# *THE VARIATION OF MARATHON PERFORMANCES WITH AGE AND SEX*

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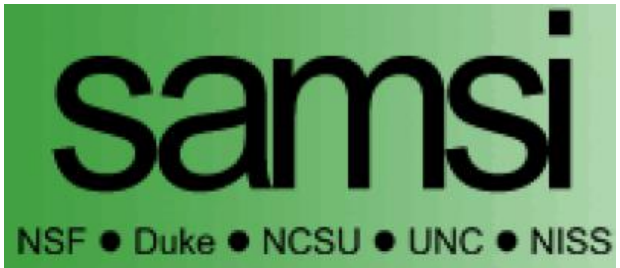
with input from:

Scott Powers (Stanford)

Jessi Cisewski (Carnegie Mellon)

Jack Fleming and Michael Pieroni (BAA)



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***PART I:*** Our work on qualifying times for the Boston Marathon (Smith, Powers, Cisewski, *Chance*, to appear)

***PART II:*** A new "longitudinal" approach to age-related performances (work in progress)

# *BACKGROUND*

- The Boston Marathon is the only major marathon to require qualifying standards of (almost) all participants
- The need to revise the standards became apparent after entries for the 2011 race closed out in one day
- My interest in this arose out of extensive press discussion, including the idea that women's standards should be tightened relative to the men's
- I sent the BAA a proposal to do some statistical analysis
- Much to my surprise, they accepted …

# Table 1: Boston Marathon Qualifying Times (up to 2012)

| Age | Men | Women |
|---|---|---|
| 18-34 | 3hrs 10min | 3hrs 40min |
| 35-39 | 3hrs 15min | 3hrs 45min |
| 40-44 | 3hrs 20min | 3hrs 50min |
| 45-49 | 3hrs 30min | 4hrs 00min |
| 50-54 | 3hrs 35min | 4hrs 05min |
| 55-59 | 3hrs 45min | 4hrs 15min |
| 60-64 | 4hrs 00min | 4hrs 30min |
| 65-69 | 4hrs 15min | 4hrs 45min |
| 70-74 | 4hrs 30min | 5hrs 00min |
| 75-79 | 4hrs 45min | 5hrs 15min |
| 80 and over | 5hrs 00min | 5hrs 30min |

# *Our Work with the BAA*

- Objective: try to determine the total number of eligible runners under existing standard and under various proposed modifications
- Total of 641 “feeder” races from which at least one person qualified for the 2010 Boston Marathon
- Eliminated 362 as being small races, or out of US/Canada, or out of qualification window
- Left 279 races from which we would estimate qualifiers
- Complete counts from 37 “top feeder” races that sent most qualifiers to the Boston Marathon
- Complete counts from 5 other large races
- Randomly sampled 25 races out of remaining 237, scaled up numbers to estimate total qualifiers in those 237 races

**Table 2: Estimated totals by age group of all male and female marathon runners in all races, and numbers of qualifiers under 2011 qualifying standards.**

| Age Group | Total Runners | | Boston Qualifiers | |
|---|---|---|---|---|
| | M | F | M | F |
| 18-34 | 126780 | 126861 | 12004 | 12782 |
| 35-39 | 67271 | 48298 | 6630 | 5787 |
| 40-44 | 70890 | 45339 | 8305 | 6594 |
| 45-49 | 60644 | 34101 | 10994 | 6783 |
| 50-54 | 45712 | 22033 | 7541 | 3420 |
| 55-59 | 27609 | 10453 | 4378 | 1533 |
| 60-64 | 15799 | 4686 | 3204 | 649 |
| 65-69 | 6270 | 1584 | 1167 | 192 |
| 70-74 | 2488 | 397 | 560 | 52 |
| 75-79 | 601 | 113 | 84 | 9 |
| 80-99 | 148 | 28 | 21 | 6 |
| All ages | 424210 | 293893 | 54888 | 37809 |
| Total | | 718106 | | 92695 |

**Table 3: Percentage of qualifiers for all races with QT adjustments**

| Age | QT1 | | QT1 - 2 | | QT1 - 5 | | QT1 - 10 | | QT1 - 15 | | QT1 - 20 | | QT1 – 30 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group | M | F | M | F | M | F | M | F | M | F | M | F | M | F |
| 18-34 | 9.5 | 10.1 | 8.2 | 8.9 | 6.7 | 7.0 | 5.3 | 5.1 | 3.6 | 3.5 | 2.7 | 2.5 | 1.4 | 1.2 |
| 35-39 | 9.9 | 12.0 | 8.4 | 10.6 | 6.8 | 8.4 | 4.8 | 6.0 | 3.6 | 4.3 | 2.2 | 3.0 | 0.9 | 1.5 |
| 40-44 | 11.7 | 14.5 | 10.0 | 13.0 | 8.2 | 10.7 | 5.9 | 7.7 | 4.3 | 5.4 | 3.1 | 3.8 | 1.0 | 1.7 |
| 45-49 | 18.1 | 19.9 | 15.6 | 17.9 | 12.6 | 14.9 | 9.3 | 11.6 | 6.8 | 8.2 | 5.0 | 6.1 | 2.4 | 3.0 |
| 50-54 | 16.5 | 15.5 | 14.6 | 14.1 | 11.9 | 12.1 | 8.4 | 8.7 | 5.9 | 6.3 | 3.9 | 4.3 | 1.7 | 1.8 |
| 55-59 | 15.9 | 14.7 | 14.1 | 13.3 | 11.8 | 11.3 | 8.6 | 9.0 | 6.0 | 6.3 | 4.1 | 4.2 | 1.7 | 2.2 |
| 60-64 | 20.3 | 13.8 | 18.1 | 12.4 | 15.3 | 11.2 | 11.5 | 9.0 | 8.8 | 7.5 | 6.7 | 5.9 | 3.5 | 3.7 |
| 65-69 | 18.6 | 12.1 | 17.0 | 11.7 | 14.6 | 9.8 | 12.1 | 8.5 | 10.0 | 6.7 | 7.9 | 5.9 | 4.5 | 3.4 |
| 70-74 | 22.5 | 13.1 | 20.8 | 12.6 | 17.4 | 12.1 | 13.6 | 9.8 | 11.5 | 7.6 | 8.8 | 6.8 | 5.2 | 5.0 |
| 75-79 | 14.0 | 8.0 | 13.6 | 8.0 | 12.8 | 7.1 | 11.5 | 6.2 | 9.8 | 4.4 | 8.3 | 3.5 | 6.2 | 2.7 |
| 80-99 | 14.2 | 21.4 | 13.5 | 21.4 | 12.2 | 21.4 | 12.2 | 21.4 | 11.5 | 21.4 | 8.1 | 21.4 | 7.4 | 21.4 |

# *Conclusions from this exercise*

- In 18-34 age group, current standards *very slightly* favor women, but this would be reversed with as little as a 2-minute adjustment to women's qualifying times
- Qualifying percentages are higher in older age groups, where there are far fewer competitors (*is this fair?* – question for second part of talk)
- In my opinion, women over 60 do get a raw deal – there are far fewer of them than men in the same age groups, but the qualifying percentages are substantially smaller than men's

# *Decision by the BAA*

- Reduced all qualifying times by 5 minutes but also eliminated 59-second cushion
- Introduced 4-tier entry system which accepted runners in order of margin under the qualifying time for their age/sex group
- 2012: Old qualifying times still in effect, accepted all runners 1 m. 14 s. or better under their qualifying time
- 2013: New qualifying times in effect, accepted all qualified runners
- 2014: Expanded field included non-finishers from 2013; accepted all runners 1 m. 38 s. or better under their qualifying time (mine was 1 m. 54 s. under QT)

# *How well did our projections hold up?*

# Figure 1: Numbers of estimated and actual qualifiers by time increment

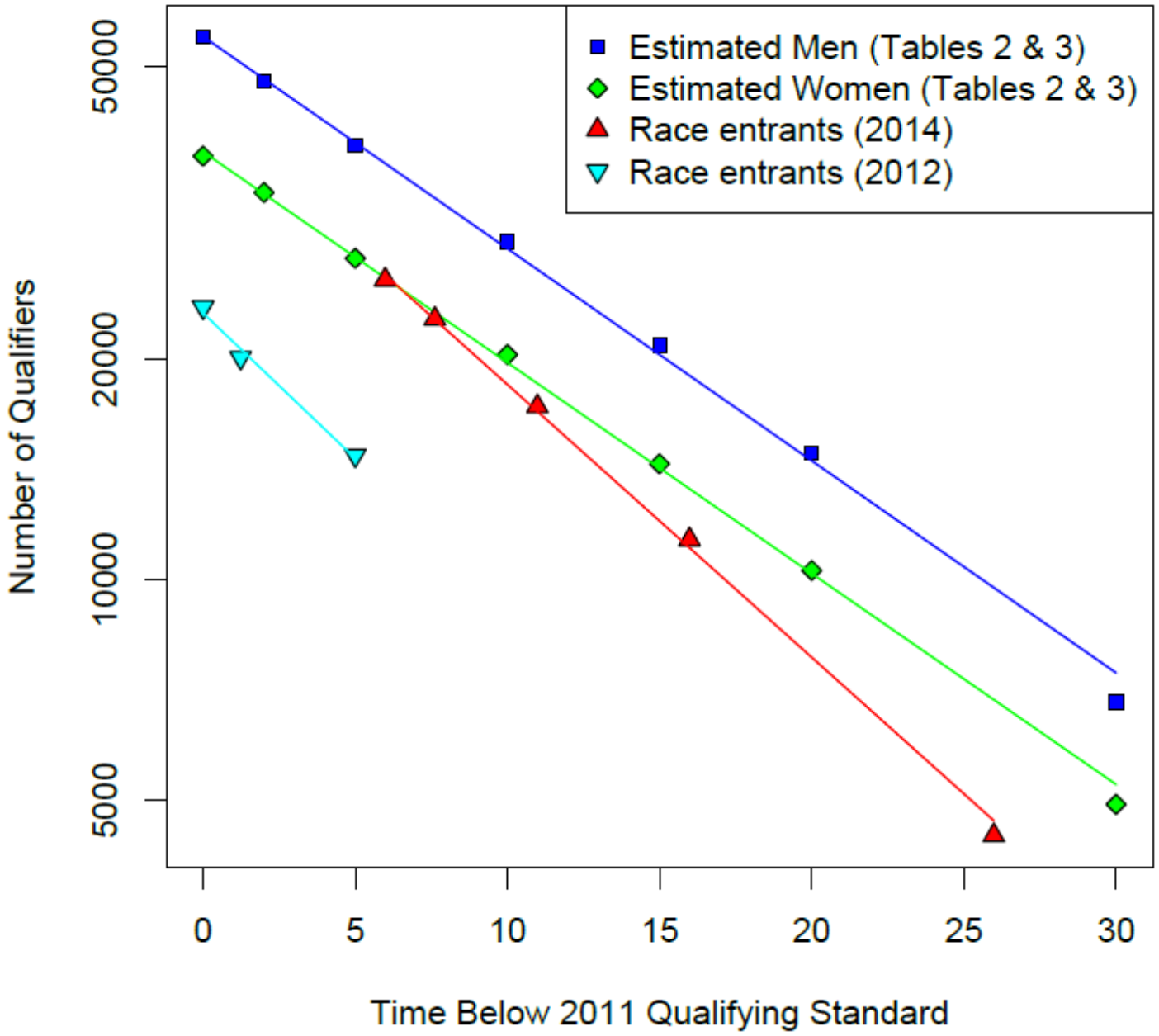

**Table 9: Changes in Expected and Observed Percentages from Old to New Qualifying Times for Each Age-Sex Category**

| Age | Expected | | Observed | |
|---|---|---|---|---|
| | Men | Women | Men | Women |
| 18-34 | -0.093 | -0.551 | -0.183 | -0.193 |
| 35-39 | -0.305 | -0.113 | -0.487 | 0.528 |
| 40-44 | -0.310 | 0.087 | -0.725 | -0.596 |
| 45-49 | -0.318 | 0.392 | -0.868 | -0.286 |
| 50-54 | 0.040 | 0.324 | -0.032 | 0.357 |
| 55-59 | 0.110 | 0.156 | 0.588 | 0.444 |
| 60-64 | 0.168 | 0.110 | 0.380 | 0.249 |
| 65-69 | 0.146 | 0.036 | 0.495 | 0.120 |
| 70-74 | 0.057 | 0.021 | 0.076 | 0.011 |
| 75-79 | 0.031 | 0.003 | 0.075 | 0.002 |
| 80 and over | 0.006 | 0.003 | 0.034 | 0.011 |

***Correlation 0.527***

# *Is This Correlation Statistically Significant?*

# *Is This Correlation Statistically Significant? Run a bootstrap …*

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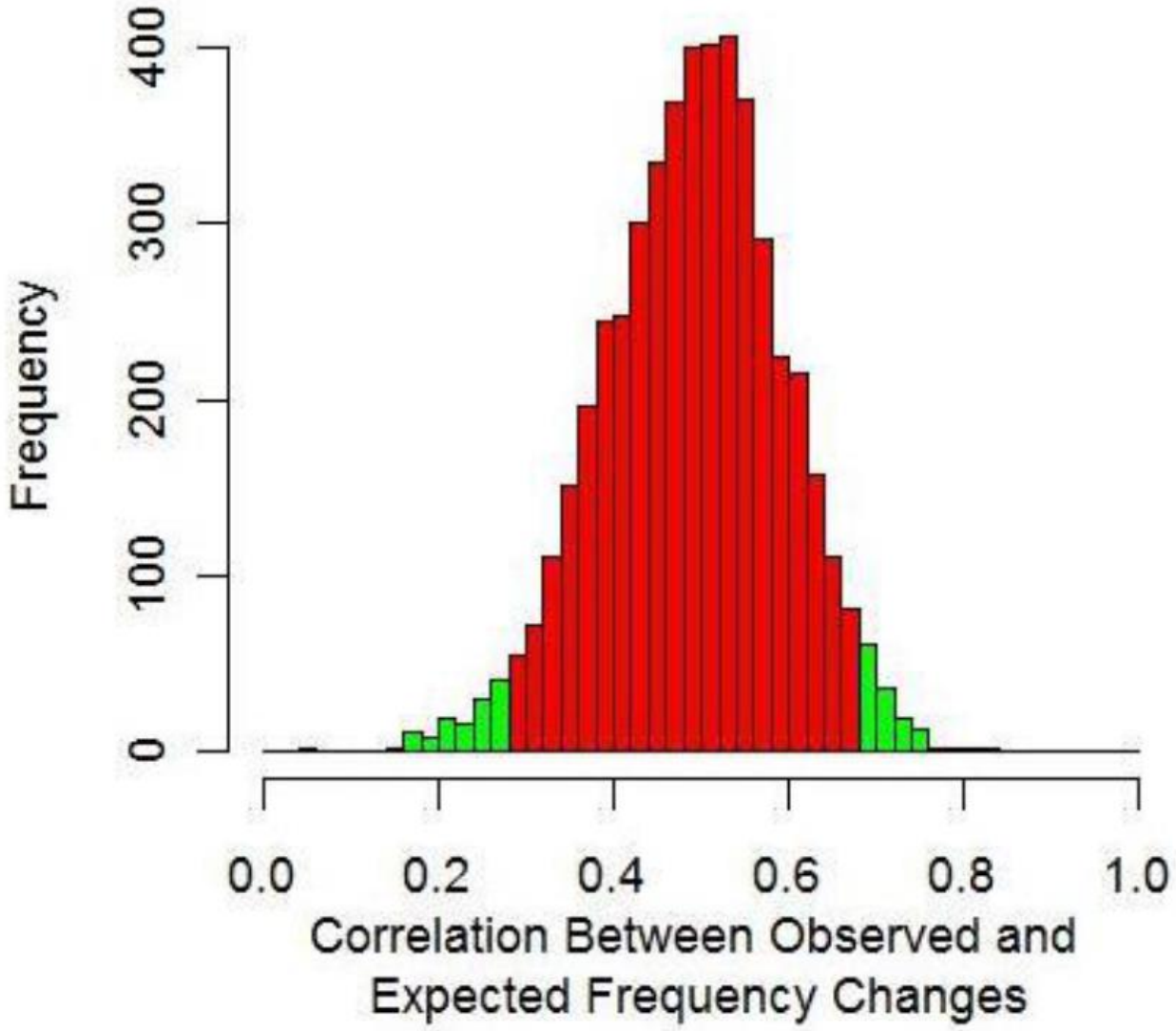
**Figure 2: Histogram of Bootstrapped Correlation Coefficients: Central 95% in Red**



