THE EVOLUTION OF SPEED IN ATHLETICS: WHY THE FASTEST RUNNERS ARE BLACK AND SWIMMERS WHITE

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ABSTRACT

Here we explain a much avoided phenomenon in the evolution of speed sports for men and women: The world records in running tend to be set by black athletes and in swimming by white athletes. We show that this phenomenon is predictable from physics. Locomotion is a 'falling-forward' cycle, in which body mass falls forward and then rises again. Mass that falls from a higher altitude falls faster, down and forward. In running, the altitude (L_1) is set by the position of the center of mass above the ground. In swimming, the altitude is set by the upper body rising above the water, and it is proportional to $H - L_1$, where H is the height of the athlete. The anthropometric literature shows that the center of mass in blacks is 3 percent higher above the ground than in whites. This means that blacks hold a 1.5 percent speed advantage in running, and whites hold a 1.5 percent speed advantage in swimming. Among athletes of the same height Asians are even more favored than whites in swimming but they are not setting records because they are not as tall.
Keywords: animal locomotion, constructal, evolution, running, speed sports, swimming.

1 THE PHENOMENON: BLACK VERSUS WHITE IN SPEED SPORTS

Speed records increase in time. Figure 1 shows two examples that cover the past century: men's record speeds in running (100 m dash) and swimming (100 m freestyle). They illustrate the evolution of the speed sports, not the evolution of an individual athlete in training. The evolution of the sport is the morphing of the societal 'flow system' in which faster individuals from the large population are recruited and trained in constantly improving institutions and facilities. The few athletes who are remembered for having climbed once on the highest podium are a small sample of how the performance of the population of runners and swimmers is evolving in time.

In a recent paper [1] we showed that the steady increases in winning speed are accompanied by increases in body mass and height. We showed that this speed-mass (or speed-height) relation is predictable from the constructal-theory scaling of animal speed versus body size [2].

Examined more closely, the evolution of the speed sports (Fig. 1) reveals a phenomenon that is as obvious as it is obviously *not discussed*. More and more, the winning runners are black athletes, particularly of West African orgin, and the winning swimmers are white. More and more, the world finalists in sprint are black and in swimming are white (Fig. 1). Here, we show that this evolutionary phenomenon too is predictable, and is an integral part of the phenomenon of speed evolution in modern athletics.

Our approach is to study phenotypic (somatotypic) differences of human locomotion in different media (terrestrial vs. aquatic), which we consider to have been historically misclassified as racial characteristics. These differences represent consequences of still not well-understood variable environmental stimuli for survival fitness in different parts of the globe during thousands of years of habitation [3–6]. Our study does not advance the notion of race, now recognized as a *social* construct, as opposed to a *biological* construct. We acknowledge the wide phenotypic and genotypic diversity among the so-called racial types.
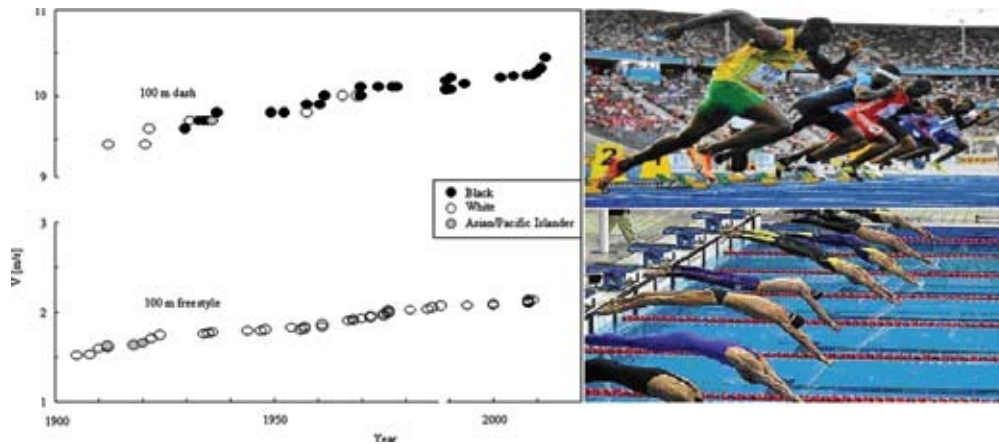
Figure 1: The evolution of men's world record speeds in running (100 m dash) and swimming (100 m freestyle) in modern athletics. The data are from Tables 1 and 2.

