THE KINETICS OF A WHEELCHAIR SPRINTER RACING THE 100M FINAL AT THE 2016 PARALYMPIC GAMES

Tiago M Barbosa[1,2,3], Eduarda Coelho[2,4]

[1] **Nanyang Technological University, Singapore**
[2] **Research Centre in Sports, Health and Human Development-CIDESD, Portugal**
[3] **Polytechnic Institute of Bragança, Portugal**
[4] **University of Tras-os-Montes and Alto Douro, Portugal**

The aim was to run a case study of a wheelchair sprinter's kinetics racing the 100m final at the 2016 Paralympic Games. The model features data collected beforehand by experimental testing, data collected over the race and a set of assumptions. Speed was measured by video analysis. Energy output and energy input (being the sum of the energy of the rolling friction, energy of the drag and kinetic energy) were estimated employing an analytical model. Energy input and output increased over the event. The E_{input} and E_{output} in the first split represents 27.66% and 17.18% of what was delivered in the end of the race. However we failed to note a steady-state or an impairment of both parameters in the last meters of the race. Data suggests that the 100m is a very short event, being the sprinter unable to achieve his maximal power in such distance.

KEY WORDS: Paralympics, race analysis, resistance, energy.

INTRODUCTION: Paralympic sports are increasingly popular these days. Among the events held in Paralympic Games, wheelchair races are some of the most exciting events. Performance in wheelchair racing is a multifactorial phenomenon being sports engineering and biomechanics claimed to be main determinants.

For support staff and researchers the assessment of the performance in competition settings is the most insightful one. This assessment is underpinned mostly by monitoring the kinematics (e.g., Chow and Woen-Sik, 2007). Race kinematics typically features the report of the speed, stroke length and stroke frequency by splits over the event (Cooper, 1990). One of the biggest challenges assessing a Paralympian in competitive settings is to monitor his kinetics (Asato et al., 1993). It is not yet possible to attach sensors or devices to the athlete or alternatively embed it in the wheelchair. Thus, a feasible alternative is to run analytical models estimating the sprinter's kinetics. At least one of these models was reported for sprinting events (Fuss, 2009). The model features as inputs data collected beforehand by experimental testing (e.g. effective drag area), data collected over the race (e.g., horizontal velocity) and a set of assumptions. The model encompasses the estimation of the energy output and energy input. The latter one is the sum of the energy of the rolling friction, energy of the drag and kinetic energy. The friction in the bearings is assumed as negligible. The accuracy of the models´ output is affected strongly by the accuracy of the input data. After running the model, it was noted that for a combined mass of 60 kg (racer plus wheelchair weights) and a time trial of 15s in the 100m, the peak energy input would be roughly 3500J and energy output 2300J (Fuss, 2009). To the best of our knowledge this model has yet to be employed in elite Paralympians such as finalists.

The aim was to carry-out a case study of a wheelchair sprinter's kinetics racing the 100m final at the 2016 Paralympic Games. It was hypothesized that the estimated sprinter's kinetics would provide a deeper insight on his performance at the final.

METHODS: The subject recruited was a male wheelchair sprinter with 43.0 kg of body mass, competing in the T52 category. He is an European medallist, finalist at the 2015 World Championships and 2016 Paralympic Games in the 100m event. A written consent was

provided by the sprinter. All procedures were in accordance to the Helsinki Declaration regarding Human research.
In the final of the 2016 Paralympic Games the sprinter set a time of 18.19s (wind: +0.1 m/s). Split times for every 8.5m were measured by a video analysis system (Kinovea, v.0.8.15) using the marks on the track for the hurdle events, with an accuracy of 0.04s by a panning HD camera set at the 50m mark. Same procedure has been reported earlier in the literature (e.g., Hobara et al., 2016). Thereafter the race was modelled by a mono-exponential equation:

$$v_H(t) = v_H \quad \cdot (1 - e^{-t/\tau}) \qquad (1)$$

Where v_H is the horizontal velocity reached at the end of the race and τ is the acceleration time constant. Similar procedure has been reported for able-bodied sprinters (Samozino et al., 2015). The modelled speed-time function was then integrated to set 20m splits over the 100m distance (Fig 1).

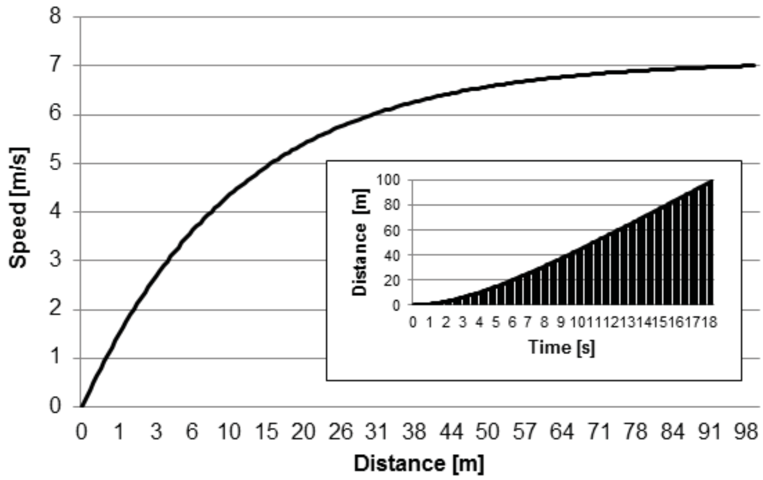

Figure 1 – The speed-time curve modelled and its integration to set the 20m splits.

