Qualifying the Effect of Aerodynamic Drag on Long Jump Performance

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Quantifying the effect of aerodynamic drag on long jump performance is of considerable interest to athletes, coaches, and statisticians. The article, "Two World's Best Long Jumps: Comparative Biomechanical Analysis", by Gusakov, Verobiev, and Ariel (T&FQR, Vol. 92 No. 4) presented graphs of the calculated changes to the length of world class jumps due to the effects of wind and altitude in the flight phase of the jump. Unfortunately, these calculations incorporated an error in the value of a key parameter, and, hence, overestimate the magnitude of the effects by a factor of four. More importantly, the analysis does not consider the influence of aerodynamic drag in the run-up phase of the jump, even though it is widely acknowledged that run-up speed is the prime determinant of long jump performance.

The influence on long jump performance of aerodynamic drag in the run-up and flight phases has been calculated previously by Ward-Smith (1985). Figures 1 and 2 show the calculated effects on a jump of 8.03m. Note that the effects during the run-up phase are 4.5 times greater than those during the flight phase.

The discrepancy between the calculations of Ward-Smith and Gusakov et al. lies in the value of the drag quotient. In the notation of Gusakov et al., the drag quotient is given by \( C_d = \frac{pACx}{2m} \), where \( p \) is the air density (1.20 kg/m\(^3\) at sea level), \( A \) is the cross sectional area of the athlete, \( Cx \) is the drag coefficient (=80kg). Ward-Smith used a drag area value of \( ACx = 0.385 \) m\(^2\) to be consistent with values obtained from wind tunnel measurements of runners, skaters and skiers. In contrast, Gusakov et al. used a much greater drag area value. The drag quotient for Powell in Table 1, \( H = 0.012 \) m\(^3\), corresponds to a drag area of \( ACx = 1.5 \) m\(^2\).

![Fig 1: Variation of distance L with wind speed Vw.](image)

![Fig 2: Variation of distance L with density p.](image)

It appears as though Gusakov et al. determined their drag area values empirically from the difference between the observed flight path of the athlete and the expected path in a vacuum. This method relies on accurate measurement of the athlete's take-off parameters, in particular, the components of the take-off velocity. Unfortunately, as many researchers have discovered, the determination of take-off velocities from film data involves inherently large measurement errors. Gusakov et al.'s values of the athlete's drag quotient must not, therefore, be considered reliable.

The non-mathematically inclined reader will be convinced of the superiority of Ward-Smith's calculations over those of Gusakov et al. by a more intuitive argument. The calculations of Gusakov et al. indicate that the aerodynamic drag, due to the atmosphere, shortens the jump by 65cm, compared to a jump in a vacuum (see Table 1, M. Powell). This is equivalent to claiming that an athlete who performs at full effort standing vertical jump in a 10 m/s wind, will be blown backwards a distance of 65 cm. (10 m/s is the take-off speed of a world class long jumper.) This calculated distance is clearly much too great. For comparison, the drag area value used by Ward-Smith gives a distance of only 10cm, and is in close accord with experience.

References