Table 1: Men's 100 m freestyle world records.

Year	Name	Time (s)	Velocity (m/s)	Race
1905	Zoltan Halmay	65.8	1.52	White
1908	Charles Daniels	65.6	1.52	White
1910	Charles Daniels	62.8	1.59	White
1912	Kurt Bretting	62.4	1.60	White
1912	Duke Kahanamoku	61.6	1.62	Asian/Pacific Islander
1918	Duke Kahanamoku	61.4	1.63	Asian/Pacific Islander
1920	Duke Kahanamoku	60.4	1.66	Asian/Pacific Islander
1922	Johnny Weissmuller	58.6	1.71	White
1924	Johnny Weissmuller	57.4	1.74	White
1934	Peter Fick	56.8	1.76	White
1935	Peter Fick	56.6	1.77	White
1936	Peter Fick	56.4	1.77	White
1944	Alan Ford	55.9	1.79	White
1947	Alex Jany	55.8	1.79	White
1948	Alan Ford	55.4	1.81	White
1954	Dick Cleveland	54.8	1.82	White
1956	John Henricks	55.4	1.81	White
1957	John Devitt	55.2	1.81	White
1957	John Devitt	54.6	1.83	White
1961	Steve Clarke	54.4	1.84	White
1961	Manuel Dos Santos	53.6	1.87	White
1967	Ken Walsh	52.6	1.90	White
1968	Zachary Zorn	52.5	1.90	White
1968	Michael Wenden	52.2	1.92	White
1970	Mark Spitz	51.9	1.93	White

Continued

Table 1: *Continued*

Year	Name	Time (s)	Velocity (m/s)	Race
1972	Mark Spitz	51.47	1.94	White
1972	Mark Spitz	51.22	1.95	White
1975	James Montgomery	51.12	1.96	White
1975	Andrew Cohen	51.11	1.96	White
1975	James Montgomery	50.59	1.98	White
1976	James Montgomery	50.39	1.98	White
1976	James Montgomery	49.99	2.00	White
1976	Jonty Skinner	49.44	2.02	White
1981	Rowdy Gains	49.36	2.03	White
1985	Matt Biondi	49.24	2.03	White
1986	Matt Biondi	48.74	2.05	White
1988	Matt Biondi	48.42	2.07	White
1994	Alexander Popov	48.21	2.07	White
2000	Michael Klim	48.18	2.08	White
2000	Pieter van den Hoogenband	47.84	2.09	White
2008	Alain Bernard	47.60	2.10	White
2008	Alain Bernard	47.50	2.11	White
2008	Eamon Sullivan	47.24	2.12	White
2008	Alain Bernard	47.20	2.12	White
2008	Eamon Sullivan	47.05	2.13	White
2009	Cesar Cielo	46.91	2.13	White

Table 2: Men's 100 m dash world records.

Year	Name	Time (s)	Velocity (m/s)	Race
1912	Don Lippincott	10.6	9.43	White
1920	Jackson Sholz	10.6	9.43	White
1921	Charlie Paddock	10.4	9.62	White
1929	Eddie Tolan	10.4	9.62	Black
1930	Percy Williams	10.3	9.71	White
1932	Eddie Tolan	10.3	9.71	Black
1932	Ralph Metcalfe	10.3	9.71	Black
1933	Ralph Metcalfe	10.3	9.71	Black
1934	Eulace Peacock	10.3	9.71	Black
1934	Chris Berger	10.3	9.71	White
1934	Ralph Metcalfe	10.3	9.71	Black
1935	Takanori Yoshioka	10.3	9.71	Asian/Pacific Islander
1936	Jesse Owens	10.2	9.80	Black
1948	Lloyd LaBeach	10.2	9.80	Black
1948	Barney Ewell	10.2	9.80	Black
1951	Emmanuel McDonald Bailey	10.2	9.80	Black
1956	Bobby Joe Morrow	10.2	9.80	White

