Accuracy of wind measurements in athletics

N.P. Linthorne
School of Exercise and Sport Science, The University of Sydney, Australia

ABSTRACT: For a 100m sprint performance to be recognised as a World Record, the performance cannot be achieved with an assisting wind in excess of 2 m/s. The official wind reading is a 10 second measurement obtained from a single wind gauge placed next to the track. Measurements at Sydney International Athletic Centre showed that the official wind reading does not always provide an accurate representation of the wind actually affecting an athlete as they run down the track. The discrepancy between the official wind reading and the wind experienced by the athlete was about ±0.9 m/s. This is less than the desired standard of ±0.2 m/s required for equitable comparison of 100m sprint performances.

INTRODUCTION

The wind may have a strong influence on performance in track-and-field athletics, particularly in sprinting. An athlete running into a head wind experiences a greater aerodynamic drag and so has a slower running velocity than in still air conditions. Likewise, a tail wind reduces the aerodynamic drag and results in a faster running speed. The influence of the wind on sprinting performance is reflected in the International Amateur Athletic Federation (IAAF) rules for recognition of World Records. A performance will not be accepted if there is an assisting wind that averages more than 2 m/s. This rule was based on an experimental study conducted in the early 1930s. At the time, 100m races were mostly hand-timed and 0.1 seconds was the minimum accepted improvement in a record. The study concluded that the assisting wind velocity must be below 1 m/s in order not to give an advantage in excess of 0.1 seconds over 100 m. 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. Since 1977 the IAAF has required record performances to be measured to 0.01 seconds using fully automatic timing, but the 2 m/s wind limit rule has been retained for continuity of records and statistics.

THE EFFECT OF WIND ON 100m SPRINT TIMES

More recent theoretical studies have predicted the effect of wind on 100m sprint performance by modelling the aerodynamic forces on the athlete and the energy generation mechanisms in the athlete's muscles (Dapena and Feltner, 1987; Ward-

Smith, 1985; Ward-Smith, 1999). The aerodynamic drag force, F, experienced by an athlete is given by

$$F = \tfrac{1}{2}\rho S C_D (V - V_w)^2 \tag{1}$$

where ρ is the air density, S is the projected frontal area of the athlete, C_D is the athlete's drag coefficient, V is the velocity of the athlete relative to the ground, and V_w is the velocity of the wind relative to the ground. (In athletics, a positive wind velocity corresponds to a tail wind, and a negative wind velocity corresponds to a head wind.) Linthorne (1994a) showed that the time adjustment, ΔT, due to the wind is described by an empirical expression of the form

$$\Delta T = \alpha(V_w - \beta V_w^2) \tag{2}$$

where α and β are constants. The constant α is approximately proportional to the air density and to the athlete's drag area (SC_D), and the constant β is given by $\beta = 1/(2\,V_{av})$, where V_{av} is the athlete's average velocity over the course of the race. For a 100m sprint recorded in 10.0 seconds in still air, the average velocity is 10.0 m/s, and so $\beta = 0.050\ (\mathrm{m/s})^{-1}$.