# *Part II: Longitudinal Approach to the Performance v. Age Problem*

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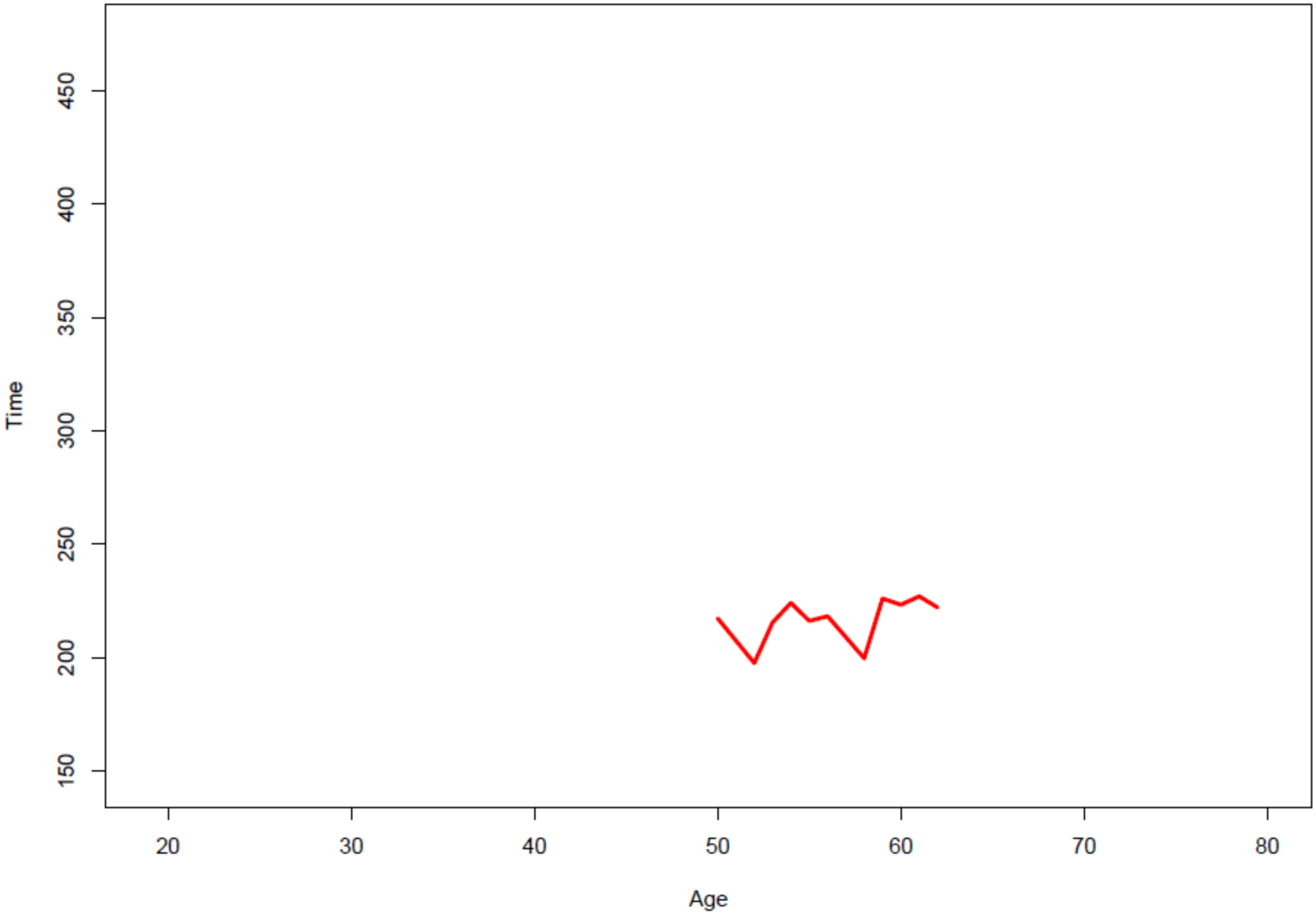
- Runners who did not finish in 2013 were estimated using Hammerling et al. (2014)
- Result: 547 men and 249 women identified (806 runners; 7,219 individual race results)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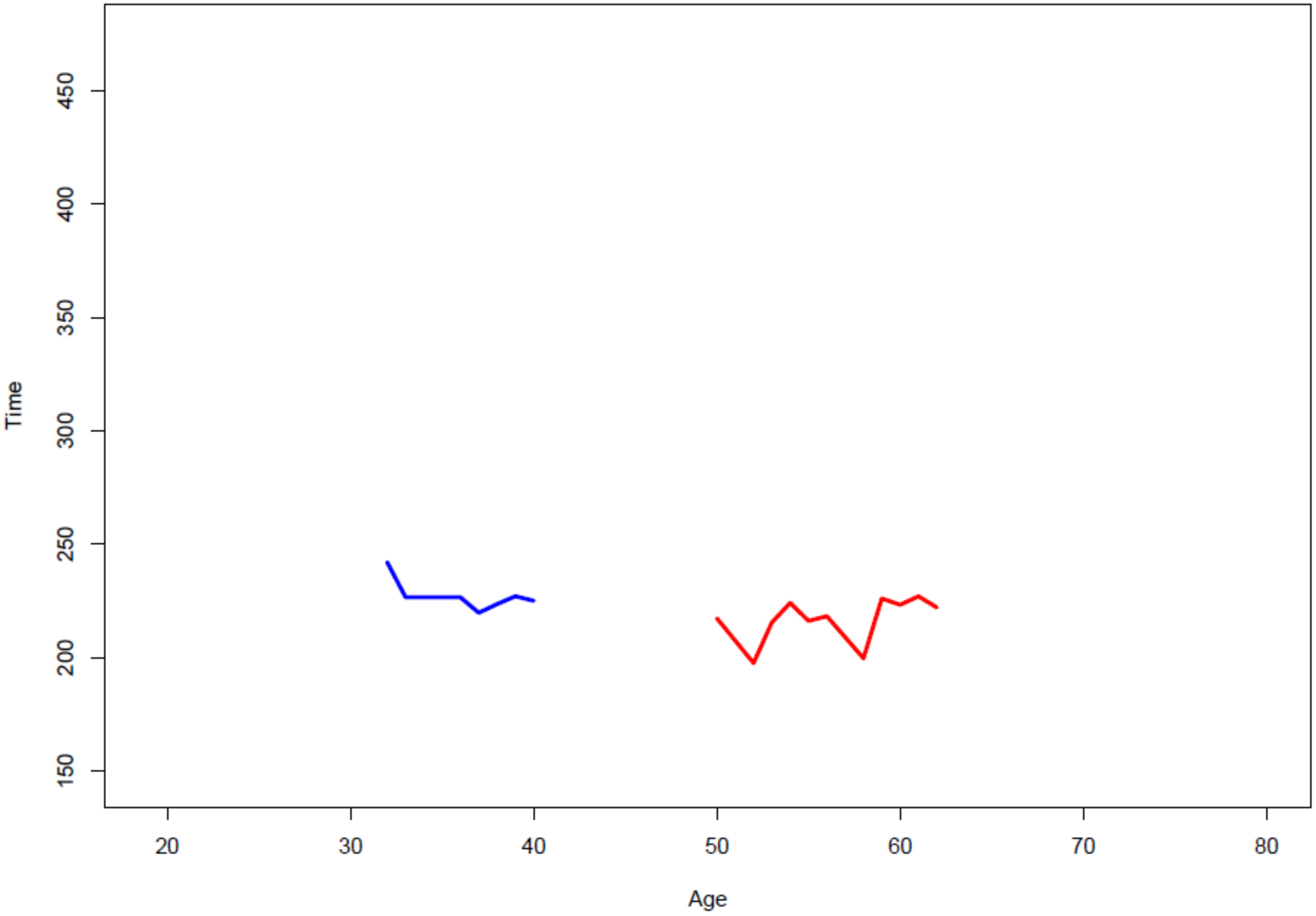
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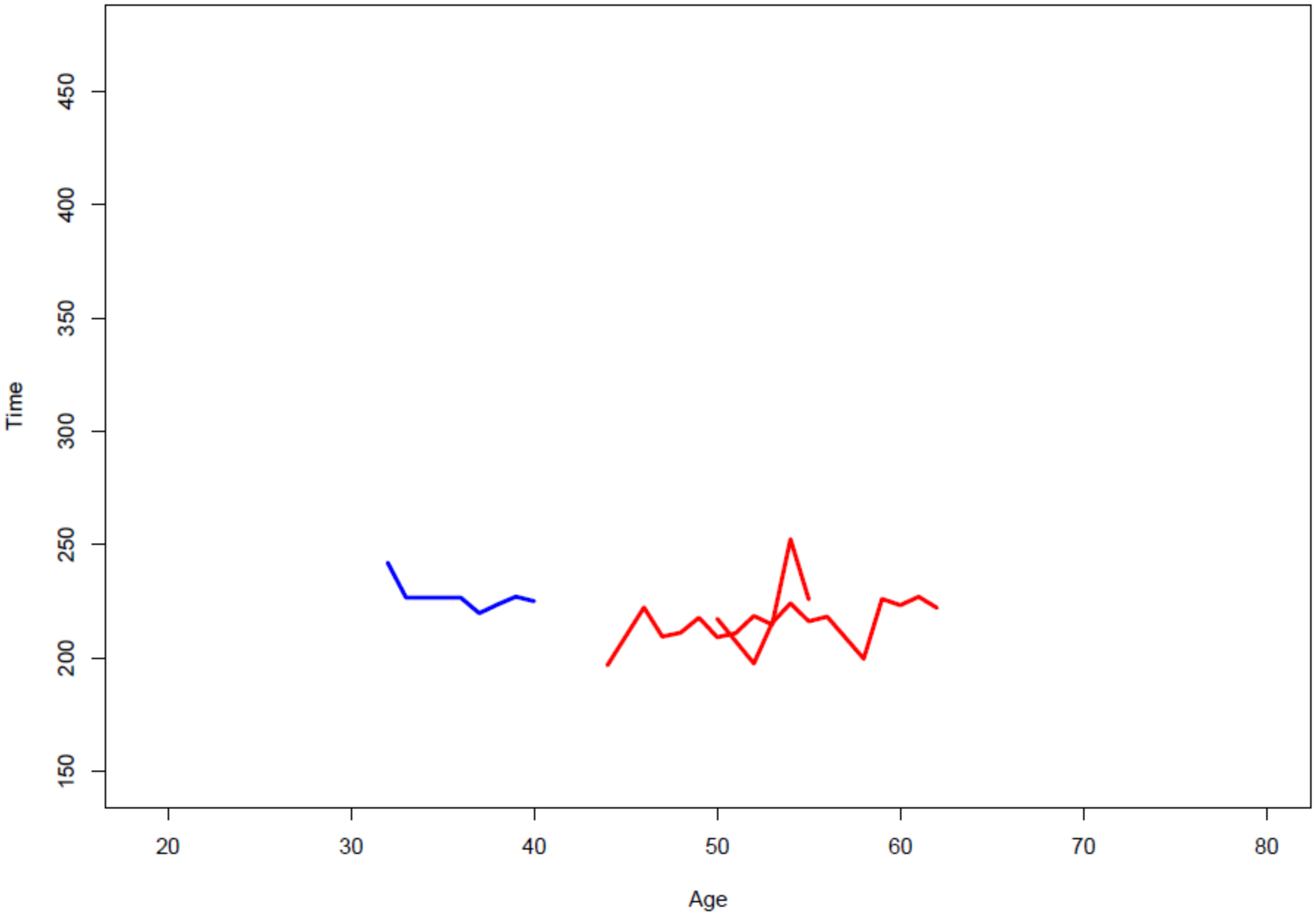
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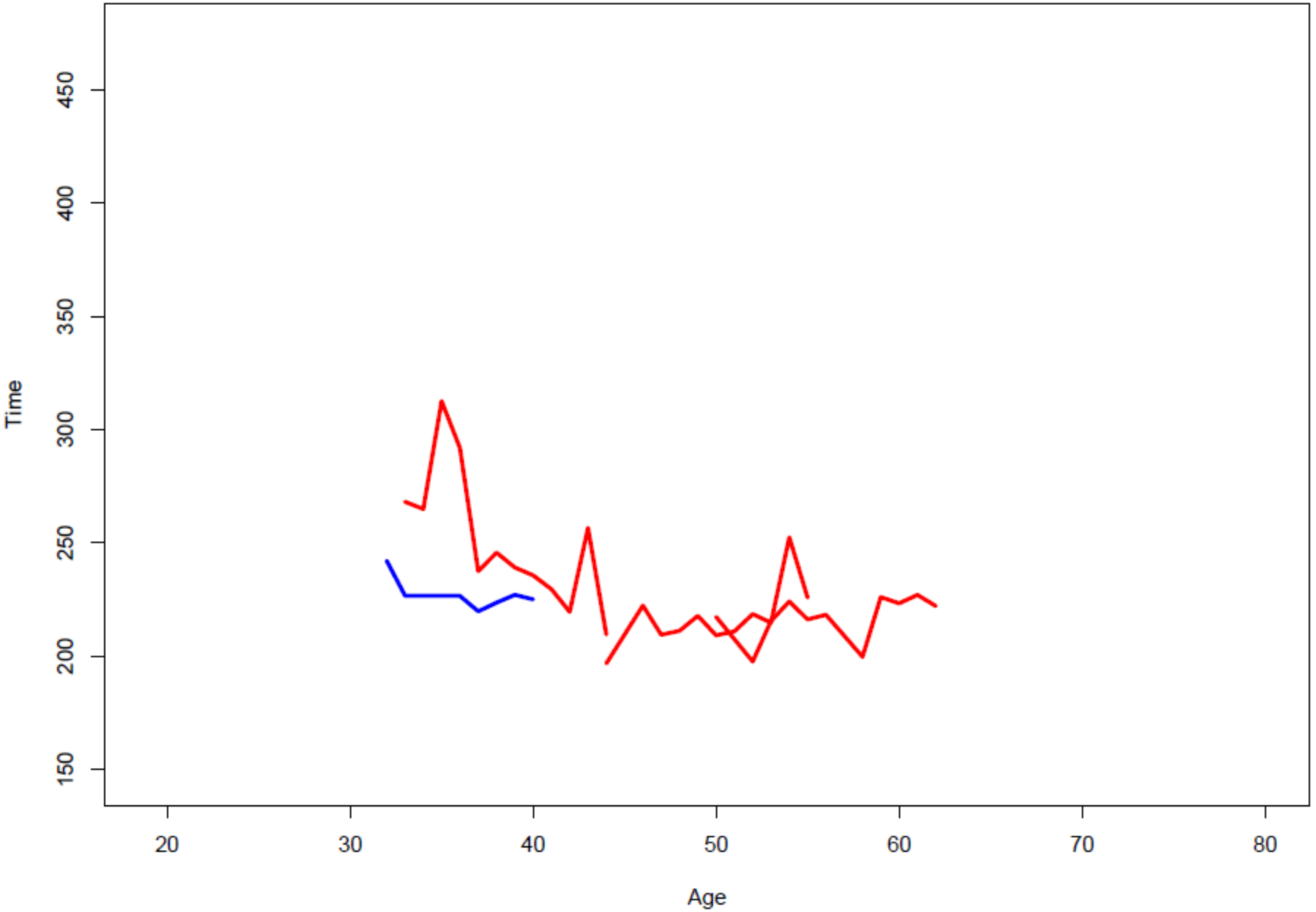