Table 2: *Continued*

Year	Name	Time (s)	Velocity (m/s)	Race
1956	Willie Williams	10.1	9.90	Black
1959	Ray Norton	10.1	9.90	Black
1960	Armin Hary	10.0	10.00	White
1960	Harry Jerome	10.0	10.00	Black
1964	Horacio Estaves	10.0	10.00	White
1964	Bob Hayes	10.0	10.00	Black
1967	Jim Hines	10.0	10.00	Black
1967	Enrique Figuerola	10.0	10.00	White
1968	Paul Nash	10.0	10.00	Black
1968	Charles Greene	10.0	10.00	Black
1968	Jim Hines	9.9	10.10	Black
1968	Ronnie Ray Smith	9.9	10.10	Black
1968	Charles Greene	9.9	10.10	Black
1972	Eddie Hart	9.9	10.10	Black
1972	Reynaud Robinson	9.9	10.10	Black
1972	Steve Williams	9.9	10.10	Black
1975	Silvio Leonard	9.9	10.10	Black
1976	Harvey Glance	9.9	10.10	Black
1976	Don Quarrie	9.9	10.10	Black
1987	Carl Lewis	9.93	10.07	Black
1987	Ben Johnson	9.83	10.17	Black
1988	Ben Johnson	9.79	10.21	Black
1988	Carl Lewis	9.92	10.08	Black
1991	Carl Lewis	9.86	10.14	Black
1999	Maurice Greene	9.79	10.21	Black
2002	Tim Montgomery	9.78	10.22	Black
2005	Asafa Powell	9.77	10.24	Black
2006	Justin Gatlin	9.77	10.24	Black
2006	Asafa Powell	9.77	10.24	Black
2006	Asafa Powell	9.77	10.24	Black
2007	Asafa Powell	9.74	10.27	Black
2008	Usain Bolt	9.69	10.32	Black
2009	Usain Bolt	9.58	10.44	Black

2 SPEED AND BODY SIZE

Broadly speaking, larger animals travel faster, undulate their bodies and limbs less frequently and can exert greater forces. It was shown that these features of 'animal locomotion' are valid over the broadest range of animal body sizes, species and environments [2] (M = 10^{-6}–10^4 kg; sea, land, air). They are part of a much larger volume of observations of how the body size determines the functioning of animals [7–10]. In the unifying theory of animal locomotion [2, 11], the speeds and frequencies of fliers, runners and swimmers were derived from the argument that animal locomotion is the evolving configuration of the flow of animal mass on earth, which is analogous to the flow of water mass in river basins. The evolution of both flow structures

(river water, animal mass) was deduced from the constructal law: 'For a finite-size flow system to persist in time (to live) it must evolve such that it provides easier and easier access to its currents' [12].

The animal was modeled as a body with a single length scale, L_b, such that $M \sim \rho L_b^3$ (see Fig. 2a). The total work requirement has two parts: the work needed to lift the moving body away from the earth (against gravity), W_1, and the work needed to penetrate through the surrounding medium in the horizontal direction, W_2. Both W_1 and W_2 depend on the horizontal speed of locomotion, V. The sum $(W_1 + W_2)$ is minimal when the vertical loss W_1 is of the same order as the horizontal loss W_2. From this balance emerge analytically all the known scaling laws of animal locomotion (speeds, forces and frequencies) in air, on land and in water. For example, the speed-mass relations predicted for swimming and flying are

$$V_{swim} \sim g^{1/2} M^{1/6} \rho^{-1/6},$$ (1)

$$V_{fly} \sim \left(\frac{\rho}{\rho_a}\right)^{1/3} g^{1/2} M^{1/6} \rho^{-1/6},$$ (2)

