Scand J Med Sci Sports 2014: 24: e238–e244
doi: 10.1111/sms.12150

© 2013 The Authors. Scandinavian Journal of Medicine & Science in Sports published by John Wiley & Sons Ltd.

SCANDINAVIAN JOURNAL OF MEDICINE & SCIENCE IN SPORTS

Increased risk of atrial fibrillation among elderly Norwegian men with a history of long-term endurance sport practice

M. Myrstad[1,3], M-L. Løchen[2], S. Graff-Iversen[2,3], A. K. Gulsvik[4], D. S. Thelle[5,6], H. Stigum[3,5], A. H. Ranhoff[1,7]

[1]Medical Department, Diakonhjemmet Hospital, Oslo, Norway, [2]Department of Community Health, UiT The Arctic University of Norway, Tromsø, Norway, [3]Division of Epidemiology, Norwegian Institute of Public Health, Oslo, Norway, [4]Department of General Internal Medicine, Oslo University Hospital, Oslo, Norway, [5]Department of Biostatistics, Institute of Basal Medical Sciences, University of Oslo, Oslo, Norway, [6]Department of Public Health and Community Medicine, Gothenburg University, Gothenburg, Sweden, [7]Kavli Research Centre for Ageing and Dementia, Department of Clinical Science, University of Bergen, Bergen, Norway
Corresponding author: M. Myrstad, MD, Medical Department, Diakonhjemmet Hospital, PO Box 23 Vindern, N-0319 Oslo, Norway. Tel: +47 92255945, Fax +47 22451776, E-mail: m-myrsta@online.no

Accepted for publication 2 October 2013

Atrial fibrillation (AF) is the most common cardiac arrhythmia. The prevalence increases with increasing age. In middle-aged men, endurance sport practice is associated with increased risk of AF but there are few studies among elderly people. The aim of this study was to investigate the role of long-term endurance sport practice as a risk factor for AF in elderly men. A cross-sectional study compared 509 men aged 65–90 years who participated in a long-distance cross-country ski race with 1768 men aged 65–87 years from the general population. Long-term endurance sport practice was the main exposure. Self-reported AF and covariates were assessed by questionnaires. Risk differences (RDs) for AF were estimated by using a linear regression model. After multivariable adjustment, a history of endurance sport practice gave an added risk for AF of 6.0 percent points (pp) (95% confidence interval 0.8–11.1). Light and moderate leisure-time physical activity during the last 12 months reduced the risk with 3.7 and 4.3 pp, respectively, but the RDs were not statistically significant. This study suggests that elderly men with a history of long-term endurance sport practice have an increased risk of AF compared with elderly men in the general population.

Marathons and long-distance cross-country ski races have become increasingly popular, also at higher ages. Young and middle-aged male endurance athletes seem to have an increased risk of atrial fibrillation (AF) (Karjalainen et al., 1998; Elosua et al., 2006; Molina et al., 2008; Graff-Iversen et al., 2012; Müller-Riemenschneider et al., 2012; Andersen et al., 2013) but the role of endurance sport practice as a risk factor for AF among elderly people has only been studied to a small extent.

AF is the most common cardiac arrhythmia, with a prevalence of 1.5–2% in the general population (Camm et al., 2012). The prevalence increases with increasing age, to 10% among 75-year-olds and between 15 and 20% in people aged over 85 years. The prevalence is highest among men, around 15% by 75 years of age (Heeringa et al., 2006; Tveit et al., 2008). The positive association with age is partly explained by increasing prevalence of risk factors for AF. Coronary heart disease (CHD), hypertension and diabetes are among the most important risk factors (Kirchhof et al., 2012), and are all preventable by regular physical activity (PA).

However, it has been hypothesized that long-term endurance sport practice facilitates structural changes in the heart, increased vagal tonus and bradycardia, which could predispose to AF (Calvo et al., 2012; Patil et al., 2012; Turagam et al., 2012; Wilhelm, 2013). Many elderly participants in long-distance endurance sports events have been exposed to endurance sports for many years. Elderly people might be more vulnerable than younger people, due to CHD, hypertension and other factors predisposing to AF, so that the association between endurance sport practice and risk of AF might be even stronger in this population. However, elderly people with a history of long-term endurance sport practice might also have a lower risk of AF, due to the protective effect of PA on important risk factors.

We are aware of only two studies that address the association between leisure-time PA (LTPA) and risk of AF in elderly people; the Cardiovascular Health Study and the Physicians Health Study (Mozaffarian et al., 2008; Aizer et al., 2009). Most participants in these studies were less physically active than required for endurance sport practice and neither of these studies

This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.

demonstrated increased risk of AF associated with PA in elderly people.