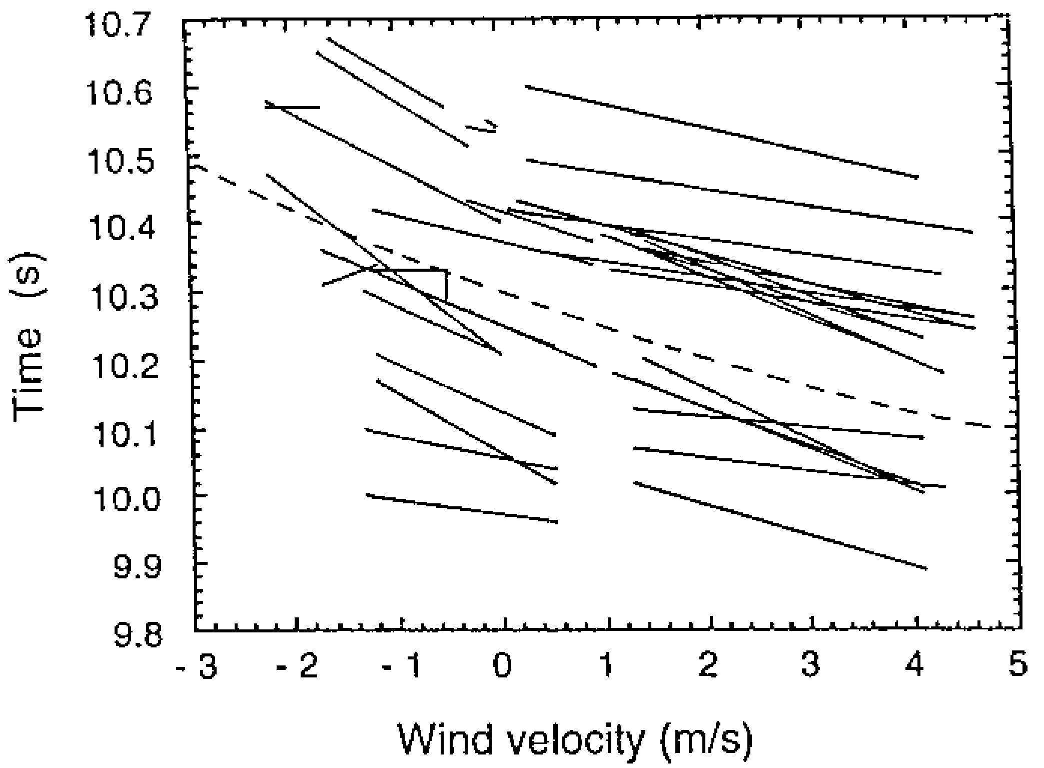

Fig. 1 Maximum-effort performances by male 100m sprinters at the 1991 IAAF World Championships and 1992 Olympic Games. Performances by an athlete in the same competition are joined by lines. The dashed line shows the relation between race time and wind velocity based on the results of the study by Linthorne (1994a).

Linthorne (1994a) experimentally determined the effect of wind on 100m sprinting through a careful analysis of performances by many athletes at the Olympic Games and World Championships. 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. The race times of the maximum-effort performances were plotted as a function of the wind velocity. Figure 1 shows an example of some maximum-effort performances in the men's 100m races. Linthorne's study confirmed that the wind has a consistent effect on 100m sprint performances. The effect of wind is described by equation 2, with $\alpha = 0.056$ s^2/m for world-class male sprinters, and $\alpha = 0.067$ s^2/m for world-class female sprinters. Note that the effect of wind on race time is not linear, and so the disadvantage of a head wind is greater than benefit of tail wind of the same magnitude.

A benchmark for assessing the influence of wind on 100m sprint times is the time advantage of a +2.0 m/s wind over still air conditions. Linthorne (1994a) showed that the advantage of a +2.0 m/s wind is 0.10 s for male sprinters and 0.12 s for female sprinters. The uncertainties in the effect of wind on race times are about 10% and 20%, respectively. These uncertainties presumably resulted from (a) inter-trial variations in the intrinsic performance level of the athletes, and (b) discrepancies between the official wind readings and the wind actually affecting the athletes as they ran down the 100m straight. It is the second effect, the accuracy of the official wind reading, that is the focus of the present study.

IS THE CURRENT WIND MEASUREMENT METHOD APPROPRIATE ?

The method used to determine the official wind velocity is governed by specific regulations (*Handbook*, 1998). The component of the wind velocity along the direction of the track is measured with a wind gauge which must be positioned 1.22 m above the ground and not more than 2 m away from the track. In the running events the wind gauge must be positioned beside the straight, adjacent to lane 1, and 50 m from the finish line. In 100m races the wind velocity is averaged over a period of 10 seconds from the start of the race.