where the additional factor $(\rho/\rho_a)^{1/3}$ is approximately 10, because the air density is of order $\rho_a \sim 1$ kg/m^3 and the body density is of order $\rho \sim 10^3$ kg/m^3. For running, the predicted speed V_{run} falls between eqns (1) and (2): the factor $(\rho/\rho_a)^{1/3}$ is replaced by a factor of order 1 for running on mud, sand and snow, and a factor below 10 for running on flat and dry surfaces.
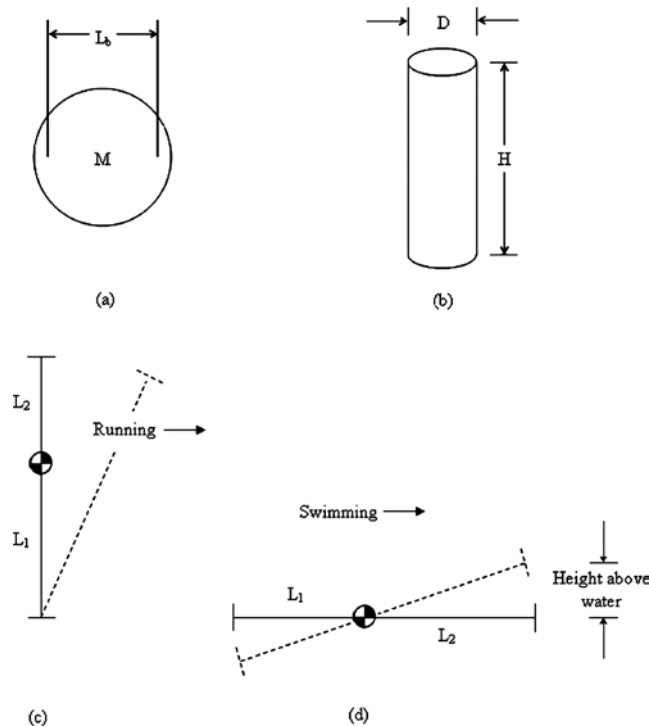

Figure 2: Models used to predict the scaling rules of animal locomotion: (a) one scale, (b) two scales. The length scales of falling-forward locomotion: (c) L_1 for running, and (d) L_2 for swimming.

To predict the evolution of speed sports, in [1] we modeled the human body as a cylinder of height H and diameter D (Fig. 2b). We showed that the same scaling relations, eqns (1) and 2), can be derived more directly by regarding every case of animal movement as 'falling-forward locomotion', i.e. as a sequence of many cycles in which a body rises, falls forward and rights itself up again. The scale of the speed of falling vertically is the same as the scale of the speed of falling forward. In swimming, the vertical length scale of the saw-toothed trajectory of the body is D. The time scale of its free fall is the Galilean time $(D/g)^{1/2}$, and the downward and forward speed scale is of order

$$V_{swim} \sim (gD)^{1/2}. \tag{3}$$

This is also the horizontal speed of the water wave (of amplitude length scale D) generated by the swimming body. In running, the vertical length scale of the human body is H, and the time scale of falling down and forward is $t \sim (H/g)^{1/2}$. The speed of falling forward is of order

$$V_{run} \sim (gH)^{1/2}. \tag{4}$$

If the one-scale model $(D \sim H \sim L_b$; Fig. 2a) is used, then the single scale is $(D, H) \sim (M/\rho)^{1/3}$, and eqns (3) and (4) reproduce the original scaling relations, eqns (1) and (2).

3 THE EFFECT OF ORIGIN

To explain the phenomenon of Fig. 1, it is tempting to begin with the observation that blacks have body densities (ρ) that are slightly (roughly 1 percent) larger than the body densities of whites [13–15]. This fact may be relevant to a comparison of the efforts needed by swimmers to stay afloat in place (treading water), but cannot explain the differences in *horizontal* speeds in running and swimming. Recall that the phenomenon of Fig. 1 is about swimming *and* running, not about swimming alone, or swimming in place.

Key is the observation that the body density does not appear in the formulas for the swimming and running speeds, eqns (3) and (4). The only physiological measure that matters is the height from which the mass falls – the water wave, eqn (3), and the human body, eqn (4).