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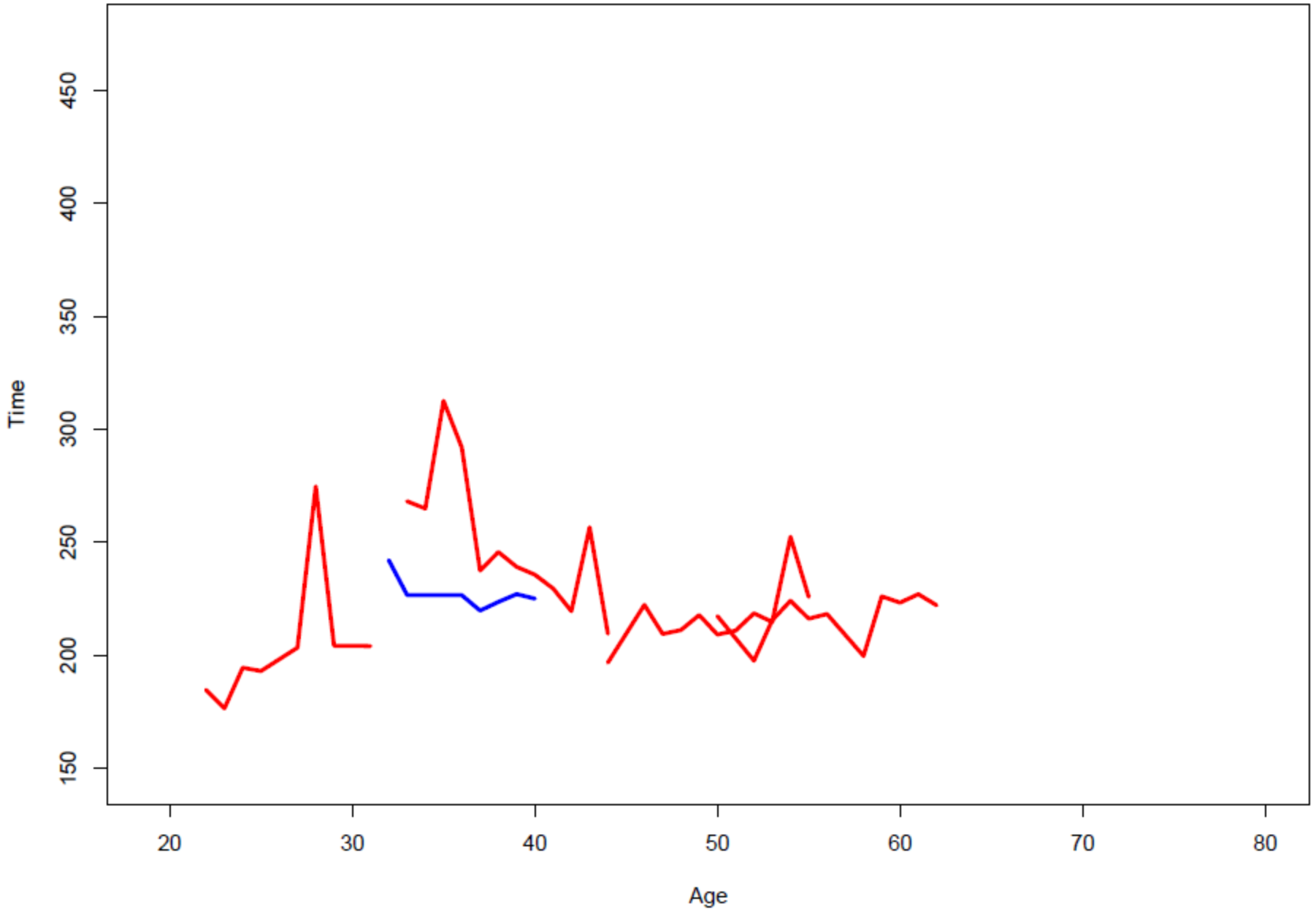
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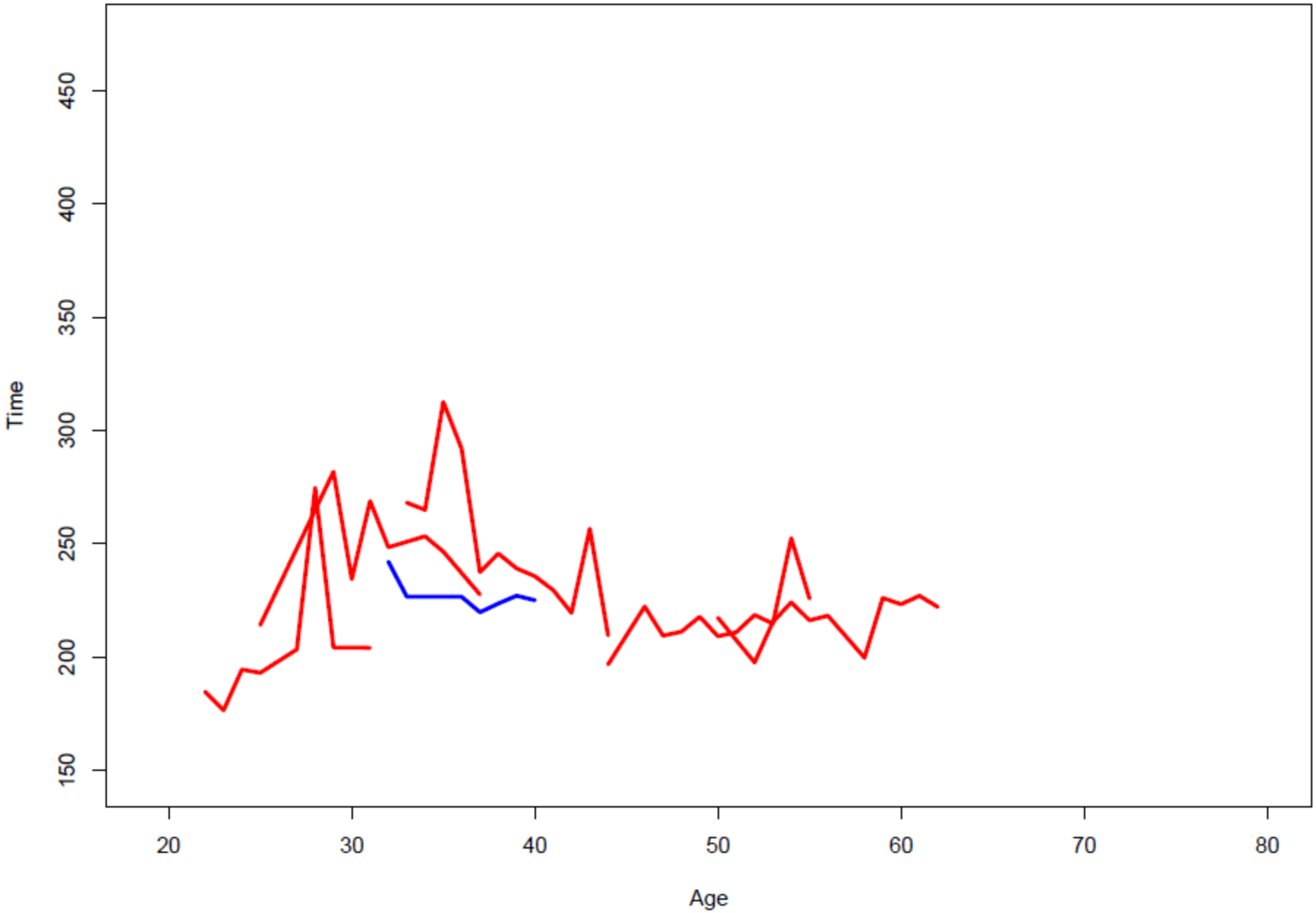
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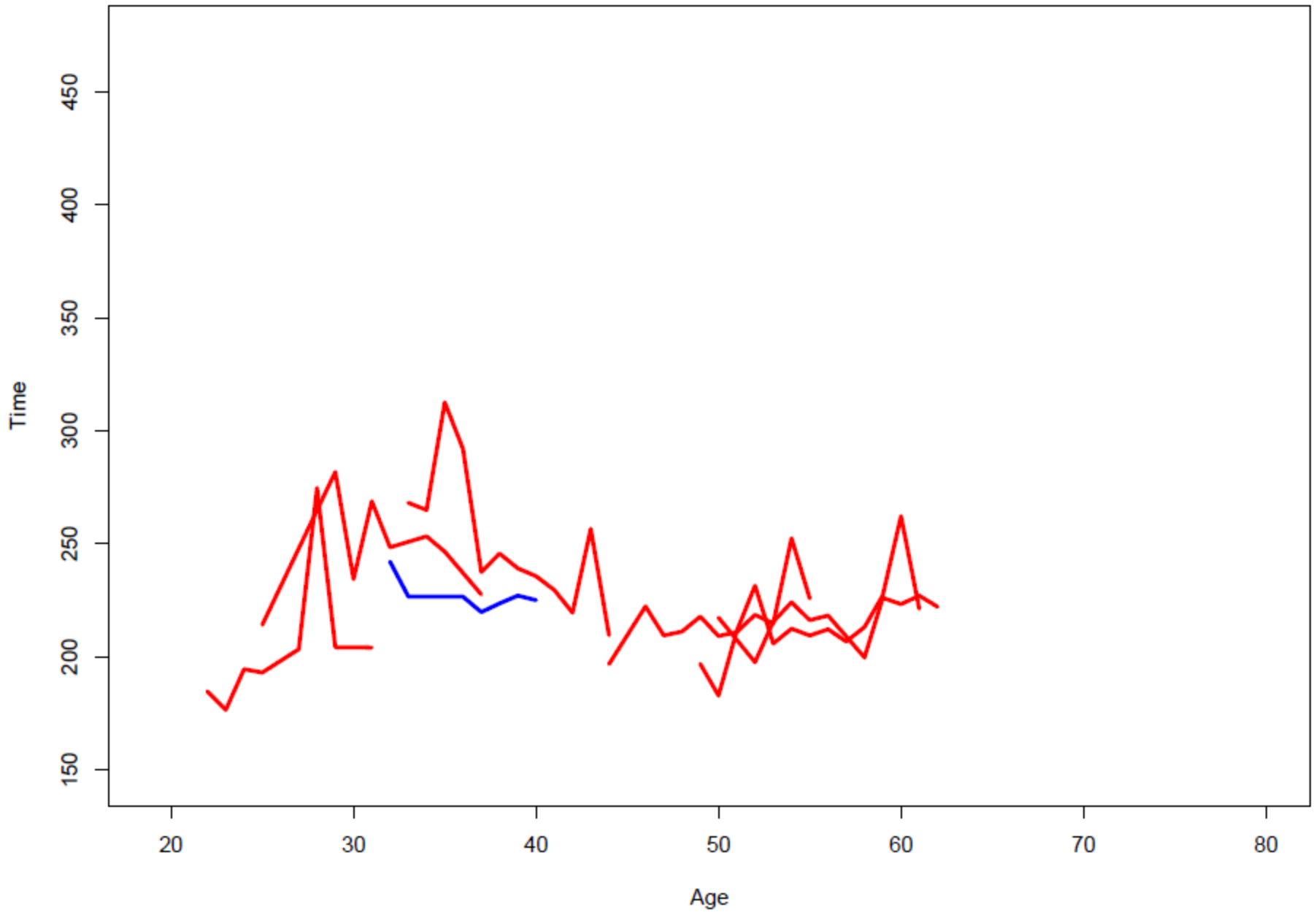
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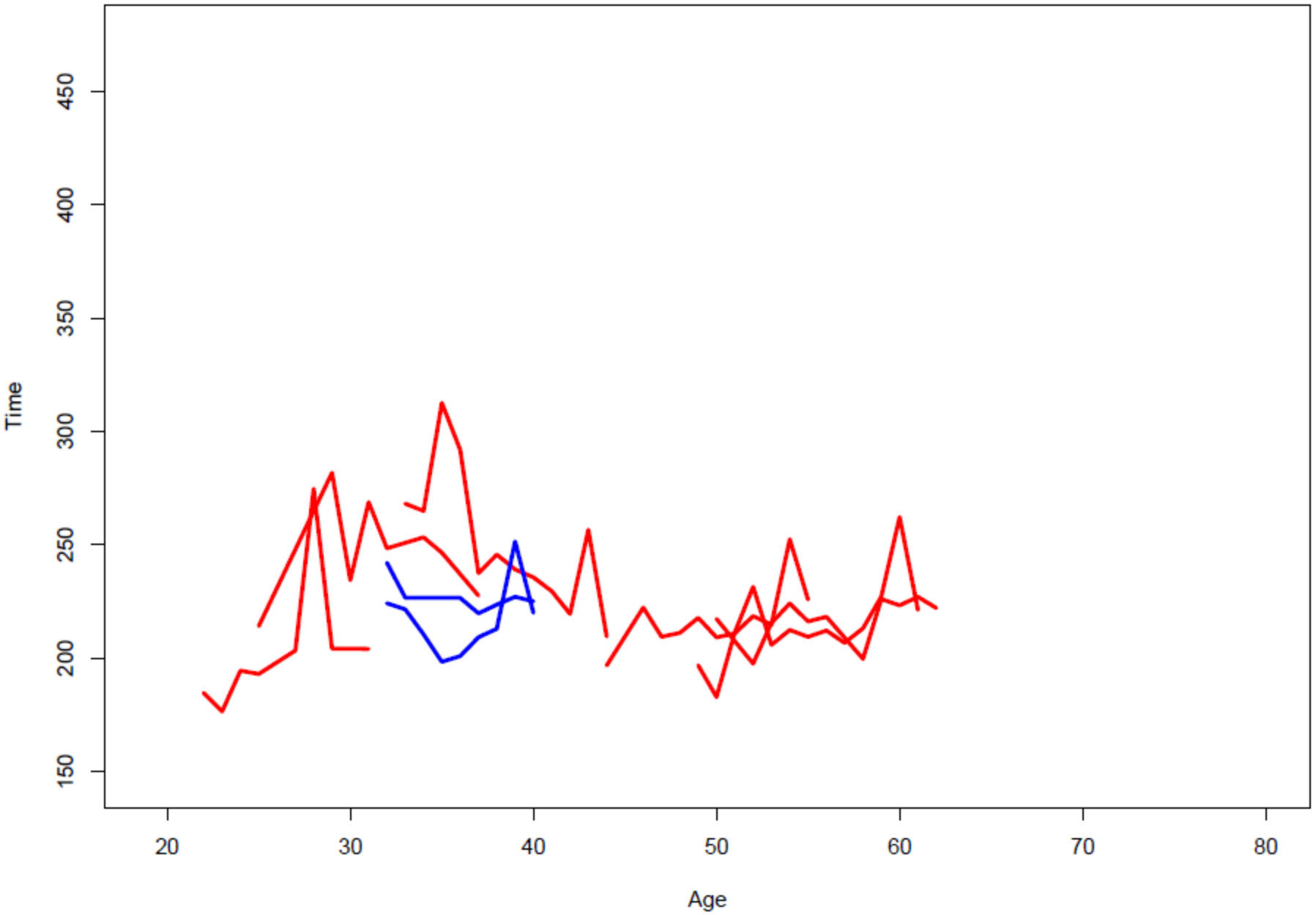
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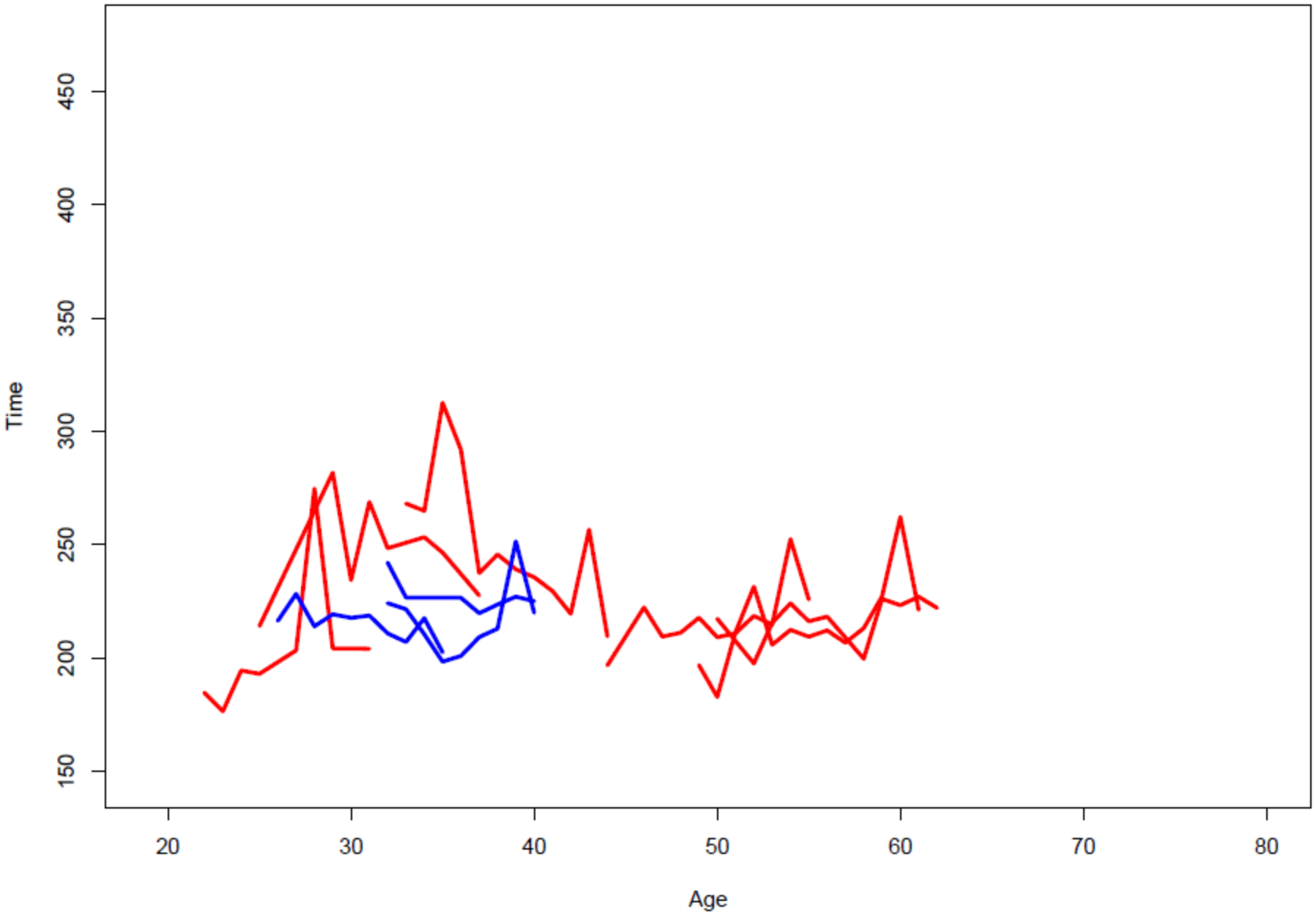
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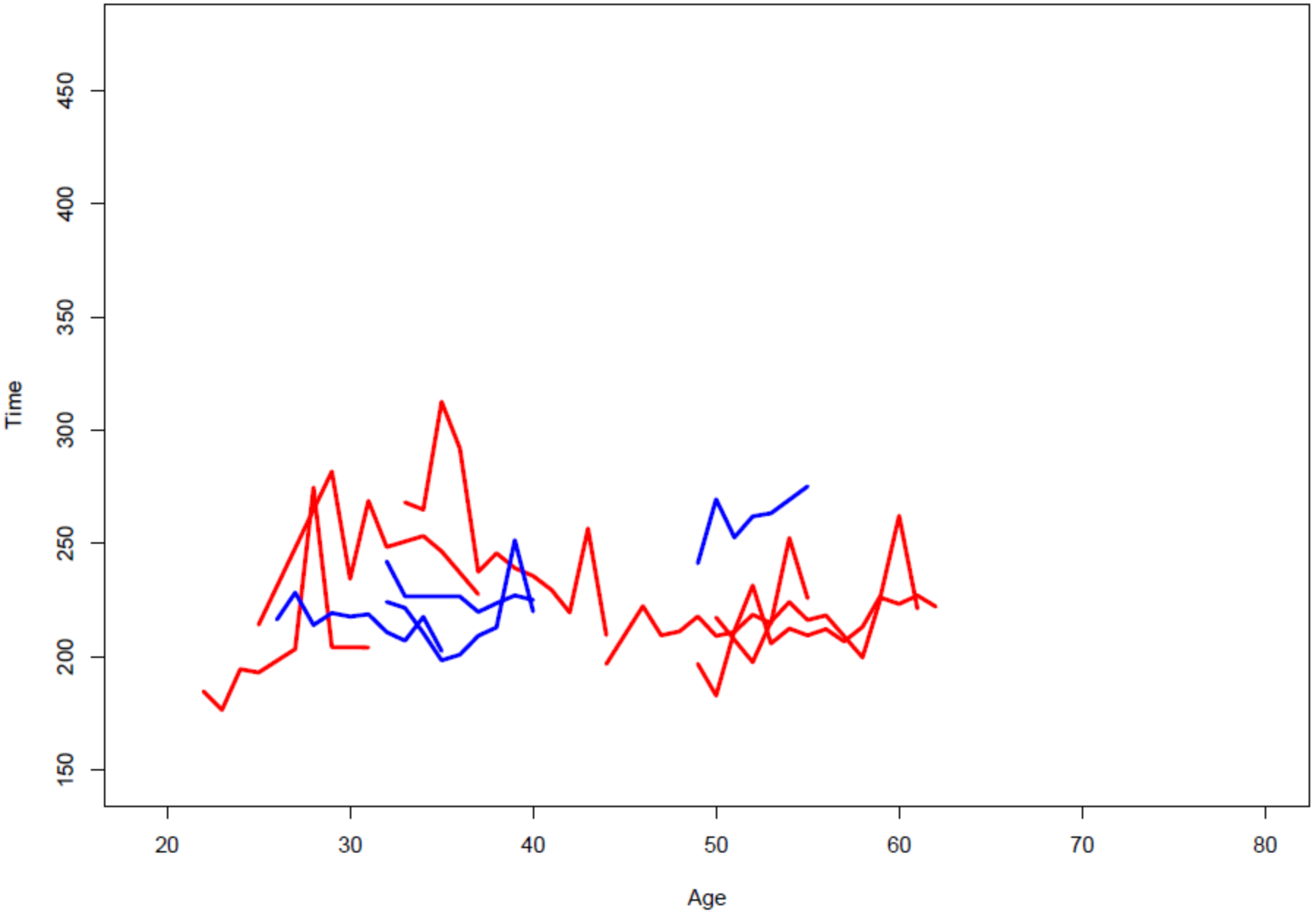
