How Low Can The Women's Marathon Record Go?

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Joint Statistical Meetings, Boston

August 4, 2026

Sebastian Sawe — 1:59:30 London Marathon

Josh Kerr — 3:42.66 Mile

Opinion: Why It's Hard To Trust Ruth Chepngetich's Marathon World Record

Last Updated: Oct 20, 2024 10:57 am

Amby Burfoot
EDITOR AT LARGE

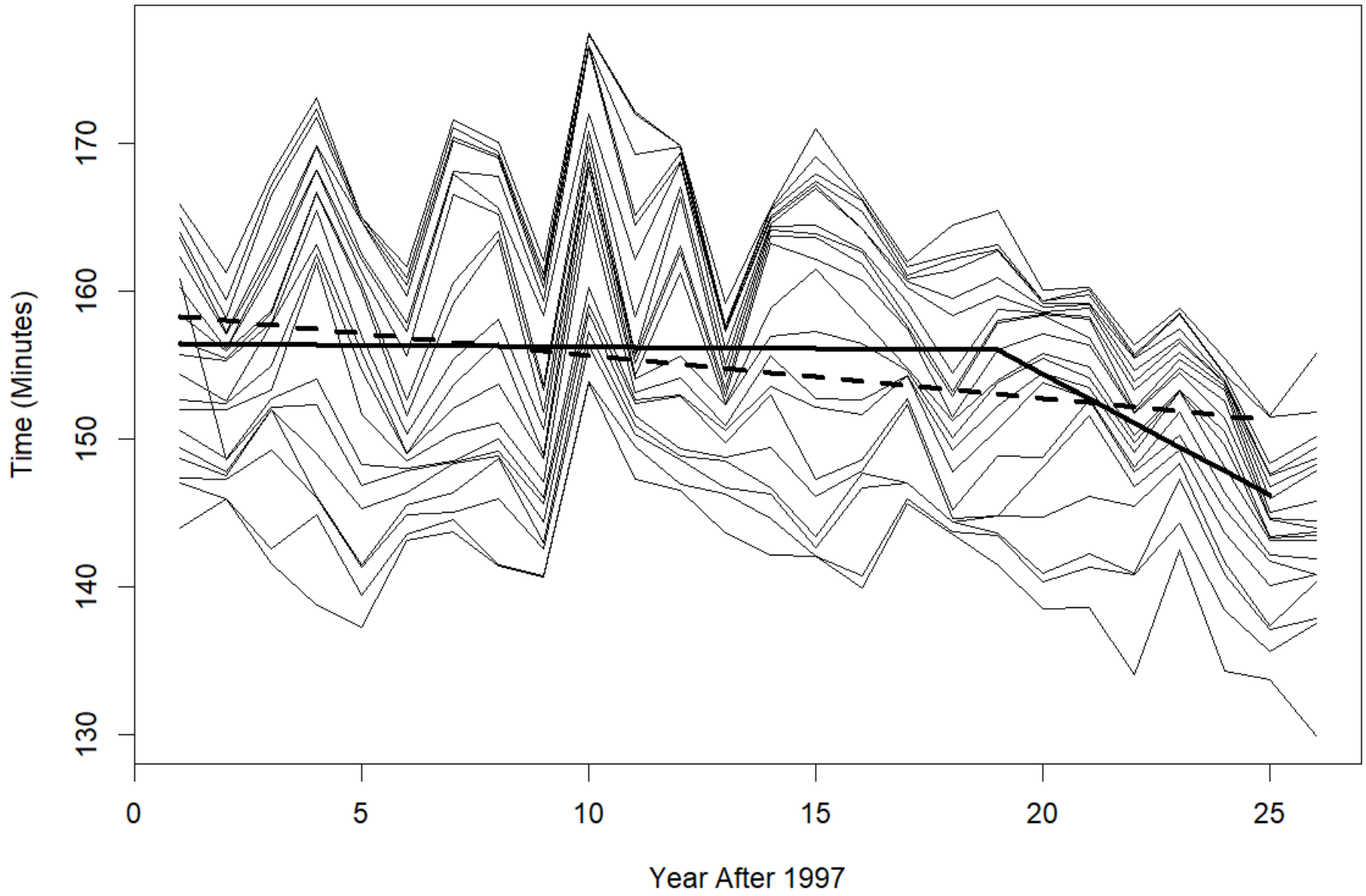
RUTH CHEPNGETICH' S MARATHON WORLD RECORD OFFICIALLY RATIFIED BY WORLD ATHLETICS

Despite the controversy Chepngetich's 2:09:56 is officially official.