Mass and height are key requirements for speed [1], but in a group of athletes with the same M and H there is another measurement that matters. During the falling-forward locomotion cycle of running, the body does not fall from the height H (the top of the head). What falls is the center of mass of the body, and it falls from the height L_1 defined in Fig. 2c. Runners with a longer L_1 should have the advantage.

For swimming, eqn (3) draws attention to the same aspect of the human body design. During the falling-forward motion of the water wave, the elevation above the water line (i.e. the amplitude of the water wave) is not the thickness of the body, D. The correct vertical length scale is proportional to the distance L_2 measured from the center of mass to the top of the head (Fig. 2d). To the observer who travels horizontally with the same speed as the swimmer, the body of the swimmer is a lever (a seesaw) that oscillates about its center of mass and generates water waves. When the arm L_2 is longer, the front part of the torso and the displaced water are lifted to and fall from a higher position, and they fall forward faster. The swimmer with a longer L_2 (i.e. with a lower center of mass) should have the advantage.

Anthropometric measurements of large populations show that systematic differences exist among blacks, whites and Asians. The published evidence is massive: blacks have longer limbs than whites [16–18], and because blacks have longer legs and smaller circumferences (e.g. calves and arms), their center of mass is higher than that in other individuals of the same height [14, 17]. Asians and whites have longer torsos, therefore their centers of mass are lower. A large volume of measurements that
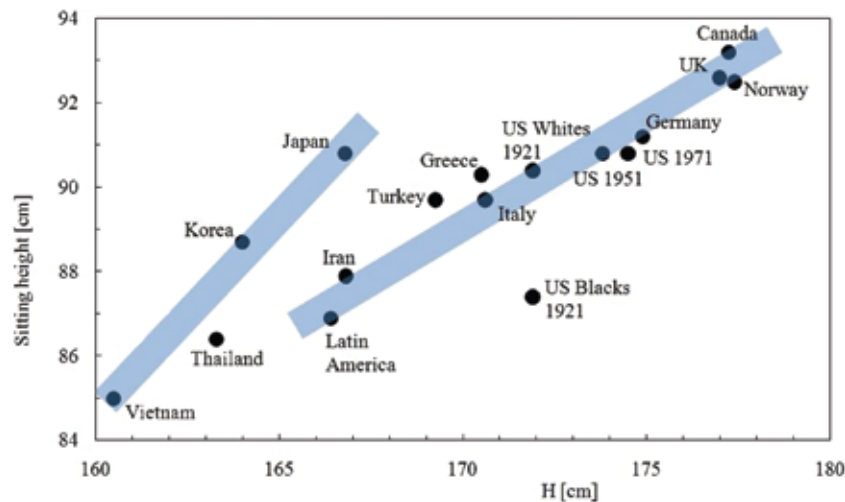
Figure 3: The heights and sitting heights of 17 groups of military men from selected populations (after Himes [19]): Vietnam [20]; Thailand [21]; Korea [22]; Latin America [23]; Iran [24]; Japan [25]; Turkey, Greece, Italy [26]; U.S. Whites 1921, U.S. Blacks 1921 [27]; U.S. Whites 1951 [28]; U.S. Whites 1971 [29]; Germany [30]; United Kingdom [31]; Canada [32]; Norway [33].

document these features is summarized in Fig. 3 and its caption. Measurements of 17 groups of military men from many parts of the globe were conducted in 14 independent studies and compiled by Himes [19] as the average stature (the height of the body, H) versus the average height while seated. The sitting height is not exactly the L_2 dimension defined in Fig. 2c, but differences between sitting heights are indicative of how L_2 varies from one group to the next.

Three conclusions follow from Fig. 3. First, Asians have the largest sitting heights among individuals with the same H. According to Fig. 2d then, Asians should be most favored among swimmers who are not tall. This, by the way, agrees with the beginnings of speed records in swimming (Fig. 1, 1912–1920).

