# Outrunning the grim reaper: longevity of the first 200 sub-4 min mile male runners

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## ABSTRACT

**Objectives** To determine the impact of running a sub-4 min mile on longevity. It was hypothesised that there would be an increase in longevity for runners who successfully completed a sub-4 min mile compared with the general population.

**Methods** As part of this retrospective cohort study, the Sub-4 Alphabetic Register was used to extract the first 200 athletes to run a sub-4 min mile. Each runner's date of birth, date of their first successful mile attempt, current age (if alive) or age at death was compared with the United Nations Life Tables to determine the difference in each runner's current age or age at death with their country of origin-specific life expectancy.

**Results** Of the first 200 sub-4 min mile runners (100% male), 60 were dead (30%) and 140 were still alive. Sub-4 min mile runners lived an average of 4.7 years beyond their predicted life expectancy (95% CI 4.7 to 4.8). When accounting for the decade of completion (1950s, 1960s or 1970s), the longevity benefits were 9.2 years (n=22; 95% CI 8.3 to 10.1), 5.5 years (n=88; 95% CI 5.3 to 5.7) and 2.9 years (n=90; 95% CI 2.7 to 3.1), respectively.

**Conclusion** Sub-4 min mile runners have increased longevity compared with the general population, thereby challenging the notion that extreme endurance exercise may be detrimental to longevity.

### WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Regular moderate exercise is considered a pillar of healthy ageing. However, there are concerns that exposing the body to extreme exercise bouts may be harmful to longevity.

### WHAT THIS STUDY ADDS

⇒ We compared the longevity of the first 200 athletes to run a sub-4 min mile (the epitome of extreme exercise and pushing the body to its physiological limits) with that of the general population.

⇒ We showed that athletes who complete a sub-4 min mile live several years longer than the general population.

### HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our findings challenge the notion that extreme endurance exercise may be detrimental to longevity, reinforcing the benefits of exercise, even at training levels required for elite performance.

## INTRODUCTION

6 May 2024 was the 70th anniversary of what is widely considered one of the most significant achievements of the modern sporting era. Specifically, at a track meet at Oxford University's Iffley Road stadium, Roger Bannister, a 25-year-old Englishman and medical trainee, became the first person to run 1 mile in under 4 min (3:59.4 min, to be exact).[1 2] This represented a monumental breakthrough as it challenged the notion of what many believed was an impenetrable barrier for human exercise physiology and sport performance.[1–3] However, it also raised questions about the potential costs of pushing the human body to the level required to achieve this feat.[3] The 70th anniversary of Bannister's world record-breaking achievement highlights the progress that can be made by demonstrating the new upper limits of human performance. Since 1954, more than 1750 athletes have joined Bannister in the halls of sub-4 min fame,[4] with the world record baton passing from Bannister to another 18 remarkable athletes, and is now held by Hicham El Guerrouj from Morocco with a time of 3:43.13 min set 25 years ago in 1999.[4] While any doubts surrounding the possibility of a human breaking the 4 min mile have been put to rest, the concerns around the health sequelae—and particularly the cardiovascular consequences of pushing the human body to its physiological limits—persist.[3 5–7]

Concerns about whether too much exercise can be harmful predate Bannister by several centuries with the tale of Pheidippides' fateful run from Marathon to Athens where he died suddenly shortly after announcing the Greeks' battlefield victory over the Persians (although a tale that has seen much embellishment over the subsequent centuries).[3 7] The protagonists of the view that extreme exercise may cause long-term adverse health effects point to evidence of a 'U-shaped' or 'reverse J-shaped' association between cardiac events and exercise dose.[5 6] This view suggests that regular moderate exercise provides health benefits but that extremes either side—sedentary behaviour on one side and high volumes of intense endurance exercise on the other—may increase the risk of premature mortality.[5 6] This hypothesis is supported by detailed physiological investigations showing that high-intensity exercise bouts and/or extreme sporting events such as marathons, endurance cycling and Ironman triathlons are associated with potentially concerning changes in cardiac structure or function including acute increases in biomarkers of cardiac injury, reduced resting left and right ventricular function and myocardial fibrosis (although in a minority of athletes).[8] There is some epidemiological evidence

