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In Search of the Asymptote: Projecting the Limits of Human Performance

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In 1906, Harvard's Arthur Kennelly went out on a limb and predicted that some day a man might run the mile in the ultimate time of 3 minutes 58.7 seconds (Kennelly, 1906). Given that the world record (WR) at that time was 4:15.6, one can appreciate how distant and impossible such a feat must have seemed. Indeed it was not until 1954 that his calculations were proven wrong by John Landy's 3:58.0 performance (Anon, 1970).

Despite the longevity of Kennelly's standard, it was far from an ultimate. With Steve Cram's current mile record at 3:46.33 and talk of a 3:30 mile beginning to round the turn, an ultimate prediction of 3:58.7 seems far short of the mark. Consider as well Bob Beamon's 17-year-old jump WR of 29' 2.5'' (8.90 m), which was generally regarded as eternal when it was set in 1968—and as recently as 1981 has been referred to by record student Ernst Jokl as a "mutation performance" unlikely to ever be surpassed (Angier, 1981). In a 1976 article in *Esquire*, Gideon Ariel produced calculations purporting to show that the ultimate long jump would be 29' 5'' (Anon, 1976). Yet Carl Lewis jumped 28' 10.25'' (8.79 m) in 1983 and, in defiance of a generation of perplexed performance prophets, has set his sights beyond 30 feet. Whether or not Lewis is the one, he has made us realize that someone will certainly pass 30 feet in the long jump before we reach forever.

Viewed in this light, it's not hard to see the ultimate foolishness of ultimate predictions. Clearly we scientists are not very good at this sort of thing. Yet this hasn't stopped generations of record prognosticators from demonstrating their fallibility (Craig, 1968; Francis, 1943; Frederick, 1977; Henry, 1954, 1955; Hill, 1927, 1950; Lloyd, 1966; Meade, 1956; Nigg, 1974; Rumball & Coleman, 1970; Ryan, 1974; Ryder, Carr, & Herget, 1976).

Ever since such records have been kept they have been inexorably broken, much to the puzzlement of scientists, like Kennelly, who delight in this ancient

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armchair sport of calculating the ultimate. What keeps these predictors continually sharpening their pencils and redefining the limits is the simple idea that there must be intrinsic limits to how high, how far, and how fast the fittest of our species can propel themselves. After all, no reasonable person would think that a human will someday run the mile in 5.4 microseconds (i.e., at the speed of light) or high jump over the moon, and few would disagree that the current records will be broken. Our scientific guesswork focuses on the vast territory in between. It is tempting to assume that there is an ultimate, a limit to human performance which we can predict, but this may not be the case.

Since 1913, when world records in athletics were first officially and carefully recorded, maximum running speeds over distances from 100 meters through the marathon have been accelerating at the constant, albeit glacial, rate of 0.75 meters per minute per year (Ryder, Carr, & Herget, 1976). This constant acceleration can be observed in Figure 1, which displays average speed against year and event for various running world-record performances from 1913 to the present. With the exception of a few pronounced bumps in the surface due to the emergence of what Jokl has dubbed "athletic geniuses," this acceleration has been gradual and virtually continuous over these 72 years.

There is no reason to believe that in the foreseeable future there will be any decline in that acceleration. Still, as with most rate-limited relationships, there is likely an asymptote, a V max if you will, which will some day cause a decrease in this rate of acceleration of world-record running speeds and which might possibly lead to virtually ultimate performances (i.e., where the rate of acceleration approaches zero). At this point in our understanding of human biomechanics, psychology, and physiology, however, we have no way of confidently estimating the magnitude of that asymptote for any of the many records currently kept.

In a 1982 analysis of the record histories of swimming, speed skating, and running, Piero Mognoni and co-workers found evidence of a slowing in the rate of record improvement in only five of 32 events studied (Mognoni, Lafortuna, Russo, & Minetti, 1982). But even this cannot be taken as evidence that true asymptotic values are being approached in those events. History has shown us that such lags in record improvement can often be reversed by radical technical improvements or new training regimens.

For example, the development of the fiberglass vaulting pole, the aerodynamic javelin, the skating technique in cross-country skiing, and the Fosbury Flop in high jumping are credited with reaccelerating the rates of improvement in those events. From 1940 to 1962 the WR in the pole vault improved only 9.25" (23.5 cm). In the 22-year increment from the introduction of the fiberglass pole in 1963 until 1985, however, the improvement has exceeded a meter and there was a 9-inch improvement in the *first year* it was used. Dillman and Nelson (1968) have detailed the biomechanical underpinning of this phenomenal technical advance. Similarly, Terauds (1974) has estimated that the improved flight characteristics of modern javelins add 35 feet or more to the distance of a throw, and Ekström (1985) has presented data predicting that the recently popularized skating technique will allow Nordic skiers to propel themselves up to 30% faster. The fact that the center of mass of the body can pass closer to the bar when using the flop high jump technique is also thought to promote better performance (Hay, 1978). And future performances in the high jump might be drastically improved by the use of a technique proposed by Hay.

