American Journal of Epidemiology
© The Author 2013. Published by Oxford University Press on behalf of the Johns Hopkins Bloomberg School of Public Health. All rights reserved. For permissions, please e-mail: journals.permissions@oup.com.
Vol. 177, No. 7
DOI: 10.1093/aje/kws301
Advance Access publication:
February 28, 2013

Original Contribution

Longevity in Male and Female Joggers: The Copenhagen City Heart Study

Peter Schnohr*, **Jacob L. Marott, Peter Lange, and Gorm B. Jensen**

* Correspondence to Dr. Peter Schnohr, the Copenhagen City Heart Study, Epidemiologic Research Unit, Bispebjerg University Hospital, DK-2400 Copenhagen NV, Denmark (e-mail peter@schnohr.dk).

Initially submitted March 5, 2012; accepted for publication June 26, 2012.

Since 1970, jogging has become an increasingly popular form of exercise, but concern about harmful effects has been raised following reports of deaths during jogging. The purpose of this study was to investigate if jogging, which can be very vigorous, is associated with increased all-cause mortality in men and women. Jogging habits were recorded in a random sample of 17,589 healthy men and women aged 20–98 years, invited between 1976 and 2003 to the Copenhagen City Heart Study. The expected lifetime was calculated by integrating the predicted survival curve estimated in the Cox model. In this study 1,878 persons (1,116 men and 762 women) were classified as joggers. During the 35-year maximum follow-up period, we registered 122 deaths among joggers and 10,158 deaths among nonjoggers. The age-adjusted hazard ratio of death among joggers was 0.56 (95% confidence interval: 0.46, 0.67) for men and 0.56 (95% confidence interval: 0.40, 0.80) for women. The age-adjusted increase in survival with jogging was 6.2 years in men and 5.6 years in women. This long-term study of joggers showed that jogging was associated with significantly lower all-cause mortality and a substantial increase in survival for both men and women.

all-cause mortality; cause-specific mortality; females; jogging; males

Abbreviations: CI, confidence interval; HR, hazard ratio; ICD-8, *International Classification of Diseases, Eighth Revision*; ICD-10, *International Classification of Diseases, Tenth Revision*; MET, metabolic equivalent.

Jogging became popular in the United States and a few other countries in the 1970s. Since that time, the number of joggers in the United States has increased to around 36 million in 2010. The same year more than 500.000 runners finished US marathons and 1.4 million finished US half-marathons (1). In the beginning of the jogging era, reports of deaths during jogging were published (2–6). On the one hand, Bassler (7) stated that athletes capable of covering the marathon distance are immune to coronary atherosclerosis, while on the other hand others such as Opie (2) described atherosclerosis in marathon runners. In Rhode Island, 12 men died while jogging, 11 from heart attacks. Five of these men were known to have heart disease. The incidence of death during jogging was 7 times the estimated death rate from coronary heart disease during more sedentary activities, suggesting that jogging may contribute to the risk of sudden death in susceptible persons (6). It is known that exercise can provoke malignant ventricular arrythmias and sudden cardiac death (8). Coronary heart disease appeared to be the major killer of conditioned runners aged 40 years or above, who died while running (5). It was recommended that physicians and exercising adults should be aware of the risk of jogging and give appropriate attention to possible prodromal symptoms. Since then, several studies have demonstrated a graded inverse relationship between physical activity in leisure time and mortality (9–16). However, a U-shaped relation has also been reported (15, 16). These findings could be interpreted to mean that sedentary living is correlated to increased mortality, but the same could be the case if the physical activity is too strenuous.

It should be kept in mind that, even for younger persons, slow jogging is considered vigorous (≥6 metabolic equivalents (METs), 5 miles per hour) and, further, that average jogging (9 METs, 6 miles per hour) and fast jogging (12 METs, 7 miles per hour) are much more strenuous than

Downloaded from https://academic.oup.com/aje/article/177/7/683/91486 by guest on 19 April 2024

average vigorous activities and, thus, may be hazardous to health. (One mile = 1.61 km.)

The purpose of this study was to investigate if jogging is associated with increased all-cause mortality in men and women in a large sample of the general population with a long follow-up.