to suggest that higher volumes of strenuous exercise have no benefit to longevity relative to sedentary adults, and may even be harmful.[9] However, this finding is based on a low number of community-dwelling individuals and, as such, extreme caution is warranted when extrapolating a potentially underpowered observation from recreationally active community-dwelling adults to the broader population of high-level endurance athletes. Indeed, epidemiological studies focused on populations selected specifically for their extreme exercise behaviour and/or physiologic capabilities (eg, Tour de France cyclists,[10 11] Olympic athletes,[12] rowers[13]) have shown increased rather than decreased longevity compared with the general population. Whether this holds true for the extreme genetic, physiological and exercise training phenotype of the sub-4 min mile runner is an intriguing question. Notably, a majority of these previous studies have focused on long-endurance sports, thereby testing the duration component of extreme exercise. The repeated bouts of near maximal to maximal exercise performed by mile runners makes them a unique population in which to test the potential impact of extreme intense exercise on longevity.

Therefore, inspired by the correspondence from Maron and Thompson exploring longevity of the first 20 4 min mile runners,[14] we endeavoured to extend their initial observations to the first 200 4 min mile runners with more robust statistical methods to determine the longevity effects of running a sub-4 min mile. We tested the hypothesis that there would be an increase in longevity for runners who successfully completed a sub-4 min mile compared with the general population.

## METHODS

### Study design

A retrospective cohort study of the first 200 sub-4 min mile runners.

### Participants

We used a publicly available database (the Sub-4 Alphabetic Register, https://nuts.org.uk/sub-4/index.htm)[4] which provides a compendium of athletes who have broken the 4 min mark for the mile as of 6 June 2022. The list includes details of 1759 runners who were tabulated and sorted by their first recorded date of sub-4 min mile achievement in order to identify and extract relevant details for the first 200 athletes to successfully break the 4 min mark. The sample size of 200 runners was selected as they would be at an age at—if not beyond—the typical life expectancy for their generation (ie, those who ran sub-4 min after this period may be too young to determine a true longevity effect compared with the general population).

### Outcome assessment

From the Sub-4 Alphabetic Register, we extracted information for the first 200 runners including each runner's name, the date and time of their first successful sub-4 min mile attempt and nationality at the time of their attempt. From this, the first 200 runners were searched online to gather their date of birth and date of death (if applicable). In those runners who were still alive (no evidence of the athlete's death in a comprehensive search), their current age was calculated with a censor date of 31 December 2023.

Searches for each athlete's date of birth and death were conducted on publicly available websites including Olympic, international and national athletic federations and Wikipedia.com. To minimise the risk of incorrect publications for cause of death online and to account for those with no publicly known cause of death, we chose to exclude cause of death from our overall analysis. After the initial search (conducted by DH) on 18 January 2024, two further independent searches were completed by two separate investigators for further confirmation.

### Survival and statistical analyses

The primary outcome was the average difference in life expectancy between the first 200 sub-4 min mile runners and the general population (matched for age, sex and nationality). The follow-up period for the runners was from the exact time of their first successful sub-4 min attempt to either the age of 100 years, the end of the study (31 December 2023) or death (if applicable) and was compared with matched population life table values. The observed life years of the runners were computed from the length of follow-up.

Life expectancy, conditional on being alive (and their age) at the time of their sub-4 min attempt was derived as follows. United Nations life tables[15] were linked to the runners by country at time of achievement, calendar year, sex and single year age for all years to age 100 or December 2023. Matching by age and year captured the changing conditions affecting survival over time. Life tables were only available until 2021, therefore 2022 and 2023 were assumed to be the same as 2021. The annual probability of survival at age of achievement and at turning age 100 were modified to account for the partial time at risk during those years. Individual life expectancy was computed using standard life table techniques.[16] The difference in life expectancy was the observed life years for a runner less their population-matched life expectancy and was then averaged over all 200 runners. The SE of the average difference in life expectancy used the leave-one-out jackknife. Survival curves used years since the first successful sub-4 min mile attempt as the time scale. Runners' survival used the Kaplan–Meier estimator and the expected survival from combining all runners used the Ederer II method.[17] Confidence intervals were set at 95%.