Under current IAAF rules the minimum recognised improvement in a 100m World Record is 0.01 seconds. Therefore, for different performances to be justly compared, the wind assistance received by an athlete must be measured to an accuracy that corresponds to an effect on race time of less than 0.01 seconds. Linthorne's (1994a) study showed that at a wind velocity of +2.0 m/s, a change in wind velocity of 0.2 m/s produces a change in race time of 0.01 seconds. This means that the method of determining the official wind reading must be accurate to ±0.2 m/s if athletes are to be treated fairly when recognising World Records.

It has long been known that the presence of grandstands or other buildings may cause non-uniform or erratic wind patterns at a running track. Murrie (1986) conducted a series of wind measurements at an open competition venue which had no stands or tall buildings in the vicinity. This venue showed only a small variation in wind velocity at different locations on the 100m track. In contrast, wind measurements at Meadowbank Stadium in Scotland indicated 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 average value of 20 wind velocity measurements taken at locations across the width of the track differed by as much as 0.4 m/s, and the average of measurements taken at locations along the length of the track differed by up to 1.0 m/s.

Dreusche (1994) reported results from a systematic examination of wind conditions at five stadiums in Germany. The study included wind measurements from major competitions at Duisburg and Konstanz, and from the 4th IAAF World Championships in Athletics in Stuttgart. In these investigations, wind gauges were placed along both sides of the 100m straight at distances of 20 m, 40 m, 60 m, and 80 m from the start line. The wind gauges were modified so as to access the one-second wind samples that are used to calculate the 10-second average wind reading. Simultaneous wind measurements by each of the eight wind gauges were taken, and both the 10-second averages and one-second samples were analysed.

These measurements showed that the wind speed at the site of a wind gauge may vary considerably during the 10 second period of the wind measurement. They also confirmed that simultaneous measurements by wind gauges at opposite ends of the track may give very different readings. The author claimed that there was no consistent air movement on the 100m track during the 10 second period of the wind measurement, and that the wind did not move in a regular or even predictable way. He concluded that the current IAAF method of measuring the wind at only one point on the track does not give a valid representation of the wind conditions experienced by the athlete.

Although the measurement methods are not in question, this study did not quantify the discrepancy between the official wind reading and the wind actually affecting the athletes. Therefore this study could not assess the implications of the current wind measurement rule on the recognition of World Records. The purpose of the present study was to quantify the variation in wind strength along the length and breadth of the 100m straight, and hence provide an estimate of the accuracy of the current IAAF wind measurement method.

METHODS

Wind measurements were performed at the Sydney International Athletic Centre, which is located in the Sydney Olympic Park precinct. The stadium was the venue for the 6th IAAF World Junior Championships in Athletics, and will be the warm-up venue for the Athletics competition at the Sydney 2000 Olympic Games. The stadium has a 5000-seat grandstand adjacent to the 100m straight, and a 3-m to 5-m high grassed bank around the remainder of the track. Although the 100m straight has 12 lanes, only lanes 1 through to 8 are usually used in major competitions.

Wind measurements were recorded using tube propeller anemometers (UCS/Spirit Precision Digital Anemometer; Model 569-262) which met IAAF specifications. An official wind measurement was recorded with a wind gauge placed in the prescribed position, and a simultaneous 10-second average reading was recorded with a second wind gauge placed elsewhere on the track. The second wind gauge was placed at one of the following locations: 10 m, 30 m, 50 m, 70 m, or 90 m from the 100m start line, and on the line between lanes 2 and 3, or on the line between lanes 6 and 7 (see

Fig. 2). This configuration of wind gauges was selected to cover the running track from 0 to 100m, and from lane 1 to lane 8, without unduly biasing the extremities of the track. On each of 4 days, a set of 20 simultaneous readings was taken for each configuration of the wind gauges.