MATERIALS AND METHODS

Study population

The Copenhagen City Heart Study is a prospective cardiovascular population study comprising a random sample of 19,329 white men and women aged 20–93 years, when drawn from the Copenhagen Population Register as of January 1, 1976 (17). The study was approved by the Committee of Biomedical Research Ethics for the capital region in Denmark. All participants gave written, informed consent. The first survey lasted from 1976 to 1978, the second from 1981 to 1983, the third from 1991 to 1994, and the fourth from 2001 to 2003. All subjects from the original sample were reinvited to the following examinations, including a new sample of younger men and women. In total, 23,891 men and women aged 20–100 years were invited, and 18,974 participated in at least 1 examination. Details have been described elsewhere (17, 18). A total of 1,878 persons (1,116 men and 762 women) were classified as joggers, at least in 1 of the 4 examinations. At baseline, there were 695 male joggers and 434 female joggers.

We excluded participants who at their first visit had experienced a history of coronary heart disease (self-reported and information from the Danish National Patient Registry; $n = 583$), stroke (self-reported and information from the Danish National Patient Registry validated by the authors; $n = 269$), and cancer (information from the Danish National Cancer Registry; $n = 567$), leaving 17,589 healthy subjects (8,121 men and 9,466 women) for analysis.

Survey methods

Established procedures and examinations for cardiovascular epidemiologic surveys were used (19). Physical activity in leisure time has in all 4 surveys been graded into 4 levels ("The Copenhagen City Heart Study Leisure Time Physical Activity Questionnaire") (18). We further added specific questions regarding walking, cycling, and jogging. At the first examination in 1976–1978, the participants were asked about whether they were joggers, and in 1981–1983 and 1991–1994 they were further asked for their weekly quantity of jogging. In the fourth survey (2001–2003), information about weekly frequency of jogging and the individual's own perception of pace (slow, average, fast) was obtained. We found that a relative scale of pace (intensity) is more appropriate than an absolute scale when the age span is very wide (20–98 years) and when the participants have wide differences in levels of physical fitness. A self-administered questionnaire concerning physical activity, smoking, alcohol consumption, socioeconomic status, cardiovascular and lung diseases, diabetes mellitus, cancer, and family history was completed and checked by the staff. Height, weight, and blood pressure measurements (while in a sitting position after a 5-minute rest, using a London School of Hygiene sphygmomanometer) were obtained, as well as electrocardiogram results and data from a comprehensive laboratory blood-sample investigation, including plasma total cholesterol (17).

Endpoints

Participants were followed from their first examination until June 2011 or death, by using the unique personal identification number in the National Central Person Register (all-cause deaths). Causes of death were obtained until January 2010 from the National Register of Causes of Death. In 1994, Denmark shifted from the *International Classification of Diseases, Eighth Revision* (ICD-8), to the *International Classification of Diseases, Tenth Revision* (ICD-10). We analyzed separate endpoints comprising deaths from coronary heart disease (ICD-8 codes 410–414 and ICD-10 codes I21–I25); deaths from stroke (ICD-8 codes 430–438 and ICD-10 codes I60–I68 and code G45, respectively); deaths from respiratory diseases (ICD-8 codes 460–519 and ICD-10 codes J00–J99); and deaths from cancer (ICD-8 codes 140–209 and ICD-10 codes C00–D09). The completion rate of follow-up for death was almost 100%.

Statistical analysis

We adjusted for the following potential confounders: age, smoking (never, former, current 1–14 g of tobacco per day, ≥15 g of tobacco per day), education (<8 years, 8–10 years, >10 years in school), household income (low, average, high), alcohol consumption (never, monthly, weekly, daily), and diabetes mellitus.

Estimates of relative risks of all-cause mortality were calculated by using Cox proportional hazards regression analysis with time-dependent covariates and age as the underlying timescale and delayed entry accordingly. This model allows subjects to change jogging status at any examination. During 1977–2010, the general life expectancy for newborns in Denmark increased by 5.9 years (from 71.2 to 77.1 years) for men and by 4.1 years (from 77.1 to 81.2 years) for women. To account for the increased longevity in the time period 1976–2010, all models were adjusted for calendar time through the examination number. Furthermore, all analyses were sex stratified with adjustment for 1) age; 2) confounders (age, smoking, education, income, drinking habits, diabetes); 3) confounders and leisure-time physical activity; and 4) confounders, leisure-time physical activity, and mediators (resting heart rate, cholesterol, body mass index, systolic blood pressure, blood pressure medication). The expected lifetime was calculated by integrating the predicted survival curve estimated in the Cox model. Subanalyses with adjustment for the confounders in model 2 above were performed on data from the second, third, and fourth surveys studying the association between quantity, pace, and frequency of jogging and mortality.