MARATHON HANDBOOK

Analysis of Chepngetich's Record

- We downloaded data from the Chicago Marathon website, best 20 women's times for each year from 1998–2024
- No race 2020 — we just left out that year
- 2007 is a possible outlier but we discuss that later
- Clear downward trend over the 27 years but strong suspicion of a changepoint in the mid-2010s
- Particular interest in a changepoint in 2016 as Nike Vaporfly shoes were only introduced in 2017


Time (Minutes)
130
140
150
160
170
0
5
10
15
20
25
Year After 1997

Statistical Model

- "r-largest (smallest) order statistics model" (Smith 1986; Coles 2001; various R packages including `extRemes`, `ismev`):
- Let $z^{(1)} \leq z^{(2)} \leq \ldots \leq z^{(r)}$ denote the r best (i.e. smallest) running times in a given year. The joint density is assumed to be

$$f_r(z^{(1)}, \ldots, z^{(r)}) = \exp\left\{ -\left[1 + \xi\left(\frac{\mu - z^{(r)}}{\sigma}\right)\right]^{-1/\xi} \right\} \cdot \prod_{k=1}^{r} \left\{ \sigma^{-1}\left[1 + \xi\left(\frac{\mu - z^{(k)}}{\sigma}\right)\right]^{-1/\xi - 1} \right\},$$

  valid when $1 + \xi\left(\frac{\mu - z^{(k)}}{\sigma}\right) > 0$ for $k = 1, \ldots, r$; here μ, σ, ξ are the "GEV parameters"
- In practice we fix a small value of r (e.g. 5, 10, 20) and let σ, ξ be constants for the whole dataset, while $\mu = \mu_t$ depends on year t
- Possible models for μ_t:
  - Model 1: $\mu_t = \beta_0 + \beta_1 t$ (linear trend)
  - Model 2: $\mu_t = \beta_0 + \beta_1(t - t_0) + \beta_2(t - t_0)_+$ (changepoint in year t_0)

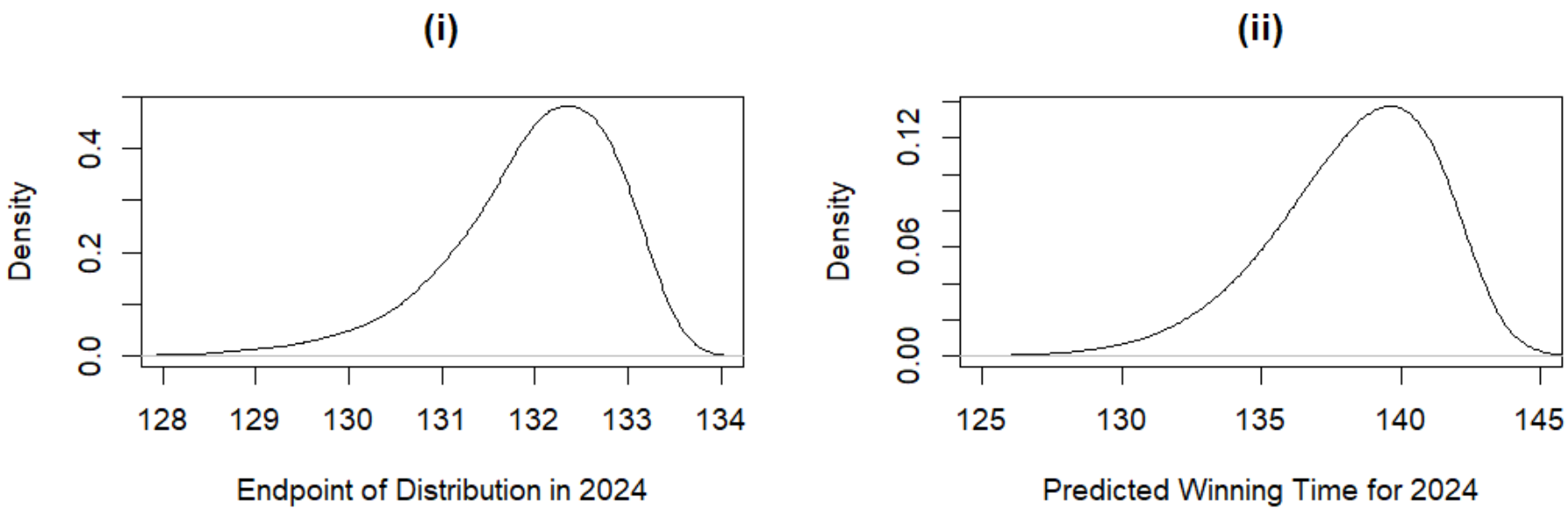
Outline of our method

- Focus on two quantities: the endpoint of the distribution (best possible time) and the actual winning time in 2024, conditional on all data prior to 2024.