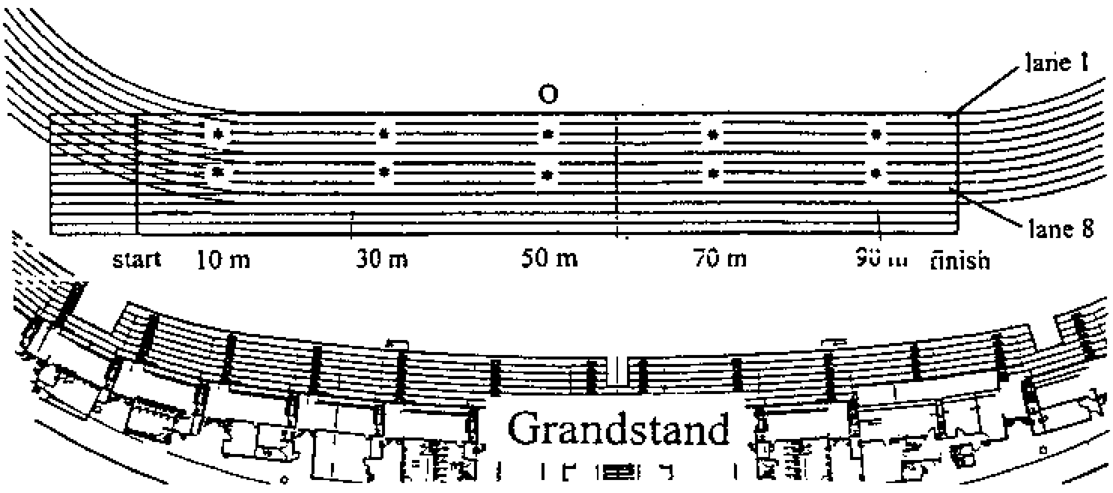

Fig. 2 Locations of the wind gauges on the 100m straight. The location of the official wind gauge site is marked "O", and the various locations of the second wind gauge are marked "*".

For each configuration of the wind gauges, the readings of the second wind gauge were plotted against the official wind readings. A hypothetical perfect agreement between the two wind gauges would result in all measurements lying along a line with gradient 1.0 that passes through the origin. In practice, the scatter of the measurements about the perfect linear relation indicates the discrepancy between the official wind reading and the wind strength at the site of the second gauge. The degree of scatter may be quantified by a wind velocity that is one standard deviation from the hypothetical perfect linear relation. For example, a standard deviation of 0.5 m/s in the wind scatter pattern means that two-thirds of the readings from the second wind gauge site are within 0.5 m/s of the reading of the official wind gauge.

Another factor to consider is that the site of the second wind gauge may be more sheltered or more exposed than the site of the official wind gauge. For a second wind gauge that is more sheltered than the official wind gauge site, the gradient of the line of best fit to the wind scatter pattern will be less than 1.0, whereas a more exposed site will have a gradient greater than 1.0. Whether a particular wind gauge site shows signs of being sheltered or exposed will depend on the direction of the wind.

RESULTS

For the wind gauges on the 30, 50, and 70m lines, the gradient of the line of best fit to the wind scatter plots was close to 1.0 (see Fig. 3). That is, the wind gauges showed little or no signs of being more sheltered by the grandstand and surrounding bank than the official wind gauge site. However, the wind gauges at the 90m line were more sheltered for headwinds, and the wind gauges at the 10m line were more sheltered for tail winds and more exposed for head winds. Sheltering effects were strongest at the 10m line because this position is closest to the grandstand and surrounding grassed bank.

