Flattening the curve: how Eliud Kipchoge's unique physiology attenuates his age-related performance decline

Hunter L. Paris[1], Chad C. Wiggins[2], Ren-Jay Shei[3]

[1]Department of Sports Medicine, Pepperdine University, Malibu, CA

[2]Department of Anesthesiology and Perioperative Medicine, Mayo Clinic, Rochester, Minnesota, USA

[3]Independent Sport Scientist, Carlsbad, CA, USA

Address for correspondence:
Hunter L. Paris, Ph.D.
Department of Sports Medicine
Pepperdine University
Malibu, CA 90263
E-mail: hunter.paris@pepperdine.edu

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Abstract
The aim of this study was to examine the physiological profile of Eliud Kipchoge in his attempt at a master's M50 (age 50-54) marathon World Record. Additionally, by comparing Kipchoge's physiology over the past two decades with those of healthy individuals, we document his age-related decline in performance, thereby demonstrating the extreme limit of what is understood to be physiologically plausible. Coupled with his eclipsing of the World Record, Kipchoge's data demonstrate that although aging remains inevitable, technological advancements and world class physiology slow age-related decrements in health and performance.

Introduction

Following the cancelation of the 2020 Tokyo Olympics due to the coronavirus pandemic (COVID-19), the world gasped when Eliud Kipchoge (EK) retired from athletics, pursuing instead his career in men's fashion (sparked by his experience with GQ magazine). Though EK continued to run recreationally and annually contributed physiological data towards a longitudinal study on aging, twenty years strode silently by before Kipchoge once again donned a bib number and race kit.

In 2039, the much anticipated return of, "the philosopher" arrived. Twenty years to the day after EK unofficially broke the 2-h marathon in the INEOS challenge, he returned to the roads, attempting to break the master's M50 (age 50-54) marathon World Record time of 2:19:29, set in 1991. We examined EK's build up to the race and his race-day performance. Additionally, using longitudinal data gathered annually we compared EK's age-related decline in fitness over the past twenty years with normative data for healthy and elite, age-matched individuals.

As we have recently demonstrated (6), advances in training methodology, technology, nutrition, and medical care have attenuated performance declines in aging athletes. Despite these advancements, however, age-related declines in performance persist and are likely attributable to, perhaps inevitable, cardiometabolic impairments, changes in musculoskeletal properties, and lifestyle alterations such as physical inactivity and increased alcohol consumption (5). The purpose of this study was to demonstrate the physiological limits in a master's-level performance given the aforementioned advancements, and to illuminate further areas of investigation in the search for the fountain of youth.

Methods

Participant

Born in Kenya's Rift Valley (1940 m), EK completed the world's first sub 2-h marathon in 2019. Following a 20-y retirement in which he continued to run recreationally—and annually reported for cardiorespiratory assessment testing—EK resumed training at age 54. Before providing written informed consent, EK was informed of possible risks. All testing procedures were approved by the local Institutional Review Board.

Experimental Design

EK underwent annual cardiorespiratory and anthropometric assessment in the laboratory (2019-present), allowing for longitudinal comparisons with reference data. His training was monitored for the three months preceding the marathon. Race-day nutrition and running technology were recorded. Cardiorespiratory testing was conducted annually as previously described (6).

Marathon

Taking place in a closed-looped course in St. James's Park, London, the marathon start time was 0600 local time. Humidity and wind at race start were 40% and 6.2 $km \cdot h^{-1}$, respectively. While starting ambient temperature was 10°C race organizers utilized temperature control technology developed for the 2032 Olympic Games in Qatar to regulate temperature throughout the race. Therefore, race temperature on the course was held steady at 3.8°C.

Marathon training

EK achieved training volumes and speeds only slightly reduced (~3%) from twenty years prior. The majority of training was performed at running velocities slower than target marathon pace. Velocities faster than marathon pace were reached during interval sessions performed weekly at altitudes close to sea-level. EK trained and competed in the Nike Vaporfly NextNextNext%, colloquially referred to as “Warp Speed Shoes.”

In-race nutrition

Dietary habits leading to the race were similar each day with the exception of a modified dietary periodization immediately preceding the race. This approach, pioneered by Burke et al. in 2033 (2), optimizes fat utilization while yet maintaining rates of carbohydrate oxidation. Prior to race start, 18 km into the race, and at 31 km, EK ingested three proprietary, individually crafted slurries (Jeukendrup Laboratories) composed of carbohydrate, salt, water, natural flavoring, and populated with *Veillonella atypica* (3).

In-race cardiorespiratory assessment

$\dot{V}O_2$, RER, and oxygen saturation, were obtained at the start, 21 km mark, and 42 km mark by use of indirect calorimetry and spectroscopy (6). At these time points, EK ran beneath a 200 m tunnel which simultaneously collected expired gases and measured the absorption of visible and infrared light. Heart rate was continuously monitored via activity watch equipped with Bluetooth® and blood glucose was sampled every twenty minutes via implantable device on the posterior triceps brachii. A summary of race-day technology is displayed in Figure 1.

