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The Two-hour Marathon: What's the Equivalent for Women?

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This viewpoint argues that the current world record (WR) in the marathon for women is at least equivalent to a sub-2-h marathon for men. The person who may eventually break the 2-h barrier in the marathon (19) will be male. Because the fastest men consistently outperform the fastest women in the marathon (3, 13, 20), an equally intriguing question is what is the 2-h equivalent for women? Here we address this question and highlight physiological, historical, and social factors that contribute to current and past sex differences in marathon performance.

The “equivalent 2-h marathon” for women has already been achieved

The simplest approach to determine the equivalent 2-h marathon time for women is to calculate the time difference (from 2 h) based on the relative sex difference in the WR (~10%). The current WR performances are 2:02:57 (h:min:s) for men (Dennis Kimetto, 2014) and 2:15:25 for women (Paula Radcliffe, 2003), so that a synonymous time for women is 2:12:00. Several indicators, however, suggest a 12–13% sex difference is more appropriate and that the WR by Radcliffe is essentially the equivalent of a 2-h marathon for women.

First, online predictors based on records in men's and women's athletic events indicate the current women's WR by Radcliffe is slightly better than the men's 2-h marathon. The Mercier score (24), for example, indicates that 2:15:34 for women is equivalent to the men's 2-h marathon (see Guenette et al.'s commentary in Ref. 29).

Second, convincing evidence comes from a comparison of the best 100 men's and women's marathon times (Fig. 1*A*) (31). The key finding is the relative drop-off for women is precipitous in the initial places and then plateaus, whereas the men display a gradual decline. The top three women's times were all accomplished by Radcliffe (2002–2005). If, however, the women's times are expressed relative to the 4th fastest time (2:18:20, 12.5% difference from the current men's WR) and Radcliffe's top three times are excluded, the rate of decline is similar to the men until ~45–50th place where the lines start to diverge and the women display a greater drop-off than the men (Fig. 1*A*). These data suggest the following.

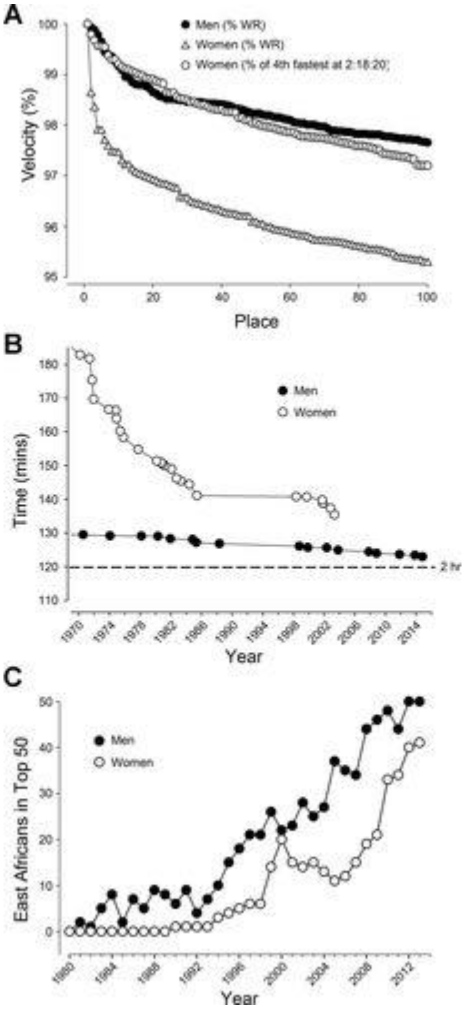

Fig. 1.1 Sex differences in the marathon. *A*: velocity of the top 100 marathons (next fastest after the WR) expressed as a percent (%) of the WR for men, women, and for women when Radcliffe's three fastest times are excluded (4th-104th fastest times relative to 4th place). [Data from (31).] *B*: world record marathon times for

men and women from 1970 to 2014. *C*: number of East African (Kenyan and Ethiopian) men and women in the top 50 marathon times in a given year (1980–2013) (1).