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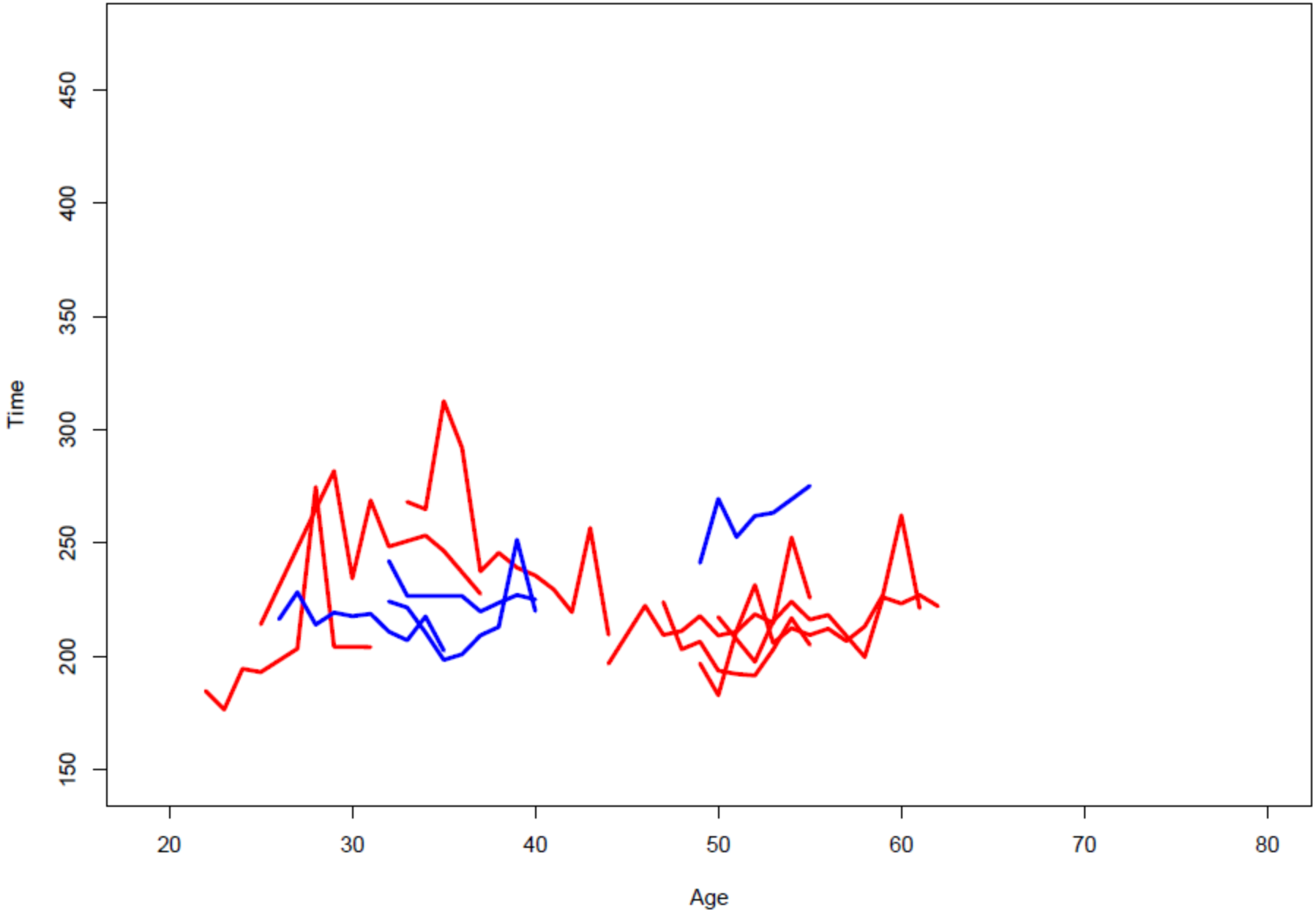
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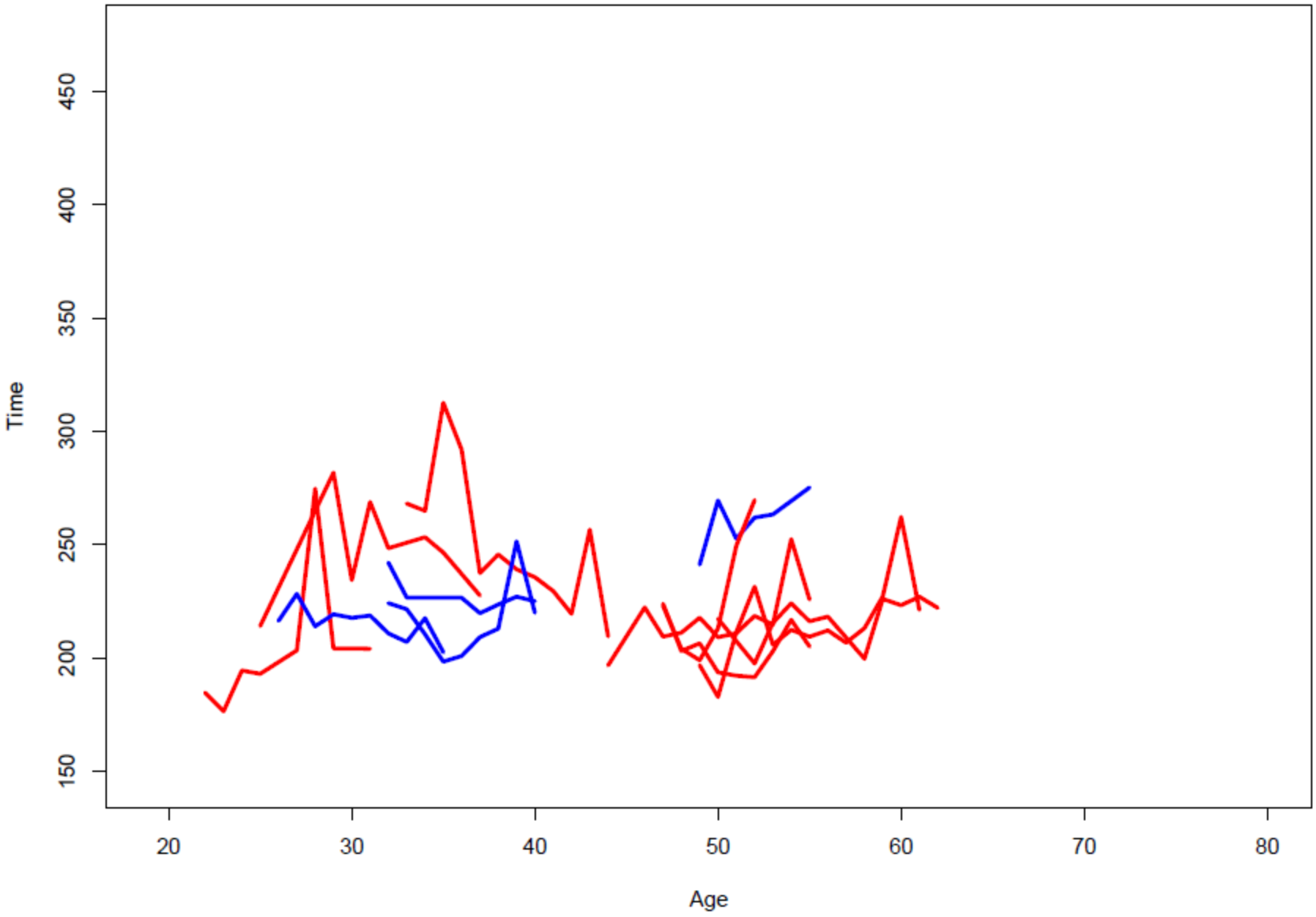
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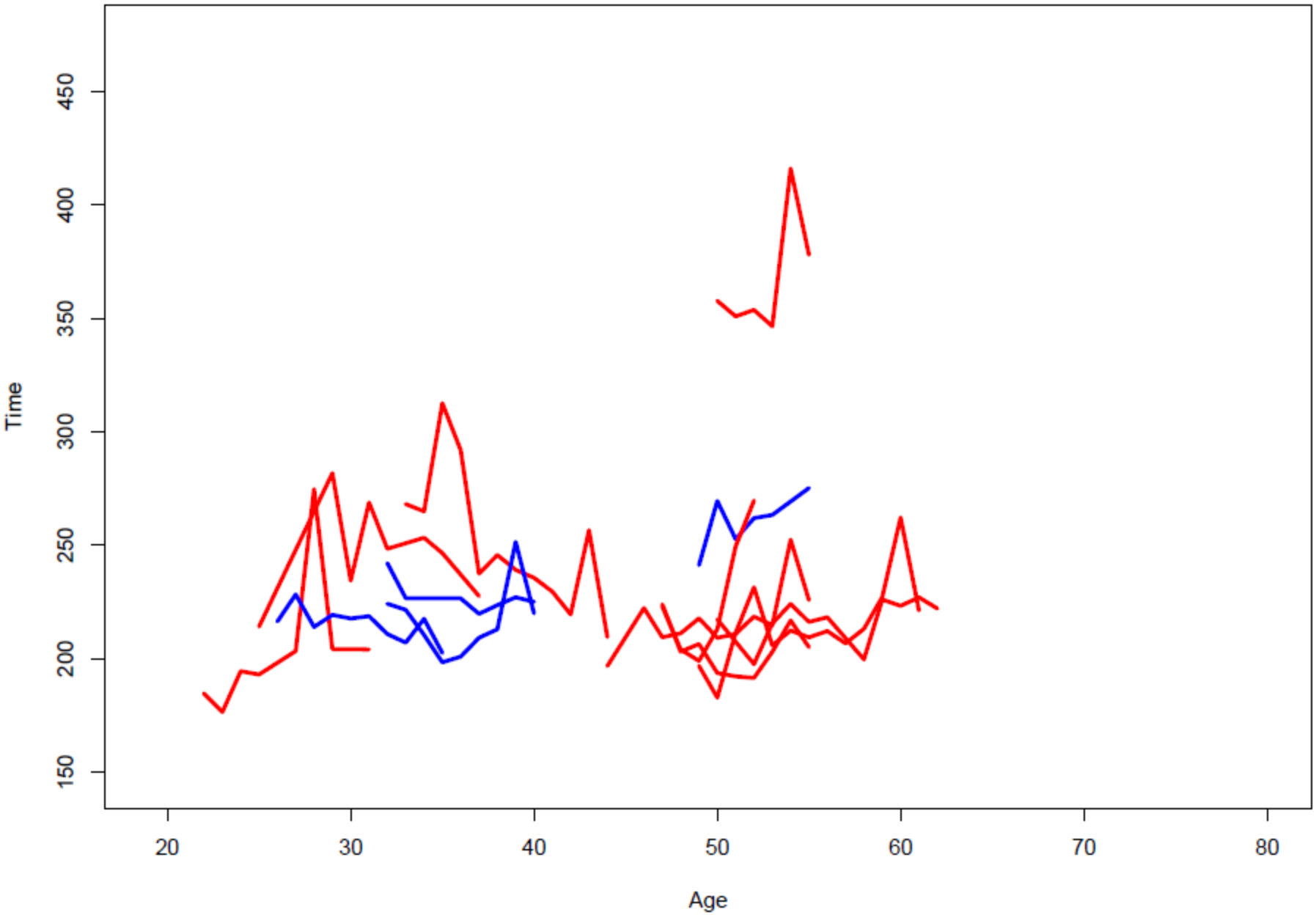
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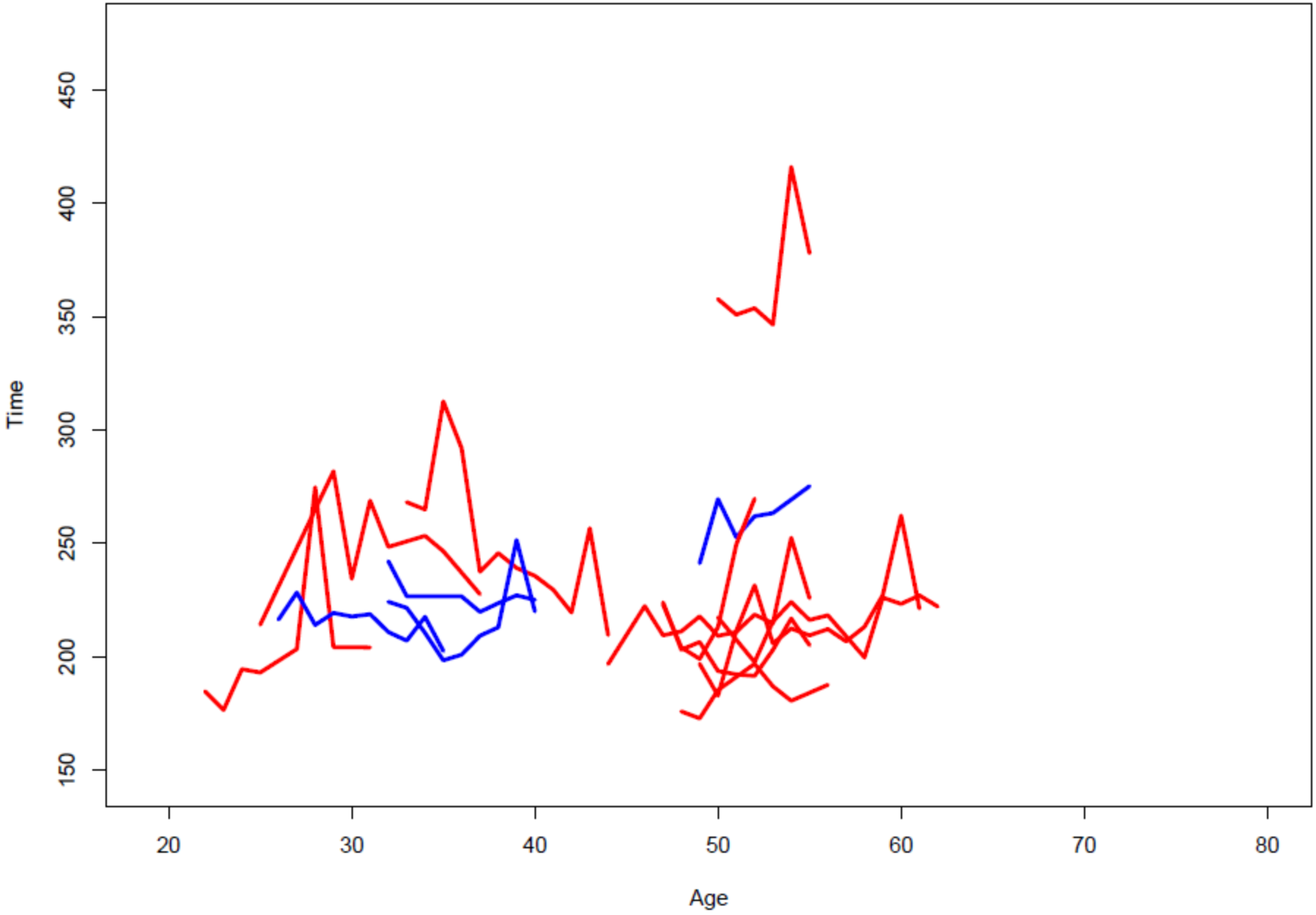
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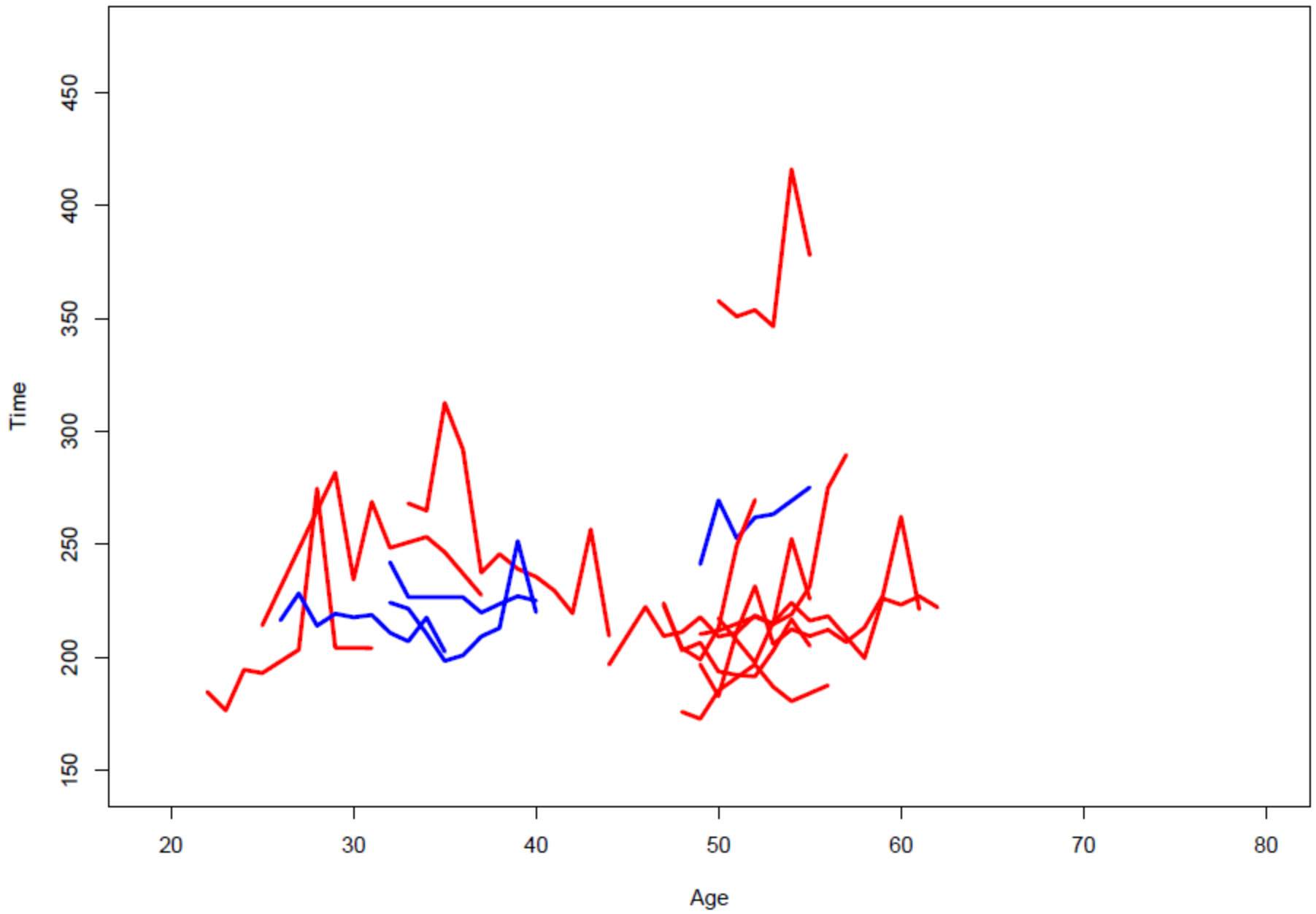
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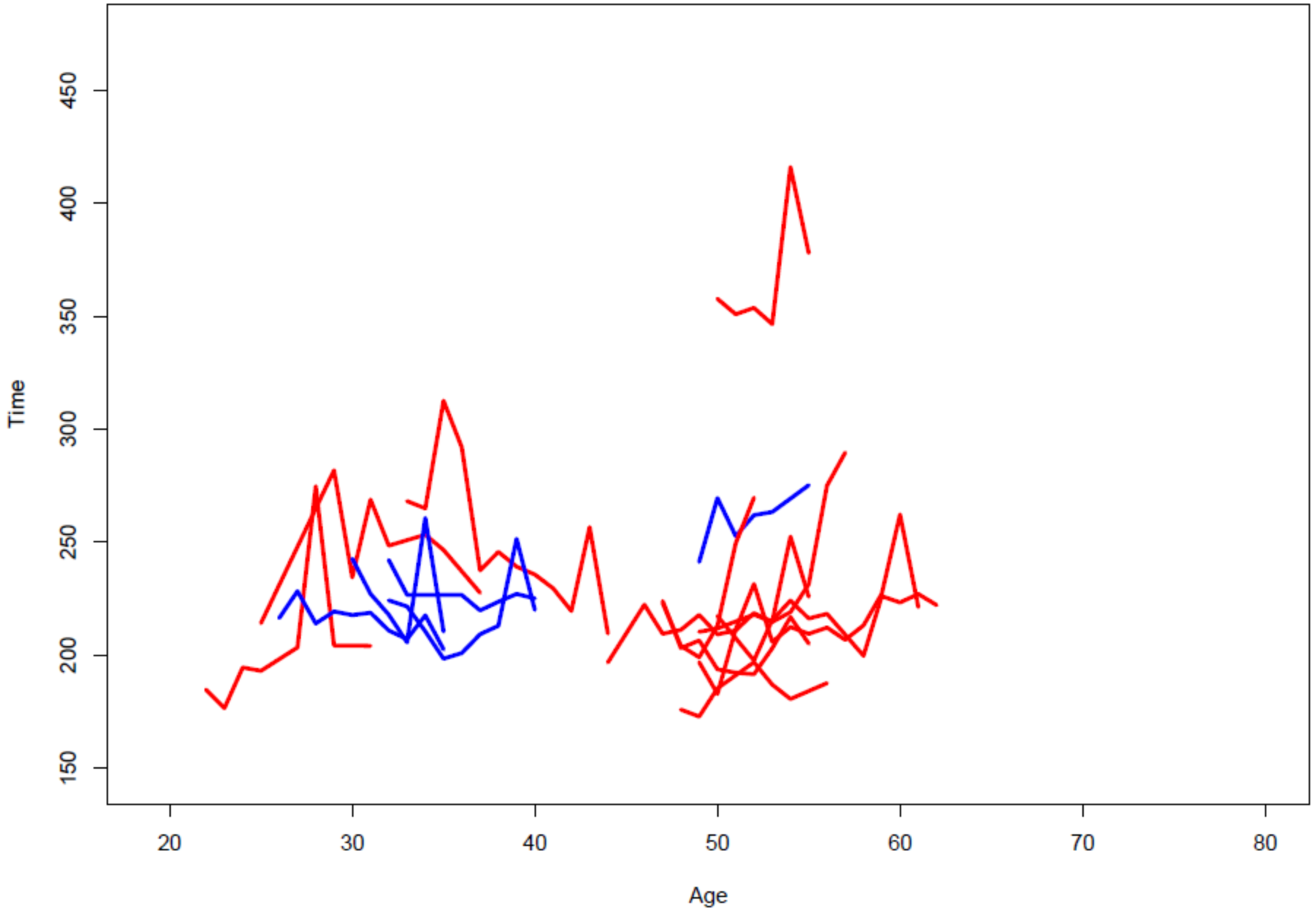