Second, whites also line up as a monotonic relation between sitting height (roughly L_2) and total height (H), but their L_2 is lower than that for Asians. This correlation stretches from the shorter (Iran, Latin America) to the taller (Norway, UK, Canada).

Third, the measurements of the group of blacks fall well below those of the other groups. Their average sitting height (87.5 cm) is 3 cm shorter than the average sitting height of the group of men with the same average height (172 cm).

If the sitting height is an approximate measure of L_2, then the dimension that dictates the speed in running (L_1) is 3.7 percent greater in blacks than in whites. At the same time, the dimension that governs speed in swimming is 3.5 percent greater in whites than in blacks.

These 3-percent differences in L_1 (or L_2) are consistent with other measurements. For example, according to [17] the upper- and lower-extremity bone lengths are significantly longer in adult black females than in white females. For the lower-extremity bone lengths, the difference is between 80.3 ± 10.4 cm (black females) and 78.1 ± 6.2 cm (white females). This difference of 2.2 cm represents 2.7 percent of the lower-extremity length, and it is of the same order as the 3.7 percent difference between the sitting heights of whites and blacks.

4 CONCLUSION

In summary, 3 percent is the order of magnitude that differentiates between the positions of the centers of mass in the bodies of blacks and whites, and favors the two groups differently in the two speed sports: blacks in running, and whites in swimming.

For runners, the 3 percent increase in the correct height [L_1 instead of H in eqn (4)] means a 1.5 percent increase in the winning speed for the 100 m dash. This represents a 1.5 percent decrease in the winning time, for example, a drop from 10 to 9.85 s. This change is enormous in comparison with the incremental decreases that differentiate between world records from year to year. In fact, the 0.15 s decrease corresponds to the evolution of the speed records over 20 years, from 1960 (Armin Hary) to 1991 (Carl Lewis). The 3 percent difference in L_1 between groups represents an enormous advantage for black athletes.

For swimming, the conclusion is quantitatively the same, but in favor of white athletes. The 3 percent increase in the correct length [L_2, instead of D in eqn (3)] means a 1.5 percent increase in winning speed, and a 1.5 percent decrease in winning time. Because the winning times for 100 m freestyle are of the order of 50 s, this represents a decrease of the order of 0.75 s in the winning time. This is a significant advantage for white swimmers, because it corresponds to evolution of the records over 10 years, for example, from 1976 (James Montgomery) to 1985 (Matt Biondi).

Further support for this explanation of the speed records phenomenon is provided by Fig. 4, which shows the evolution of the speed records set by women in the 100 m dash and the 100 m freestyle. Figure 4 for women is the same as Fig. 1 for men. The female sprinters that set the records tend to be black. This trend is a bit more recent than for men, but it is as evident. In swimming, the dominance of white women is evident throughout the modern era, just as it is for men.
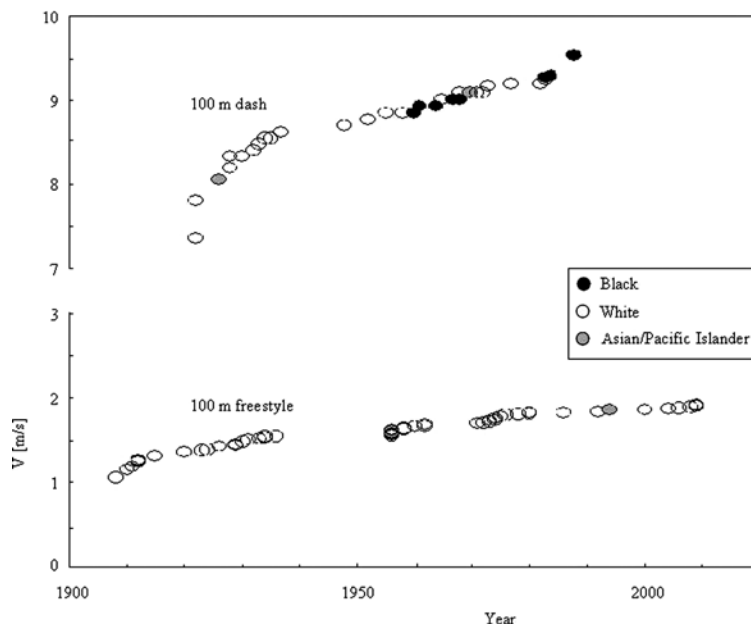

Figure 4: The evolution of women's world record speeds in running (100 m dash) and swimming (100 m freestyle). The data are from Tables 3 and 4.