CHD among Norwegian long-distance cross-country skiers was studied by Lie and Erikssen in the 1970s. They found a low incidence among the skiers after 5 years follow-up (Lie & Erikssen, 1984). After a 28–30-year follow-up of the same cohort, Grimsmo et al. (2010) demonstrated a high prevalence of AF among the elderly skiers, but the skiers were not compared with a control group.

The aim of our study was to investigate the role of long-term endurance sport practice as a risk factor for AF in elderly men, by comparing the prevalence of AF among participants of a long-distance cross-country ski competition with the prevalence of AF in the general elderly population.

Materials and methods

Design and study populations

The Birkebeiner Ageing Study (BiAS) is a longitudinal study of skiers aged 65 years and older participating in the Norwegian Birkebeiner cross-country ski race, with the main purpose to study associations between long-term exercise and health in advanced age. With a course of 54 km and a total of about 1000 uphill altitude meters, the Birkebeiner race is among the world's most challenging. Based on result lists provided by the organizer, all 658 Norwegian skiers aged 65 years and older who completed the race in 2009 or 2010 were invited to participate. A questionnaire and an invitation letter were sent to the participants, and the completed questionnaire was returned by post. Due to low number of female participants in BiAS, only men were included in this study.

In order to assess the association between endurance sport practice and risk of AF, cross-sectional baseline data from BiAS were compared with data from the sixth survey of the Tromsø Study (Tromsø 6) which took place in 2007–2008. The Tromsø Study is a population-based general health study with repeated cross-sectional surveys in the largest city in Northern Norway (Jacobsen et al., 2012). In Tromsø 6, 19 762 inhabitants in Tromsø aged 30 years and older were invited. A total of 12 982 participated (66%).

For this study, 1768 out of 2757 invited men aged 65 to 87 years were included from Tromsø 6 (67.7%). From BiAS, 509 out of 607 invited men aged 65 to 90 years were included (83.9%).

The Tromsø Study was approved by the Norwegian Data Inspectorate and the Norwegian Directorate of Health. Both studies were approved by the Regional Committees for Medical and Health Research Ethics, and comply with the Declaration of Helsinki. All participants gave informed written consent.

Assessment of atrial fibrillation, physical activity and exercise

AF was assessed with the question "Do you have, or have you had atrial fibrillation?" in both studies.

In both studies, an identical question with a four-level scale was used to assess LTPA: "How physically active have you been during the past year in your leisure time. If your activity level varies between summer and winter, note an average value. Tick one only." Levels of activity were defined as follows: (a) sedentary (reading, watching television, other sedentary activity); (b) light PA (walking, cycling or other activity for at least 4 h per week); (c) moderate PA (light sports, heavy gardening, for at least 4 h per week); (d) high PA (regular hard exercise or competitive sports several times per week). This scale was originally developed by Saltin & Grimby (1968) and was used in middle-aged and elderly Swedish athletes. It discriminates between sedentary persons and their more active counterparts with respect to maximal oxygen uptake (Saltin, 1977), and has been validated in the Tromsø population (Emaus et al., 2010).

The participants in BiAS were asked for the total number of years they had practiced systematic endurance training, the age when they first participated in the Birkebeiner race, how many years they had participated in the race, and how many Birkebeiner medals they had won. Participants with a finishing time not exceeding 25% of the average finishing time of the five fastest participants in each 5-year age class are awarded a Birkebeiner medal.

Assessment of health status and other characteristics

Age was registered at inclusion. Body mass index (BMI) was calculated as weight (kg) divided by squared height (m). CHD was assessed with the two questions "Have you had a heart attack?" and "Do you have or have you had angina pectoris?" Hypertension was assessed with the question "Do you take or have you ever taken blood pressure lowering medicines?" Diabetes was assessed with the question "Do you have diabetes?" Education level, health status, smoking habits and alcohol consumption were assessed with slightly different questions and categories, and recoded into common categories. In Tromsø 6, height and weight were measured with subjects wearing light clothing and no shoes. Except from height and weight in Tromsø 6, all variables were self-reported by questionnaires, with only minor differences between the studies. English translations are available on websites (http://www.kavlisenter.no; http://www.tromsostudy.com).

Statistical analysis

Characteristics of the study populations were compared by Student's *t*-test for means of continuous variables and Pearson's Chi-square of independence for categorical variables.

A history of endurance sport practice, defined as belonging to the study population of skiers, was the main exposure. Total prevalence and prevalence after exclusion of persons with CHD were reported for the variable self-reported AF outcome.