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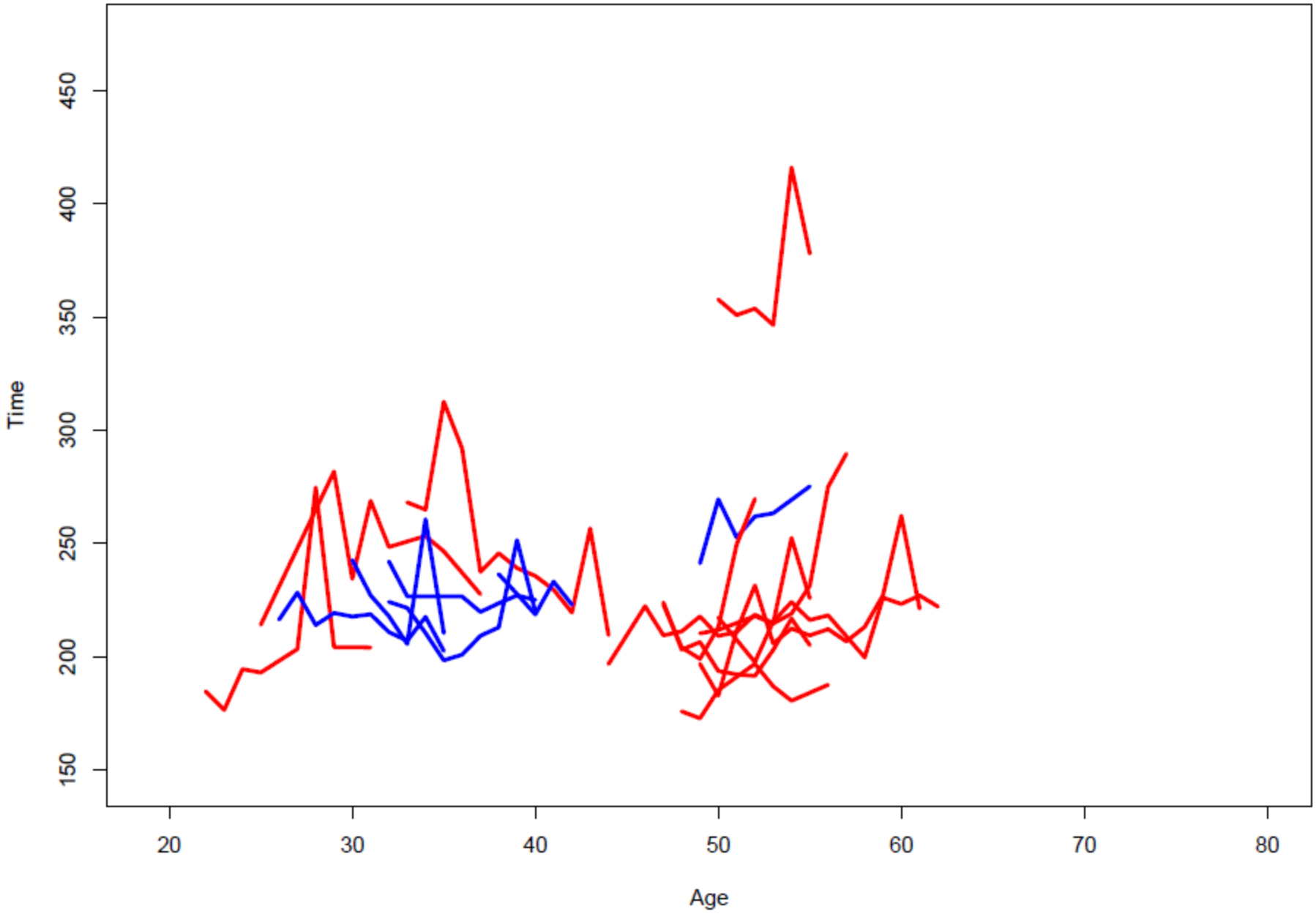
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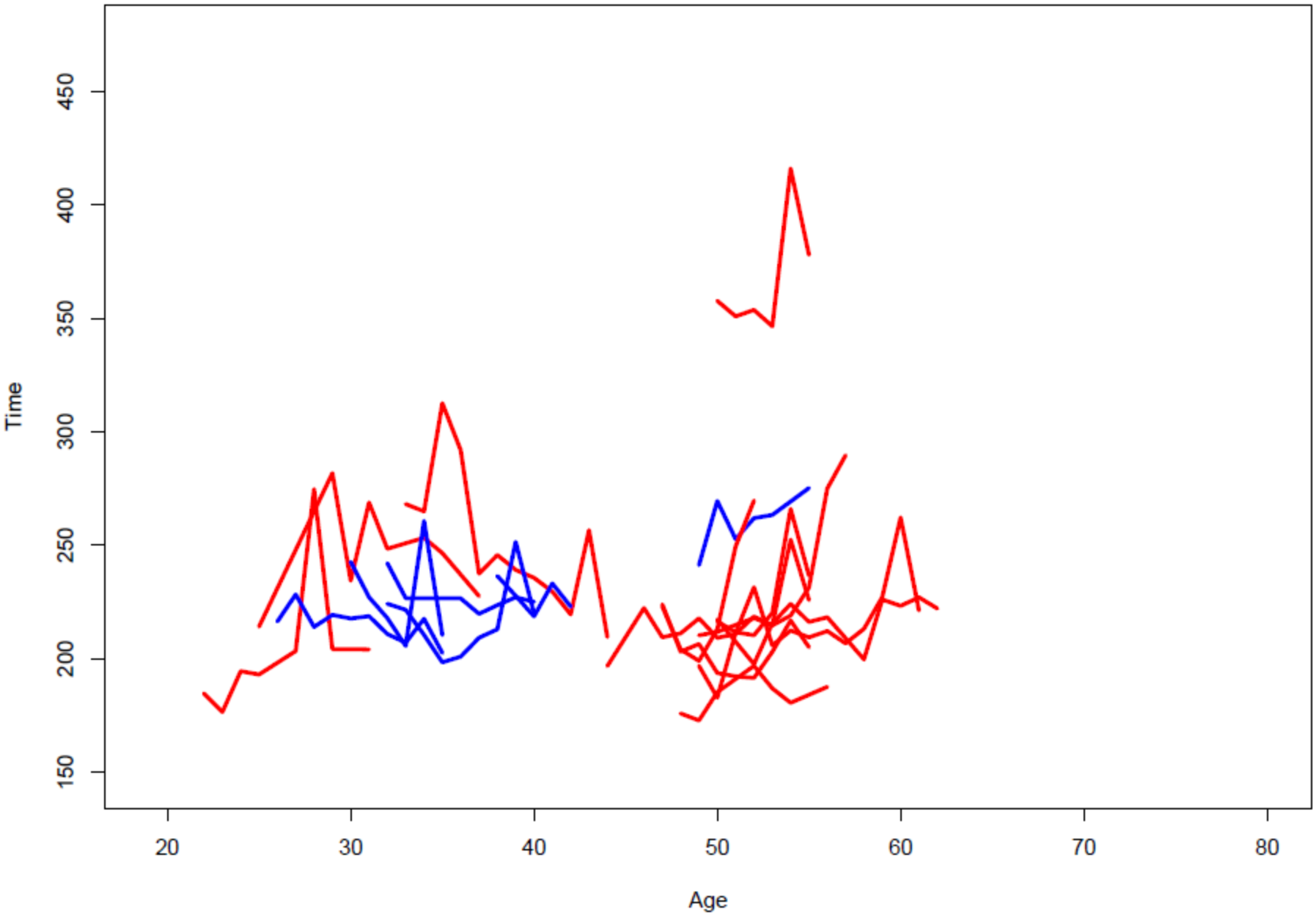
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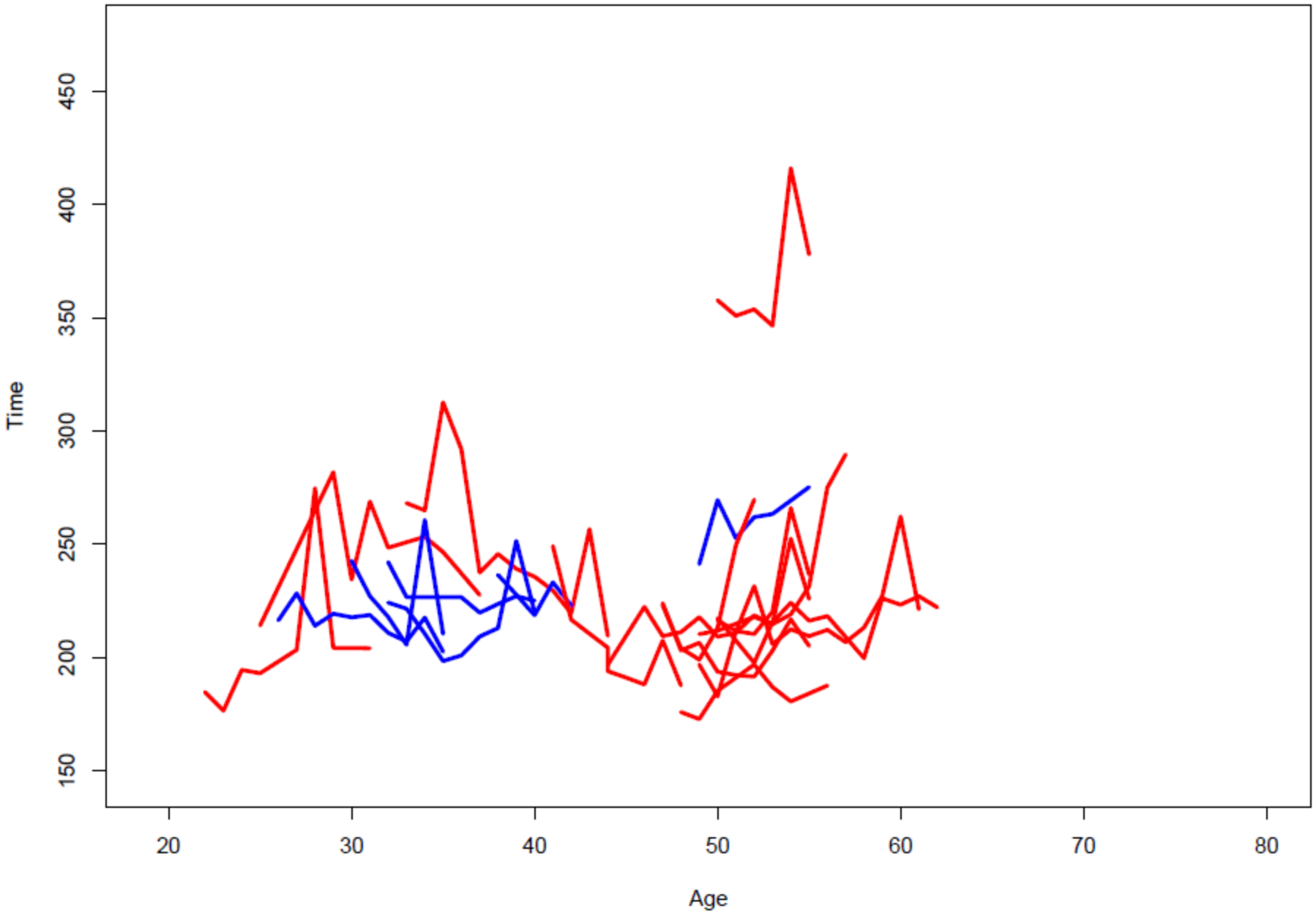
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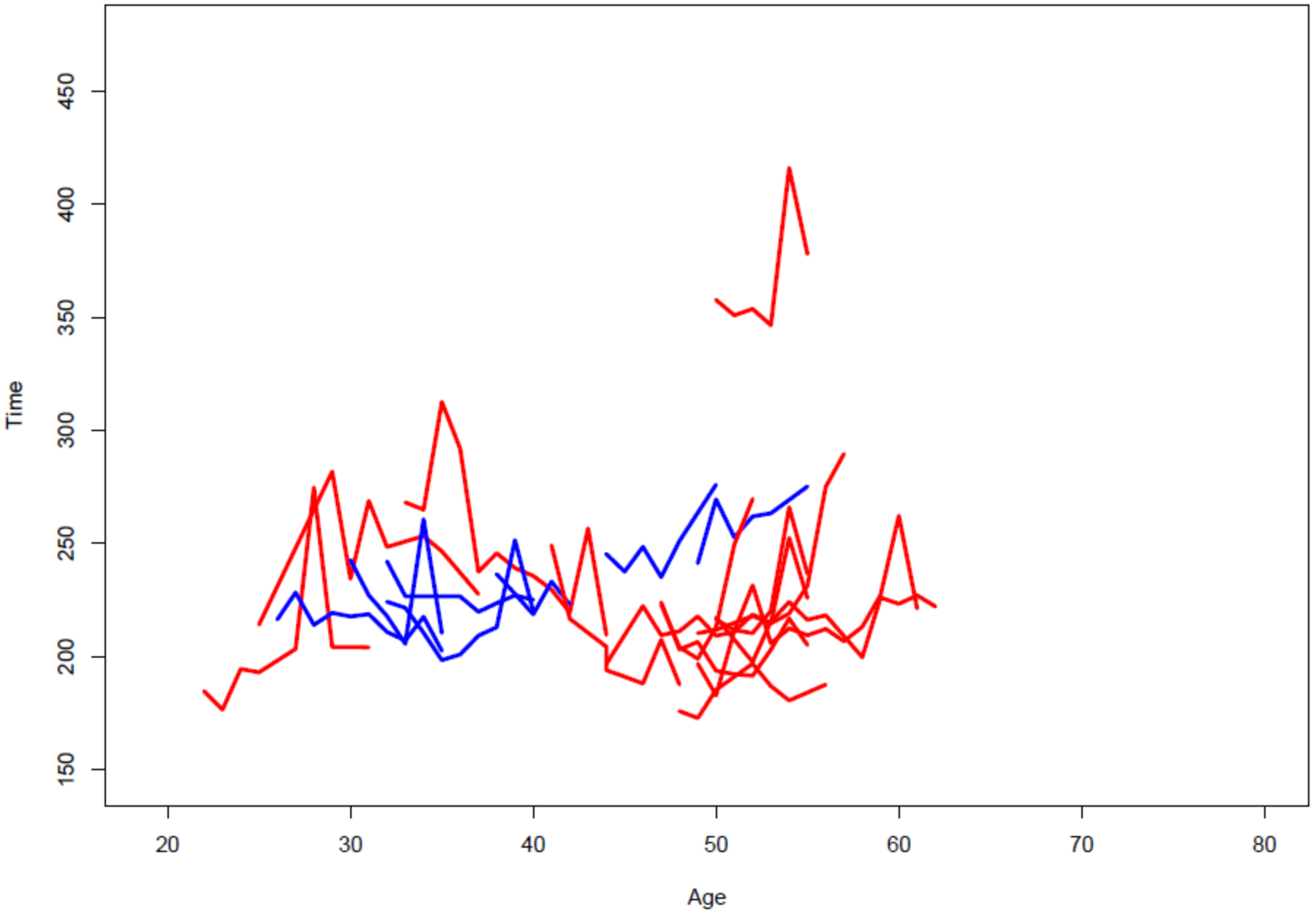
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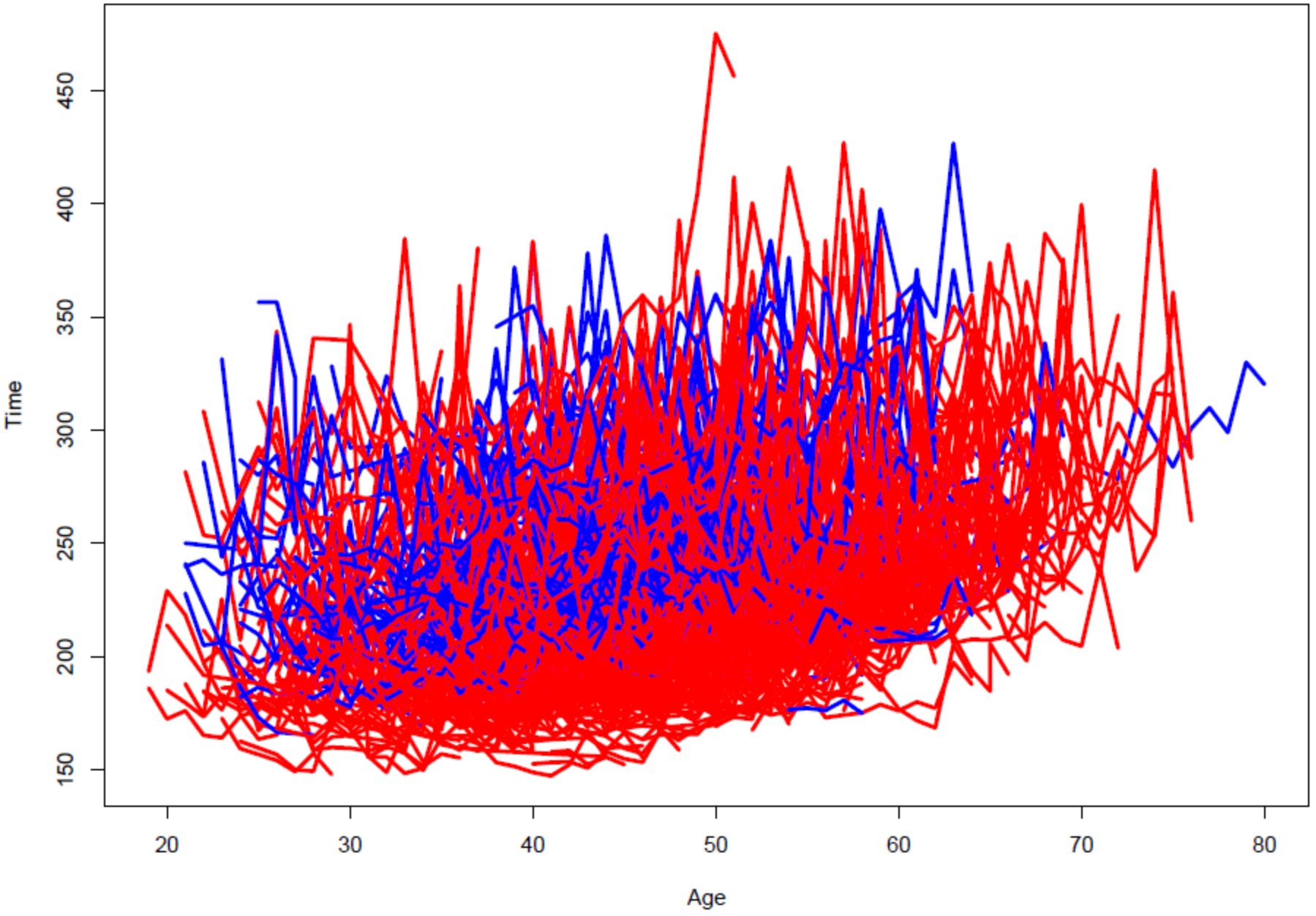
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# *The Idea*

