WIND ASSISTANCE IN THE 100m SPRINT

by Nick Linthorne, Australia

This article and the one that follows are companions. Linthorne, a physicist at the University of Western Australia, has written two excellent technical pieces on wind assistance which are quite accessible to the non-scientist. Both of these articles originally appeared in the January, 1994 issue of Modern Athlete and Coach.

The effect of wind on sprint times is of considerable interest to athletes, coaches, and statisticians. I have recently developed a method of comparing the relative merit of 100m sprint times recorded under diverse wind conditions (Linthorne, 1993). A curve was derived that gives the amount of time assistance or hindrance in a race relative to a performance produced in windless conditions. The curve was deduced from an analysis of performances by athletes at recent Olympic Games and World Championships.

For each competition, I plotted the race times as a function of the wind velocity and examined the series of performances by each athlete. (Video recordings of all the races were viewed to identify instances when the athletes did not run to the best of their ability, and these performances were disregarded.)

As expected, faster times were recorded as the wind velocity increased. However, the rate of improvement in the race time gradually decreased with increasing wind velocity (see Figure 1). The disadvantage of a headwind is therefore greater than the benefit of a tailwind of the same magnitude. For international-standard male sprinters the benefit of a +2.0 m/s wind is about 0.10 seconds, and for female sprinters the benefit is about 0.12 seconds.

I also examined the dependence of the race times on the wind velocity for the 100m finalists at the U.S. Olympic Trials and TAC Championships over the last ten years. This study yielded similar results to the study of sprinters at the Olympic Games and World Championships.

The dependence of the race times on the wind velocity was in good agreement with a time adjustment curve that was derived from a mathematical model (Ward-Smith, 1985; Dapena & Feltner, 1987). At any instant, the forward acceleration of a sprinter is determined by the propulsive force generated by the athlete and by the aerodynamic drag opposing the athlete's motion. The aerodynamic drag depends on the relative velocity of the athlete and the air. Tailwinds reduce the drag on the athlete, whereas headwinds increase the drag.

The relation between the time adjustment, ΔT, and the wind velocity, V, is given by

$$\Delta T = a(V - bV^2)$$

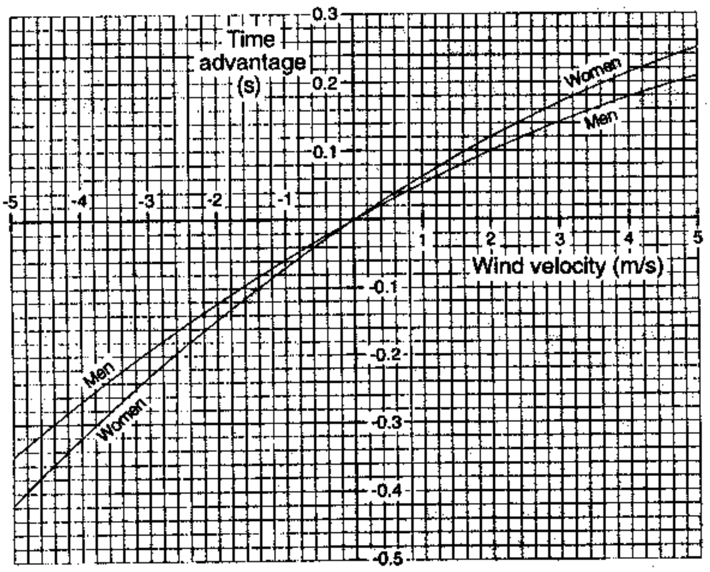
where a=0.056 for male sprinters, a=0.067 for female sprinters, and $b=0.050=1/(2V_{av})$, where V_{av} is the athlete's average velocity over the course of the race. The value of a is proportional to the atmospheric density and to the athlete's drag area. The drag area is determined by the athlete's frontal area.