Both study populations were analyzed together in a linear regression model with a robust variance estimator. The model gives risk differences (RDs) with 95% confidence intervals (CI) for AF. When designing the model, a direct acyclic graph (DAG) was used to identify covariates that are appropriate for adjustment. The DAG shown in Figure 1 is simplified to aid readability. Covariates and arrows not influencing the analysis are excluded. The highlighted arrow represents the direct association between endurance sport practice and AF. CHD, hypertension, diabetes, age, height, BMI, education level, alcohol consumption, smoking habits and LTPA were adjusted for in the model. Health consciousness in the DAG represents unmeasured confounding lifestyle factors. In the variable "number of alcohol units usually consumed when drinking," there were over 10% missing data among the skiers. Analysis after exclusion of cases with missing data for alcohol consumption did not change the effect estimates.

Since odds ratios (ORs) are commonly reported for binary outcomes like AF, we also report results from a logistic regression model using the same covariates as the linear model.

All statistical analyses were conducted using SPSS version 20.0 (IBM, Armonk, New York, USA).

Results

Some characteristics of the study populations are shown in Table 1. Participants in BiAS were on average 2.7 years younger, had a lower BMI, and were taller compared with the general population. Higher proportions of the skiers reported college or university education and

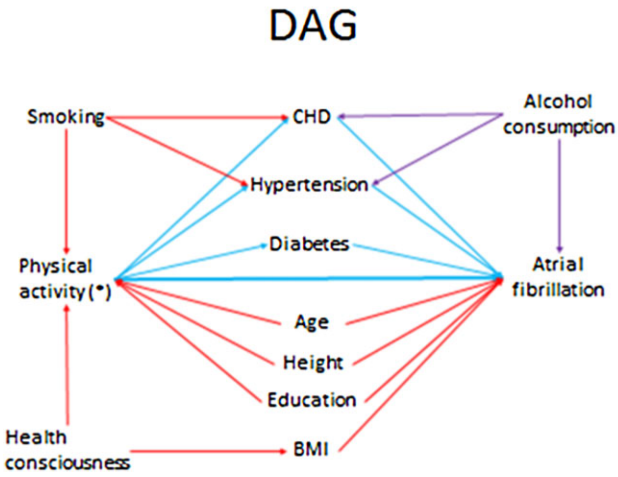

Fig. 1. Simplified direct acyclic graph (DAG). Arrows and covariates not influencing the analysis are excluded. The highlighted arrow illustrates the direct association between sport practice and atrial fibrillation. The other arrows illustrate intermediate covariates in the association (blue), confounding (red) and colliding (violet) covariates.
(*) Endurance sport practice is covered by the term physical activity. Due to different underlying mechanisms in the association with AF, self-reported leisure time PA was adjusted for when estimating risk differences for AF.

current full-time employment. There were fewer smokers and more alcohol consumers among the skiers. They also reported higher levels of LTPA and valued their own health as better than the general population in Tromsø. All these differences were statistically significant. Among the skiers, the average BMI was normal and the prevalence of traditional risk factors for AF was very low. The crude prevalence of AF was 13.2% in the skiers and 11.6% in the general population. The prevalence of AF after exclusion of persons with CHD was 13.0% in the skiers and 9.8% in the general population.

Figure 2 and Supporting Information Table S1 show adjusted RDs with 95% CIs by selected covariates based on the linear regression model. The constant term shown in the first line of the table describes the risk of AF for a reference person, and was estimated to 11.3%. This equals the expected prevalence of AF when all covariates are set at their reference values. Endurance sport practice gave an added risk for AF of 6.0 percent points (pp) (95% CI 0.8–11.1). The risk of AF increased with 0.4 pp per added year of age. The risk of AF increased with 0.3 and 0.6 pp per cm of height and unit of BMI added, respectively. Also hypertension and CHD were associated with added risk for AF. RDs were not significant for diabetes, smoking, lipid-lowering treatment or alcohol consumption (Fig. 2).

Example

The estimated risk of AF for a sedentary 71-year-old man, 175 cm tall, with a BMI of 26.3, non-smoker with average alcohol consumption and education level, no CHD, diabetes or hypertension and not practicing endurance sports was 11.3%. For a man with the same characteristics but who practices endurance sports, the estimated risk was 13.0% if reporting moderate PA (11.3+6.0–4.3%), and 17.6% if reporting the highest level of PA (11.3+6.0+0.3%).

Associations expressed as relative effects (ORs) were calculated by logistic regression. The adjusted OR (aOR) for AF in men practicing sport was 1.28 (95% CI 0.94–1.73) after adjustment for age and 1.90 (95% CI 1.14–3.18) after multivariable adjustment for age, traditional risk factors for AF and education. After exclusion of persons with CHD and multivariable adjustment, the aOR for AF was 1.81 (95% CI 1.04–3.14) ($n = 1713$).

