with sedentary nonjoggers, whereas these health benefits were absent in strenuous joggers (HR: 1.97; CI: 0.48 to 8.14). Hence, the investigators concluded that a U-shaped association between exercise dose and all-cause mortality was present, which suggested an upper limit of the health benefits of exercise.

Interestingly, strenuous exercise was established as >4 h of jogging per week at a fast pace. Although this amount of physical activity clearly exceeded the current exercise recommendations, these doses were typically observed in amateur and professional athletes. Other studies investigated the life expectancy of athletic populations. Finnish skiers (2) and world-class endurance athletes (3) demonstrated an increased life expectancy of 2.8 to 6 years compared with reference cohorts. A study that included 15,174 Olympic medallists confirmed these findings, and found 2.8 years of increased life expectancy compared with matched cohorts from the general population (4). Furthermore, a large Swedish study reported a 52% reduction of all-cause mortality among participants of the Vasaloppet cross-country ski-race, with the highest life expectancy found in older participants and athletes who participated in multiple races (5).

These findings suggest that high volumes of exercise training improve longevity and are in contradiction to the U-shaped association between exercise dose and all-cause mortality as suggested by Schnohr et al (1). The small sample size of the strenuous jogger group (n = 40), with only 2 deaths during the 12 years of follow-up, may contribute to these conflicting findings. In addition, the lack of insight into the cause of death may confound the results; if only 1 of the 2 death cases was caused by a nonnatural death (e.g., accidents, suicide), the study outcomes would be completely different. Finally, the arbitrarily chosen cutpoints for classification of the light, moderate, and strenuous jogger groups may not appropriately reflect the spectrum of light to extreme doses of exercise training.

Therefore, we believe, that the evidence for an upper limit (>4 h/week) of exercise health benefits and associated all-cause mortality is premature. With physical inactivity as 1 of the most influential risk factors for worldwide morbidity and mortality, we would recommend to keep on running.

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http://dx.doi.org/10.1016/j.jacc.2015.02.080

Please note: The authors have reported that they have no relationships relevant to the contents of this paper to disclose.

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Strenuous Exercise Worse Than Sedentarism?

Schnohr et al. (1) reported a U-shaped association between all-cause mortality and exercise dose in a Danish cohort. Jogging 1 to 2.4 h/week was associated with the lowest mortality, whereas jogging >3 times/week was no better than being inactive and was worse than light jogging (adjusted hazard ratio [HR]: 9.08; 95% confidence interval [CI]: 1.87 to 44.01). Furthermore, older (61.3 ± 16.2 years) sedentary nonjoggers with cardiovascular disease (CVD) risk factors (high body mass index, high blood pressure, smoking, and diabetes) had even lower mortality rates than younger (37 ± 13.9 years) intense joggers without these risk factors (adjusted HR: 1.97; 95% CI: 0.48 to 8.14) (1). Besides challenging well-established medical knowledge (i.e., that physical inactivity is a risk factor for CVD), the notion that high exercise doses might be worse than sedentarism for health in a specific cohort could lead to misinterpretations and erroneous generalizations. For example, the press in Spain recently also suggested a "killing" effect of "too much exercise." However, among 10.9 million U.S. individuals who ran in marathons from 2000 to 2010, only 59 experienced cardiac arrest/sudden death,

with underlying CVD and poor preparation accounting for most events (2). The epidemiological benefits of exercise could even be stronger at high doses, with research in much larger cohorts revealing greater gains in life expectancy (+4.5 years; 95% CI: 4.3 to 4.7) when exercising ≥450 min/week (3). Evidence also exists of exercise-related survival benefits in extreme endurance exercisers. In a recent meta-analysis, we detected considerably lower all-cause (0.67; 95% CI: 0.55 to 0.81; $p < 0.001$) and CVD-related standard mortality ratios (0.73; 95% CI: 0.65 to 0.82; $p < 0.001$) in professional athletes ($n = 42,807$, including marathoners) versus the general population (4). These data are consistent with those from large cohorts of Scandinavian endurance athletes (5).

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http://dx.doi.org/10.1016/j.jacc.2015.02.081

Please note: The authors have reported that they have no relationships relevant to the contents of this paper to disclose.

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REPLY: Exercise and Mortality Reduction

Recurring Reverse J- or U-Curves

We thank Dr. Andersen, Drs. Burtscher and Pesta, Drs. Charansonney and Cohen-Solal, Mr. Maessen and colleagues, and Dr. Sanchis-Gomar and colleagues for the interest in our paper and their many insightful comments (1).

The 1986 paper by Paffenbarger et al. was the first of many studies to report a U-shaped association between leisure-time physical activity and mortality. In the short interim since our study was published in the *Journal*, 2 more large prospective observational studies have reported similar U-shaped or reverse J-shaped associations. The recurring theme is that moderate doses of exercise markedly reduce risks for long-term mortality (both all-cause and cardiovascular deaths), but the subgroups that perform very high doses of exercise appear to lose some of the mortality benefit conferred by moderate exercise. The Million Women Study (2) found that regular physical activity was associated with dramatically lower risks of coronary heart disease (CHD); however, the women who did not take at least 1 day/week off of strenuous exercise appeared to lose some of the cardioprotection (**Figure 1A**). Another large study recently reported that exercise dramatically reduced the risk of death during follow-up (3); however, again, the maximal benefits were noted in the moderate range, with the familiar reverse J-curve suggesting an attenuation of benefit at the highest level of exercise (**Figure 1B**). In 2013, we published a study of a random sample of 1,878 joggers who were followed for up to 35 years and compared with 16,827 nonjoggers. The increase in survival among joggers was similar between the sexes (6.2 years in men and 5.6 years in women), but surprisingly those who jogged for the longest time (>4 h/week), at a fast pace, and >3 times/week appeared to lose much of the longevity benefit that was noted with less strenuous jogging (4).

We analyzed the association between mortality and quantity, pace, and frequency of jogging, both individually and combined, in 1,098 healthy joggers and 3,950 healthy nonjoggers; the reference group was the 413 nonjoggers who reported being sedentary during leisure time. The analyses of pace and frequency of jogging suggested a U-shape. In the combined analysis, we found that light joggers had the lowest hazard ratio compared with sedentary nonjoggers. We also found that moderate joggers had a significantly higher hazard ratio compared with light joggers. This finding suggested a U-shape between jogging dose and mortality. The strenuous joggers also had a significantly higher hazard ratio compared with light joggers. In addition, we