Table 3: Women's 100 m freestyle world records.

Year	Name	Time (s)	Velocity (m/s)	Race
1908	Martha Gerstung	95.0	1.05	White
1910	C. Guttenstein	86.6	1.15	White
1911	Daisy Curwen	84.6	1.18	White
1912	Daisy Curwen	80.6	1.24	White
1912	Fanny Durack	79.8	1.25	White
1912	Fanny Durack	78.8	1.27	White
1915	Fanny Durack	76.2	1.31	White
1920	Ethelda Bleibtrey	73.6	1.36	White
1923	Gertrude Ederle	72.8	1.37	White
1924	Mariechen Wehselau	72.2	1.39	White
1926	Ethil Lackie	70.0	1.43	White
1929	Eleanor Ganatti	69.8	1.43	White
1929	Albina Osinowich	69.4	1.44	White
1930	Helene Madison	68.0	1.47	White
1931	Helene Madison	66.6	1.50	White
1933	Willy den Ouden	66.0	1.52	White
1934	Willy den Ouden	65.4	1.53	White
1934	Willy den Ouden	64.8	1.54	White
1936	Willy den Ouden	64.6	1.55	White
1956	Dawn Fraser	64.5	1.55	White
1956	Cocky Gastelaars	64.2	1.56	White
1956	Cocky Gastelaars	64.0	1.56	White
1956	Dawn Fraser	63.3	1.58	White
1956	Lorraine Crapp	63.2	1.58	White
1956	Lorraine Crapp	62.4	1.60	White
1956	Dawn Fraser	62.0	1.61	White
1958	Dawn Fraser	61.5	1.63	White
1958	Dawn Fraser	61.4	1.63	White
1958	Dawn Fraser	61.2	1.63	White
1960	Dawn Fraser	60.2	1.66	White
1962	Dawn Fraser	60.0	1.67	White
1962	Dawn Fraser	59.9	1.67	White
1962	Dawn Fraser	59.5	1.68	White
1971	Shane Gould	58.9	1.70	White
1972	Shane Gould	58.5	1.71	White
1973	Kornelia Ender	58.25	1.72	White
1973	Kornelia Ender	58.12	1.72	White
1973	Kornelia Ender	57.61	1.74	White
1973	Kornelia Ender	57.54	1.74	White
1974	Kornelia Ender	57.51	1.74	White
1974	Kornelia Ender	56.96	1.76	White
1975	Kornelia Ender	56.38	1.77	White
1975	Kornelia Ender	56.22	1.78	White

Continued

Table 3: *Continued*

Year	Name	Time (s)	Velocity (m/s)	Race
1976	Kornelia Ender	55.73	1.79	White
1976	Kornelia Ender	55.65	1.80	White
1978	Barbara Krause	55.41	1.80	White
1980	Barbara Krause	54.98	1.82	White
1980	Barbara Krause	54.79	1.83	White
1986	Kristin Otto	54.73	1.83	White
1992	Jenny Thompson	54.48	1.84	White
1994	Jingyi Le	54.01	1.85	Asian/Pacific Islander
2000	Inge de Bruijn	53.80	1.86	White
2000	Inge de Bruijn	53.77	1.86	White
2004	Lisbeth Lenton	53.66	1.86	White
2004	Jodie Henry	53.52	1.87	White
2006	Lisbeth Lenton	53.42	1.87	White
2006	Britta Steffen	53.30	1.88	White
2008	Lisbeth Trickett	52.88	1.89	White
2009	Britta Steffen	52.85	1.89	White
2009	Britta Steffen	52.56	1.90	White
2009	Britta Steffen	52.22	1.91	White
2009	Britta Steffen	52.07	1.92	White

Table 4: Women's 100 m dash world records.