### Equity, diversity and inclusion statement

Our study included all identified sub-4 min mile runners regardless of ethnicity/nationality or socioeconomic status. No women have yet broken the sub-4 min mile barrier, so we were unable to incorporate sex or gender into our analysis. The multidisciplinary authorship team included representation from exercise physiology, sports cardiology and population health, two women and five men, and two early-career and one junior scientist.

## RESULTS

### Cohort characteristics

Of the first 200 sub-4 min mile runners, the first successful attempt was Roger Bannister in 1954 and the 200th runner in 1974. The nationalities of the included runners spanned 28 different countries across Europe (n=88), North America (n=78), Oceania (n=22) and Africa (n=12). Year of birth for the 200 studied runners ranged from 1928 to 1955. The mean±SD age of runners at completion was 23.4±2.8 years and times to complete the mile ranged between 3:52.86 and 3:59.9 min. For two runners, only year of birth could be determined so we used 31 December for the corresponding year to ensure longevity was not overestimated.

#### Longevity in sub-4 min mile runners versus the general population

Of the first 200 runners to achieve a sub-4 min mile, 60 (30%) were found to be dead and 140 were alive at the time of the analysis. The average age at death was 73.6±13.7 years (range

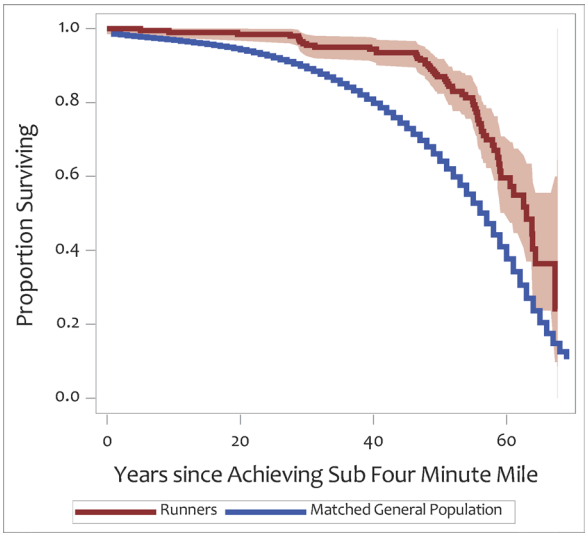


**Figure 1** Proportion (and associated 95% CI) of surviving sub-4 min mile runners (n=200) by each year since their successful attempt compared with referents from the general population (matched for sex, age and nationality).

24.3–91.9 years) while the average age of the surviving runners was 77.6±5.5 years (range 68.3–93.8). We were unable to ascertain specific causes of death in many of the deceased runners and therefore did not add this to the analysis. However, of the seven runners who died before age 55 with a confirmed reported cause of death, six were due to traumatic deaths or suicide and one was due to pancreatic cancer.

Based on the observed versus expected survival analysis, sub-4 min mile runners showed an increase of 4.74 years (95% CI 4.66 to 4.82; n=200) beyond their predicted life expectancy based on sex, age, year of birth, age at sub-4 min mile completion and nationality (figure 1). When accounting for the decade of completion, those whose first successful attempt was in the 1950s lived an average of 9.2 years (95% CI 8.3 to 10.1; n=22) longer than the general population during an average 67.0 years of follow-up, while those whose first successful attempt was in the 1960s and 1970s showed an increase of 5.5 years (95% CI 5.3 to 5.7; n=88) and 2.9 years (95% CI 2.7 to 3.1; n=90) during average follow-up times of 58.2 and 51.3 years, respectively (figure 2).