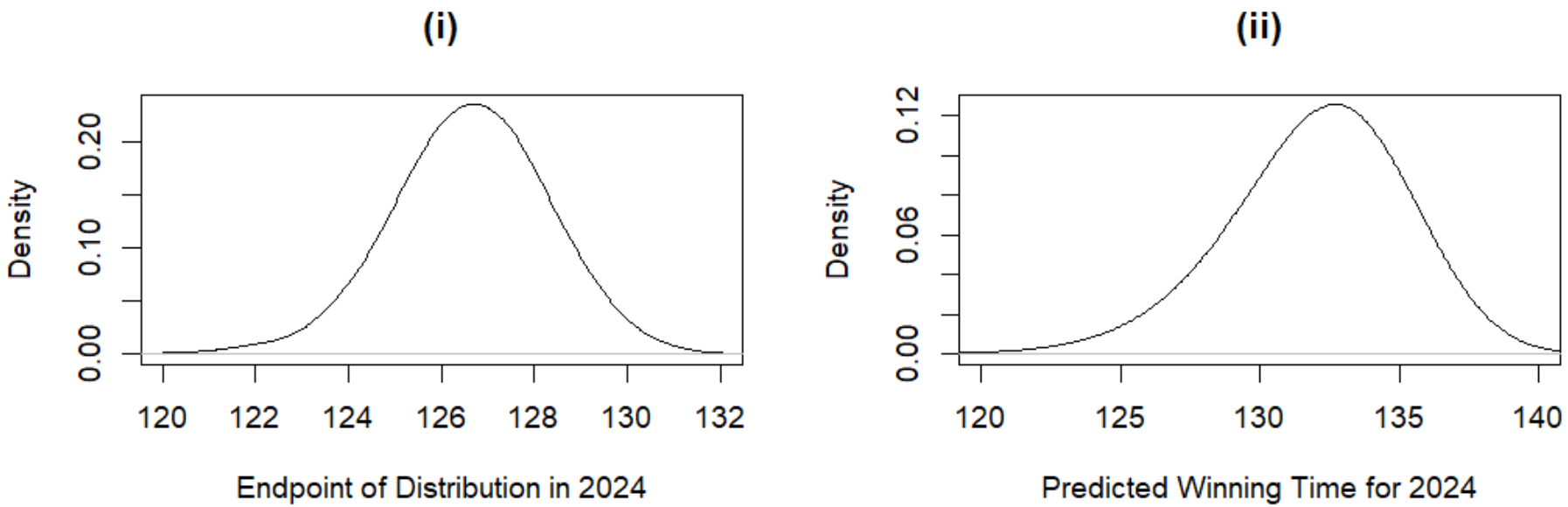
- Compute posterior density curves for both quantities

- Two trend models: linear or changepoint

- Other assumptions: $r = 10$, start year 1998, changepoint in 2016 (for the changepoint model)



Posterior density plots for the endpoint and the predicted 2024 winning time under linear trend. The (estimated) probability that the winning time is < 130 minutes is about 0.011 — "unlikely but not impossible"



Posterior density plots for the endpoint and the predicted 2024 winning time under changepoint model. The (estimated) probability that the winning time is < 130 minutes is about 0.25 — maybe even too large to be believable?

Sensitivity analysis I

Start Year	Endpoint				Winning Time			
	r=5	r=10	r=15	r=20	r=5	r=10	r=15	r=20
1998	0.17	0.034	0.031	0.091	0.004	**0.011**	0.013	0.014
2002	0.273	0.045	0.067	0.172	0.006	0.011	0.015	0.016
2005	0.211	0.07	0.121	0.213	0.015	0.022	0.024	0.024
2008	0.433	0.481	0.552	0.627	0.055	0.063	0.062	0.053
2005x	0.198	0.061	0.068	0.141	0.01	0.018	0.021	0.019
1998x	0.188	0.03	0.027	0.084	0.004	0.011	0.013	0.014
1998y	0.181	0.028	0.031	0.078	0.004	0.011	0.014	0.014

Posterior probability that the endpoint or the winning time is under 130 minutes, based on linear trend, for four values of r and different starting years.
2005x: analysis starting in 2005 but omitting 2007.
1998x: analysis with changepoint in 2013 instead of 2016.
1998y: analysis with changepoint in 2010 instead of 2016.

Sensitivity analysis II

Start Year	Endpoint				Winning Time			
	r=5	r=10	r=15	r=20	r=5	r=10	r=15	r=20
1998	0.931	0.983	0.992	0.996	0.097	**0.25**	0.306	0.315
2002	0.967	0.988	0.996	0.996	0.168	0.324	0.392	0.34
2005	0.918	0.964	0.978	0.981	0.182	0.283	0.283	0.256
2008	0.596	0.73	0.771	0.847	0.079	0.116	0.132	0.125
2005x	0.92	0.973	0.976	0.98	0.151	0.262	0.297	0.258
1998x	0.686	0.722	0.796	0.874	0.037	**0.069**	0.092	0.106
1998y	0.477	0.469	0.584	0.656	0.029	**0.057**	0.065	0.066

Same as previous table, but based on changepoint model.

