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PLATFORM FOR RACING WHEELCHAIR PERFORMANCE ENHANCEMENT

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SUMMARY

Performance enhancement in racing wheelchair is a challenging issue. Variability in environmental conditions makes it difficult to perform outdoor investigations while indoor testing is often limited by the size of the indoor track. Moreover, kinematic and kinetic measurements are not easy to achieve either indoors or outdoors. To overcome such problems, the use of a laboratory ergometer is essential. The ergometer can be used to characterize performance of the actual wheelchair and compare it with configuration changes that can be tested on an adjustable wheelchair. Our experience shows, however, that high accuracy is required in velocity signals and sampling frequency in the power signal must be at about 1000 Hz to obtain meaningful data, given practical limitations in the number of tests that can be realistically performed with National athletes.

INTRODUCTION

Performance enhancement in racing wheelchair is a challenging issue. Aside from the fact that the problem is multivariable, including both mechanical and physiological variables, validation of any changes made to the athlete motor performance or its wheelchair is often difficult because of variable environmental conditions when testing outdoors. Indoor testing is helpful in this regard, but it is also limiting when there is no access to a 400 m field track because of dynamic instability that occurs when attacking curves in indoor shorter tracks. Finally, field testing often use kinematic and kinetic measurements with a quality (both in resolution and precision) usually lower than what is achieved in laboratory settings. Passive roller ergometers have been used in the past [1], very few with computer control and an adjustable wheelchair [2].

The aim of this project was to develop a laboratory platform to enhance racing wheelchair performance of Paralympic Canadian athletes for the London 2012 Paralympic Games. A custom designed computer controlled ergometer adapted for racing wheelchairs was designed for that purpose. Use of high precision instrumentation, simulation of outdoor conditions and ability of using both the athlete own wheelchair as well as an adjustable wheelchair contributed to the ergometer usefulness for performance optimization.

METHODS

Initial discussions with coaches and athletes told us that a 4% increase in performance (that is 0.6 s over a 100 m race) would be desirable to reach the podium. Fitting a step response of a first order system to the velocity curve of an all-out 15 s acceleration run, it can be shown that a 4% increase in performance leads to a 4% increase in top speed performance for a 100 m race.

From a practical standpoint, given the number of variables that can be tested to improve performance, it is desirable to limit the number of repetitions per testing condition at about 3 to 5. Hence, the ergometer platform must be designed to provide sufficient precision (stochastic biases) in kinematic and kinetic data to address these statistical needs. In addition, it must eliminate deterministic biases as much as possible to provide results that are meaningful in real situations.

To that end, the ergometer (Figure 1) was custom-made using 10.6 inches diameter steel rollers actuated by a single AKM-54H Kollmorgen (Radford, VA) brushless motor. The motor was controlled at 2 kHz by a National Instruments CRIO 9022 system (Austin, TX), using feedback from a Sick optical encoder DFS60 (Waldkirch, Germany) in quadrature, resulting in a 262144 pulses per revolution, i.e. 3.2 μm in virtual ground displacement. Taking mechanical errors into account, experimental validation showed an actual 30 μm displacement precision, and a velocity error in the order of 0.2%, sufficient for the statistical power required, i.e. 20 times lower than the minimum difference expected of 4%.

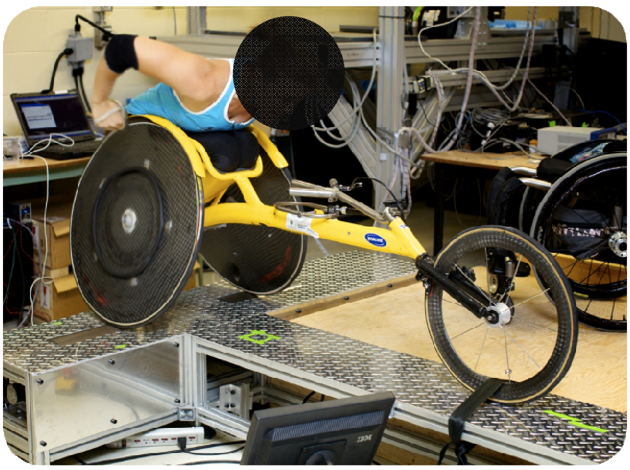

Figure 1: Athlete testing on the ergometer with her own racing wheelchair.

Deterministic biases were alleviated by programming the ergometer to simulate both rolling and aerodynamic force resistance that occur outdoors, as well as the combined wheelchair/athlete inertia. Aerodynamic resistance was obtained from experimental data acquired in a wind tunnel at the National Research Council (Ottawa, Canada).