### Longevity in Olympians and non-Olympians

We did not account for specific socioeconomic status other than gender and nationality; however, there was no benefit from being an Olympian compared with a non-Olympian. In fact, there was a trend for non-Olympians to live slightly longer (non-Olympians (n=79): 5.68 years (95% CI 5.6 to 5.76); Olympians (n=121): 4.13 years (95% CI 3.97 to 4.3)).

## DISCUSSION

To the best of our knowledge, this study represents the largest report of the longevity of runners to successfully run 1 mile in under 4 min. Whether such an elite feat has consequences for health and longevity is an important question. In studying the longevity of the first 200 4 min mile runners we show that they have a longer lifespan than the general population and, as a corollary, our analysis shows that breaking previously conceived boundaries of running physiology does not come at the cost of a shortened lifespan. This finding challenges the upper ends of the U-shaped exercise hypothesis (as it relates to longevity)[5 6] and, once again, reiterates the benefits of exercise on the lifespan, even at the levels of training required for elite performance.

The overall cost-benefit of extreme exercise has been a concern for athletes, medical professionals and the broader public at large for some time.[3 5–7] Sub-4 min mile runners represent a unique population to address this question as it is an event that pushes the respiratory, cardiovascular, skeletal muscle and metabolic systems (aerobic and anaerobic) to their maximal limit.[3] Moreover, while the duration of their event is relatively short compared with prototypical endurance sports, the high aerobic and anaerobic requirements of middle distance events such as the mile necessitates completing relatively high training volumes (~9–12 hours or 120–170 km per week),[18 19] although with a higher proportion of this weekly volume (up to 20–30%) including repeated bouts of high-intensity or near maximal efforts.[18 19] The combination of extreme physiological

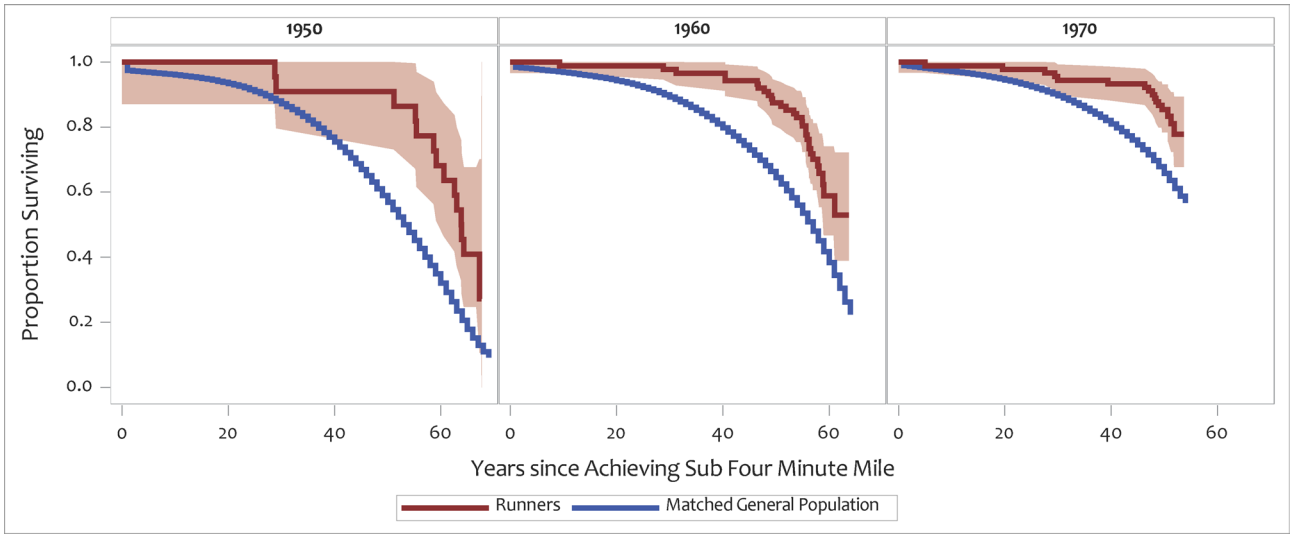


**Figure 2** Proportion (and associated 95% CI) of surviving sub-4 min mile runners by each year since their successful attempt according to the period of their successful attempt (1950–1959, n=22; 1960–1969, n=88; 1970–1979, n=90) compared with referents from the general population (matched for sex, age and nationality).