Conclusions from Chicago analysis

- Trends in the data are clearly significant, and there is also strong evidence that a changepoint model fits better than a linear trend model, though not necessarily based on 2016 as the changepoint

- For estimated probabilities that the winning time for 2024 is below 130 minutes, conditional on previous times up to 2023, is never exceptionally small (smallest is 0.004, but most of our estimated probabilities are quite a bit larger than that), so we cannot say that Chepngetich's performance is "too good to be true"

- The results contrast strongly with similar analyses for Chinese women runners in 1993 (Smith 1997, *Applied Statistics*)

- Punchline: **no reason to dispute the record!**

Ruth Chepngetich Officially Banned For Doping, Marathon WR Holder

Ruth Chepngetich has officially been banned from the sport by the AIU after being provisionally suspended earlier this year.

Oct 23, 2025 by John Davern

Michael Reaves/Getty Images

Modified Conclusion

Even without Chepngetich, it's highly likely that *some runner* will break 2:10 for the women's marathon, if not in 2024, then in some near-future year

Our Work with the Boston Marathon

BOSTON MARATHON
April 18, 1994
Marathon Foto

From: Richard Smith [mailto:rls@email.unc.edu]
Sent: Wednesday, November 10, 2010 10:02 PM
To: Info Account
Subject: project regarding Boston qualifying times

I am a statistics professor at the University of North Carolina. I am also a keen marathon runner and will be running my tenth Boston in 2011 (yes, I did get in ...)

I am aware that there has been much discussion of Boston qualifying times. Together with two students, I have started on the following project. We are downloading results from major marathons and looking at the distribution of times within different age and sex categories. We are doing this with a view to showing what times are comparable across different age and sex categories. For example, about 10% of all runners over all marathons qualify for Boston. Our method aims at calculating the time that this corresponds to within each age/sex category, first doing the calculation separately for each marathon race, but then combining results across races to get overall standards. We believe our results would be valuable in evaluating whether current Boston standards are equally fair across all categories, or in deciding on new standards in the event that Boston decided to change the requirements.

At the moment, this is purely an academic project. One of the students is an undergraduate who will earn honors credit for his report. The three of us intend to write up a paper for one of the professional journals that publish papers on sports statistics. However, if there were an actual interest in what we were doing by the organizers of the Boston Marathon, we could work with you to develop the results in a form that you could use.

If you're interested in knowing more about what we're doing, please let me know. We could then continue the discussion by email or phone to work out the best way forwards.

Sincerely yours,

Richard Smith
University of North Carolina
Chapel Hill, NC

-----Original Message-----
From: Jack Fleming <XXXXX@XXXXX>
Sent: Thursday, November 11, 2010 6:56 PM
To: Smith, Richard L <rls@email.unc.edu>

Richard-
Please give me a call on Friday.
Or, please give me a number where I can reach you on Friday.
Thanks,
Jack Fleming
Director of Marketing and Communications Boston Athletic Association fleming@baa.org
617-XXX-XXXX (office/desk)

Qualifying Times for the Boston Marathon

• A http://chance.amstat.org/category/articles/

Richard L. Smith, Scott Powers, and Jessi Cisewski

Patriots' Day of 1897 marked the first of what is now the oldest annual marathon in the world: the Boston Marathon. The Boston Athletic Association (BAA) operates this marathon in which runners from around the world strive to participate. The Boston Marathon is not only historically appealing for runners, but is also considered a grueling course—topped off with "Heartbreak Hill" after mile 20 of 26.2. An extra twist to the allure of the Boston Marathon is that runners have to satisfy the BAA qualifying time standards in a certified marathon within about a year and a half of the desired Boston Marathon. Qualifying standards for the Boston Marathon were first established in the 1970s, when they were viewed as a means of controlling the size of the field while continuing to allow established marathon runners to participate. They have since been revised a number of times.

Table 1 contains the qualifying times used for the 2011 Boston Marathon (QT1), which had been in place since 2003. An additional 59 seconds is accepted for each standard. For instance, a man aged 18–34 could have run up to 3:10:59 and still been accepted into the race. Also, while race organizers may publish both "gun" and "chip" times, the chip time (representing net time between crossing the start and finish lines) is accepted as the basis of Boston

Chance 27 (3), 25-33.

The Problem

- Boston is the only major marathon race where the primary mode of entry is through qualifying times
- The capacity of the course is limited to about 30,000 runners
- The ideal solution would be to set the qualifying times so that the number of qualified entrants exactly matches the number of available places
- Our task is essentially *predict the number of entrants*, but also show how this changes if the qualifying times are adjusted

2027 Boston Marathon Qualifying Standards

AGE GROUP	MEN'S STANDARD	WOMEN'S STANDARD	NON-BINARY STANDARD
18-34	2:55:00	3:25:00	3:25:00
35-39	3:00:00	3:30:00	3:30:00
40-44	3:05:00	3:35:00	3:35:00
45-49	3:15:00	3:45:00	3:45:00
50-54	3:20:00	3:50:00	3:50:00
55-59	3:30:00	4:00:00	4:00:00
60-64	3:50:00	4:20:00	4:20:00
65-69	4:05:00	4:35:00	4:35:00
70-74	4:20:00	4:50:00	4:50:00
75-79	4:35:00	5:05:00	5:05:00
80 AND OLDER	4:50:00	5:20:00	5:20:00