Downloaded from https://academic.oup.com/aje/article/177/7/683/91486 by guest on 19 April 2024

The assumption of proportionality in the Cox regression models was tested with the score process test of Lin et al. (20). Misspecifications of the functional form of the covariates were tested by plotting the continuous covariates against the cumulative residuals and comparing them to random realizations under the model.

RESULTS

Baseline characteristics of the 17,589 participants are presented in Table 1. At baseline, 1,129 were joggers and 16,423 were nonjoggers. In general, the joggers were younger and had a higher educational level, a lower body mass index, and a lower resting heart rate. Further, they had a lower systolic blood pressure, lower alcohol intake, lower cholesterol, and lower frequency of diabetes. This was true for both sexes. The massive overlap in age range between joggers (20–86 years) and nonjoggers (20–98 years) and the flexible age adjustment ensured by the Cox model made comparisons between joggers and nonjoggers very feasible, although large differences in the mean age were observed for these groups.

Mortality in joggers

During the maximum 35-year follow-up period, we registered 122 deaths among the joggers and 10,158 among the nonjoggers. As shown in Table 2, the age-adjusted hazard ratio of jogging was 0.56 (95% confidence interval (CI): 0.46, 0.67) for men and 0.56 (95% CI: 0.40, 0.80) for women. With adjustment for the above-mentioned confounders, the hazard ratio was 0.69 (95% CI: 0.57, 0.83) for men and 0.60 (95% CI: 0.42, 0.85) for women. All results were highly significant. Similar results were seen in models 3 and 4, although overadjustment could be present because jogging is part of leisure-time physical activity and, in addition, could have a positive effect on the mediators. There was no interaction between jogging and gender ($P = 0.35$).

For men <50 and ≥50 years of age, the hazard ratios for jogging adjusted for confounders were 0.66 (95% CI: 0.42, 1.03) and 0.71 (95% CI: 0.57, 0.87); for women <50 and ≥50 years of age, these values were 0.75 (95% CI: 0.35, 1.61) and 0.57 (95% CI: 0.38, 0.85), respectively. There was no interaction between jogging and age ($P > 0.35$ in both sexes).

Increase in survival

The age-adjusted increase in survival with jogging was 6.2 years for men and 5.6 years for women (Table 1). Adjusted for confounders, the increases in survival were 3.8 years and 4.7 years, respectively.

Quantity of jogging and mortality

A subanalysis was performed on participants from the second, third, and fourth surveys to examine the association between jogging quantity and mortality. To increase power, we included the nonjoggers and pooled both sexes by inclusion of gender-specific baseline hazards. Compared with those for nonjoggers, the hazard ratios for joggers adjusted for the confounders in model 2 were 0.68 (95% CI: 0.48, 0.95) for <1 hour per week of jogging (626 joggers, 30 deaths), 0.58 (95% CI: 0.41, 0.82) for 1–2.4 hours per week (594 joggers, 30 deaths), 0.79 (95% CI: 0.52, 1.19) for 2.5–4 hours per week (508 joggers, 22 deaths), and 0.86 (95% CI: 0.59, 1.24) for >4 hours per week (166 joggers, 16 deaths). These results showed a tendency of a U-shaped relation to mortality risk, so the optimal quantity of jogging seemed to be 1–2.4 hours per week. However, small numbers of deaths and wide confidence intervals result in uncertainty about mortality risk at higher levels. Irrespective of jogging duration, the mortality was lower among all joggers than nonjoggers.