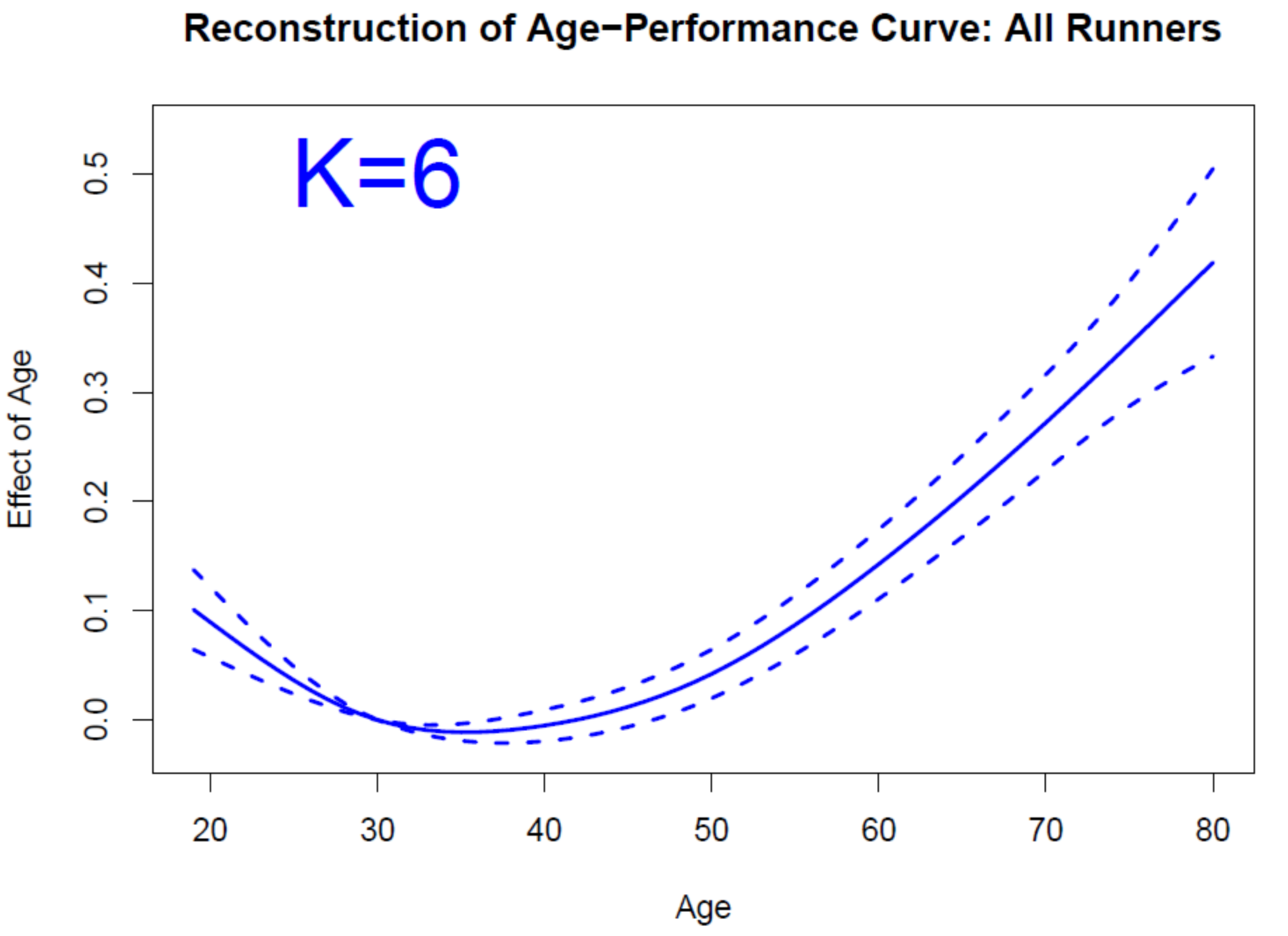
- Each individual runner record is a part-trace of the performance v. age curve for that runner
- Allow for a random “runner effect”
- Also allow for a random “calendar year” effect (2004 and 2012 were very hot)
- Separate men’s and women’s performance
- A refinement (later): also distinguish runners of different ability levels