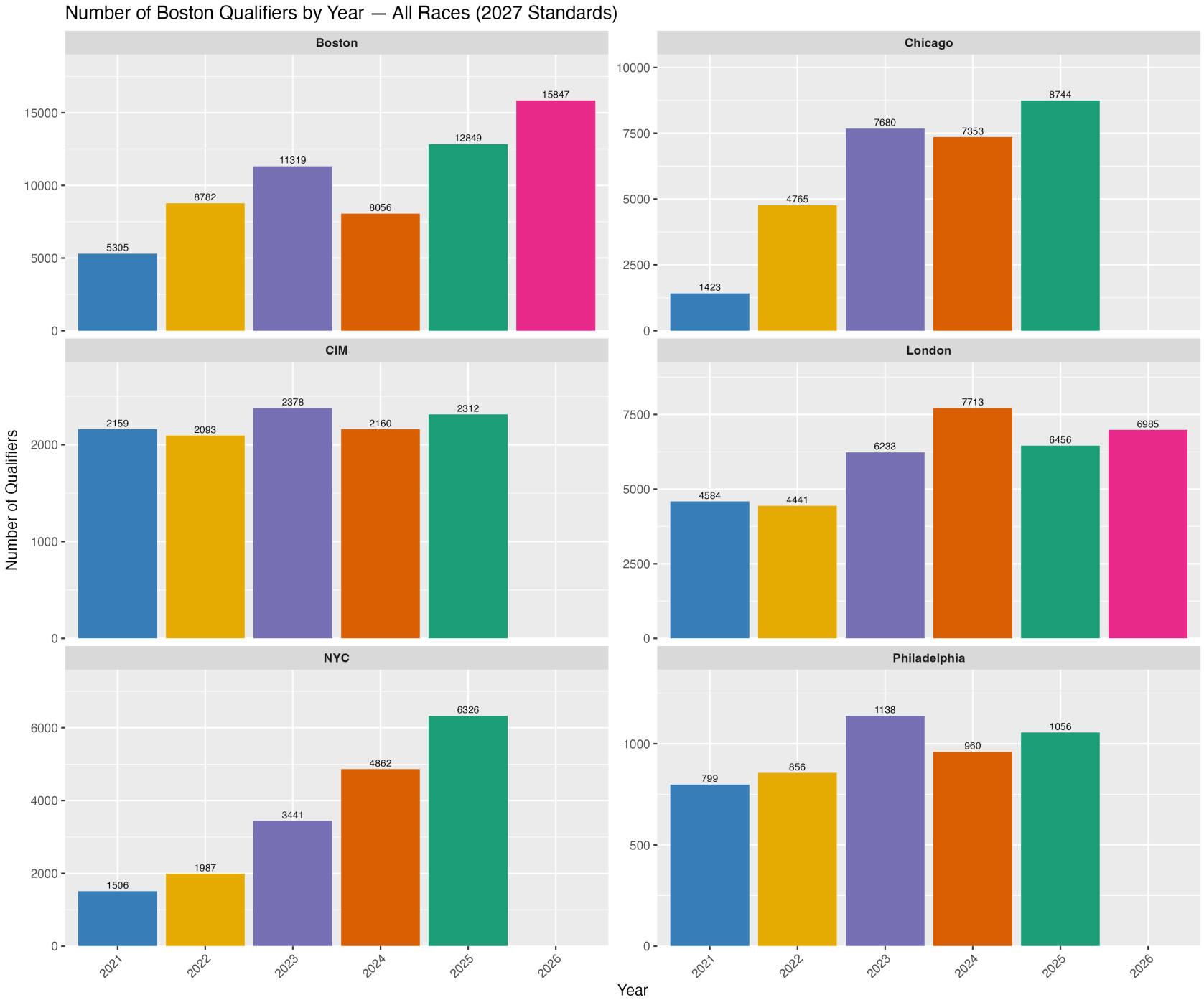
What's New in 2026?

