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PERFORMANCE ENHANCEMENT THROUGH CONFIGURATION OPTIMIZATION FOR RACING WHEELCHAIR ATHLETES

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SUMMARY

Podiums often result in a reduction of a few seconds in racing wheelchair performance. Athlete configuration optimization is a promising avenue for that purpose. However, very few studies have optimized athlete configuration. Moreover, those that did often used submaximal speed conditions [1,2] and data were not normalized to athlete anthropometry [2,3], such that generalization of their conclusions is not possible. The purpose of our study was to investigate how three configuration variables affect top speed performance using an ergometer with an adjustable wheelchair. Results show that two of the selected variables led to a 1.4 km/h top speed improvement, namely the shoulder abduction angle and a specific length ratio associated with the upper limb length. Multivariable optimization was not considered until theoretical optimization based on pushing dynamic models were achieved.

INTRODUCTION

Very few studies optimized configuration for racing wheelchair athletes. Those that performed such optimization did not normalize optimization variables based on athlete anthropometry, nor through testing conditions representative of actual racing conditions since testing protocols often used submaximal speeds. The purpose of our study was to optimize athletes configurations in their wheelchair based on maximal speed testing conditions. This study provides preliminary results from one male national team athlete.

METHODS

A Paralympics racing wheelchair athlete, classified T54 and performing in the 400 to 5000 m, participated to this study. Informed consent and approval from the institution ethic committee were obtained. The athlete used hard gloves including a wedge at their contact surface.

Three variables were considered in the optimization process (Figure 1A): the distance ratio *LR* (distance from the acromion to the second metacarpophalangeal joint *l* divided by the distance from the acromion to the pushrim *r*); the shoulder abduction angle α (Figure 1B) and the shoulder extension angle θ, defined when the extended upper limb is aligned with the wheel axis (Figure 1A).

The athlete seated in a custom fit bucket rigidly attached to an adjustable wheelchair (Figure 2). Both wheels were fixed to the adjustable wheelchair in such a way that they made nonslip contact with inertial steel rollers actuated by a brushless motor. For each test, athletes had to perform an acceleration run starting at 65% of their estimated maximum speed, until they reached their maximal speed, followed by a 10 minutes resting period. Maximal speed achieved during testing varied between 36.5 and 42.4 km/h. Five configurations were tested for variable *LR* including the reference configuration, assumed to be the actual athlete configuration. Three different configurations were tested for the other two variables because of geometric limitations. Tests for each optimization variables occurred over a period of two days to complete three repetitions per configuration.

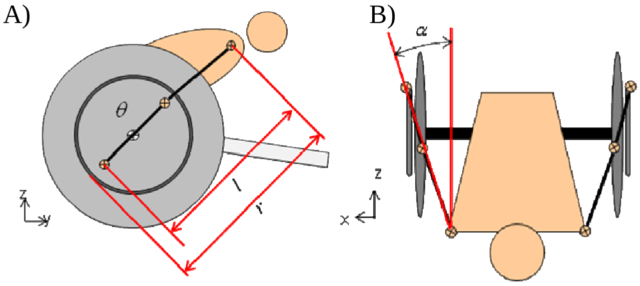

Figure 1: A) Definition of two optimization variables. *LR*: distance from the acromion to the second metacarpophalangeal joint *l* divided by the distance from the acromion to the pushrim *r*; and θ: shoulder extension angle. B) Definition of shoulder abduction angle α.

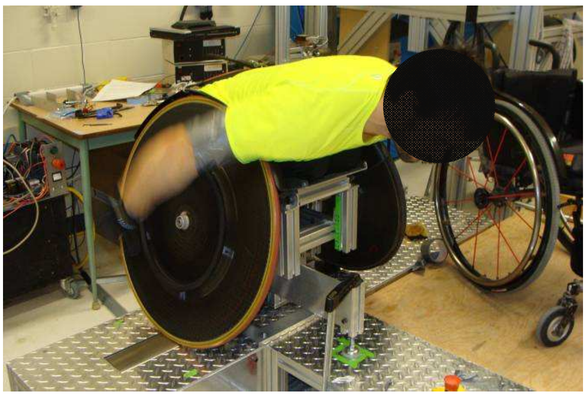

Figure 2: Paralympics athlete in the adjustable wheelchair on the ergometer.

RESULTS AND DISCUSSION

Figures 3 to 5 illustrate maximum speed reached for each tested configuration, normalized to the maximum speed reached over a given day.

Results on Figure 3 show that maximum speed is achieved when the athlete is seated for a ratio *LR* of 0.928, that is, more forward and higher than the reference configuration (i.e. +1.3 km/h over the reference configuration). Such results may be explained by strength-velocity-length curves or by kinematic/kinetic upper limb changes relative to the pushrim. Current dynamic models are being developed to figure out the most important factors underlying such performance improvement.

