

Sex Differences in the Chicago Marathon: A Window into Sampling Bias in Rehabilitation

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BACKGROUND

- Females participate in athletics, including most major marathons, **at a lesser rate** than males, particularly among older age groups (1).
- Males are ~11% faster than females in marathon running at the elite level, due to sex differences in physiology and anatomy.
- Males on average run are faster than females because of testosterone induced adaptations in puberty. Males have larger hearts, more muscle mass, less body fat to carry more hemoglobin in the blood and hence a larger maximal oxygen uptake (VO₂ max) than females (1).**
- This sex difference in performance, however, is often greater than the expected ~11% especially in older runners that have a lower proportion of females participating.
- Prior research has also shown that up to **34% of the difference in running velocity** between male and female runners can be accounted for based on the **ratio of male to female runners** (1).

Aims

To provide insight into the effects of sampling bias of males and females in studies of performance, we determined:

- the participation ratios (numbers of males to females) across a range of age groups in the Chicago Marathon from 1996-2018, and
- whether the sex difference in performance was predicted by male:female participation ratios.

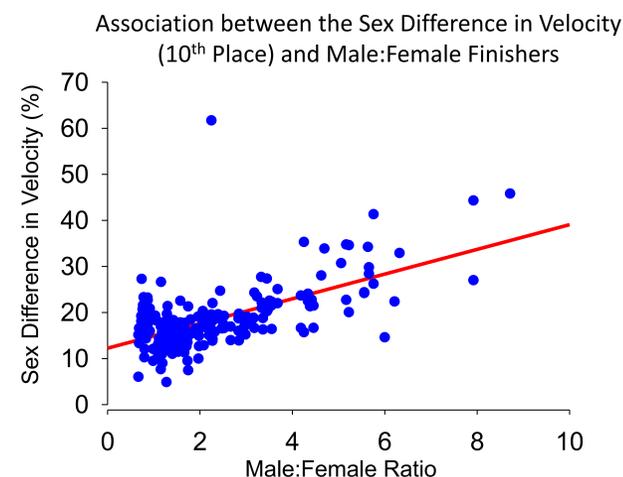
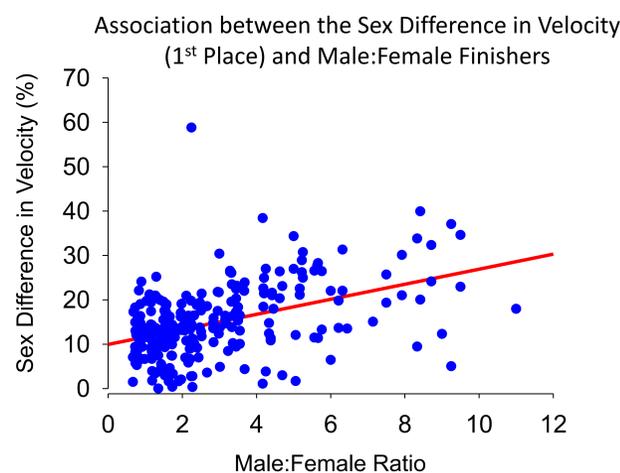
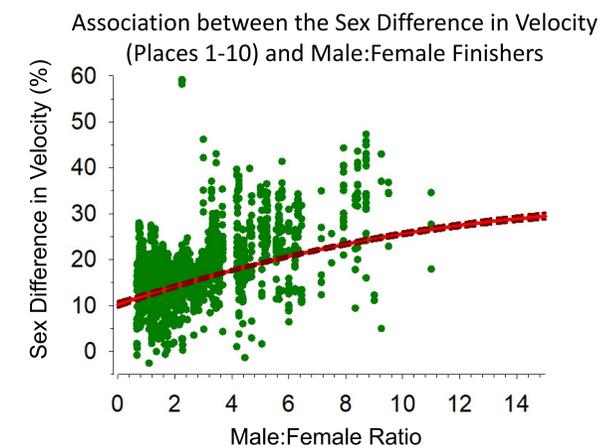
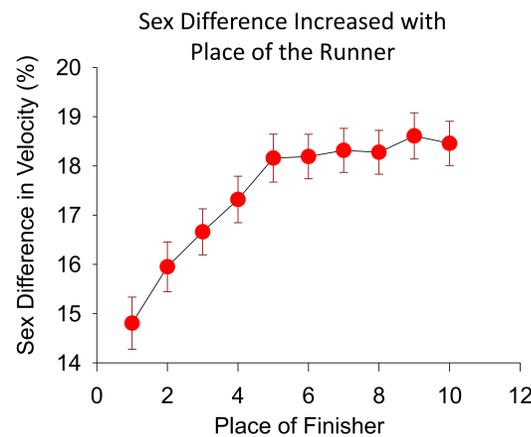
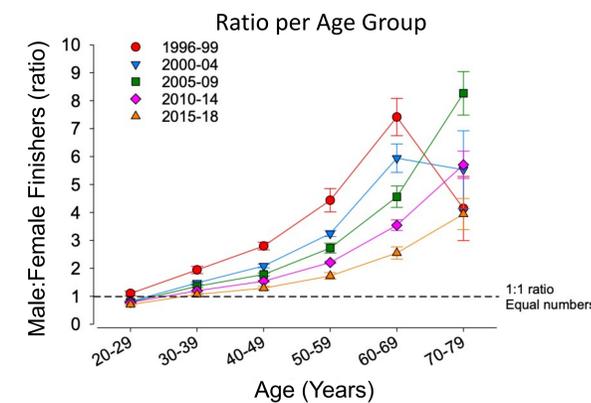
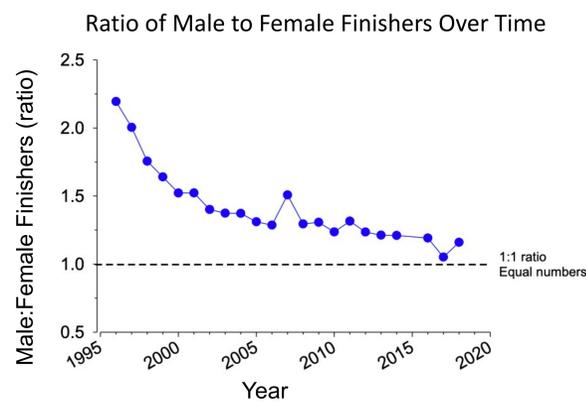
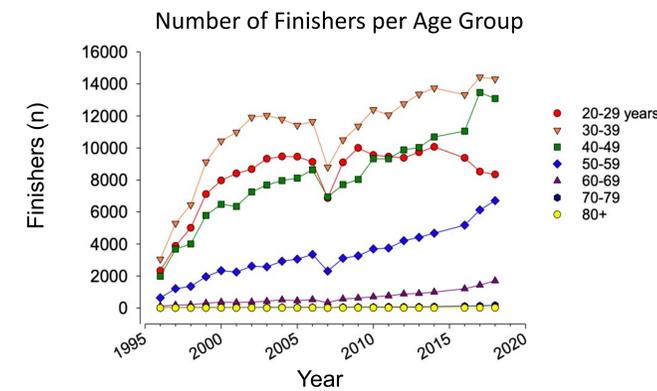
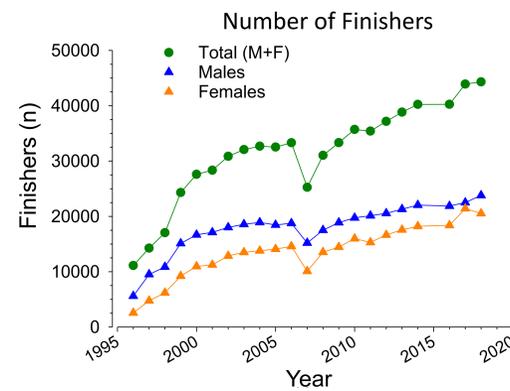
Hypothesis