Radcliffe's performances were exceptional. Between 2002 and 2005, she ran the three fastest marathon times ever recorded by a woman, and her WR performance (2003) still stands 12 years on.

There is less depth in women's running than men's, because the drop-off in performance is greater for women; this is obvious with the inclusion of Radcliffe's times and more subtle when viewed vs. the fourth best time after ∼50th placed runners (Fig. 1*A*); this widening continues to at least 200th place (men at 97.0%; women at 96.4%) and beyond. Accordingly, the top 100 men's times were achieved primarily over 7 years (2007–2014) with several in 2002–2003 and one in 1999, whereas the women's are more spread (2000–2013), with several between 1994–1999 and in 1985 (31). Less depth in women's running is also found among elite and subelite runners (12, 13) with there being a greater sex difference when fewer women compete relative to men (12).

Sex Differences in Physiology: What is Unique about Paula Radcliffe?

Human performance in distance running is strongly related to the maximal oxygen consumption ($\dot{V}o_{2max}$). However, among elite runners, the better athletes are distinguished by the highest sustainable oxidative metabolic rate (related to the “critical velocity” and the “lactate threshold”) and running economy (18, 19). Critical velocity represents the highest intensity that $\dot{V}o_2$, blood lactate, and intramuscular metabolites such as H^+, PCr, and P_i can be stabilized (16). The difference between “critical velocity” and the “lactate threshold” is compressed in elite runners compared with recreational runners (16). There is limited difference, however, between elite men and women runners in the relative $\dot{V}o_2$ they are able to sustain for several hours (∼85–90% $\dot{V}o_{2max}$) (4, 9, 10, 17). In highly trained men and women, running economy is similar and does not appear to explain sex differences in performance either (2, 4, 9, 21). In general, in equally trained men and women, the sex difference in performance is mostly dictated by men's larger $\dot{V}o_{2max}$ because men have a larger heart size, larger muscle mass, less body fat, greater hemoglobin concentration, and consequently a higher $\dot{V}o_{2max}$ than women (17, 28). Elite male runners usually have a $\dot{V}o_{2max}$ of ∼70–85 $ml\cdot kg^{-1}\cdot min^{-1}$ and elite females ∼60–75 $ml\cdot kg^{-1}\cdot min^{-1}$ so the sex difference is 10–14% (2, 7, 15, 18, 25–27). Other factors that potentially affect the sex difference in performance among recreational runners such as substrate utilization (14, 30), muscle fatigability (11), pacing (6), and competitiveness (5), likely have minimal influence among elite distance runners. Whether there are sex differences in the influence of genetic factors that affect elite runners is not known.

There are several aspects of Radcliffe's physiology that explain her extraordinary marathon performances. First, Radcliffe has a superior $\dot{V}o_{2max}$ relative to many of her elite counterparts of ∼70 $ml\cdot kg^{-1}\cdot min^{-1}$ (15). Second, her lactate threshold occurred at a high fraction of her $\dot{V}o_{2max}$ and at a high absolute running speed (18.5 km/h) and it can be estimated that her critical velocity was very high (19.4 km/h^{-1}) (15). Finally, Radcliffe had exceptional running economy (∼175 $ml\cdot kg^{-1}\cdot km^{-1}$ compared with the “typical” value of ∼200 $ml\cdot kg^{-1}\cdot km^{-1}$) that improved ∼15% over many years of training (15). Radcliffe's superior economy and critical velocity allowed her to run at high absolute speeds for extended periods.

Sex Differences in Opportunity: A Reason for Less Depth among the Women?

In 1992, Whipp and Ward (32) made the provocative prediction that women would outrun men in 1998 with a time of 2:01:59. In retrospect, their statistical projections were influenced by the rapid increase in competitive opportunities for women in the 1970-80s that coincided with increased participation (Fig. 1*B*) (12, 13, 17). Women first competed in the World Championship marathon in 1983 (Helsinki, Finland) and the Olympic Games in 1984 (Los Angeles, CA). Before the 1970s, women were banned from the marathon because of the belief they would not be able to withstand the demands of the distance (22). Since then, the number of women runners has steadily increased in major marathons across all age groups (12). Recent improvements in record marathon times have been incremental (Fig. 1*B*) and reflect more accurately the sex differences in physiology that allow elite men to run faster than elite women.