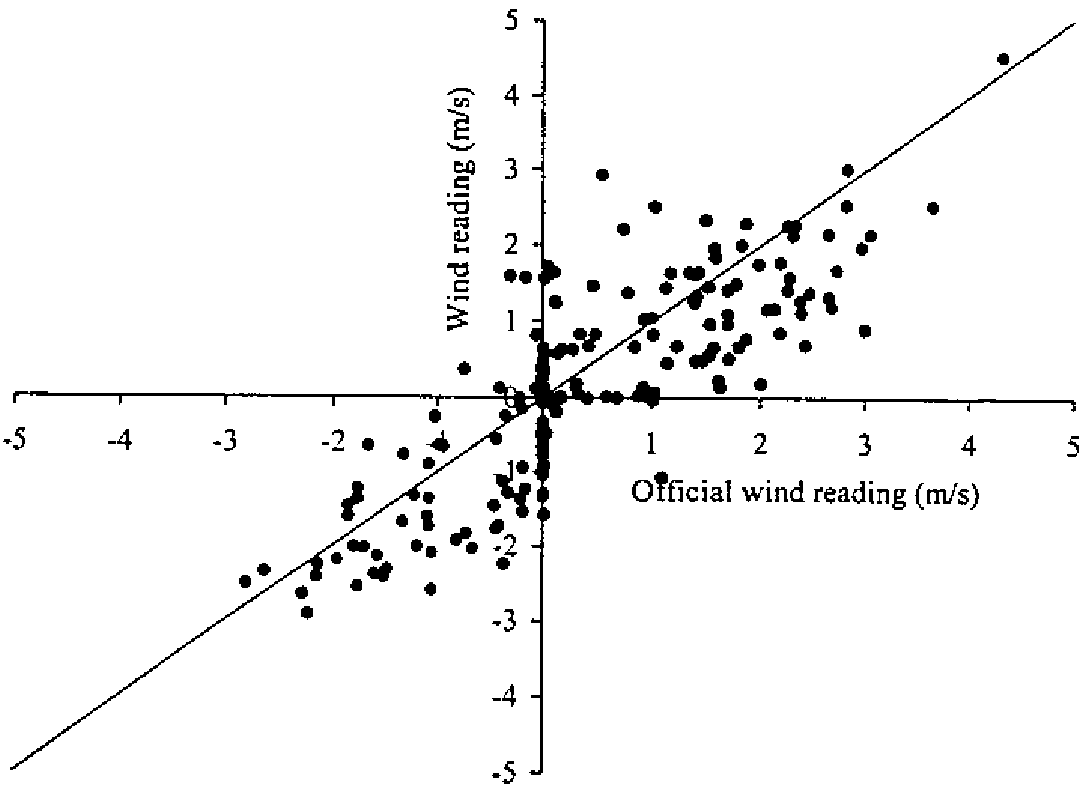

Fig. 3 Relation between the official wind reading and a simultaneous wind reading from a second wind gauge placed at the 30m line. Also shown is the line of hypothetical perfect agreement between the two wind gauges.

The scatter in the wind measurement plots increased the farther the second wind gauge was from the official wind gauge site (see Fig. 4). At the 50m line, the wind gauge at lane 2/3 showed a slightly lesser discrepancy with the official wind gauge than the gauge at lane 6/7. At the 10, 30, 70, and 90m lines there was no discernible difference between the two lane positions.

The accuracy of the official wind reading was calculated by averaging the wind scatter measures obtained at sites along the length of the 100m straight. The measurements indicate that in two-thirds of 100m races at the Sydney International Athletic Centre, the official wind reading reflects the wind acting over the length of the 100m straight to within about ±0.9 m/s. This level of accuracy is less than the ±0.2 m/s standard required for equitable comparison of potential World Record performances.

The inaccuracy in the official wind reading is similar to the uncertainty observed by Linthorne (1994a) in the effect of wind on competition race times (see Fig. 1). That is, most of the fluctuations in the effect of wind on race time appear to be due to the inaccuracy of the official wind reading, rather than variations in the intrinsic performance level of the athletes.