Jogging pace and mortality

In a subanalysis of the fourth survey, the hazard ratios adjusted for sex and the confounders in model 2 were 0.37 (95% CI: 0.12, 1.17) for slow pace (178 joggers, 3 deaths), 0.53 (95% CI: 0.29, 0.95) for average pace (704 joggers, 12 deaths), and 1.22 (95% CI: 0.49, 3.04) for fast pace (201 joggers, 5 deaths), compared with those for nonjoggers. This analysis comprised only a few deaths among the joggers and should be met with caution, but the results suggest that a slow or average pace could be related to the lowest mortality.

Frequency of jogging and mortality

A subanalysis of the fourth survey yielded similar results for frequency of jogging with hazard ratios of 0.40 (95% CI: 0.15, 1.10) for ≤1 time per week (323 joggers, 4 deaths), 0.40 (95% CI: 0.16, 0.98) for 2–3 times per week (474 joggers, 5 deaths), and 1.24 (95% CI: 0.51, 3.02) for >3 times per week (84 joggers, 5 deaths), compared with values for nonjoggers. Hence, these data should also be interpreted with caution. A frequency of jogging of ≤3 times per week was associated with the lowest mortality, and we could find no increase in survival with >3 jogging sessions per week compared with nonjogging.

Consistency of jogging

In our newly started fifth survey, we further asked the joggers for the number of years they have been jogging. Of the first 150 participants, 42 were joggers. The average number of years of jogging was 10.1 years. Of all joggers ($n = 518$) in the third survey (1991–1994), 64% were still joggers in the fourth survey (2001–2003). Thus, jogging seems to be a fairly stable habit.

Causes of death among joggers and nonjoggers

Compared with those for nonjoggers, the hazard ratios for joggers and death adjusted for the confounders in model 2 were the following: coronary heart disease (for men, hazard ratio (HR) = 0.32, 95% CI: 0.15, 0.67; for women, HR = 0.48, 95% CI: 0.12, 1.96); respiratory

Downloaded from https://academic.oup.com/aje/article/177/7/683/91486 by guest on 19 April 2024

Table 1. Baseline Characteristics of 1,129 Joggers and 16,423 Nonjoggers by Sex, the Copenhagen City Heart Study, 1976–2003, Denmark

Characteristic	Men							Women						
	Nonjoggers (*n* = 7,416)			Joggers (*n* = 695)			*P* Value	Nonjoggers (*n* = 9,007)			Joggers (*n* = 434)			*P* Value
	Mean (SD)	No.	%	Mean (SD)	No.	%		Mean (SD)	No.	%	Mean (SD)	No.	%	
Age, years[a]	51.0 (13.0)			36.4 (12.1)			<0.001	50.4 (13.0)			33.3 (10.4)			<0.001
Leisure time physical activity[b]														
Low		1,425	19.2		19	2.7			1,661	18.5		8	1.8	
Moderate		3,611	48.7		126	18.1			5,193	57.7		111	25.6	
High		2,372	32.0		550	79.1	<0.001		2,141	23.8		315	72.6	<0.001
Household income														
Low		1,691	23.5		173	26.2			2,728	32.4		149	37.2	
Moderate		3,896	54.0		317	48.0			4,048	48.1		181	45.1	
High		1,624	22.5		170	25.8	0.012		1,639	19.5		71	17.7	0.138
School education														
<8 years		3,142	42.4		97	14.0			3,773	42.0		39	9.0	
8–10 years		2,633	35.6		177	25.5			3,372	37.5		71	16.4	
>10 years		1,627	22.0		420	60.5	<0.001		1,846	20.5		323	74.6	<0.001
Body mass index[c]	25.7 (3.8)			24.4 (3.0)			<0.001	24.5 (4.5)			22.5 (2.8)			<0.001
Resting heart rate, beats/minute	74.0 (13.6)			65.8 (12.5)			<0.001	74.1 (12.8)			67.5 (11.8)			<0.001
Smoking														
Never		925	12.5		273	39.7			2,522	28.1		198	46.0	
Former		1,363	18.5		155	22.5			1,330	14.8		82	19.1	
Current														
1–15 g of tobacco/day		1,702	23.1		125	18.2			2,637	29.4		92	21.4	
>15 g of tobacco/day		3,391	45.9		135	19.6	<0.001		2,488	27.7		58	13.5	<0.001
Systolic blood pressure, mm Hg	139.0 (20.6)			128.9 (14.6)			<0.001	132.4 (22.2)			117.8 (14.6)			<0.001
Antihypertensive drugs		338	4.6		11	1.6	<0.001		564	6.3		7	1.6	<0.001
Alcohol														
Never drinker		765	10.4		47	6.8			2,415	27.1		67	15.4	
Monthly drinker		1,411	19.2		214	30.9			3,249	36.4		221	50.9	
Weekly drinker		2,174	29.5		315	45.5			2,237	25.1		136	31.3	
Daily drinker		3,011	40.9		117	16.9	<0.001		1,018	11.4		10	2.3	<0.001
Cholesterol, mmol/L	5.9 (1.2)			5.2 (1.2)			<0.001	6.1 (1.3)			4.9 (1.0)			<0.001
Diabetes mellitus		266	3.8		4	0.6	<0.001		159	1.8		1	0.2	0.023