Additionally, elite women runners rapidly adopted training approaches developed over decades by men, spurring the improvement in WR during the 1970-80s. Consequently, the sex difference among the best runners has fluctuated minimally over the last 30 years (13). Furthermore, Fig. 1*C* shows about a 10-yr lag in the globalization of women's running, with East African dominance emerging later for women compared with men.

Conclusions

We provide evidence that the 2-h equivalent marathon time for women was achieved by Paula Radcliffe in her 2003 WR. Furthermore, comparison of records of elite men and women marathoners indicates a lack of depth among lower-placed women runners and a sex difference in the ethnic origin of the best runners. Radcliffe's WR may stand for many more years until a woman, possibly an East African, who possesses superior running economy and high critical velocity is afforded the opportunity to compete.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

AUTHOR CONTRIBUTIONS

Author contributions: S.K.H., M.J.J., and A.M.J. conception and design of research; S.K.H. analyzed data; S.K.H., M.J.J., and A.M.J. interpreted results of experiments; S.K.H. prepared figures; S.K.H., M.J.J., and A.M.J. drafted manuscript; S.K.H., M.J.J., and A.M.J. edited and revised manuscript; S.K.H., M.J.J., and A.M.J. approved final version of manuscript.

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AUTHOR NOTES

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REFERENCES

1. Association of Road Racing Statisticians. Introductory page. arrs.net [accessed September 30, 2014].
2. Bunc V, Heller J. Energy cost of running in similarly trained men and women. ***Eur J Appl Physiol Occup Physiol*** **59**: 178–183, 1989.
3. Cheuvront SN, Carter R, Deruisseau KC, Moffatt RJ. Running performance differences between men and women: an update. ***Sports Med*** **35**: 1017–1024, 2005.
4. Davies CT, Thompson MW. Aerobic performance of female marathon and male ultramarathon athletes. ***Eur J Appl Physiol Occup Physiol*** **41**: 233–245, 1979.
5. Deaner RO. Distance running as an ideal domain for showing a sex difference in competitiveness. ***Arch Sex Behav*** **42**: 413–428, 2013.
6. Deaner RO, Carter RE, Joyner MJ, Hunter SK. Men are more likely than women to slow in the marathon. ***Med Sci Sports Exerc*** **47**: 607–611, 2015.
7. Durstine JL, Pate RR, Sparling PB, Wilson GE, Senn MD, Bartoli WP. Lipid, lipoprotein, and iron status of elite women distance runners. ***Int J Sports Med*** **8**, Suppl 2: 119–123, 1987.