The sex difference in marathon running times is strongly predicted by the ratio of male:female runners among lower placed and older runners.

METHODS

- Data was retrieved from a publicly available online data source for the Chicago Marathon (www.chicago-history.r.mikatiming.com) for the years 1996 until most recently available data (2018).
- Finishing times for the top 10 placed finishers in both the male and female category for each year and for each 5-year age bracket above 20 years old was retrieved.
- Sex differences in running velocity (% Δ males and females/males) was calculated as the primary measure of marathon performance.
- Participation ratios were male to female
- Univariate ANOVA determined sex differences in velocity and ratio of the numbers of males:females between 10-year age groups and years (5 year intervals) and place of the runner (1st to 10th).
- Pearson's correlation analysis determined associations between the ratios of male:female finishers and the sex difference in velocity.
- Statistical significance was $p < 0.05$

RESULTS



RESULTS SUMMARY

- Sex Differences in Participation:** The ratio in the number of male-to-female runners (all ages) decreased linearly from 2.19 (1996) to 1.15 (2018) due to a larger increase in the number of female than male runners
- In the **20–29-year age category**, females outnumbered men from 1999 onward.
- The **ratio of male:female runners increased with older age groups** ($p < 0.001$) and decreased across the years ($p < 0.001$).
- Sex Differences In Velocity:** Males were faster than females across all age groups ($17.4\% \pm 0.2\%$).
- The sex difference, however, was smallest for 1st placed runners and largest for the 10th placed finishers ($14.8 \pm 0.5\%$ to $18.5 \pm 0.4\%$).
- Associations**
- The ratio of the number of male:female runners was correlated with the sex difference in velocity (%) ($n = 2325$, $r = 0.53$, $r^2 = 0.28$, $p < 0.001$): lower female participation was associated with a larger sex difference in running velocity.
- The strength of the associations progressively increased between 1st and 10th place, and with older age up to but not including the 70-79 year old.
- The association for 20-29 year olds was $r^2 = 0.14$ ($p < 0.001$, $n = 440$) and 60-69 year olds, $r^2 = 0.37$ ($p < 0.001$, $n = 406$).

CONCLUSIONS

- Males outnumber females in participation in the Chicago marathon in most older groups but not the youngest age group (20-29 years)
- This imbalance inflated the sex difference in performance above expectations based on physiological differences.
- This form of sampling bias (less female than male participants) can be similarly misleading when evaluating the results of human performance and rehabilitation studies.

Clinical Implications

A lack of representation of females in rehabilitation studies (sampling bias) may provide an inaccurate understanding of the differences between men and women in response to treatment and rehabilitation.

REFERENCES

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- Fitzsimmons B, Mason A, Nesburg R, Hunter S. Increased Marathon Participation in the Last Decade is Driven by Women and Older Runners. Poster presentation at the ACSM Annual Meeting, San Diego, June, **2022**.