Abbreviation: SD, standard deviation.

[a] For continuous variables, values are mean (SD) with analysis of variance.

[b] For categorical variables, Pearson's χ^2 test was performed.

[c] Body mass index: weight (kg)/height (m)^2.

Downloaded from https://academic.oup.com/aje/article/177/7/683/91486 by guest on 19 April 2024

Table 2. Risk of All-Cause Mortality and Increase in Survival for Joggers Stratified by Gender, the Copenhagen City Heart Study, 1976–2003, Denmark

Jogging Status	No. of Participants	No. of Deaths	Hazard Ratio	95% CI	Increase in Survival, years
Adjusted for age					
Men					
Nonjoggers	7,678	5,040	1.00	Referent	0.0
Joggers	1,116	94	0.56	0.46, 0.67	6.2
Women					
Nonjoggers	9,149	5,118	1.00	Referent	0.0
Joggers	762	28	0.56	0.40, 0.80	5.6
Adjusted for confounders (age, smoking, education, income, drinking habits, diabetes)					
Men					
Nonjoggers	7,501	4,922	1.00	Referent	0.0
Joggers	1,098	93	0.69	0.57, 0.83	3.8
Women					
Nonjoggers	8,875	4,941	1.00	Referent	0.0
Joggers	745	26	0.60	0.42, 0.85	4.7
Adjusted for confounders (age, smoking, education, income, drinking habits, diabetes) and leisure-time physical activity					
Men					
Nonjoggers	7,499	4,921	1.00	Referent	0.0
Joggers	1,098	93	0.75	0.62, 0.90	3.0
Women					
Nonjoggers	8,873	4,940	1.00	Referent	0.0
Joggers	745	26	0.66	0.46, 0.93	3.8
Adjusted for confounders (age, smoking, education, income, drinking habits, diabetes), leisure-time physical activity, and mediators (resting heart rate, cholesterol, body mass index,[a] systolic blood pressure, antihypertensive drugs)					
Men					
Nonjoggers	7,398	4,843	1.00	Referent	0.0
Joggers	1,089	91	0.78	0.64, 0.94	2.6
Women					
Nonjoggers	8,737	4,852	1.00	Referent	0.0
Joggers	741	26	0.71	0.50, 1.01	3.1

Abbreviation: CI: confidence interval.
[a] Body mass index: weight (kg)/height (m)^2.

diseases (for men, HR = 0.85, 95% CI: 0.39, 1.83; for women, HR = 0.87, 95% CI: 0.27, 2.84); stroke (for men, HR = 0.95, 95% CI: 0.42, 2.18; for women, HR = 0.85, 95% CI: 0.21, 3.42); cancer (for men, HR = 0.82, 95% CI: 0.58, 1.16; for women, HR = 0.68, 95% CI: 0.38, 1.23).

DISCUSSION

This observational study of almost 18,000 healthy men and women aged 20–98 years, including 1,878 joggers, has shown that jogging is associated with significantly lower mortality than is nonjogging. To our knowledge, this is the largest report on this topic. The age-adjusted increase in survival was 6.2 years for men and 5.6 years for women.

A subanalysis of causes of death showed a significantly lower risk of coronary heart disease death for men. For women, the association was similar although not significant. For both sexes, mortality from respiratory diseases, cancer, and stroke was insignificantly lower for joggers compared with nonjoggers.