Results in Figure 4 show that the athlete reached higher speeds when the shoulder abduction angle was lower (+1.4 km/h on average compare to the widest configuration), i.e. when the wheels are closer to the body (α=3.5°). Instrumented wheels are currently being developed to measure the 3D pushing force vector on the pushrim with the purpose of clarifying what kinematic and kinetic advantages may be associated with such configuration.

Finally, results in Figure 5 show that a decrease in shoulder extension angle led to an increase in maximum speed (+0.7 km/h for the lowest angles). For the athlete tested, we noticed that in such configuration, the athlete had a tendency to tilt forward since the back belt was unable to maintain him stable in the bucket.

CONCLUSIONS

Preliminary results show that all three optimization variables had a significative impact on maximum speed, in the order of 0.7 to 1.4 km/h, the most important being the *LR* ratio and the shoulder abduction angle. Before further multivariable experimental optimization is achieved, dynamic modeling and pushing force measurements on the pushrim are required to reduce the number of testing conditions needed. In practice, a 1.4 km/h top speed increase may represent a 3% increase in performance in a marathon race, a non-negligible improvement for professional athletes.

ACKNOWLEDGEMENTS

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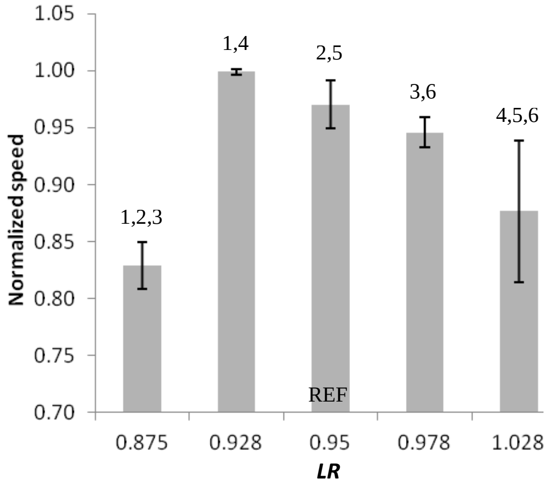

Figure 3: Normalized speed versus different *LR* ratios. For *LR*=0.875: athlete is sitting higher and forward; for *LR* =1.028: athlete is sitting lower and backward, compared to reference configuration (*LR*=0.95). [1]p=0.0002, [2]p=0.0010, [3]p=0.0023, [4]p=0.0050, [5]p=0.0137, [6]p=0.0347.

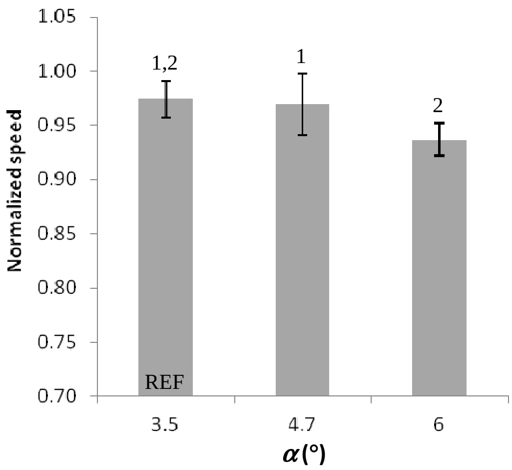

Figure 4: Normalized speed versus different shoulder abduction angles. α=3.5°: wheels are narrower and 6°: wheels are wider then reference configuration (α=3.5°). [1]p=0.0004, [2] p=0.0010.

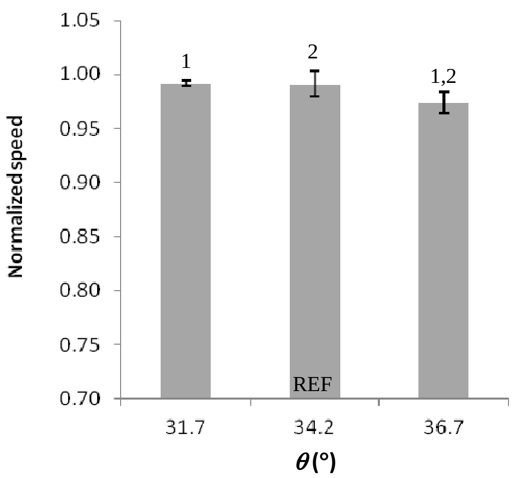

Figure 5: Normalized speed versus different shoulder extension angles. θ=31.7°: athlete buttock is lower; θ= 36.7°: athlete buttock is higher than reference configuration (θ=34.2°). [1]p=0.0175, [2]p=0.0146.