Results

Age-related declines in physiology and performance

At 76 $ml \cdot kg^{-1} \cdot min^{-1}$, EK’s $\dot{V}O_2max$ is among the highest ever recorded for his age, declining 1.5% per decade. Results for EK’s annual fitness test are displayed in Figure 2 (green line). His HRmax, $\dot{V}_Emax$, running economy, and anthropometric data saw minimal decline in the twenty-year span from age 34 to 54 years old.

Physiological profile during the marathon and marathon performance

EK completed the marathon in 2:14:17. Pacing strategy revealed a negative split strategy and a running velocity of 98.4% of critical speed. EK ran at 85% of $\dot{V}O_2max$ for the duration of the race. At an average RER of 0.89, 35.8% of calories were derived from fat. Blood glucose remained 4-5 $mmol \cdot l^{-1}$ throughout the marathon. Oxygen saturation ranged from 93% to 99%.

Discussion

By completing the marathon distance in 2:14:17, EK established a new M50 World Record, lowering the previous mark by over five minutes. Cardiorespiratory assessment demonstrated that his combination of superior $\dot{V}O_2max$ and running economy facilitated his record-breaking performance. Additionally, longitudinal assessment of EK's physiologic profile provides novel insight into how his unique physiology attenuated his age-related decline in performance.

Marathon performance

Advancements in racing strategy, individualized nutrition, and injury prevention, combined with superior cardiorespiratory physiology and running economy allowed EK to maintain a high fractional utilization of critical speed and execute a negative split pacing strategy, thereby optimizing his performance (1). Advancements in dietary periodization upregulated fat utilization, while yet retaining the functionality of glycogen phosphorylase and preserving the capacity for carbohydrate oxidation, thus reducing the need for time-consuming in-race feeding. The in-race nutrition EK *did* consume was likely sufficient to retain central drive via carbohydrate sensing in the mouth, as well as promote lactate metabolism through microbial optimization. Finally, EK's race performance benefited from consistency of training due to injury reduction afforded especially by retention of musculoskeletal integrity, joint stability, and tendon stiffness, as well as near complete retention in muscle mass over the twenty year span.

Age-related declines in physiology and performance

Remarkable advancements in training, nutrition, medical care, technology, and recovery tools have significantly reduced the incidence of running-related injuries and attenuated the rate of age-related performance declines. Previously, we demonstrated (6) that what was considered physiologically plausible for a 50-59 year old in the year 2020 has been eclipsed by the healthy 50-59 year old in 2040. For example, whereas in 2020 an elite, aging athlete could expect a 5.5% decline in $\dot{V}O_2max$ per decade (4), today, elite individuals experience an average decline of $< 3\%$ per decade.

The near negligible decrements in EK's physiology demonstrates further advancements in delaying the age-related declines in performance and represent, perhaps, a physiological limit. These longitudinal data particularly highlight the role of physical activity in maintaining fitness across the lifespan. We surmise that EK's regular activity, even during his hiatus from competition, were key drivers in maintaining his health and cardiorespiratory fitness.

Conclusions

Advancements in science and technology have attenuated the age-related decline in health and performance. Amidst this backdrop of advancements, EK's maintenance of cardiorespiratory fitness and running economy are unique and represent a true outlier in terms of age-related performance declines. It is likely that a combination of daily physical activity, balanced nutrition, genetics, and excellent preventative medicine contributed to EK's dramatically limited age-related physiological and performance declines. These lifestyle and training habits no doubt have translatable application to improving the health of the broader, aging global population.

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Conflict of Interest Disclosure

HLP, CCW, and R-JS declare no conflicts of interest.

References

1. Billat V et al. 2020. Race analysis of the world's best female and male marathon runners. *Int J Environ Res Public Health* 17(4):1177.

2. Burke LM et al. 2033. Low carbohydrate high fat diet plus glycogen phosphorylase promoter enhances glycogen availability and endurance performance. *Nat Med* 39(11):1748-1755.

3. Jeukendrup A et al. 2039. A proprietary, individualized approach to in-race nutrition enhances endurance performance in elite marathon runners. *Eur J Sport Sci* 39(1):27-34.

4. Rogers MA et al. 1990. Decline in VO_2max with aging in master athletes and sedentary men. *J Appl Physiol* 68(5):2195-2199.

5. Shei R-J, Paris HL, Wiggins CC. 2038. Age-related declines in athletic performance. *Physiol Rev* 118(3):957-988.

6. Wiggins CC, Shei R-J, Paris HL. 2039. Longitudinal assessment of age-related performance declines in elite and recreational runners. *Eur J Sport Sci* 39(3):278-284.