The model reported by Fuss (2009) was employed to estimate the race kinetics. The kinetic energy (E_{kin}, also known as energy output) is the sum of the kinetic energy of all mobile parts if v>0 m/s (the limb's actions perform movements with a mean null velocity):

$$E_{kin} = \frac{m \cdot {v_H}^2 + \sum_{i=1}^{3} I_i \cdot \omega_i^2}{2} \qquad (2)$$

Where E_{kin} is the kinetic energy (or energy output), m is the mass of the athlete and the chair combined, v_H the velocity, I the moment of inertia for each wheel and ω the angular velocity for each wheel. The E_{kin} equals the inertial force (F_I) integrated with distance (x):

$$E_{kin} = \int_{x1}^{x2} F_I \, dx \qquad (3)$$

So combining equations 2 and 3:

$$F_I = a \cdot \left(m + \sum_{i=1}^{3} \frac{I_i}{r_i^2} \right) \qquad (4)$$

Where F_I is the inertial force, m is the mass of the athlete and the chair combined, a the acceleration, I the mass of wheel times its radius gyration squared. To calculate the inertial term we have referred to the specs of the three wheels selected by the sprinter for this race.

The energy input is the sum of the energy of the rolling friction, energy of the drag and kinetic energy (E_{kin}):

$$E_{input} = E_R + E_D + E_{kin} \qquad (5)$$

The rolling friction and energy of drag were computed as reported elsewhere (Barbosa et al., 2016).

RESULTS AND DISCUSSION: It was noted a reasonably slow increase of the E_{input} and E_{output} in the first meters (Fig 2). Indeed by the end of the race it seems that both did not reach yet its maximal value. I.e., we failed to verify clearly a steady-state or an impairment of these two terms in the last few meters.

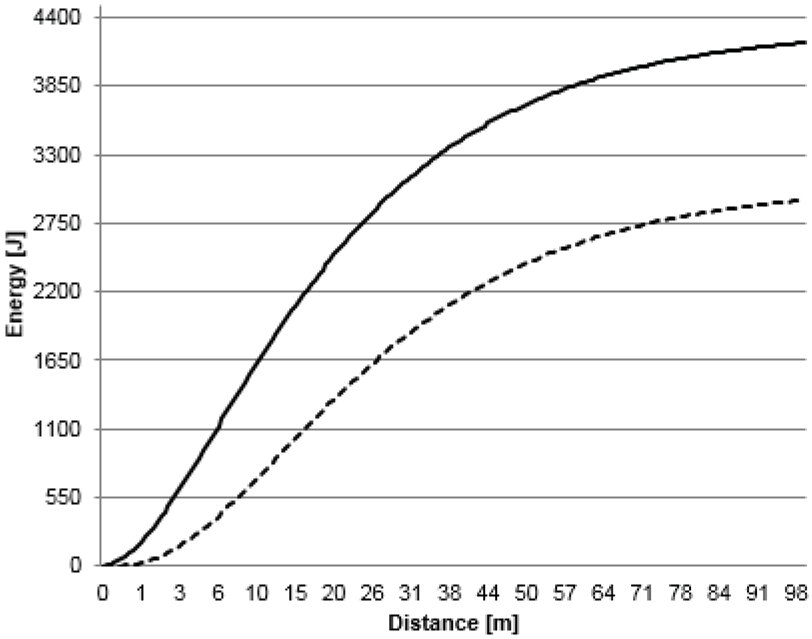

Figure 2 – The T52 100m finalist's kinetics at the Paralympic Games 2016 over the event. Energy input (denoted by solid black line), energy output (denoted by dash black line).

The E_{input} and E_{output} reached mean values in the last split of 4153J and 2887J, respectively; whereas at the start (i.e. first split; 0-20m) the magnitude was rather lower (table 2). The E_{input} and E_{output} in the first split represent 27.66% and 17.18% of what was delivered in the end of the race.

In the model by Fuss (2009) a wheelchair-sprinter system of 60 kg racing the 100m in 15s is expected to reach an E_{input} of 1500J by the 20m; even though our Paralympian delivered only 1149J. In the model, it was set an E_{output} of 1200J, albeit we noted only 496J. In the last split, E_{input} and E_{output} delivered by the racer at Rio 2016 was much higher than the figures reported by Fuss (2009). The latter author reported an E_{input} and E_{output} of 3500J and 2200J, respectively; whereas our sprinter delivered 4153J and 2887J. The differences may be

explained by the level of impairment or handicap between subjects even if competing under the same category.
One may wonder if the sprinter was able to reach his truly maximal power or not. Hence, one of two: (i) the 100m is a too short distance to reach the maximal output, being this achieved at a distance beyond the 100m mark, or alternatively; (ii) because the start was too slow, he did not have enough time to deliver his maximal power. Indeed, the T52 category is known for the athletes having some challenges accelerating. Due to their physical impairment it is harder (i.e. lower trainability) for them to build-up strength and muscle power that is needed in the start and acceleration/drive phase. A forward extrapolation of the functions portrayed in Fig. 2 beyond the finish line (i.e. 100m) reveal that the a steady-state would be reached by the 115m mark (114.56m).

Table 1 - The T52 100m finalist's kinetics at the Paralympic Games 2016 by splits.

Split	Energy input [J]	Energy Output [J]
0-20m	1149	496
20-40m	3020	1790
40-60m	3685	2412
60-80m	4003	2731
80-100m	4153	2887

CONCLUSION: It is possible to gather a deeper insight on wheelchair sprinter's performance in competitive settings assessing the kinetics by an analytical approach. A reasonably slow increase in the mechanical energy in first meters and the absence of a steady-state or an impairment in the end of the race was noted. This suggests that the 100m is a very short event and the racer was unable to achieve the maximal power.

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