# Statistical Model:

$$\log t_{ij} = \alpha_i + \beta_{y_{ij}} + S(a_{ij}; K) + \epsilon_{ij}, \quad (1)$$

where

- $t_{ij}$ is the $j$th finish time of runner $i$,
- $y_{ij}$ is the year of the $j$th finish time of runner $i$,
- $a_{ij}$ is the $i$th runner's age in her $j$th finish time,
- $\alpha_i$ represents the overall ability level of runner $i$ (small $\alpha_i$ means a faster runner),
- $\beta_{y_{ij}}$ is a year effect,
- $S(a_{ij}; K)$ represents a nonlinear function of age with $K$ degrees of freedom,
- $\epsilon_{ij}$ is a random error.
  - In practice replace $S(a_{ij}; K)$ with $S(a_{ij}; K) - S(30; K)$.
  - Use R package `lme4` to fit.


Reconstruction of Age−Performance Curve: All Runners
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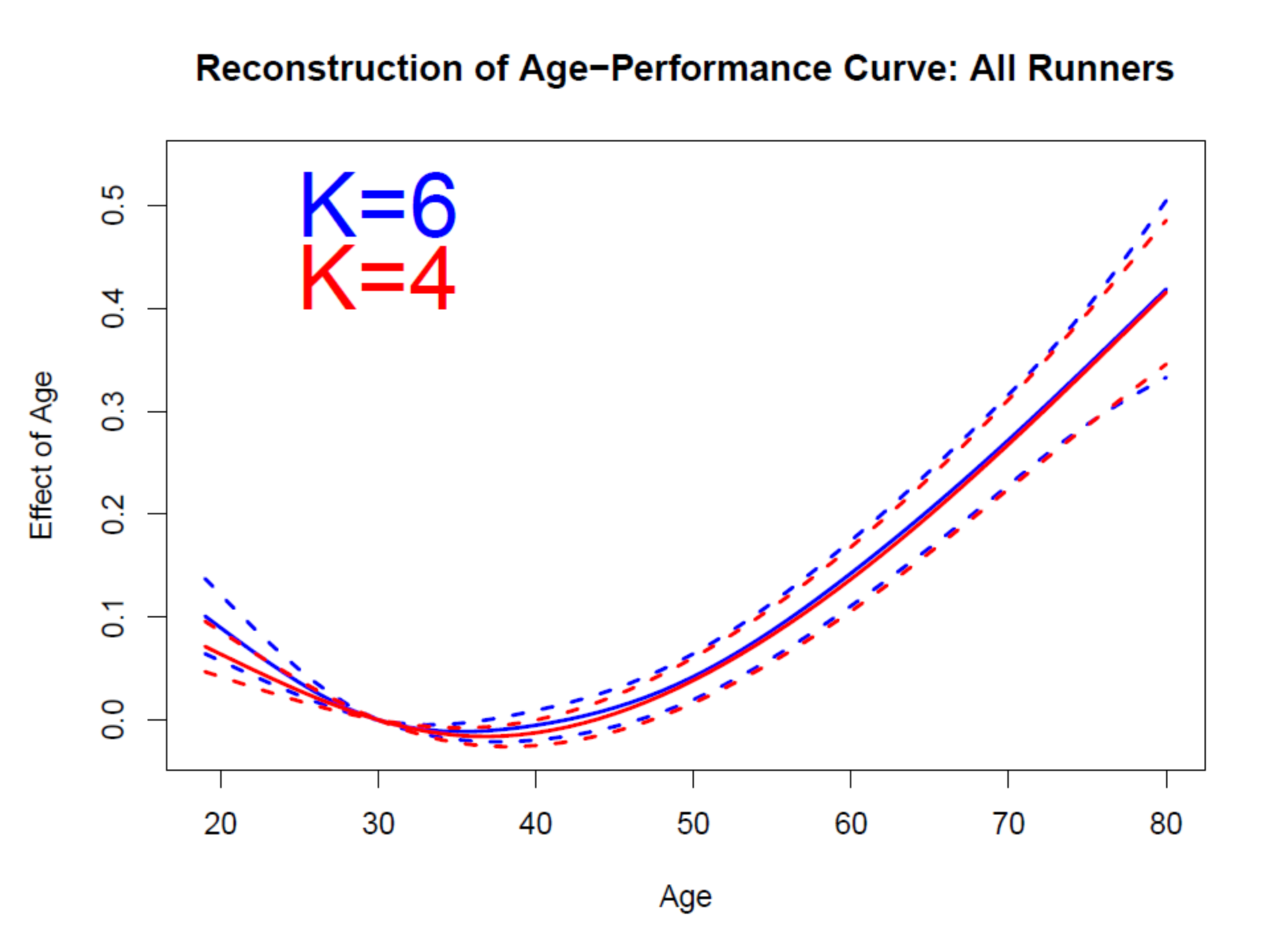
Reconstruction of Age−Performance Curve: All Runners
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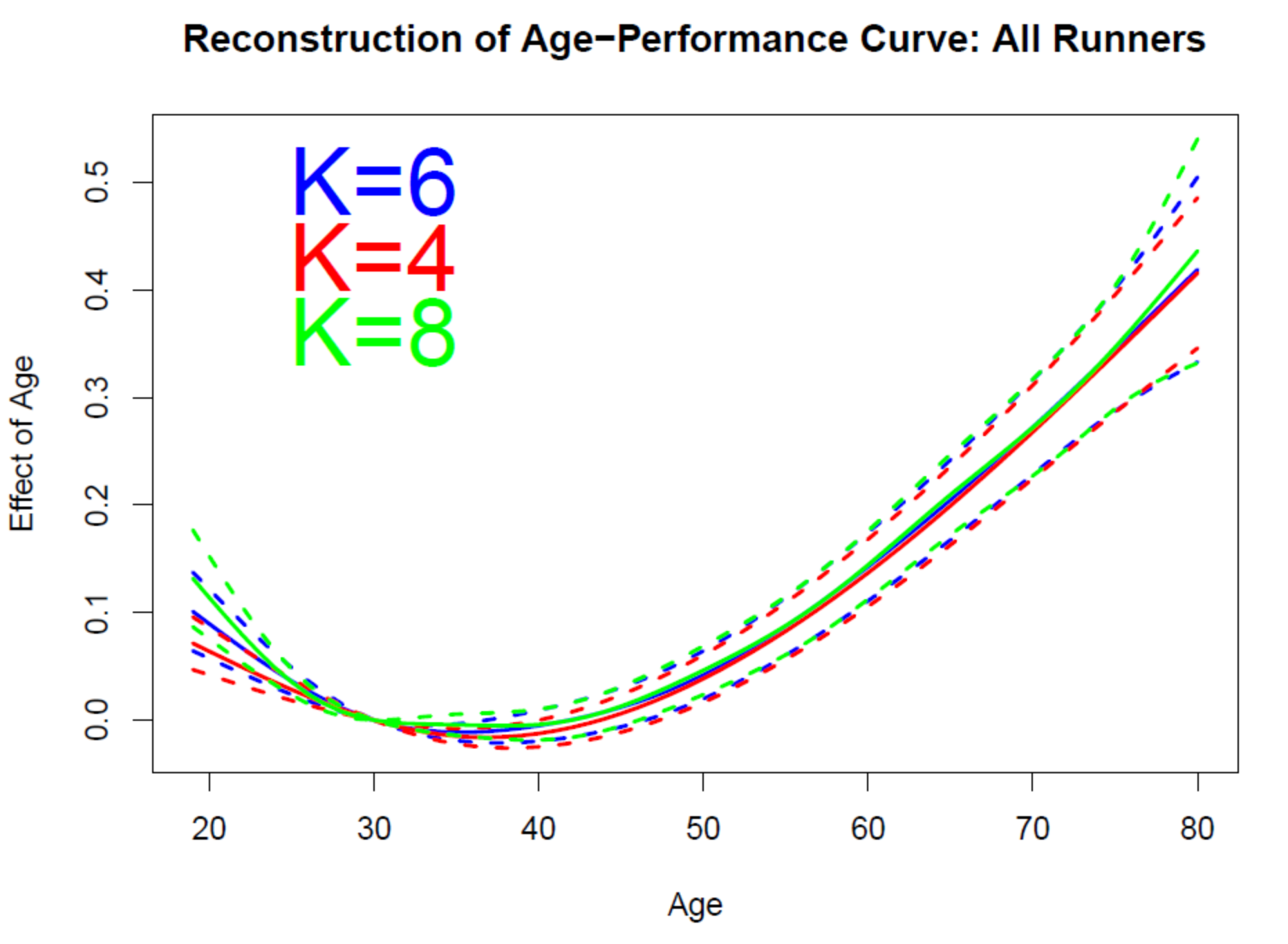
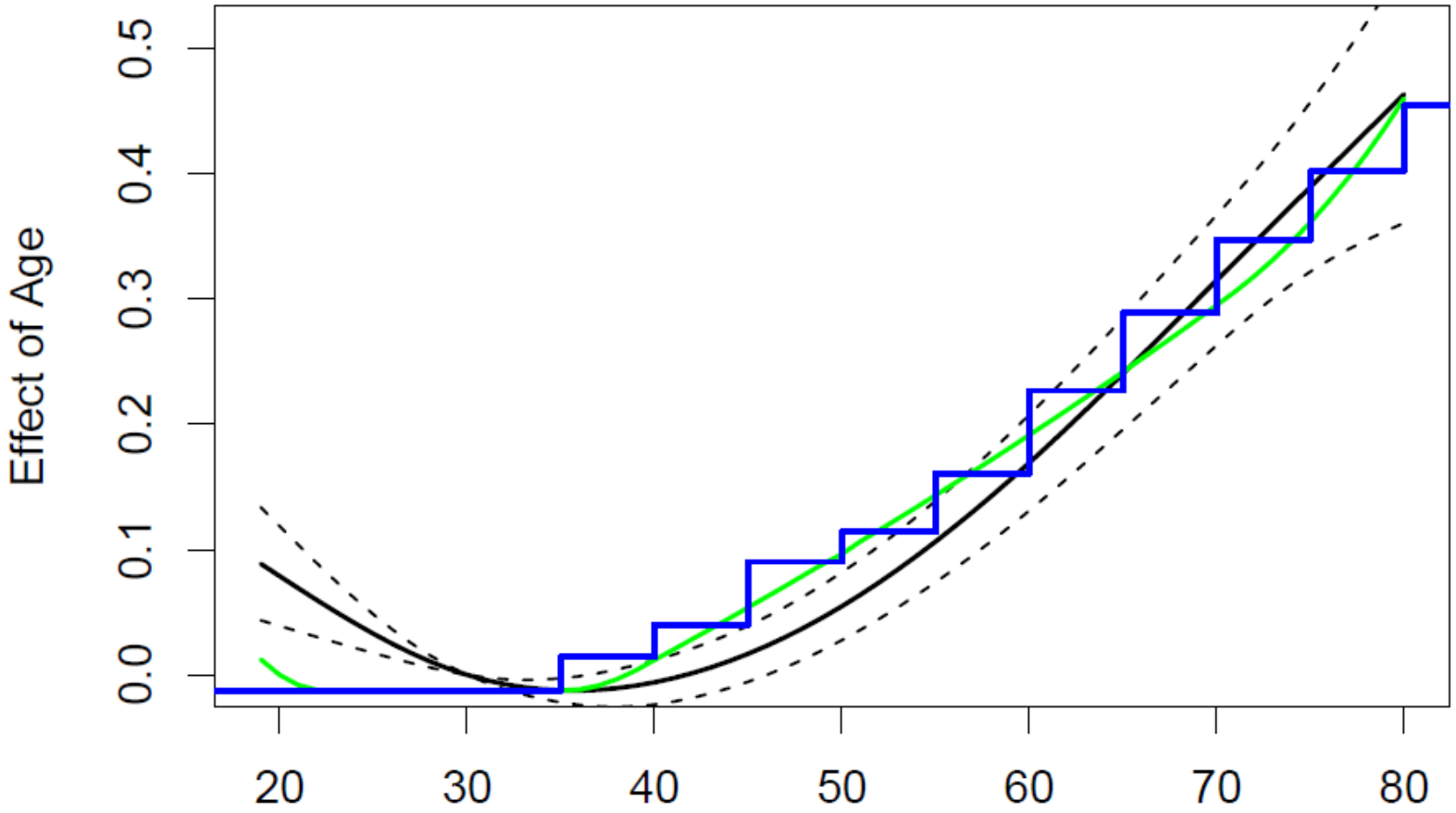
80
Age