Sensitivity analysis after exclusion of skiers who had participated less than three times in the Birkebeiner race did not change the effect estimates.

Discussion

This study suggests that elderly men with a history of long-term endurance sport practice have a higher risk of AF than elderly men in the general population. Light and moderate LTPA during the previous year may reduce the risk of AF, although this is not statistically significant in this study.

Our study confirms earlier findings of a high prevalence of AF among elderly male long-distance cross-country skiers (Grimsmo et al., 2010), and the association between repeated participation in long-distance cross-country ski races and increased risk of AF, recently discovered among Swedish skiers (Andersen et al., 2013). Consistent with previous results from Tromsø (Nyrnes et al., 2013), we did not find an increased risk of AF associated to level of LTPA. In contrast, recently published results from a large population-based study indicate that LTPA is associated with an increased risk of AF in the middle-aged general population (Thelle et al., 2013). The cohorts in these two studies were younger than our study populations.

In accordance with previous studies, both body height and BMI were positively associated with the risk of AF (Mont et al., 2008; Nyrnes et al., 2013). The added risk of AF per unit of BMI of 0.7 pp is similar to the OR of 1.08 for AF per unit of BMI found in a population-based cohort of Danish men (Frost et al., 2005).

Study population

In the Cardiovascular Health Study of elderly people, the most active people had the lowest incidence of AF [hazard ratio (HR) 0.64, 95% CI 0.52–0.79] (Mozaffarian et al., 2008) but they reported exercise corresponding to an average of only 1840 kilocalories per week, which is probably much less than average in our study population. Interestingly, exercise intensity was associated with risk of AF in a U-shaped pattern: While moderate intensity was associated with lower incidence

Table 1. Characteristics of participants of the Birkebeiner cross-country ski race and the general population in Tromsø, men 65–90 years old

	Athletes *n* = 509 Mean (median, range)	General population *n* = 1867* Mean
Age	68.9	71.6
Height	178.5	174.3
Body mass index	23.6	27.0
Age at first Birkebeiner race participation	43.6 (42, 18–76)	–
Number of completed Birkebeiner races	17.0 (14, 1–53)	–
Number of achieved Birkebeiner medals	11.5 (6, 0–49)	–
Total years of systematic endurance training	33.2 (34, 1–67)	–
	% of 509	% of 1867
Live with a spouse or partner	88.2	79.1
College or university education	41.0	28.5
Occupation		
Retired	60.9	86.1
Full-time work	37.9	9.1
Good or excellent self-reported health status	86.2	60.3
Self-reported leisure-time physical activity		
Sedentary	0.2	19.4
Light	9.9	58.0
Moderate	50.9	21.9
High	39.0	0.7
Frequency of alcohol consumption		
Never	9.6	14.2
1–4 times a month	72.6	64.0
2–3 times a week	14.7	15.6
4 or more times a week	3.1	6.2
Daily smoking		
Current daily smoker	0.8	15.4
Previous daily smoker	28.5	60.6
Never smoked daily	70.7	24.0
Coronary heart disease	3.1	23.8
Diabetes	0.8	8.2
Current or previous lipid-lowering treatment	14.3	33.0
Current or previous antihypertensive treatment	14.9	39.0

*All P-values ≤ 0.001.

of AF, people reporting the highest intensity had the same incidence as people not exercising. In The Physicians Health Study, no association was found between exercise frequency and risk of AF in physicians aged 50–84 years, although the most active doctors exercised five to seven days per week (Aizer et al., 2009).

In our study, 61% of the skiers reported LTPA below the highest level during the last 12 months. This might be important in the interpretation of our results, as the increased risk of AF associated with endurance sport practice might partly be balanced by light or moderate PA. This reduction in AF risk might be explained by a reduced prevalence of AF risk factors, as demonstrated in the DAG (Fig. 1).

The added risk of AF by long-term endurance sport practice found in our study corresponds to an aOR of 1.90 (95% CI 1.14–3.18). A meta-analysis reported an OR for AF of 5.3 (95% CI 3.6–7.9) in athletes compared with non-athletes (Abdulla & Nielsen, 2009). The higher ORs reported in the meta-analysis and previous publications (Karjalainen et al., 1998; Elosua et al., 2006; Molina et al., 2008) might reflect exposure to sport practice at higher levels than in our non-elite skiers, that different types of endurance sports might be differently associated to the risk of AF, or that the volume of training between competitions varies between the study cohorts.