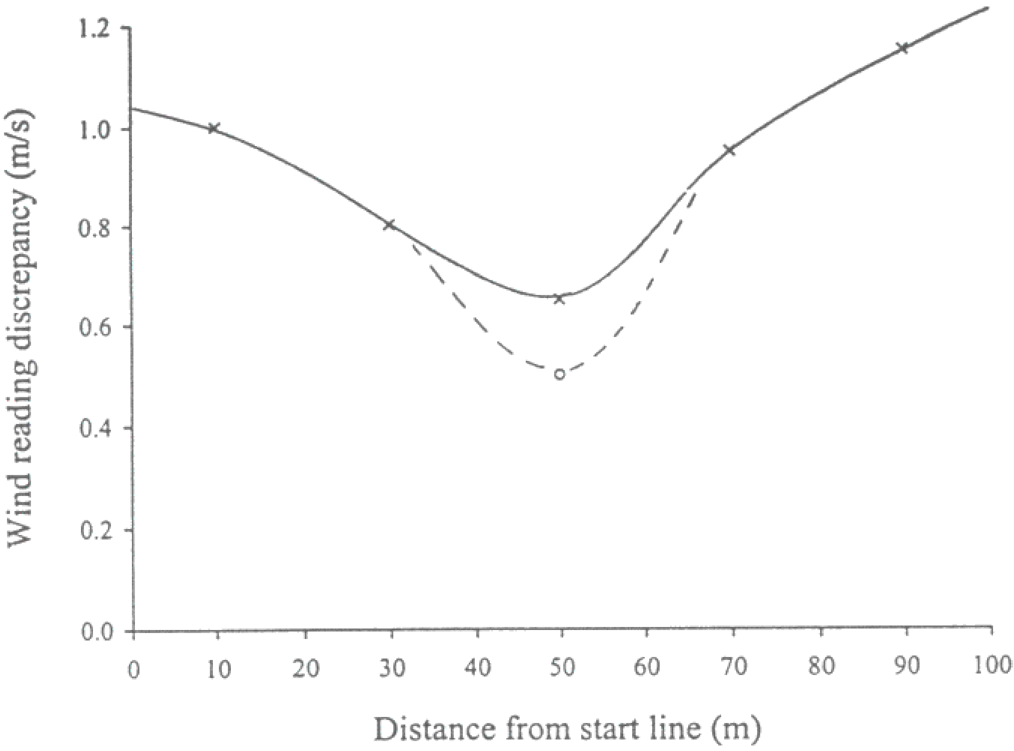

Fig. 4 Discrepancy in wind reading as the second wind gauge was positioned along the length and breadth of the 100m straight. The solid line is for lane 6/7; the dashed line is for lane 2/3.

DISCUSSION

The IAAF may wish to continue with the current wind measurement method, and accept that the official wind reading may result in injustices in awarding World Records. If so, it would be appropriate to round the official wind reading to the nearest 1 m/s, rather than the present 0.1 m/s, to reflect the uncertainty in the amount of wind actually affecting the athletes.

The accuracy of the official wind reading could be improved to the ±0.2 m/s level by using several wind gauges placed along both sides of the 100m straight. An instantaneous wind measurement would be taken as the runners passed by each wind gauge. However, this approach would greatly increase the cost and complexity of organising an event that meets the requirements for consideration of World Records.

The results from this study may be used to estimate the accuracy of the official wind reading in the long jump. In the long jump, the official wind reading is taken by a wind gauge placed alongside the runway and 20 m from the take-off board. A five-second average measurement is taken from the time the competitor passes a mark that is 40 m from the take-off board. Linthorne (1994b) calculated that for a jump of 8.00 m, a +2.0 m/s wind produces an advantage of about 0.12 m. The minimum possible improvement in a World Record is 0.01 m, and so to be equitable to all competitors the wind must be measured to an accuracy of ±0.2 m/s. The results from the 30, 50 and 70m lines in the 100m sprint study indicate that the official wind reading represents the wind experienced by an athlete as they run down the long jump runway to only about ±0.7 m/s.

CONCLUSION

The accuracy of the current official wind reading method does not attain the standard required for equitable comparison of potential 100m and long jump World Record performances.

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