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Analysis of the Aerodynamics by Experimental Testing of an Elite Wheelchair Sprinter

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Abstract

The aim was to compare the resistive forces acting upon an European wheelchair medallist. The coast-down technique was selected to estimate the resistance in the upright position and racing positions with the neck in hyperextension and flexion, respectively. In the upright position, racing position with the neck in flexion and hyperextension the effective surface area was 0.1747, 0.1482 and 0.1456m^2, respectively. The coefficient of rolling friction was 0.00119, 0.00489, 0.00618 and the power to overcome drag 26.62, 22.59, 22.19W for the same positions. As a conclusion, the resistance acting upon the sprinter is different according to his position on the chair. Slight changes in the head position over the race can affect by almost 2% the power output.

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Keywords: Sprinting; Race time; Kinetics; Aerodynamics; Power

1. Introduction

Despite not as popular as Olympic sports, Paralympic events have become very competitive in the last few decades. One of the highlights in the Paralympics Games, and other multi-sport events, are the wheelchair races in Athletics. As for the all-body counterparts, the support by sport science and technology are now quite common among Paralympic athletes. As far as wheelchair sprinting concern, the performance is strongly speed-dependent [1]:

$$v = \sqrt{\frac{2 \cdot E_{kin}}{m}} \tag{1}$$

Where v is the wheelchair velocity, E_{kin} the kinetic energy and m the mass. The wheelchair-athlete system has an overall efficiency lower than 1.0. So, the kinetic energy of an athlete-wheelchair system is:

$$E_{kin} = E_{in} - E_{loss} \tag{2}$$

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Where E_{kin} is the kinetic energy, E_{in} the energy delivered by the athlete and E_{loss} the energy lost by the system. Therefore, combining equations 1 and 2:

$$v = \sqrt{\frac{2 \cdot \left(E_{in} - E_{loss}\right)}{m}} \tag{3}$$

The rolling friction and the drag force are the main sources of losing energy [2]. The total resistance encompasses the sum of both external forces. To excel wheelchair racers should consider diminishing as much as possible the total resistance [3]. Hence, the total resistance acting on the athlete is the sum of drag and rolling friction. Depending on the pace, rolling friction may account up to 65-75% and drag 35-25% of total resistance in world-ranked wheelchair racers [3]. Over a stroke cycle, the athlete can assume an upright position or a racing position keeping the torso flexed. One concern for the athletes is the head's alignment in the racing position. The advice is keeping the neck in hyperextension so that the helmet is properly aligned to the body. However, over an event often the athlete performs neck flexions, disrupting the body alignment. This misalignment may increase significantly the resistance acting upon the athlete just like in cycling [4], albeit, evidence on this is scarce in wheelchair racing. A feasible way to gather insight on the effects of the body position in the rolling friction and the drag force is the cost-down technique [4]. Indeed, this is an experimental testing procedure reported on regular basis in motor sports and cycling [4], besides other wheeled vehicles. Follow-up estimations can be run to compute the mechanical power and energy expenditure over an official race inputting the resistive forces obtained beforehand [4].

The aim was to compare the resistive forces acting upon an elite wheelchair racer, keeping different body positions. It was hypothesized that even slight changes in the body position would have an effect on the sprinter's aerodynamics and rolling friction.

2. Methods

2.1. Sample

The subject was a male wheelchair sprinter with 43.0kg of mass, competing in the T52 category. He holds the national records at the 100m and 400m events, being also an European medallist at the 100m event and at the time of this research ranked 2nd in the world. All procedures carried out in this research are in accordance to the Declaration of Helsinki.

2.2. Procedures

The wheelchair sprinter was invited to perform 3 sets of 8 repetitions at different speeds, randomly assigned. He was advised to perform one lap on the track per repetition. By the end of the last curve, before the finish line, he should stop performing stroke cycles and keep the position coasting-down.

The 3 sets were performed keeping the: (i) torso in the upright position on the wheelchair; (ii) torso in the racing position (i.e. trunk bended in the horizontal position) and neck in hyperextension (so that the trailing edge of the helmet would be pointing backwards); (iii) racing position but the neck in flexion (i.e. trailing edge of the helmet pointing upwards) (fig 1.)

Fig. 1. The three positions adopted by the wheelchair racer.