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## Record-Breaking Performance in a 70-Year-Old Marathoner

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### TO THE EDITOR:

We determined the physiological profile of a 70-year-old male marathoner who ran the event in 2:54:23 (6:39 minutes per mile [4:09 minutes per kilometer]) on December 15, 2018, breaking the record time for men over the age of 70 years set in 2004.<sup>1</sup> Endurance performance is determined by three primary physiological variables: maximum oxygen uptake, running economy (oxygen use for a given running velocity), and lactate threshold (exercise intensity at which lactate begins to accumulate).<sup>2</sup> These measures are influenced by age, general physical health, and training.<sup>2-4</sup>

As part of the evaluation, the marathoner underwent both medical screening and performance testing. (Details are provided in the Supplementary Appendix, available with the full text of this letter at [NEJM.org](https://www.nejm.org).) Performance testing consisted of running on a graded treadmill with gas-exchange measurements for determination of maximum oxygen uptake, testing of running economy (12 to 16 km per hour at 0% grade, 5 minutes each), and lactate threshold (by means of venous blood sampling).

The marathoner's height was 176.5 cm, his weight was 64.2 kg, and he had exceptional cardiometabolic health (body fat, 19.1%; blood pressure, 122/75 mm Hg; blood glucose, 86 mg per deciliter [4.8 mmol per liter]; and total cholesterol, 173 mg per deciliter [4.5 mmol per liter]). His training consisted of running 40 to 50 miles per week.

Performance data are presented in Figure 1. His maximum oxygen uptake was 46.9 ml per kilogram of body weight per minute, a level that was exceptional for his age (the average for an age-matched male is approximately 26 ml per kilogram per minute) but much lower than

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expected for an athlete who can run a marathon in less than 3 hours.<sup>2</sup> His running economy was similar to values reported in younger competitive runners.<sup>2</sup> He reached the lactate threshold at approximately 14 km per hour (6:54 minutes per mile [4:16 minutes per kilometer]), which corresponds to a maximum oxygen uptake of approximately 93%. Notably, his record marathon pace of 6:39 minutes per mile is faster than that threshold, which is remarkable, because it is generally thought that marathon runners maintain approximately 75 to 85% of their maximum oxygen uptake.<sup>5</sup>

We considered the possibility that this athlete's measured running economy on the treadmill was worse than his overground running, which would lead to spurious conclusions. Several observations make this unlikely. First, during overground training, the marathoner reported heart rates in the lower 140s at marathon-race pace, similar to what we measured while he was running at a nearly marathon pace on the treadmill (14 km per hour, for a marathon pace of 3:00:28). Second, his running economy as measured on the treadmill was similar to that of elite younger runners.<sup>2,4</sup> Third, even a 5% improvement in running economy during overground running would still indicate that he could probably sustain a marathon pace of at least 90% of his maximum oxygen uptake, a remarkably high value. In conclusion, these data suggest that this master athlete's ability to maintain a remarkably high percentage of his maximum oxygen uptake played a role in enabling him to run a marathon in 2:54:23.

## Supplementary Material

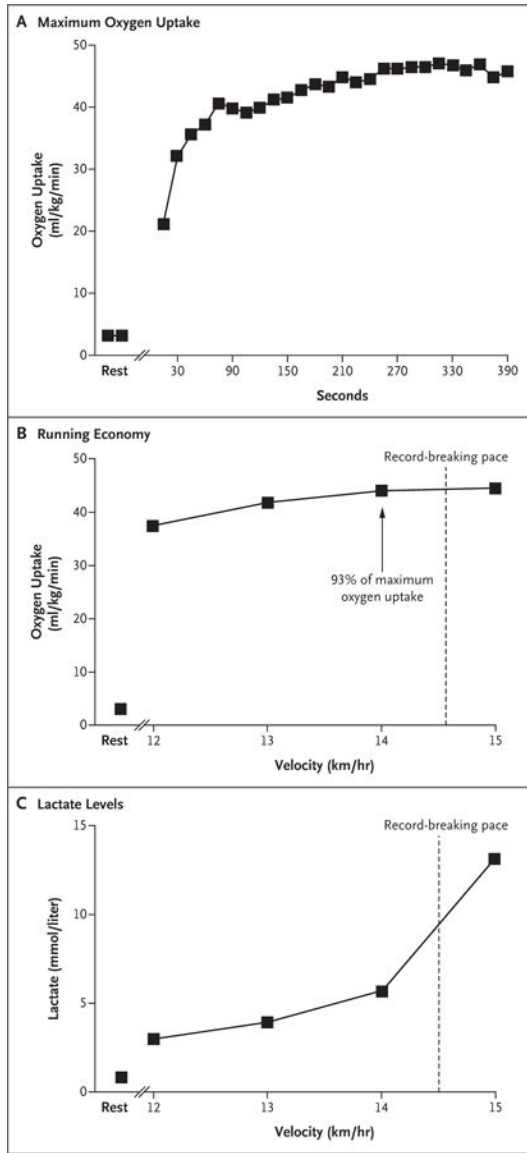
Refer to Web version on PubMed Central for supplementary material.

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**Figure 1. Results of Performance Testing in Marathon Runner.**

Shown are the marathoner’s performance-testing results, including the maximum oxygen uptake (Panel A). During this evaluation, the maximum heart rate was 156 beats per minute (104% of the age-predicted maximum heart rate), the maximum ventilation was 112 liters per minute, and the rating of perceived exertion was 19/20. Also shown are oxygen uptake values obtained at different running velocities (running economy, Panel B) and lactate values at the same velocities (Panel C). The dashed line represents an interpolated value for a running speed of 14.5 km per hour (6:39 minutes per mile [4:09 minutes per kilometer]), the average pace of this runner during his record-breaking marathon performance.