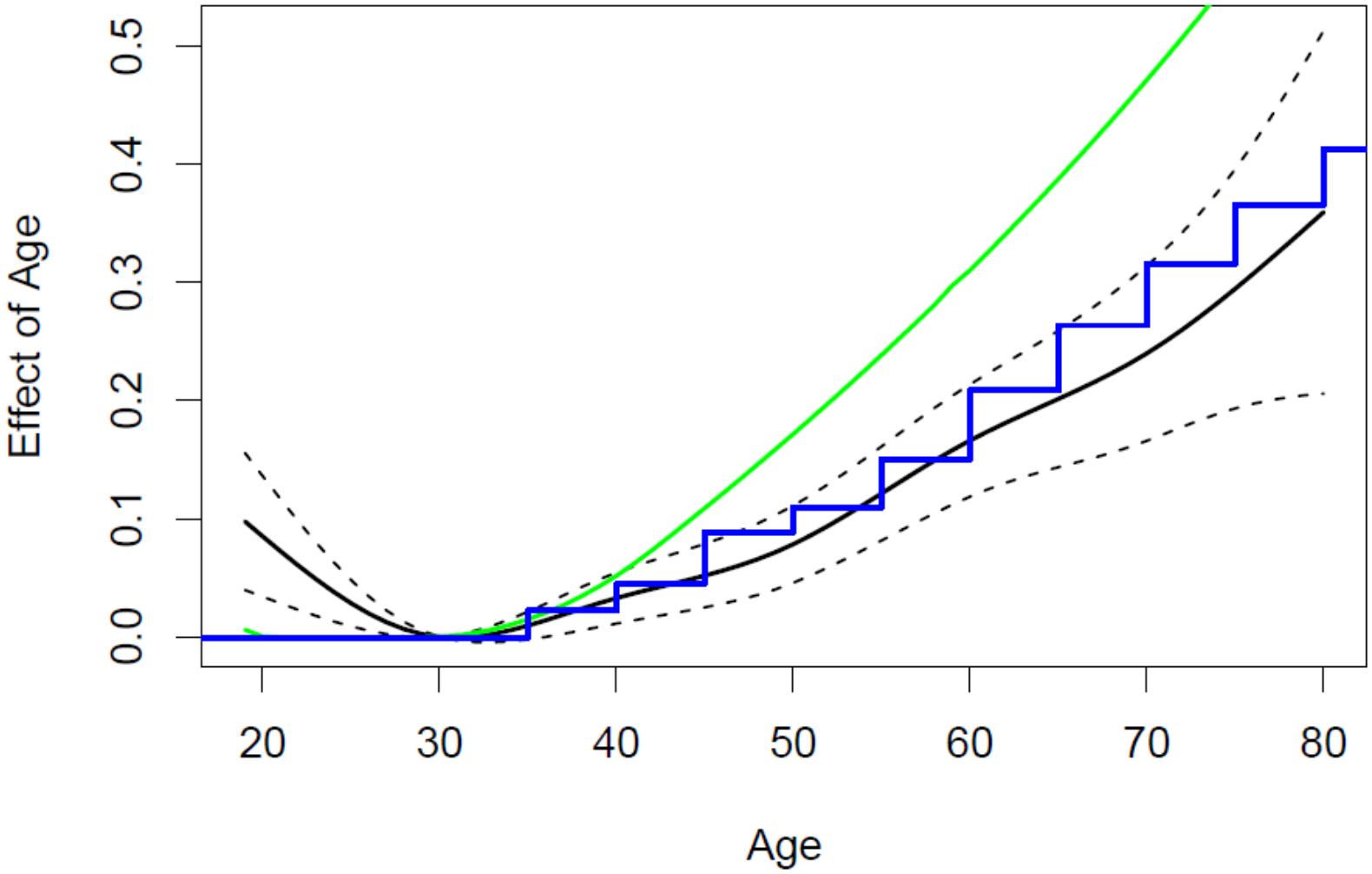

Reconstruction of Age−Performance Curve: All Runners
K=6
K=4
K=8
Effect of Age
0.0
0.1
0.2
0.3
0.4
0.5
20
30
40
50
60
70
80
Age

In practice, we compute separate curves for men and women and also compare with the age-performance curves that are implicit in the current Boston Marathon qualifying times, and in age-graded performances

Age-graded performances: a method of comparing performances for different age/sex categories by relating them to current world or national records

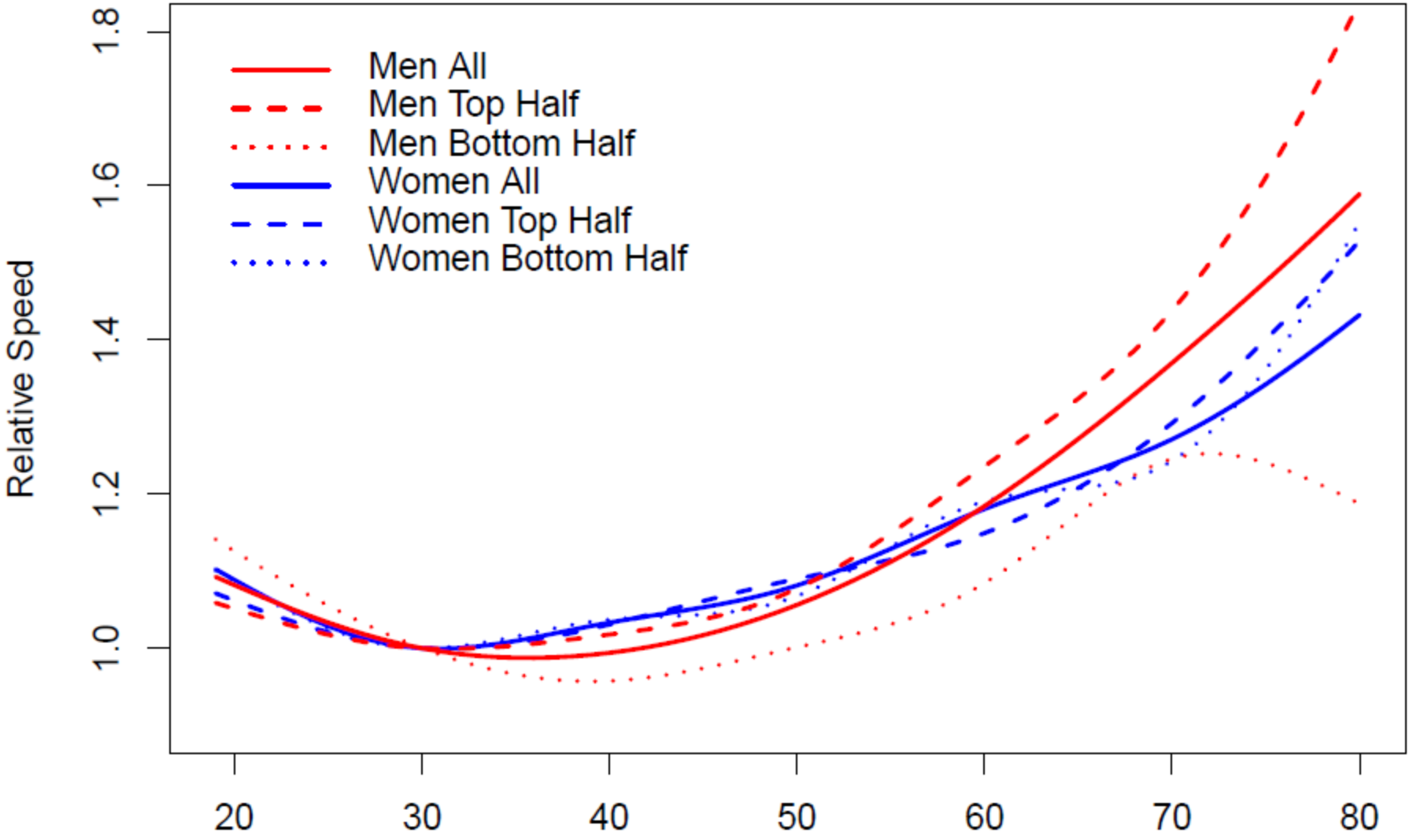



Age-performance curve for men. Solid black curve is spline-based estimate of age effect relative to age 30; dotted black curves are pointwise 95% confidence bounds. Blue step function based on Boston marathon qualifying times; green curve based on age-graded performances. Both the blue step function and the green curve are normalized so that their minimum is the same as that for the estimated spline curve.

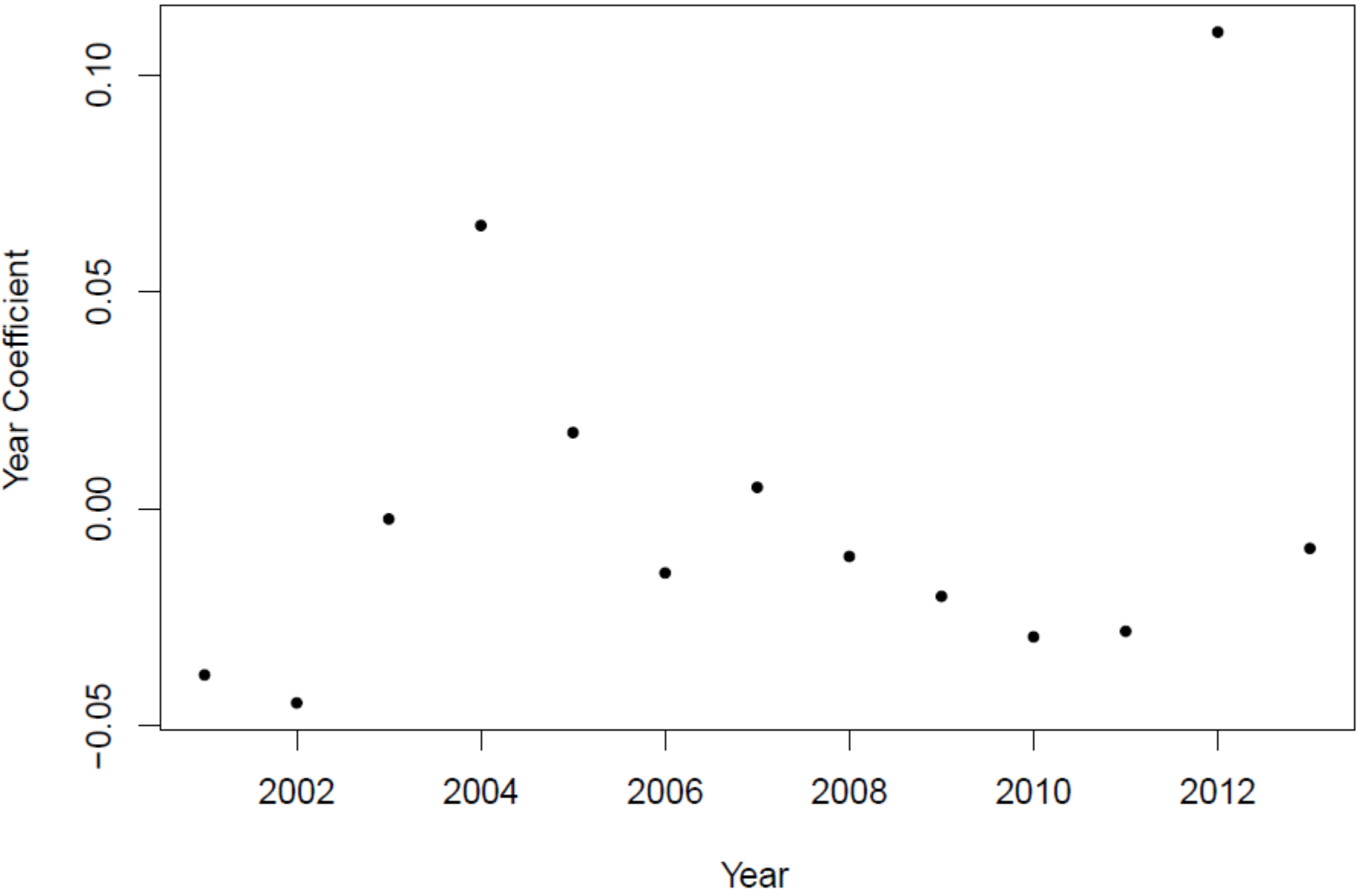



Same as previous page, but for women's performances.

# *We can also directly compare men with women, and different subsets of each*



# *Also look at the year effect*



# *We can also consider the implications of these results for Boston Marathon qualifying times*

*(Warning: These results are quite sensitive to which curve is used and how it is processed)*

| Age Group | Women | | | Men | | |
|---|---|---|---|---|---|---|
| | Now | Proposed | Age-Graded | Now | Proposed | Age-Graded |
| 35–39 | 3:40 | 3:39 | 3:41 | 3:10 | 3:05 | 3:05 |
| 40–44 | 3:45 | 3:44 | 3:52 | 3:15 | 3:08 | 3:12 |
| 45–49 | 3:55 | 3:49 | 4:06 | 3:25 | 3:13 | 3:20 |
| 50–54 | 4:00 | 3:58 | 4:22 | 3:30 | 3:22 | 3:29 |
| 55–59 | 4:10 | 4:10 | 4:41 | 3:40 | 3:35 | 3:39 |
| 60–64 | 4:25 | 4:22 | 5:22 | 3:55 | 3:53 | 3:50 |
| 65–69 | 4:40 | 4:34 | 5:28 | 4:10 | 4:15 | 4:02 |
| 70–74 | 4:55 | 4:50 | 5:57 | 4:25 | 4:43 | 4:16 |
| 75–79 | 5:10 | 5:14 | 6:37 | 4:40 | 5:15 | 4:37 |

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- Thank you for your attention!