The quantity, pace, and frequency of physical activity to be recommended to the general public have been discussed for several years. In 1965, the President's Council on Physical Fitness recommended 20 minutes of vigorous exercise 3 times per week (21). In 1995, Pate et al. from the Centers for Disease Control and Prevention and the American College of Sports Medicine recommended, "Every US adult should accumulate 30 minutes or more of moderate-intensity physical activity on most, preferably all, days of

Downloaded from https://academic.oup.com/aje/article/177/7/683/91486 by guest on 19 April 2024

the week" (22, p. 404). An updated recommendation was published in 2007 when a combination of moderate- and vigorous-intensity physical activity (e.g., jogging) was recommended (23).

Surprisingly, we found that up to 2.5 hours of jogging a week at a slow or average pace and a frequency of ≤3 times per week seems to be associated with the lowest mortality. Thus, we found a U-shaped relationship between jogging and mortality, so we don't have evidence to support faster or more frequent jogging, nor do our limited data rule out this possibility. Irrespective of jogging duration, pace, and frequency, the mortality was lower among joggers than nonjoggers. As even slow jogging is considered vigorous, especially for middle-aged and older persons, jogging could be unhealthy, in particular for persons with heart disease, including silent ischemia.

In a study of 21,481 healthy male physicians, the relative risk of sudden death during and up to 30 minutes after vigorous exertion was 16.9 (95% CI: 10.5, 27.0) ($P < 0.001$) compared with other time points, but habitual vigorous exercise attenuates the risk of sudden death during vigorous exertion (24). In a study of 10.9 million marathon and half-marathon runners in the United States identified in the years 2000 through 2010, 59 runners presented cardiac arrest, resulting in a quite low incidence rate of 0.54 per 100,000 participants, but the incidence rate was significantly higher during marathons (1.01 per 100,000) than during half-marathons (0.27 per 100,000) (25). A meta-analysis including 80 studies with 1,338,143 participants (118,121 deaths) found that higher levels of total physical activity were associated with reduced all-cause mortality and that the most pronounced risk reductions were associated with the most vigorous exercise (26).

To our knowledge, only 1 small study has examined all-cause mortality among male joggers. This study comprised 96 male joggers and 4,335 nonjoggers. During 16 years of follow-up, 5 of the joggers and 1,297 of the nonjoggers died. The adjusted relative risk was 0.39 (95% CI: 0.19, 0.73) between joggers and nonjoggers. The number of female joggers in the cohort was too small to allow for mortality calculations (27).

Regular running has a beneficial effect on the cardiovascular risk, but the extent of calcified coronary plaque is underestimated from the risk factor profile, with a third of marathon runners aged ≥50 years having a coronary artery calcification score of ≥100. The possibility that marathon running and the required training aggravates preexisting noncalcified atherosclerosis is clearly speculative, but it is interesting given the recent reports of myocardial injury during marathon running (28).

In general, physical activity improves maximal oxygen uptake, lowers the resting heart rate, increases insulin sensitivity, improves lipid profiles, lowers blood pressure, reduces platelet aggregation, increases fibrinolytic activity, improves endothelial function, stabilizes vulnerable plaques, improves bone density and immune function, prevents obesity, and improves psychological function. These improvements are related to both the amount and the intensity of exercise, and they are more pronounced in vigorous exercise, such as jogging (18, 22–34). All of these mechanisms are mainly related to the cardiovascular system and may explain to some degree the reduced coronary heart disease mortality among the joggers.

We have in 2 other studies addressed the question of what is of most importance in relation to all-cause mortality: intensity or duration of walking or cycling (35, 36). Both studies found that the relative intensity, not the duration, was of the most importance in relation to all-cause mortality. As even slow jogging is considered vigorous or intensive, these studies are in line with our new results. Lee et al. (11) found vigorous activities (≥6 METs), but not nonvigorous exercise (<6 METs), to be associated with decreased mortality. They mentioned that vigorous exercise, for example, jogging, which is sustained and dynamic, is effective for cardiorespiratory conditioning, whereas heavy yard work is unlikely to be sustained and is thus less effective for conditioning.

