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Section: Invited Commentary

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INVITED COMMENTARY

NATURE VS. NURTURE: HAVE PERFORMANCE GAPS BETWEEN MEN AND WOMEN REACHED AN ASYMPOTOTE?

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ABSTRACT

Men outperform women in sports requiring muscular strength and/or endurance, but the relative influence of “nurture” versus “nature” remains difficult to quantify. Performance gaps between elite men and women are well-documented using world records in second, centimeter or kilogram sports. However, this approach is biased by global disparity in reward structures and opportunities for women. Despite policies enhancing female participation (Title IX legislation), USA women only closed performance gaps by 2 and 5% in Olympic Trial swimming and running, respectively, from 1972 to 1980 (with no change thereafter through 2016). Performance gaps of 13% in elite mid-distance running and 8% in swimming (~4 min duration) remain, the 5% differential between sports indicative of load carriage disadvantages of higher female body fatness in running. Conversely, sprint swimming exhibits a greater sex difference than sprint running suggesting anthropometric/power advantages unique to swim block starts. The ~40 y plateau in the performance gap suggests a persistent dominance of biological influences (e.g., longer limb levers, greater muscle mass, aerobic capacity, lower fat mass) on performance. Current evidence suggests women will not swim or run as fast as men in Olympic events, which speaks *against* eliminating sex segregation in these individual sports. Whether hormone reassignment sufficiently levels the playing field in Olympic sports for transgender females (born and socialized male) remains an issue to be tackled by sport governing bodies.

Key Words: athletics; track; swimming; gender; sex difference

could account for other biologically-relevant differences in performance. Furthermore, any historical change would estimate the magnitude of the effect that socio-cultural factors played in male-female differences, while any plateau thereafter theoretically representing the extent to which biological factors persist.

The Olympic Trials represents the most highly competitive event in the USA with all top athletes competing in a single competition. Thus, this yields a representative sample distribution of elite performances (as opposed to a random individual swim or track meet) under similar environmental conditions (unlike world records). Performance times for top eight finishers were extracted from official archived results on the websites of USA Swimming¹⁵ and USA Track and Field News.¹⁶ Only 100 to 1500 m events in athletics were extracted due to incomplete historical data (several female events not added until 1984), and distance only up to 400 m swimming where both men and women compete in the Olympics (with change to occur in 2020). The % sex difference was calculated for each pairwise comparison (1st place male vs. 1st place female through 8th place) similar to other studies^{7,10,17} using the following equation (where n = nth placing for a given event): Sex Difference (%) = [(Female_n (s) – Male_n (s)) / Male_n (s)] * 100.

Historical progression of the performance gap

Data are illustrated each year by distance with a locally weighted polynomial regression for swim and run events (Figure 1 A and B), with an early plateau clearly observed in both sports. Following Title IX, overall mean swim performance gap was higher in 1972 (13.2 ± 2.0%) and 1976 (12.4 ± 1.7%) versus all subsequent years (1980-2016), remaining stable thereafter at 11.2 ± 1.7% (across all swim strokes/distances a net change of 2%). Surprisingly, the swimming performance gap was actually lower in 1968 compared to 1972, possibly due to the Olympic Trials held in different pools and dates (influencing performance due to timing of taper/rest cycles). For

male advantage²² in 400 m pool swimming, based upon slightly lower differences (~7%) in elite 10 km open water swimming.¹⁷ Reduced sex differences as swim distance increases is consistent with others,^{7,23} but contrasts with ultra-distance running where the magnitude of performance gaps may widen (up to ~17% faster for men).^{24,25} A lower disadvantage for women in open water distance swimming^{26,27} is attributed to enhanced center of buoyancy,²⁸ swimming economy,¹⁹ greater mechanical efficiency²⁹ and lower underwater torque (tendency for feet to sink).³⁰ However, data from select ultra-distance events (i.e., non-representative samples)^{26,27} led to speculation that if competitive events are long enough, women may eventually close the performance gap in distance running¹¹ and swimming.¹² Unlike predictions of eventual closure,¹² current evidence using representative elite populations¹⁷ suggests a sex difference will persist.

