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ORIGINAL INVESTIGATIONS

Dose of Jogging and Long-Term Mortality

The Copenhagen City Heart Study

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ABSTRACT

BACKGROUND People who are physically active have at least a 30% lower risk of death during follow-up compared with those who are inactive. However, the ideal dose of exercise for improving longevity is uncertain.

OBJECTIVES The aim of this study was to investigate the association between jogging and long-term, all-cause mortality by focusing specifically on the effects of pace, quantity, and frequency of jogging.

METHODS As part of the Copenhagen City Heart Study, 1,098 healthy joggers and 3,950 healthy nonjoggers have been prospectively followed up since 2001. Cox proportional hazards regression analysis was performed with age as the underlying time scale and delayed entry.

RESULTS Compared with sedentary nonjoggers, 1 to 2.4 h of jogging per week was associated with the lowest mortality (multivariable hazard ratio [HR]: 0.29; 95% confidence interval [CI]: 0.11 to 0.80). The optimal frequency of jogging was 2 to 3 times per week (HR: 0.32; 95% CI: 0.15 to 0.69) or ≤1 time per week (HR: 0.29; 95% CI: 0.12 to 0.72). The optimal pace was slow (HR: 0.51; 95% CI: 0.24 to 1.10) or average (HR: 0.38; 95% CI: 0.22 to 0.66). The joggers were divided into light, moderate, and strenuous joggers. The lowest HR for mortality was found in light joggers (HR: 0.22; 95% CI: 0.10 to 0.47), followed by moderate joggers (HR: 0.66; 95% CI: 0.32 to 1.38) and strenuous joggers (HR: 1.97; 95% CI: 0.48 to 8.14).

CONCLUSIONS The findings suggest a U-shaped association between all-cause mortality and dose of jogging as calibrated by pace, quantity, and frequency of jogging. Light and moderate joggers have lower mortality than sedentary nonjoggers, whereas strenuous joggers have a mortality rate not statistically different from that of the sedentary group. (J Am Coll Cardiol 2015;65:411–9) © 2015 by the American College of Cardiology Foundation.

The most famous case of sudden death in connection with running is that of Pheidippides, a professional running courier who in 490 B.C. is believed to have run from Marathon to Athens, Greece, a distance of approximately 25 miles, to bring news of the Athenian victory over the Persians. Upon reaching the Athenian Agora, he exclaimed "Nike!" ("victory"), collapsed, and died. Some historians, believing this is a myth, favor another version: that after his run from Marathon to Athens, Pheidippides continued to Sparta for military help. He ran the distance from Athens to Sparta, 137 miles, in 48 h (1).

In 1953, Morris et al. (2) published a paper showing that mortality from coronary heart disease (CHD) was more than twice as high in sedentary London bus

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ABBREVIATIONS AND ACRONYMS

CHD = coronary heart disease
CI = confidence interval
CV = cardiovascular
DM = diabetes mellitus
HR = hazard ratio
METs = metabolic equivalents

drivers compared with physically active conductors. This pioneering work gave rise to the hypothesis that physical activity might be of importance in prevention of CHD.

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As part of a report from the President's Council on Youth Fitness, a message in 1965 from President Lyndon B. Johnson stated the following: "Medical evidence tells us that our hearts, lungs, muscles and even our minds need the effects of regular and vigorous exercise" (3). Since then, numerous recommendations about physical fitness in leisure time have been published, and they have in general recommended that every adult should perform >30 min of moderate-intensity physical activity preferably every day of the week. National guidelines also call for a combination of moderate- and vigorous-intensity activity, such as walking briskly for 30 min twice a week and then jogging for 20 min on 2 other days. The data strongly support an inverse association between regular exercise and mortality. In longitudinal studies, physically active men and women have an approximately 30% lower risk of death during follow-up compared with inactive people. No upper threshold for physical activity has ever been recommended (4–6).

In 1969, the first running race in Europe (the Eremitage Race) took place in Denmark; 2,344 men and women finished the distance of 7.6 miles. Unfortunately, a 46-year-old naval officer died of a myocardial infarction during this event. As a result of this death, the event organizers hesitated to continue running races, reasoning that perhaps they were too strenuous and possibly dangerous for the general population. (The race has continued and has gained in popularity.) Subsequently, during the 1970s, when jogging gained momentum, several reports of deaths during jogging were published (7–13).

The Copenhagen City Heart Study (14,15) reported that the relative intensity of walking and cycling and not the duration was of most importance in relation to all-cause and CHD mortality. Subsequently, the Copenhagen City Heart Study showed that the increase in survival among joggers was 6.2 years in men and 5.6 years in women. This particular analysis was performed in a random sample of 1,878 joggers who were followed for up to 35 years and compared with 16,827 nonjoggers. Jogging up to 2.5 h per week at a slow or average pace and a frequency of ≤3 times per week was associated with the lowest mortality. Those who jogged >4 h per week, at a fast pace, and >3 times per week appeared to lose many of the longevity benefits noted with less strenuous doses of jogging (16). This finding was somewhat surprising.

In the present study, we explore in more detail whether a U-shaped association exists between mortality and dose of jogging as calibrated by pace, quantity, and frequency of jogging.

METHODS

STUDY POPULATION. The prospective Copenhagen City Heart Study is composed of a random sample of 19,329 white men and women between 20 and 93 years of age drawn from the Copenhagen Population Register as of January 1, 1976. The current study used the fourth examination from 2001 to 2003. All subjects from the original sample were invited to all subsequent examinations, and a new random sample of younger men and women was included. Details have been described elsewhere (1,17).

In the present analyses, we excluded participants with a history of CHD (n = 513), stroke (n = 262), and cancer (n = 469), leaving 5,048 men and women (1,098 healthy joggers and 3,950 healthy nonjoggers) for analyses.

SURVEY METHODS. Established procedures and examinations for cardiovascular (CV) epidemiological surveys were used (18). Physical activity in leisure time was graded as 1 of 4 levels in all 4 surveys using The Copenhagen City Heart Study Leisure Time Physical Activity Questionnaire (1). Levels of activity were defined as follows: group I, almost entirely sedentary (e.g., reading, watching television or movies, engaging in light physical activity, such as walking or biking for <2 h per week); group II, light physical activity for 2 to 4 h per week; group III, light physical activity for more than 4 h per week or more vigorous activity for 2 to 4 h per week (e.g., brisk walking, fast biking, heavy gardening, sports that cause perspiration or exhaustion); and group IV, high vigorous physical activity for more than 4 h per week or regular heavy exercise or competitive sports several times per week. The activity questionnaire has been shown to discriminate between sedentary people and their more active counterparts with respect to maximal oxygen uptake (19).

In the 2001 to 2003 survey, we included questions on the weekly quantity of jogging, frequency of jogging, and the subject's own perception of pace (slow, average, fast). We found that a relative scale of pace (intensity) is more appropriate than an absolute scale when the age span is very wide (20 to 95 years) and when the participants have wide differences in levels of physical fitness. Compared with the