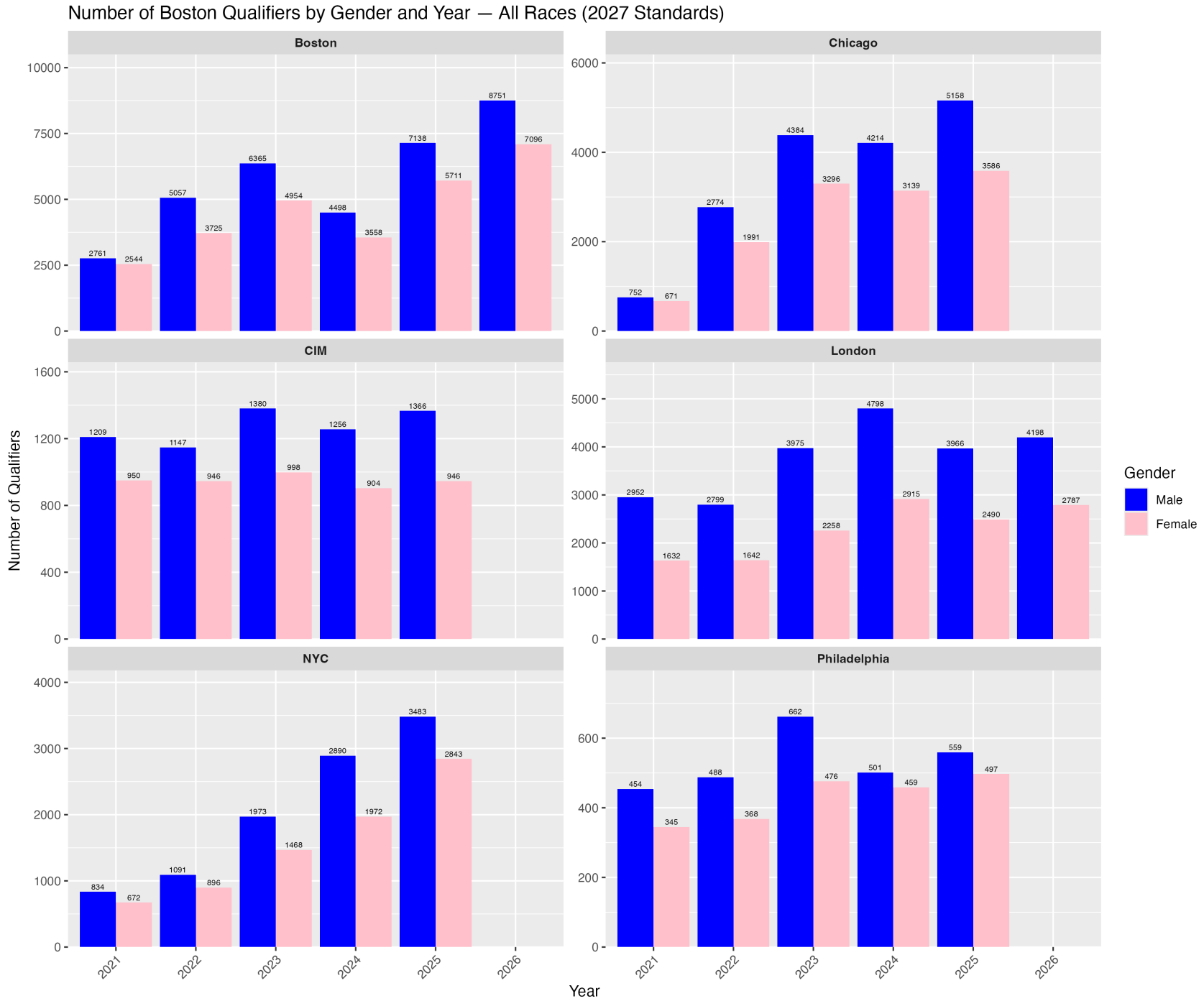
- In recent years, the race has generally been oversubscribed
- Their solution is to impose a "cutoff time" — you have to beat the qualifying time by at least the cutoff to be accepted for the race
- For the 2026 race, the cutoff was 4 minutes, 34 seconds and 8,887 qualified runners were rejected
- But the runners keep getting faster ...

Our Team

- Lily Feingold (PhD student in statistics, UNC)
- Coleman Ferrell (PhD student in statistics, UNC)
- Abigail Mabe (MS student in biostatistics, UNC)
- Kendall Thomas (PhD student in statistics, UNC)
- Richard Smith (professor of statistics, UNC)