Control group

Even more importantly, the prevalence of AF in the control groups influences the effect estimates strongly. While the Finnish orienteering runners in Karjalainen et al.'s study (1998) were compared with middle-aged men with a low prevalence of AF, the skiers in our study were compared with the general population with an AF prevalence of 11.6%. The comparison of a highly selected cohort of skiers with the general population might be questioned. However, a control group of elderly people with very low prevalence of traditional risk factors for AF and without a history of endurance sport practice might be difficult to find. In the study of Swedish long-distance cross-country skiers, the HR for AF among participants who had completed five or more races was only 1.29 (95% CI 1.04–1.61), and no significant association was found between finishing time and AF risk. The lack of comparison of the skiers with inac-

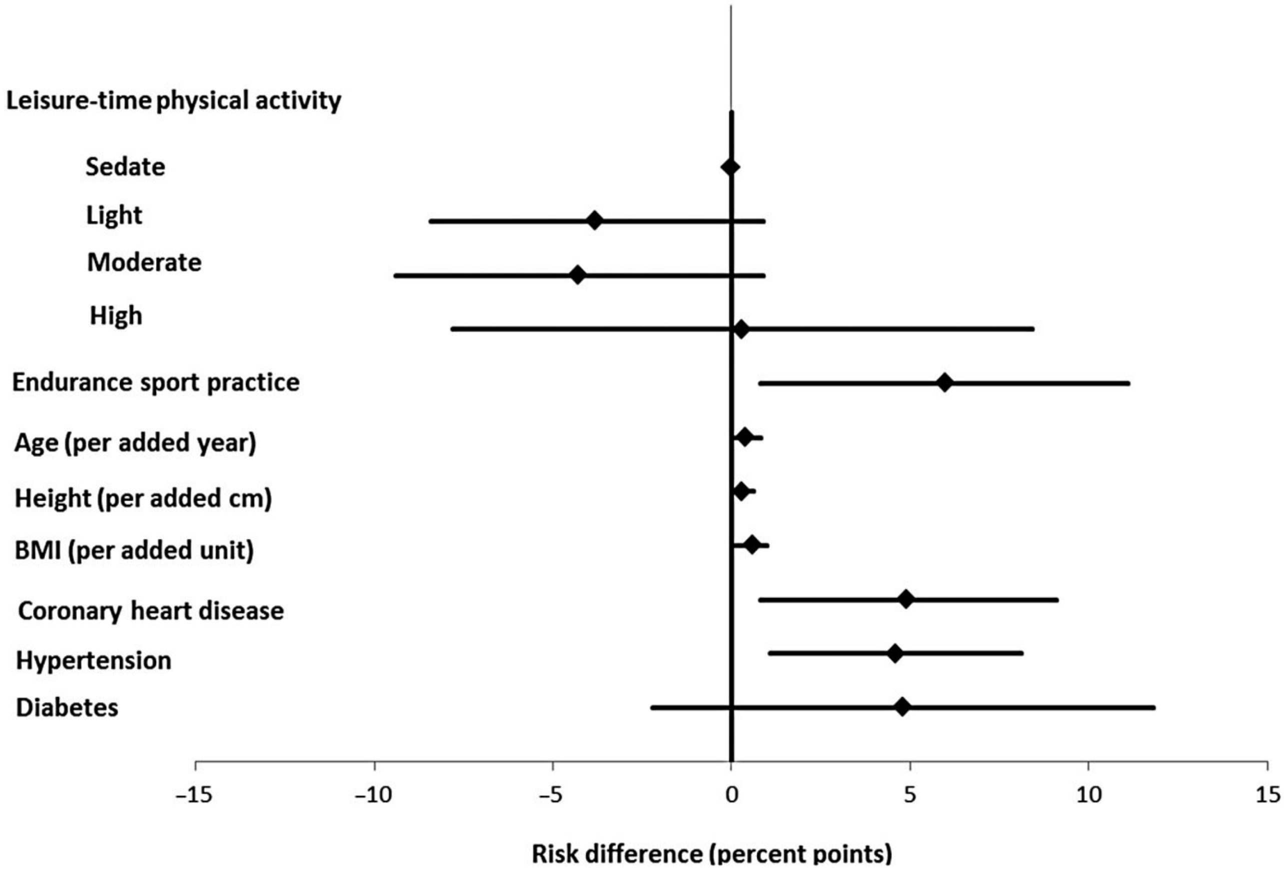

Fig. 2. Studied risk factors for atrial fibrillation. Estimated atrial fibrillation risk differences with 95% confidence intervals by selected covariates. Both study populations analyzed together, men 65–90 years old.

tive people is discussed by the authors as an important limitation of the study (Andersen et al., 2013).