Year	Name	Time (s)	Velocity (m/s)	Race
1922	Marie Mejzlikova	13.6	7.35	White
1922	Mary Lines	12.8	7.81	White
1926	Gundel Whittmann	12.4	8.06	White
1928	Kinue Hitomi	12.2	8.20	Asian/Pacific Islander
1928	Myrtle Cook	12.0	8.33	White
1930	Tollien Schuurman	12.0	8.33	White
1932	Tollien Schuurman	11.9	8.40	White
1932	Stanislawa Walasiewicz	11.9	8.40	White
1933	Stanislawa Walasiewicz	11.8	8.47	White
1934	Stanislawa Walasiewicz	11.7	8.55	White
1935	Helen Stephens	11.7	8.55	White
1937	Stanislawa Walasiewicz	11.6	8.62	White
1948	Fanny Blankers-Koen	11.5	8.70	White
1952	Marjorie Jackson	11.4	8.77	White
1955	Shirley Strickland	11.3	8.85	White
1958	Vera Krepkina	11.3	8.85	White
1960	Wilma Rudolph	11.3	8.85	Black
1961	Wilma Rudolph	11.2	8.93	Black

Table 4: *Continued*

Year	Name	Time (s)	Velocity (m/s)	Race
1964	Wyomia Tyus	11.2	8.93	Black
1965	Irena Kirszenstein	11.1	9.01	White
1967	Barbara Ferrell	11.1	9.01	Black
1968	Lyudmila Samotyosova	11.1	9.01	White
1968	Irena Szewinska	11.1	9.01	White
1968	Wyomia Tyus	11.0	9.09	Black
1970	Chi Cheng	11.0	9.09	Asian/Pacific Islander
1970	Renate Meißner*	11.0	9.09	White
1971	Renate Meißner*	11.0	9.09	White
1972	Renate Meißner*	11.0	9.09	White
1972	Ellen Strophal*	11.0	9.09	White
1972	Eva Gleskova	11.0	9.09	White
1973	Renate Meißner*	10.9	9.17	White
1973	Renate Meißner*	10.9	9.17	White
1977	Marlies Oelsner*	10.88	9.19	White
1982	Marlies Gohr*	10.88	9.19	White
1983	Marlies Gohr*	10.81	9.25	White
1983	Evelyn Ashford	10.79	9.27	Black
1984	Evelyn Ashford	10.76	9.29	Black
1988	Florence Griffith-Joyner	10.49	9.53	Black

*East German athlete (steroid usage suspected).

Even more support for the theoretical explanation advanced here is the relative absence of Asian record holders, especially during the past two decades. According to the physics of falling-forward locomotion (Figs 2c and d), Asians should have an advantage in swimming, but not in running, because their torsos are relatively longer (cf. Fig. 3, if the height H is fixed). This is in accord with the evolution of records for men (Fig. 1) and women (Fig. 4). Asians would be favored among swimmers with the same height. However, the quest for speed has driven the sport toward longer torsos (L_2), not longer relative torsos (L_2/H). This is why the current trend in swimming is toward tall individuals (large H), and in this direction Asians are at a disadvantage relative to athletes of European origin. Still, because female swimmers are not (yet) as tall as male swimmers, Asians continue to be competitive in the 100 m freestyle for women. This opportunity will end (as it did in men's swimming), because the winners' podium is being taken over (predictably, cf. [1]) by taller and taller athletes.

One of the reviewers suggested that our discovery in this paper and in Ref. [1] has much broader implications in the evolution of speed in sports. The reviewer questioned the evolution of size and shape in dog racing. We believe that the answer is the same as in this paper and Ref. [1]: the evolution of dog racing should be toward dogs that are taller, with longer legs and higher centers of mass off the ground. The same prediction holds for the evolution of winning horses in horse racing. Furthermore, bicycle racing and boat racing (crew) should follow the same trend—the winners should tend to be taller athletes riding on taller bicycles, and athletes that sit taller in longer boats.

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