One might assume performance gaps would be greatest in events requiring explosive muscular power/sprinting ability, but we found this only in swimming, not running. The greater gap in sprint swimming (13%) vs. running (10-11%) suggests anthropometric advantages associated with the start and/or upper body power in swimming contribute an additional ~2% beyond advantages for men assumed during sprint running. The gap was predicted to eventually close in sprints,³¹ an interesting position given our lowest performance gap in the 100 m run. A small rise in performance gap of sprint events during the 1980s was attributed to improved drug testing, presumably reducing anabolic steroid abuse in women.¹⁰ Physical characteristics advantages under the influence of testosterone (muscular hypertrophy/strength) are well known.³² However, if power/strength advantages are the primary determinants of sprint performance, then in both swimming and running the shortest Olympic distances (50 m and 100 m, respectively) we might expect a greater male advantage, which was observed only in swimming and not running. Our data was consistent with the proposal that less inertia to be overcome by women to accelerate

a smaller body mass on land might explain lower sex differences associated with the shortest running events on the track.³³

A significant portion of the residual sex difference observed in elite sprint running (~10%) is likely due to greater male muscle mass to generate peak horizontal power, although few studies on anaerobic power differences are available.³⁴ Testosterone levels do not predict performance in sprint/power events in elite athletics.³⁵ Furthermore, sex is not binary with examples of genetic intersex conditions, which may be more prevalent in elite female Olympians.¹⁸ The validity of sex testing for sport classification (based on testosterone levels) remains a controversial issue beyond the scope of this commentary. However, looming as a future issue is whether testosterone hormone reassignment (after some minimal time following “completion of anatomic changes”) sufficiently levels the playing field in Olympic sports for transgender females (born and socialized male).^{36,37} Longitudinal studies following post-pubertal hormone reassignment might quantify the impact of testosterone per se on performance. Although few IOC cases are under consideration, post-pubertal anthropometric advantages (stature, lever length) would presumably persist along with any potential socio-cultural “advantage” during growth and development.³⁶

Nurture factors remaining to be quantified

In terms of other “nurture” factors, increasing age of elite athletes reflects motivation to train and remain competitive in sport. Men and women may peak at similar ages (late 20s), but top placing marathoners were older for women.³⁸ Older swimmers are returning due to professional sponsorships available (e.g., 41 y old female 2008 Olympic silver medalist). Recent reports³⁹ suggest 20 y is the peak age for international swimming with “little sex difference” consistent with Olympic medalists in swimming.⁴⁰ Although some key factors (increased professional opportunity, later competitive age) appear “equivalent” between the sexes, other possible “nurture”

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Disclosure statement

No potential conflict of interest was reported by the authors.

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Table 1. %Sex Difference by Swimming Event Over 44 Years (1972 vs. 2016)

SWIMMING Event	Mean (\pm SD) Sex Difference by Event (1972 vs. 2016)		1 st Place Time (s)		2016 Top Woman’s Place in Men’s 1972 Race
	1972	2016	1972 Men	2016 Women	
50 m Free	14.3 \pm 0.5% ^A	13.1 \pm 0.5% [*]	23.07	24.28	70 th
100 m Free	13.2 \pm 0.4%	10.9 \pm 0.6% [*]	51.91	53.28	9 th
200 m Free	11.2 \pm 0.6%	9.3 \pm 0.6% [*]	113.58	114.88	5 th
400 m Free	9.5 \pm 0.8%	8.5 \pm 1.5%	240.70	238.98	1 st
100 m Back	14.6 \pm 0.9%	11.8 \pm 1.3% [*]	58.61	59.02	2 nd
200 m Back	14.4 \pm 1.3%	10.9 \pm 0.5% [*]	126.57	126.90	3 rd
100 m Breast	16.2 \pm 1.0%	12.0 \pm 0.9% [*]	65.99	65.20	1 st
200 m Breast	13.5 \pm 0.7%	12.3 \pm 1.1% [*]	143.27	144.08	2 nd
100 m Fly	14.9 \pm 1.1%	12.7 \pm 1.4% [*]	54.56	56.48	2 nd
200 m Fly	12.7 \pm 1.1%	11.4 \pm 0.9% [*]	121.53	126.80	12 th
200 m IM	13.0 \pm 1.2%	10.7 \pm 1.0% [*]	129.30	129.54	Tie 2 nd
400 m IM	12.0 \pm 1.1%	9.0 \pm 0.8% [*]	270.81	273.73	3 rd
Overall	13.2 \pm 2.0%	11.1 \pm 1.5%	-	-	-

^A For 50 m Free, 1980 is the earliest year available for women so compared both groups from 1980

^{*} Performance gap narrowed ($p < 0.05$) for all events except 400 m Free