Age

Age is another factor with an impact on effect estimates and the younger age of the cohort of Swedish skiers probably contributes to the weaker association. Long-term PA and endurance sport practice reduces the risk of CHD, hypertension and diabetes. These are all important risk factors for AF and are increasingly prevalent with increasing age. While the relative importance of other modifiable risk factors decreases with increasing age, PA is shown to be a robust health-promoting factor in elderly people (Gulsvik et al., 2011). It is unclear how a potentially stronger beneficial effect of exercise in this age group might influence the risk of AF. In the heterogeneous group of elderly, there might be both individuals who benefit from their history of endurance sport practice with reduced risk of AF and individuals who experience an increased risk due to age-related vulnerability to strenuous endurance sport practice.

Strengths

The main strength of the study is the unique sample of elderly and active long-distance cross-country skiers, which on average has been exposed to endurance sport practice over many years at a much higher level than the general population. Previous studies of the association between sport practice and risk of AF have been questioned (Delise et al., 2012) because many of the participants were exposed to cardiovascular risk factors like smoking (Molina et al., 2008). The low prevalence of traditional risk factors for AF in BiAS is another asset of our study. Very few of the skiers were smokers, had CHD or diabetes, and the prevalence of hypertension was much lower than in the general population. Due to the high response rate of almost 84%, we assume the study population in BiAS to be representative for elderly men participating in long-distance endurance competitions. Finally, our results are strengthened by multivariable adjustment for possible confounding from various life style factors, health conditions and socioeconomic status.

Limitations

The main limitation of the study is self-reporting of AF. AF often remains unrecognized for a long time, especially in elderly people (Engdahl et al., 2013) and because AF is often paroxysmal, the diagnosis might be difficult to confirm. Palpitations and other symptoms might be interpreted as AF, leading to false positive reports. Thus, the validity and completeness of the outcome measure is a weakness of many studies assessing prevalence or risk of AF. The skiers might also be more aware of heart rhythm disturbances than others and more interested in participating in the study, which could possibly lead to an overestimation of the risk of AF in this population.

The cross-sectional design limits the possibility to investigate causal associations, as it is unclear if the outcome has preceded the exposure. However, in this study it is unlikely that AF has preceded the participation in endurance sport, as most participants have practiced long-distance cross-country skiing for many years.

Endurance sport practice was not recorded in Tromsø 6. We assume from the low number of participants reporting the highest levels of LTPA that the number of subjects participating in long-distance endurance competitions in this study population is low or zero and that the difference between the study populations could therefore be interpreted as binary. However, this could lead to an underestimation of the effect estimate in our study.

Elderly populations are heterogeneous and, despite adjustment for chronological age, the degree of biological ageing is likely to be differential between the study populations, as expressed by differences in CHD and cardiovascular risk factors. The study populations may also differ in terms of unmeasured characteristics. In population-based studies, the proportions of people with ethnic minority background (Christensen et al., 2012) and with poor health status (Knudsen et al., 2010) tend to be larger among non-responders than among responders and this trend tends to counteract selection bias in our study. However, selection bias may have influenced our results.

People without AF are more likely to continue participation in long-distance endurance sport competitions into old age, corresponding to a healthy worker effect (Thygesen et al., 2011). This assumption is supported by the fact that there were no cases of AF among the skiers aged 80 years and older and probably leads to an underestimated risk of AF among the skiers. On the contrary, some skiers with AF might have been motivated to continue skiing because of the beneficial effects of exercise.

Perspective

This study adds to the current knowledge regarding the association between endurance sport practice and risk of AF. In elderly men, a history of endurance sport practice was found to be a risk factor for AF with an effect comparable to traditional risk factors for AF like CHD and hypertension. Light or moderate LTPA during the last 12 months seems to partly balance the increased risk of AF. It is still unclear if sport practice in different life phases influences the risk of AF differentially and how AF in this population of very active elderly men might influence the risk of stroke. Regular PA reduces mortality, functional decline and the risk of several age-related diseases. Elderly people should therefore be encouraged to be physically active.

Key words: sports cardiology, arrhythmias, endurance exercise, master athletes, elderly, cross-country skiing, skiers, heart disease.

Acknowledgements

We wish to thank Ida Kristine Sangnes at The Kavli Research Centre for Ageing and Dementia, for her substantial contribution in the data collection and processing of BiAS and Wenche Nystad and Knut Gjesdal for advice in the preparation of the manuscript.

Funding

This work was supported by Diakonhjemmet Hospital, The Kavli Research Center for Ageing and Dementia, and the Norwegian EXTRAFoundation for Health and Rehabilitation through EXTRA FUNDS.