demands, the profound adaptations along the oxygen cascade and repeated bouts of high-intensity exercise training required to achieve such a feat raises the possibility of pushing the body beyond its limits, particularly from an intensity perspective. Our analysis showed that sub-4 min mile runners do not experience a reduced lifespan as a consequence of achieving sporting success but, rather, lived almost 5 years longer than the life expectancy of their peers. This confirms and extends the initial reports from Maron and Thompson of the first 20 sub-4 min mile runners[14] who they reported lived an average of 12 years beyond their life expectancy. Our sub-analysis focused on this same generation of runners (ie, those who completed their attempt in the 1950s) reports a slightly shorter longevity benefit (9.2 years), which likely reflects the more robust statistical and epidemiological approach we used to determine longevity. Interestingly, we found that this benefit remained significant but was progressively attenuated with each subsequent decade of completion (ie, 1960s and 1970s). This may reflect improvements in life expectancy from the general population over this period secondary to advances in diagnosis and management of several major communicable and non-communicable diseases.[20] However, it should be noted that we calculated the cumulative longevity benefit accrued from the time of each athlete's successful sub-4 min mile attempt until the end of the evaluation period (or their death if it occurred earlier). Therefore, the 1960–69 and 1970–79 cohorts may have up to 10–20 years less time to accrue the longevity benefit than the 1950–59 cohort. The positive longevity effects seen in the sub-4 min mile runners is not specific to middle distance runners. Our results are comparable to the longevity benefits seen in other athletic populations with similarly extreme physiological features and exercise training habits including former Olympians,[12 21–24] Tour de France cyclists,[10 11] elite long distance runners,[23] and Olympic rowers.[13] Taken together, these results continue to challenge the most concerning component of the U-shaped or reverse J-shaped hypothesis (ie, reduced longevity from excessive exercise[9]) by illustrating that sub-4 min mile runners and other extreme athletic populations do not experience detrimental consequences to their lifespan as a result of their sporting endeavours. However, we extend previous reports focused on athletes representing the duration-dependent mechanism of exercise-induced cardiac injury to a population that performed high volumes of exercise at near maximal to maximal intensity.[18 19]

The factors contributing to increased longevity in our cohort and others are yet to be definitively established. The longevity benefits seen in high-level athletic populations are greatest in those participating in endurance sport (ie, running, cycling, rowing), with studies reporting on the longevity of elite power and/or strength athletes showing smaller or no clear longevity benefits.[12 22 23 25] While we could not determine the cause of death for the majority of runners, studies reporting on Tour de France cyclists and cohorts of Olympians (that include middle-to-long distance runners) suggest the longevity effects are primarily mediated by decreased rates of cardiovascular and cancer-related mortality.[11 12 22 25] The physiological mechanisms for these benefits are yet to be determined, but likely reflect the positive adaptations of endurance exercise on cardiovascular, metabolic and immune-related health and function. Indeed, common to all endurance athletes (including middle distance runners) is the development of a high maximal oxygen uptake,[26] which is one of the strongest independent predictors of incident cardiovascular disease, cancer and all-cause mortality.[27] It is also likely that these populations possess favourable genetics and engage in additional healthy lifestyle behaviours beyond exercise training and competition. Indeed, there appears to be a likely genetic component to athletic performance[28 29] that extends to successfully running a sub-4 min mile. Intriguingly, 20 sets of brothers, including six sets of twins, and father and son combinations were among the first 200 sub-4 min mile runners.[4] Of note, three brothers (Jakob, Henrik and Filip Ingebritsen) have achieved the sub-4 min mile, with Jakob being the youngest athlete to achieve the sub-4 min mile at 16 years of age. Whether the genetic, epigenetic (and subsequent phenotypic) features that allow one to run the sub-4 min mile also contribute to their increased longevity is an intriguing question, and highlights the unique health insights that can be gained from studying elite athletic populations.

