to-hip ratio

Supplementary Information

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Supplementary Material 1

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Author contributions

XDL conceived and designed the study; HD and YM analyzed the data and drafted the manuscript; CG, CW, ZL, JH, MZ, JC, YX, HF, and XW collected the data; YMX, SW, and XDL reviewed and edited the manuscript. All co-authors provided comments and approved the final version.

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Data availability

The data used to support the findings of this study are available from the corresponding author upon request. A proposal with a detailed description of study objectives and a statistical analysis plan will be needed for the evaluation of the reasonability of requests if someone requests data sharing.

Declarations

Ethical approval

This study was approved by the Medical Research Ethics Committee of Guangdong Provincial People's Hospital and by the Ethical Review Committee for Biomedical Research, School of Public Health, Sun Yat-sen University. The study was performed in line with the Declaration of Helsinki and all participants provided informed consent.

Consent to participants

The participants were required to sign a written informed consent form before joining the study. Patients and/or the public were not involved in the design, conduct, reporting, or dissemination plans of this research.

Consent for publication

All co-authors provided comments and approved the final version.

Competing interests

The authors declare no competing interests.

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