References

Abdulla J, Nielsen JR. Is the risk of atrial fibrillation higher in athletes than in the general population? A systematic review and meta-analysis. Europace 2009: 11: 1156–1159.

Aizer A, Gaziano JM, Cook NR, Manson JE, Buring JE, Albert CM. Relation of vigorous exercise to risk of atrial fibrillation. Am J Cardiol 2009: 103: 1572–1577.

Andersen K, Farahmand B, Ahlbom A, Held C, Ljunghall S, Michaëlsson K, Sundström J. Risk of arrhythmias in 52 755 long-distance cross-country skiers: a cohort study. Eur Heart J 2013: doi:10.1093/eurheartj/eht188

Calvo N, Brugada J, Sitges M, Mont L. Atrial fibrillation and atrial flutter in athletes. Br J Sports Med 2012: 46 (Suppl 1): i37–i43.

Camm AJ, Lip GY, De Caterina R, Savelieva I, Atar D, Hohnloser SH, Hindricks G, Kirchhof P; ESC Committee for Practice Guidelines (CPG). 2012 focused update of the ESC guidelines for the management of atrial fibrillation: an update of the 2010 ESC guidelines for the management of atrial fibrillation. Eur Heart J 2012: 33 (21): 2719–2747.

Christensen AI, Ekholm O, Glümer C, Andreasen AH, Hvidberg MF, Kristensen PL, Larsen FB, Ortiz B, Juel K. The Danish National Health Survey 2010. Study design and respondents characteristics. Scand J Public Health 2012: 40: 391–397.

Delise P, Sitta N, Berton G. Does long-lasting sports practice increase the risk of atrial fibrillation in healthy middle-aged men? Weak suggestions, no objective evidence. J Cardiovasc Med 2012: 13: 381–385.

Elosua R, Arquer A, Mont L, Sambola A, Molina L, García-Morán E, Brugada J, Marrugat J. Sport practice and the risk of lone atrial fibrillation: a case-control study. Int J Cardiol 2006: 108: 332–337.

Emaus A, Degerstrøm J, Wilsgaard T, Hansen BH, Dieli-Conwright CM, Furberg AS, Pettersen SA, Andersen LB, Eggen AE, Bernstein L, Thune I. Does a variation in self-reported physical activity reflect variation in objectively measured physical activity, resting heart rate, and physical fitness? Results from the Tromsø study. Scand J Public Health 2010: 38 (5 Suppl): 105–118.

Engdahl J, Andersson L, Mirskaya M, Rosenqvist M. Stepwise screening of atrial fibrillation in a 75-year old population: implications for stroke prevention. Circulation 2013: 127 (8): 930–937.

Frost L, Hune LJ, Vestergaard P. Overweight and obesity as risk factors for atrial fibrillation and flutter: the Danish Diet, Cancer, and Health Study. Am J Med 2005: 118: 489–495.

Graff-Iversen S, Gjesdal K, Jugessur A, Myrstad M, Nystad W, Selmer R, Thelle DS. Atrial fibrillation, physical activity and endurance training. Tidsskr Nor Laegeforen 2012: 132: 295–299.

Grimsmo J, Grundvold I, Maehlum S, Arnesen H. High prevalence of atrial fibrillation in long-term endurance cross-country skiers: echocardiographic findings and possible predictors – a 28–30 years follow-up study. Eur J Cardiovasc Prev Rehabil 2010: 17: 100–105.

Gulsvik AK, Thelle DS, Samuelsen SO, Myrstad M, Mowé M, Wyller TB. Ageing, physical activity and mortality – a 42-year follow-up study. Eur J Epidemiol 2011: 26 (3): 221–228.

Heeringa J, van der Kuip DA, Hofman A, Kors JA, van Herpen G, Stricker BH, Stijnen T, Lip GY, Witteman JC. Prevalence, incidence and lifetime risk of atrial fibrillation: the Rotterdam Study. Eur Heart J 2006: 27 (8): 949–953.

Jacobsen BK, Eggen AE, Mathiesen EB, Wilsgaard T, Njølstad I. Cohort profile: the Tromsø study. Int J Epidemiol 2012: 41: 961–967.

Karjalainen J, Kujala UM, Kaprio J, Sarna S, Viitasalo M. Lone atrial fibrillation in vigorously exercising middle aged men: case-control study. BMJ 1998: 316: 1784–1785.