There is also a scale factor called the drag coefficient which depends on the shape and surface roughness of the athlete's body and clothing. Because of their greater frontal area, tall well-built athletes experience a greater effect of wind than short, light athletes. For example, Linford Christie gains more of a benefit from a tailwind and suffers a greater disadvantage from a headwind than Andre Cason. However, the time adjustment for most athletes are within ±10% of the curves shown in Figure 1.

THE 2 M/S WIND LIMIT RULE

A study of the effect of wind on sprint times was first conducted on behalf of the IAAF over 50 years ago. It was suspected that a disproportionately high number of record performances were being achieved with strong assisting winds. At the time, races were hand-timed, and so 0.1 seconds was the minimum possible improvement in a

FIGURE 1: EFFECT OF WIND ON 100m SPRINT TIMES.



record.

The study indicated that the assisting wind velocity must be above 1 m/s in order to give an advantage in excess of 0.1 seconds over 100m. At the 1936 Congress of the IAAF it was agreed that for official recognition of records the assisting wind velocity must be 2 m/s or less.

This rule regarding wind assistance still stands, even though performances must now be timed to 0.01 seconds using fully automatic photofinish timing. With the introduction of automatic timing the 1 m/s rule no longer has any significance, but the rule has been retained for continuity.

An alternative to the 2 m/s wind limit is to adjust all race times to zero wind conditions. However, it is not currently possible to adjust race times with 100% certainty. For the time adjustment to be accurate to within ±0.01 seconds, the athlete's effective drag area would have to be precisely measured somehow.

An even greater problem is the accurate measurement of the wind affecting the athletes. According to IAAF rules, the component of the wind velocity along the direction of the track is measured using a wind-gauge that must be positioned halfway along the straight, 1.22m above the ground, and not more than 2m away from the track.

The wind velocity is recorded in meters per second, rounded to the next highest tenth of a meter per second in the positive direction. In 100m races the wind velocity is measured for a period of 10 seconds from the start of the race. Only the component of the wind parallel to the direction of running is measured because the perpendicular component has a negligible effect on sprint times.

A study by Murrie (1986) showed that the presence of high grandstands causes the strength and direction of the wind to vary considerably over the width and length of the track. The wind in Lane 1 is not necessarily the same as that in Lane 8, and the wind at each end ot the track may differ considerably from that at the wind-gauge site.

However, I have examined all the 100m races at the Olympic Games and World Championships since 1983 and the race times deviated by only a few hundredths of a second from the times expected from my wind-assistance curve. That is, the official wind reading was usually within ±0.5 m/s of the effective wind experienced by the athletes. In these competitions the official wind reading was a reasonably accurate indicator of the wind experienced by the athletes during the races.

Whether an athlete is credited with a record or not is a bit of a lottery. A sprinter could have a record performance disallowed with an official wind reading of +2.1 m/s, when the effective wind he experienced was only +1.6 m/s. By the same token, a sprinter may run a race with an official wind reading of +2.0 m/s, and be credited with a record, when the actual wind he experienced was +2.5 m/s.

Short of placing wind-gauges in all the lanes, and at every 10m along the length of the track, we will just have to live with this irregularity. It may be more appropriate to round the official wind velocity measurement to ±0.2 m/s, or even ±0.5 m/s, so as to reflect the uncertainty in the amount of wind actually affecting the athletes.

ALTITUDE ASSISTANCE

Sprinters generally run faster at competition venues that are more than a few hundred metres above sea level. The mechanism behind the improvement in race time with increasing altitude is related to that of a following wind, as the altitude of the competition site affects the air density and hence the aerodynamic drag experienced by the athlete.

The IAAF does not currently place a restriction on the maximum altitude of the competition site for the acceptance of records, but statisticians usually consider sprint performances achieved at sites higher than 1,000m to be "altitude assisted."

A direct experimental study to quantify the effect of altitude on 100m sprint times has not been conducted. Mathematical models predict that when running at altitude, sprinters receive a time advantage which, at any given wind velocity, is very nearly directly proportional to the altitude. When sprinting in still air at an altitude of 1,000m, the improvement in race time is expected to be about 30% of the improvement due to a +2 m/s wind at sea level. The results from my wind-assistance study indicate that an altitude of 1,000m provides an advantage of about 0.03 seconds for international-standard male sprinters. For athletes competing at Mexico City (altitude 2,250m) the expected advantage is 0.07 seconds.