## Study limitations

Limitations in the details that were available for the athlete cohort mean that we could not determine the cause of death for the majority of individuals. However, as noted above, athletes for whom a definitive cause of death was available primarily died as a result of traumatic accidents, which is consistent with other studies of longevity in athletes.[11 22 25] We also do not have any information on the lifelong exercise habits (or other health behaviours) of our cohort, so we cannot determine the precise relationship between lifelong exercise dose and longevity. Studies of elite athletes suggest that a majority continue to regularly perform high-volume and high-intensity exercise training after retirement from competition,[22 25] so part of the longevity benefit reported in our study could also reflect the accrual of the cumulative benefits from lifelong exercise in some athletes. Regardless, the fact that a single metric of performance in early adulthood was able to predict a longevity benefit up to 60 years later suggests a legacy effect of running a sub-4 min mile. Whether that is due to the features required to achieve success or reflects the clustering of lifelong healthy exercise and lifestyle behaviours remains an important question. Moreover, while the lack of exercise training history precludes a dose-response analysis, the broader cohort of sub-4 min mile runners includes some notable athletes such as Nick Willis of New Zealand who has broken the 4 min mile for 20 consecutive years and Steve Scott of the USA who has broken the 4 min mile 137 times in his career, both of whom are still alive today and do not appear to experience major detrimental health effects as a result of these performances.

We also did not see better survival outcomes in the Olympian cohort, which suggests that socioeconomic factors one might expect to be more common in Olympians (financial support, ancillary health behaviour and support) do not mediate the longevity effects. Our comparison against the general population (similar to other studies of elite athletes) precludes assessment of how other lifestyle factors (eg, diet, smoking status), cardiometabolic risk factors and other potential medical confounders to longevity (eg, hypertension, hypercholesterolaemia) or genetics contributed to the increased longevity. It is possible that the extreme exercise required to run a sub-4 min mile is deleterious to the lifespan, but the effect is not large enough to overcome the positive effects of other factors seen in athletes such as favourable genetics, healthy diet, low rates of smoking and other health conditions. However, this is a difficult question to address as it requires comparison against a population with similar characteristics (with the exception of completing extreme exercise). Importantly, our data speak to the mean longevity effects in sub-4 min mile runners, although it should be noted that a minority of athletes (such as those with genetic predisposition)

may develop cardiac complications as a direct result or accelerated by exposure to high volumes of intense or long-duration exercise,[6] highlighting the importance of individualised assessment and management in athletic cohorts.[6]

Last, our cohort consisted entirely of male athletes. Indeed, to this day, no female has accomplished the sub-4 min mile, with the closest time run by Faith Kipyegon from Kenya at 4:07.64 in 2023 (World record). Unfortunately, we could not readily address this question as there was no comparable database of female athletes. This may also reflect the exclusion of women from middle-to-long distance events at major sporting events such as the Olympics due to prior (and misguided) concerns about the potential ill effects of female athletes performing such extreme exercise (with the women's 1500 m not introduced until 1972).[30] This latter point in particular highlights the importance of future research to address the longevity of female middle distance runners (either in female mile or 1500 m runners). However, it may require several years to ensure adequate follow-up time has accrued to test the potential longevity effects.

## CONCLUSIONS

Analysis of the first 200 runners to break the sub-4 min mile shows that they live an average of 4.7 years longer than the general population. This challenges the hypothesis that extreme exercise may be detrimental to longevity and reinforces the benefits of exercise to the lifespan, even at the levels of training required for elite performance.

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