Further reduction in deterministic biases was achieved by providing means to test athlete performance on the ergometer with both his/her own wheelchair and an adjustable wheelchair. Once the athlete performance is characterized on his/her own wheelchair on the ergometer, the athlete is then seated in an adjustable wheelchair to study variations in a number of optimization variables (Figure 2). Performance variations are then compared with those obtained for the athlete wheelchair to figure out where improvements can be achieved. Comparisons with athlete wheelchair ergometer data is essential to reduce deterministic biases that would occur when comparing ergometer data to outdoors data, often acquired with different instrumentation.

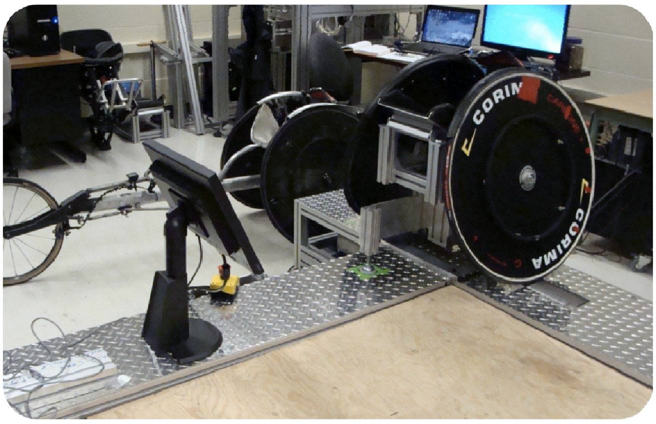
Figure 2: Adjustable wheelchair on the ergometer.

RESULTS AND DISCUSSION

A typical acceleration run obtained on the ergometer is illustrated in Figure 3. The jagged profile of the curve is due to the push phase that occurs about twice a second. A zoom on a section of the curve is shown. One can clearly observe the push phase and the recovery phase in the speed profile. Estimation of produced power by the athlete is shown in Figure 4. Push phase duration is in the order of 100-150 ms depending on speed, and peak power produced is over 600 W for this specific athlete, even larger for lower speeds. Such power curve demonstrates the need to sample power signals at about 1000 Hz minimum in order to get accurate power measurements (100 position samples per push). Many researchers use mean power per cycle at a much lower frequency. Use of mean power does not provide the ability of acquiring much insight about what is changing in the push cycle for different configuration variations.

CONCLUSIONS

A custom-made ergometer was designed to study configuration changes on athlete wheelchair performance. Results show that high accuracy is required in velocity signals to reduce the number of experimental tests required for studying performance changes in Paralympic national athletes. Given the short duration of the push phase and the sharp profile of the power signal, sampling at 1000 Hz seems a minimum requirement, from our point of view, for obtaining meaningful results in the course of an extensive optimization process.

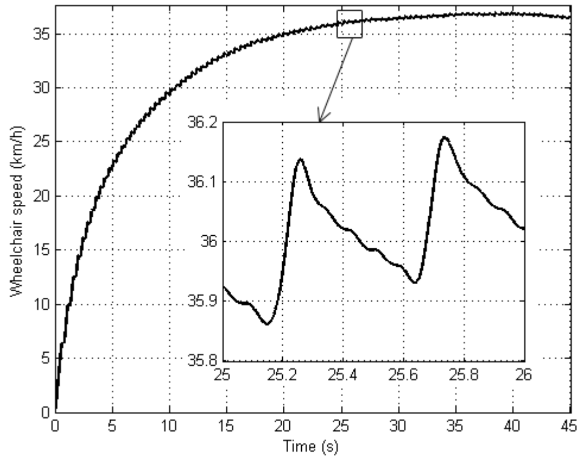

Figure 3: Typical speed profile for one athlete during an all-out run, acquired at 1000 Hz.

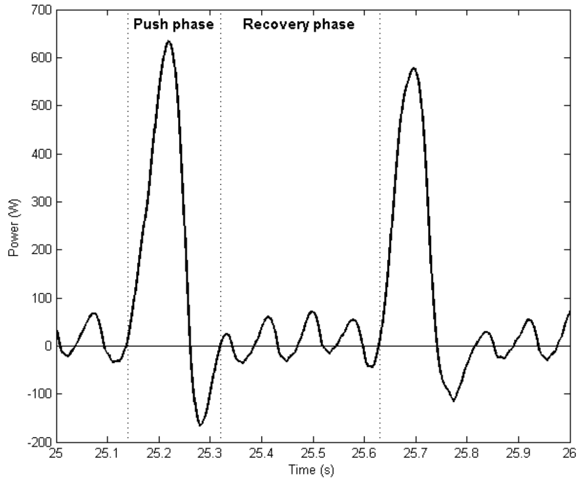

Figure 4: Typical power curve for one athlete during an all-out run, acquired at 1000 Hz, at about 36 km/h.

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