Wearing aerodynamic clothing can also significantly reduce 100m sprint times. Because about 5% of the power

TABLE 1: 100m SPRINT PERFORMANCES ADJUSTED TO ZERO WIND CONDITIONS.

Competitions	Competitor	Offical Wind	Official Time	Time in Zero Wind
Stuttgart '93	Linford Christie	+0.3	9.87	9.89 (!)
	Andre Cason	+0.3	9.92	9.94
Barcelona '92	Linford Christie	+0.5	9.96	9.99
	Leroy Burrell	-1.3 (semi)	9.97	9.89 (!)
	Linford Christie	-1.3 (semi)	10.00	9.92 (!)
Tokyo '91	Carl Lewis	+1.2	9.86 (WR)	9.92
	Leroy Burrell	+1.2	9.88	9.94
	Dennis Mitchell	+1.2	9.91	9.97
TAC '91	Leroy Burrell	+1.9	9.90 (WR)	10.00
Seoul '88	Ben Johnson	+1.1	9.79 (Disq)	9.85
	Carl Lewis	+1.1	9.92 (WR)	9.98
Olympic Trials '88	Carl Lewis	+5.2	9.78	9.99
Rome '87	Ben Johnson	+1.0	9.83 (Disq)	9.88
	Carl Lewis	+1.0	9.93	9.98
Stuttgart '93	Gail Devers	-0.3	10.82	10.80
	Merlene Ottey	-0.3	10.82	10.80
Barcelona '92	Gail Devers	-1.0	10.82	10.75 (!)
	Juliet Cuthbert	-1.0	10.83	10.76
	Irina Privalova	-1.0	10.84	10.77
Tokyo '91	Katrin Krabbe	-3.0	10.99	10.76 (!)
	Gwen Torrence	-3.0	11.03	10.80
Seoul '88	Flojo	+3.0	10.54	10.71 (!)
	Flojo	+2.6 (semi)	10.70	10.85
	Flojo	+1.0 (quart)	10.62	10.68 (!)
Olympic Trials '88	Flojo	+1.2	10.61 (WR)	10.69 (!)
	Flojo	+1.6 (semi)	10.70 (WR)	10.80
	Flojo	+5.5 (quart)	10.49	10.76
	Flojo	+3.2 (heat)	10.60	10.78

expended by a sprinter is used to overcome aerodynamic drag, even a small reduction in the athlete's drag coefficient will result in appreciably faster times. Swapping loose-fitting clothing for a tight body suit will reduce a 100m sprint time by about 0.02 seconds (Kyle, 1986). Using a tight-fitting cap, or shaving the head, results in a further 0.02 second improvement.

WHO'S THE FASTEST?

I have compiled a list of some of the best recent 100m performances (see Table 1). The race times have been adjusted to what the athlete would have recorded in zero wind conditions. The adjusted times are very likely correct to within a few hundredths of a second. Ben Johnson's (discredited) times are still better than everyone else's. Leroy Burrell was fortunate at the '91 TAC Champonships when he set his 9.90 world record as the wind was near to the maximum allowable. Burrell and Linford Christie ran sensational times in the semifinals in Barcelona, but did not perform at quite the same level in the final. Christie's performance at the recent World Championships is intrinsically superior to Carl Lewis' current world record. Christie would have run 9.79 with the benefit of a +2.0 m/s wind.

For the women, the times recorded in Barcelona were not very far behind Florence Griffith Joyner's best times. Note that Flojo's 10.49 world record was actually assisted by a +5.5 m/s wind (see the next article). The official world record should be the 10.61 that she recorded in the final at the 1988 U.S. Olympic Trials. Gail Devers would have run 10.63 in Barcelona had she had the benefit of a +2.0 m/s wind.

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