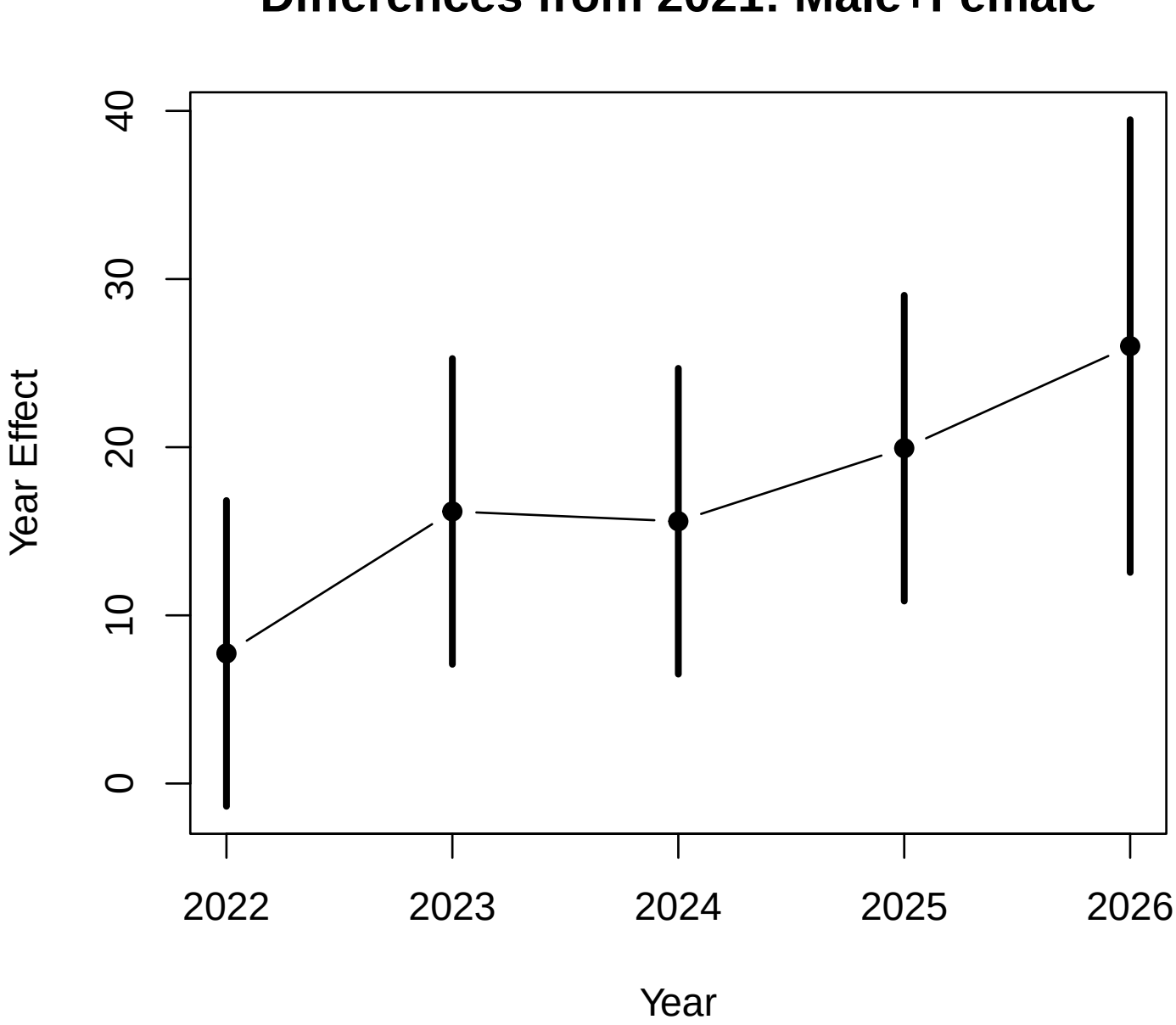

399

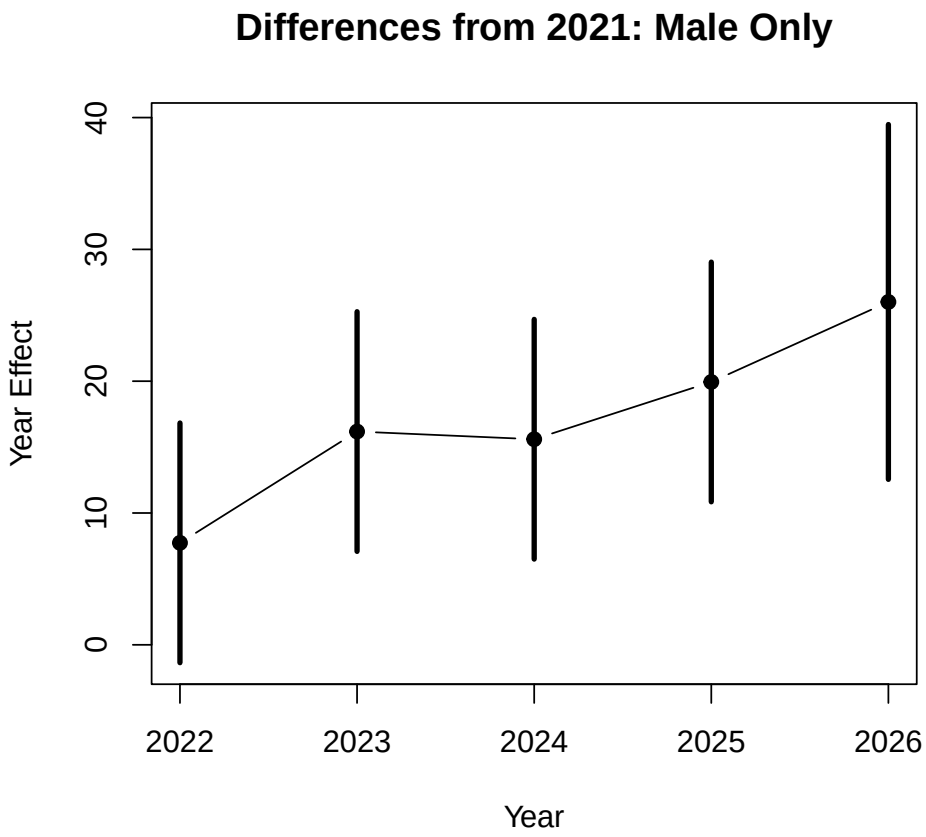

Number of Boston Qualifiers by Year — All Races (2027 Standards)
Boston
5305
8782
11319
8056
12849
15847
Chicago
1423
4765
7680
7353
8744
CIM
2159
2093
2378
2160
2312
London
4584
4441
6233
7713
6456
6985
NYC
1506
1987
3441
4862
6326
Philadelphia
799
856
1138
960
1056
Number of Qualifiers
Year
2021
2022
2023
2024
2025
2026