Strengths of the present study included the prospective design, the large size of a random sample of both men and women representative of the population of Copenhagen, the detailed information about potential confounding variables, and the almost 100% follow-up.

However, there are also some limitations. It may be hypothesized that only healthy people took up jogging, thus creating the opportunity for reverse causation. Even after adjustment for multiple possible confounders, residual confounding cannot be ruled out in observational studies. Because our study was observational and not a randomized trial, we can demonstrate associations but not a casual relationship. A large controlled trial of joggers and nonjoggers would be valuable, but it has been determined not to be feasible (37).

In conclusion, our results based on a long-term follow-up of a large random sample of men and women show that joggers live, on average, 6 years longer than do nonjoggers.

ACKNOWLEDGMENTS

Author affiliations: The Copenhagen City Heart Study, Bispebjerg University Hospital, Copenhagen, Denmark (Peter Schnohr, Jacob L. Marott, Peter Lange, Gorm B. Jensen); Department of Respiratory Medicine, Hvidovre Hospital, Hvidovre, Denmark (Peter Lange); Department of Cardiology, Hvidovre Hospital, Hvidovre, Denmark (Gorm B. Jensen); and Department of Social Medicine, Institute of Public Health, University of Copenhagen, Copenhagen, Denmark (Peter Lange).

This study was supported by grants from the Danish Heart Foundation.

Conflict of interest: none declared.

REFERENCES

1. Lamppa R. Marathon, half-marathon and state of sport report. Colorado Springs, CO: Running USA; 2011. (http://www.runningusa.org/node/76115). (Accessed June 26, 2012).

Downloaded from https://academic.oup.com/aje/article/177/7/683/91486 by guest on 19 April 2024