9. Helgerud J. Maximal oxygen uptake, anaerobic threshold and running economy in women and men with similar performances level in marathons. ***Eur J Appl Physiol Occup Physiol*** **68**: 155–161, 1994.
10. Helgerud J, Ingjer F, Stromme SB. Sex differences in performance-matched marathon runners. ***Eur J Appl Physiol Occup Physiol*** **61**: 433–439, 1990.
11. Hunter SK. Sex differences in human fatigability: mechanisms and insight to physiological responses. ***Acta Physiol (Oxf)*** **210**: 768–789, 2014.
12. Hunter SK, Stevens AA. Sex differences in marathon running with advanced age: physiology or participation? ***Med Sci Sports Exerc*** **45**: 148–156, 2013.
13. Hunter SK, Stevens AA, Magennis K, Skelton KW, Fauth M. Is there a sex difference in the age of elite marathon runners? ***Med Sci Sports Exerc*** **43**: 656–664, 2011.
14. Isacco L, Duche P, Boisseau N. Influence of hormonal status on substrate utilization at rest and during exercise in the female population. ***Sports Med*** **42**: 327–342, 2012.
15. Jones AM. The physiology of the world record holder for the women's marathon. ***Int J Sports Sci Coaching*** **1**: 101–116, 2006.
16. Jones AM, Vanhatalo A, Burnley M, Morton RH, Poole DC. Critical power: implications for determination of VO2max and exercise tolerance. ***Med Sci Sports Exerc*** **42**: 1876–1890, 2010.
17. Joyner MJ. Physiological limiting factors and distance running: influence of gender and age on record performances. ***Exerc Sport Sci Rev*** **21**: 103–133, 1993.
18. Joyner MJ, Coyle EF. Endurance exercise performance: the physiology of champions. ***J Physiol*** **586**: 35–44, 2008.
19. Joyner MJ, Ruiz JR, Lucia A. The two-hour marathon: who and when? ***J Appl Physiol*** **110**: 275–277, 2011.
20. Lepers R, Cattagni T. Do older athletes reach limits in their performance during marathon running? ***Age*** **34**: 773–781, 2012.
21. Loftin M, Sothern M, Tuuri G, Tompkins C, Koss C, Bonis M. Gender comparison of physiologic and perceptual responses in recreational marathon runners. ***Int J Sports Physiol Perform*** **4**: 307–316, 2009.
22. Lovett C. ***Olympic Marathon: A Centennial History of the Games' Most Storied Race***. Westport, CT: Praeger, 1997.
24. Mercier Scoring Tables Development Center. myweb.lmu.edu/jmureika/track/Mercier.com [accessed September 30, 2014].
25. Pate RR, O'Neill JR. American women in the marathon. ***Sports Med*** **37**: 294–298, 2007.
26. Pollock ML. Submaximal and maximal working capacity of elite distance runners. Part I: Cardiorespiratory aspects. ***Ann NY Acad Sci*** **301**: 310–322, 1977.
27. Saltin B, Astrand PO. Maximal oxygen uptake in athletes. ***J Appl Physiol*** **23**: 353–358, 1967.
28. Sparling PB. A meta-analysis of studies comparing maximal oxygen uptake in men and women. ***Res Q Exerc Sport*** **51**: 542–552, 1980.
29. Stellingwerff T, Perrey S, Shephard RJ, Schubert MM, Millet GP, Skiba PF, Marabotti C, Ely MR, Parker BA, Markert CD, Braga VA, Fletcher JR, Hunter SK, Buchheit M, Donato AJ, Capelli C, Flouris AD, Earnest CP, Drew RC, Guenette JA, Chapman RF, Marino FE, Chicharro JL, Dumke CL, Smoliga JM, Ade CJ, Delliaux S, Williams AG, Joumaa WH, Kano Y, Merkus D, Hanson ED, Foster C, Zoladz JA, Olson TP, Boullosa DA, Bay Nielsen H, Lim CL, Jeukendrup AE, Girard O, Jones AM, Montain SJ, Corona BT, Nunes FC, Esau SP, Holash RJ, MacIntosh BR, Edwards AG, Ferretti G, Carrillo AE, Sinoway LI, White MJ, Mureika JR, O'Donnell DE, Laymon A, Lundby C, Levine BD, Vicente-Campos D, Rundell KW, Broxterman RM, Barstow TJ, Boussuges A, Rossi P, Okada H, Morioka Y, Zhou Z, Jenkins NT, Roth SM, de Koning JJ, Daanen HA, Majerczak J, Grassi B, Taylor BJ, Johnson BD, Alves de Almeida J, Simões HG, Seifert T. Commentaries on Viewpoint: The two-hour marathon: Who and when? ***J Appl Physiol*** **110**: 278–293, 2011.
30. Tarnopolsky MA. Sex differences in exercise metabolism and the role of 17-beta estradiol. ***Med Sci Sports Exerc*** **40**: 648–654, 2008.
31. Web Marketing Associates. Marathon Guide.www.marathonguide.com [accessed September 30, 2014].
32. Whipp BJ, Ward SA. Will women soon outrun men? ***Nature*** **355**: 25, 1992.