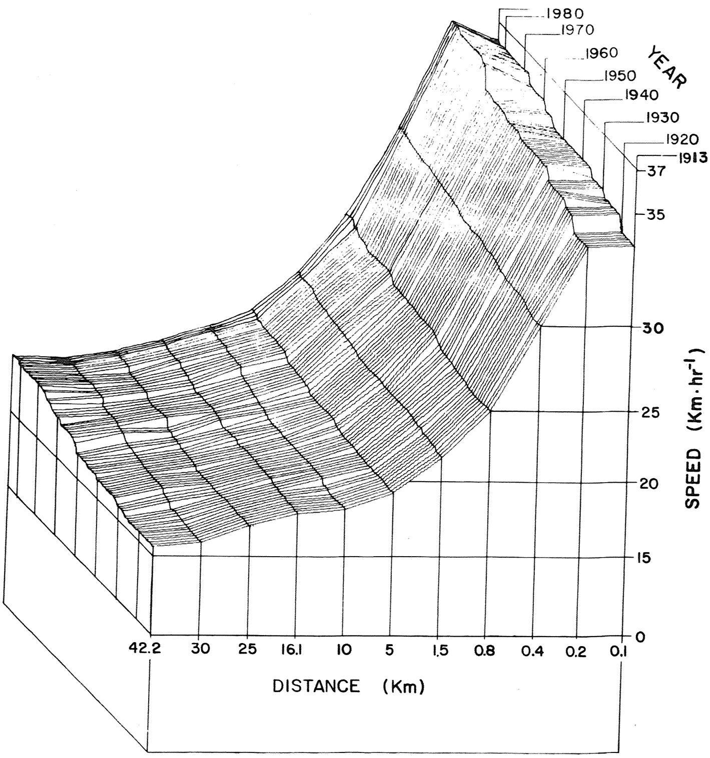

Figure 1 — Average speed for world running records from 1913 to 1984 at distances from 100m to 42.2 km. Speed is displayed as an exponential function to exaggerate the appearance of improvements. To avoid an overemphasis on the shorter distances, distances are not to scale. Note the gradual acceleration in speed over the years for each of these record performances. Data were plotted with the technical assistance of James Larsen and are taken from *The IAAF Progressive World Record Lists* (Anon., 1970) and from recent summaries in *Track and Field News*.

The stagnation of the marathon world best that occurred in the 1930s and 1940s was similarly overcome by innovation. In this case, the high mileage and interval training techniques popularized in the 1950s by Jim Peters and Emil Zatopek overcame that particular slowing in the rate of improvement. It is clear from these examples that one of the factors missing from the equations of record prognosticators is the inventiveness and adaptability of the human spirit.

Another factor that keeps us from having a better idea of our limits is the utter embryonic stage of our understanding of the limits of human performance. Much like the records themselves, our estimates of what is biomechanically and physiologically possible are also being revised on a regular timetable. In 1927 the distinguished physiologist and kinesiologist A.V. Hill reported the highest maximum oxygen uptake ($\dot{V}O_2$ max) at that time (Hill, 1927). A high $\dot{V}O_2$ max is a prerequisite to record performance in endurance events. Relying on these data from a champion rower of 4.4 LO_2/min, Hill speculated that 5.5 LO_2/min would be the highest value that a human would ever achieve. In recent years, however, values near 6.0 LO_2/min have been recorded and $\dot{V}O_2$ max's in the range of 5.5 L are not unusual in elite caliber cross-country skiers (Daniels, 1974; Saltin & Åstrand, 1967).

Considering that $\dot{V}O_2$ max is just one of dozens of anthropometric, biomechanical, environmental, psychological, physiological, social, and technical variables that can affect performance, it's not hard to understand why we have done so poorly in our predictions. The truth is that we have no way of knowing of what we are capable. Consider the well-documented 1960 example of an hysterical 123 lb woman who lifted a 3,600 lb automobile to free her trapped son (McWhirter & McWhirter, 1971). Even if one is generous with leverage, she probably lifted at least 1,000 lbs! Just as our current athletic achievements would be beyond the imagination of past prognosticators like Kennelly, so are the ultimate limits beyond the ken of all but the dreamers among us.

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