Kirchhof P, Lip GY, Van Gelder IC, Bax J, Hylek E, Kaab S, Schotten U, Wegscheider K, Boriani G, Brandes A, Ezekowitz M, Diener H, Haegeli L, Heidbuchel H, Lane D, Mont L, Willems S, Dorian P, Aunes-Jansson M, Blomstrom-Lundqvist C, Borentain M, Breitenstein S, Brueckmann M, Cater N, Clemens A, Dobrev D, Dubner S, Edvardsson NG, Friberg L, Goette A, Gulizia M, Hatala R, Horwood J, Szumowski L, Kappenberger L, Kautzner J, Leute A, Lobban T, Meyer R, Millerhagen J, Morgan J, Muenzel F, Nabauer M, Baertels C, Oeff M, Paar D, Polifka J, Ravens U, Rosin L, Stegink W, Steinbeck G, Vardas P, Vincent A, Walter M, Breithardt G, Camm AJ. Comprehensive risk reduction in patients with atrial fibrillation: emerging diagnostic and therapeutic options – a report from the 3rd Atrial Fibrillation Competence NETwork/European Heart Rhythm Association consensus conference. Europace 2012: 14 (1): 8–27.

Knudsen AK, Hotopf M, Skogen JC, Overland S, Mykletun A. The health status of nonparticipants in a population-based health study. The Hordaland study. Am J Epidemiol 2010: 172: 1306–1314.

Lie H, Erikssen J. Five-year follow-up of ECG aberrations, latent coronary heart disease and cardiopulmonary fitness in various age groups of Norwegian cross-country skiers. Acta Med Scand 1984: 216: 377–383.

Molina L, Mont L, Marrugat J, Berruezo A, Brugada J, Bruguera J, Rebato C, Elosua R. Long-term endurance sport practice increases the incidence of lone atrial fibrillation in men: a follow-up study. Europace 2008: 10: 618–623.

Mont L, Tamborero D, Elosua R, Molina I, Coll-Vinent B, Sitges M, Vidal B, Scalise A, Tejeira A, Berruezo A, Brugada J; GIRAFA (Grup Integrat de Recerca en Fibril-lació Auricular) Investigators. Physical activity, height, and left atrial size are independent risk factors for lone atrial fibrillation in middle-aged healthy individuals. Europace 2008: 11: 15–20.

Mozaffarian D, Furberg CD, Psaty BM, Siscovick D. Physical activity and incidence of atrial fibrillation in older adults: the Cardiovascular Health Study. Circulation 2008: 118: 800–807.

Müller-Riemenschneider F, Andersohn F, Ernst S, Willich SN. Association of physical activity and atrial fibrillation. J Phys Act Health 2012: 9: 605–616.

Nyrnes A, Mathiesen EB, Njølstad I, Wilsgaard T, Løchen ML. Palpitations are predictive of future atrial fibrillation. An 11-year follow-up of 22,815 men and women: the Tromsø Study. Eur J Prev Cardiol 2013: 20: 729–736.

Patil HR, O′Keefe JH, Lavie CJ, Magalski A, Vogel RA, McCullough PA. Cardiovascular damage resulting from chronic excessive endurance exercise. Mo Med 2012: 109: 312–321.

Saltin B. Physiological effects of physical conditioning. In: Hansen AT, Schnohr P, Rose G, eds. Ischaemic heart disease: the strategy of postponement. Chicago, IL: Year Book Medical Publishers, 1977: 104–115.

Saltin B, Grimby G. Physiological analysis of middle-aged and old former athletes. Comparison with still active athletes of the same ages. Circulation 1968: 38: 1104–1115.

Thelle DS, Selmer R, Gjesdal K, Sakshaug S, Jugessur A, Graff-Iversen S, Tverdal A, Nystad W. Resting heart rate and physical activity as risk factors for lone atrial fibrillation: a prospective study of 309 540 men and women. Heart 2013: 99: 1755–1760.

Thygesen LC, Hvidtfeldt UA, Mikkelsen S, Brønnum-Hansen H. Quantification of the healthy worker effect: a nationwide cohort study among electricians in Denmark. BMC Public Health 2011: 11: 571.

Turagam MK, Velagapudi P, Kocheril AG. Atrial fibrillation in Athletes. Am J Cardiol 2012: 109: 296–302.

Tveit A, Abdelnoor M, Enger S, Smith P. Atrial fibrillation and antithrombotic therapy in a 75-year-old population. Cardiology 2008: 109 (4): 258–262.

Wilhelm M. Atrial fibrillation in endurance athletes. Eur J Prev Cardiol 2013: doi:10.1177/2047487313476414

Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Table S1. Estimated atrial fibrillation risk differences for endurance sport practice and other selected covariates. Both study populations analyzed together, men 65–90 years old.