2. Opie LH. Sudden death and sport. *Lancet.* 1975;(i):263–266.
3. Noakes TD, Lionel MB, Opie LH, et al. Autopsy-proved coronary atherosclerosis in marathon runners. *N Engl J Med.* 1979;301(2):86–89.
4. Thompson PD, Stern MP, Williams P, et al. Death during jogging or running: a study of 18 cases. *JAMA.* 1979; 242(12):1265–1267.
5. Waller BF, Roberts WC. Sudden death while running in conditioned runners aged 40 years or over. *Am J Cardiol.* 1980;45(6):1292–1300.
6. Thompson PD, Funk EJ, Carleton RA, et al. Incidence of death during jogging in Rhode Island from 1975 through 1980. *JAMA.* 1982;247(18):2535–2538.
7. Bassler TJ. Marathon running and immunity to atherosclerosis. *Ann N Y Acad Sci.* 1977;301(1):579–592.
8. Siscovick DS, Weiss NS, Fletcher RH, et al. The incidence of primary cardiac arrest during vigorous exercise. *N Engl J Med.* 1984;311(14):874–877.
9. Powel KE, Thompson PD, Caspersen CJ, et al. Physical activity and the incidence of coronary heart disease. *Annu Rev Public Health.* 1987;8:253–287.
10. Sherman SE, D'Agostino RB, Cobb JL, et al. Does exercise reduce mortality rates in the elderly? Experience from the Framingham Study. *Am Heart J.* 1994;128(5):965–972.
11. Lee IM, Hsieh CC, Paffenbarger RS Jr. Exercise intensity and longevity in men. The Harvard Alumni Health Study. *JAMA.* 1995;273(15):1179–1184.
12. Blair SN, Kohl HW III, Barlow CE, et al. Changes in physical fitness and all-cause mortality. *JAMA.* 1995; 273(14):1093–1098.
13. Hakim AA, Petrowitch H, Burchfiel CM, et al. Effects of walking on mortality among nonsmoking retired men. *N Engl J Med.* 1998;338(2):94–99.
14. Schnohr P, Scharling H, Jensen JS. Changes in leisure-time physical activity and risk of death: an observational study of 7,000 men and women. *Am J Epidemiol.* 2001;158(7): 639–644.
15. Paffenbarger RS, Hyde RT, Wing AL, et al. Physical activity, all-cause mortality, and longevity of college alumni. *N Engl J Med.* 1986;314(10):605–613.
16. Leon AS, Cornett J, Jacobs DR, et al. Leisure-time physical activity levels and risk of coronary heart disease and death. The Multiple Risk Factor Intervention Trial. *JAMA.* 1987; 258(17):2388–2395.
17. Schnohr P, Jensen G, Lange P, et al. The Copenhagen City Heart Study. Tables with data from the third examination 1991–1994. *Eur Heart J.* 2001;3(suppl H):H1–H83.
18. Schnohr P. Physical activity in leisure time: impact on mortality. Risks and benefits [thesis]. *Dan Med Bull.* 2009; 56(1):40–71.
19. Rose GA, Blackburn H. Cardiovascular survey methods. In: *World Health Organization Monographs Series 56.* Geneva, Switzerland: World Health Organization; 1968.
20. Lin DY, Wei LJ, Ying Z. Checking the Cox model with cumulative sums of martingale-based residuals. *Biometrika.* 1993;80(3):557–572.
21. President's Council on Physical Fitness. Adult physical fitness: a program for men and women. Prepared by the President's Council on Physical Fitness. Washington, DC: US Government Printing Office; 1965.
22. Pate RR, Pratt M, Blair SN, et al. Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA.* 1995;273(5):402–407.
23. Haskell WL, Lee IM, Pate RR, et al. Physical activity and public health. Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation.* 2007;116(5):1081–1093.
24. Albert CM, Mittleman MA, Chae CU, et al. Triggering of sudden death from cardiac causes by vigorous exertion. *N Engl J Med.* 2000;343(19):1355–1361.
25. Kim JH, Malhotra R, Chiampas G, et al.. Cardiac arrest during long-distance running races. *N Engl J Med.* 2012; 366(2):130–140.
26. Samitz G, Egger M, Zwahlen M. Domains of physical activity and all-cause mortality: systematic review and dose-response meta-analysis of cohort studies. *Int J Epidemiol.* 2011;40(5):1382–1400.
27. Schnohr P, Parner J, Lange P. Mortality in joggers: population based study of 4,658 men. *BMJ.* 2000; 321(7261):602–603.
28. Möhlenlenkamp S, Lehmann N, Breuckmann F, et al. Running: the risk of coronary events. Prevalence and prognostic relevance of coronary atherosclerosis in marathon runners. *Eur Heart J.* 2008;29(15):1003–1010.
29. Tanesescu M, Leitzman MF, Rimm EB, et al. Exercise type and intensity in relation to coronary heart disease in men. *JAMA.* 2002;288(16):1994–2000.
30. Kesanniemi YA, Danforth E Jr, Jensen MD, et al. Dose-response issues concerning physical activity and health: an evidence-based symposium. *Med Sci Sports Exerc.* 2001; 33(suppl):S351–S358.
31. Speed CA, Shapiro LM. Exercise prescription in cardiac disease. *Lancet.* 2000;356(9237):1208–1210.
32. Rauramaa R, Salonen JT, Seppänen K, et al. Inhibition of platelet aggregation by moderate-intensity physical exercise: a randomised clinical trial in overweight men. *Circulation.* 1986;74(5):939–944.
33. Geffken DF, Cusman M, Burke GL, et al. Associations between physical activity and markers of inflammation in a healthy elderly population. *Am J Epidemiol.* 2001;153(3): 242–250.
34. Schnohr P, Kristensen TS, Prescott E, et al. Stress and life dissatisfaction are inversely associated with jogging and other types of physical activity in leisure time—The Copenhagen City Heart Study. *Scand J Med Sci Sports.* 2005;15(2):107–112.
35. Schnohr P, Scharling H, Jensen JS. Intensity versus duration of walking, impact on mortality: the Copenhagen City Heart Study. *Eur J Cardiovasc Prev Rehabil.* 2007;14(1):72–78.
36. Schnohr P, Marott JL, Jensen JS, et al. Intensity versus duration of cycling, impact on all-cause mortality: the Copenhagen City Heart Study. *Eur J Prev Cardiol.* 2012; 19(1):73–80.
37. Leon AS, Blackburn H. The relationship of physical activity to coronary heart disease and life expectancy. *Ann N Y Acad Sci.* 1977;301(1):561–578.

Downloaded from https://academic.oup.com/aje/article/177/7/683/91486 by guest on 19 April 2024