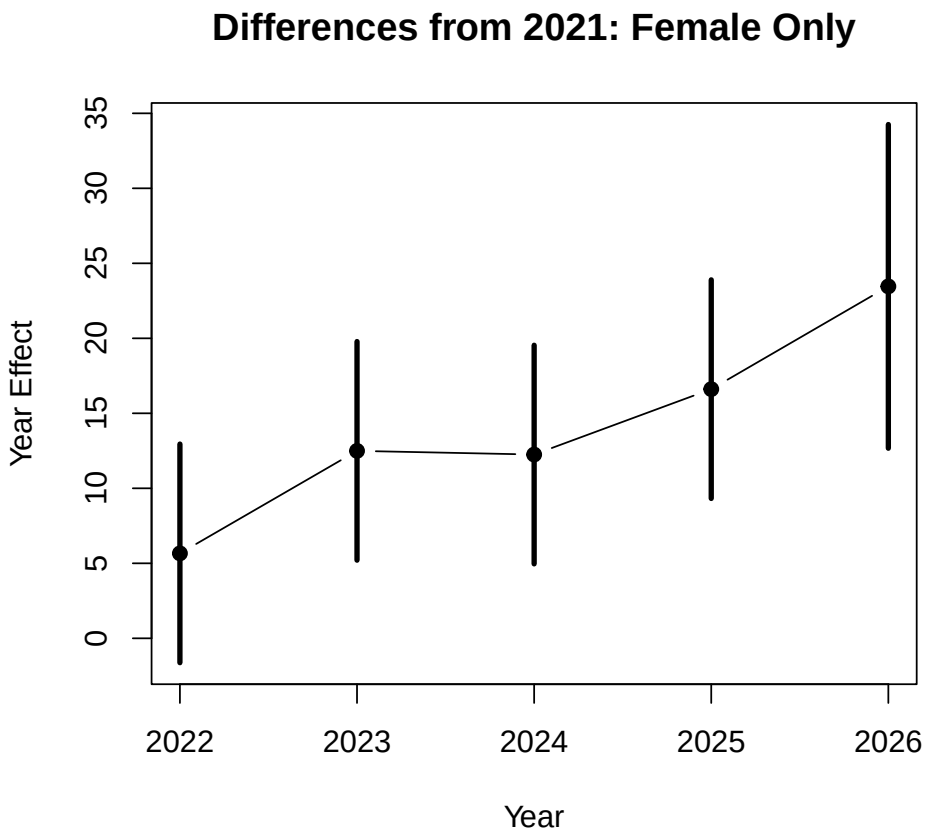

Number of Boston Qualifiers by Gender and Year — All Races (2027 Standards)
Boston
Chicago
CIM
London
NYC
Philadelphia
Number of Qualifiers
Year
Gender
Male
Female
2761
2544
5057
3725
6365
4954
4498
3558
7138
5711
8751
7096
752
671
2774
1991
4384
3296
4214
3139
5158
3586
1209
950
1147
946
1380
998
1256
904
1366
946
2952
1632
2799
1642
3975
2258
4798
2915
3966
2490
4198
2787
834
672
1091
896
1973
1468
2890
1972
3483
2843
454
345
488
368
662
476
501
459
559
497
2021
2022
2023
2024
2025
2026

Looking for Trends

- ANOVA analysis — treat both "year" and "race" as categorical variables
- year as a fixed effect, race as a random effect
- applied to square root of counts of qualified runners by 2026/27 standards
- Result: estimates of the year effect for each year, with confidence intervals


Differences from 2021: Male+Female
Year Effect
0
10
20
30
40
2022
2023
2024
2025
2026
Year


Differences from 2021: Male Only
Year Effect
0
10
20
30
40
2022
2023
2024
2025
2026
Year


Differences from 2021: Female Only
Year Effect
0
5
10
15
20
25
30
35
2022
2023
2024
2025
2026
Year

Conclusions from Boston Qualifiers Analysis

- The number of Boston Qualifiers from our six selected races has increased (almost) each year since 2021
- No sign that the trend is ending
- Other possible fixes (under way):
  - Tougher standard for downhill races
  - Introduce a partial lottery system
  - But...
- Even tougher standards may be on the way!

Thank you for your attention!

Preliminary draft paper at:

https://rls.sites.oasis.unc.edu/ChepngetichRecord.pdf

Slides at:

https://rls.sites.oasis.unc.edu/JSM2026.pdf