AEROBIC AND ANAEROBIC METABOLISM DURING LOCOMOTION WITH TWO DIFFERENT WHEELCHAIR TYPES

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The hand rim propulsion system generally employed by most wheelchairs (WHCH)presents a very low efficiency. This. coupled to the fact that propulsion requires the use of relatively small muscle mass. leads to the onset of fatigue even during low speed locomotlon. To overcome these disadvantages different types of WHCHS have been designed in order to increase the efficiency of locomotion and thus to decrease the energy required to achieve a given speed.

Wheelchair confined subjects frequently report that locornotlon with dlfferent types of dally use wheelchalrs may induce qulte different physiological responses. In partlcular. dyspnea and muscle fatigue can be easily achieved with a partlcular wheelchair type. On the contrary with other wheelchalrs. even If apparently very similar in size, fatigue occurs at higher speeds.

In an attempt to realize the reasons for such a different response evoked by similar wheelchalrs, a coupled bioenergetic–blomechanical analysis was performed. In the present paper the aerobic and anaerobic metabolism and the physiological responses to locomotion with two widely used wheelchalr was assessed. A large difference in the energy cost of locomotlon and lactate production was observed between the two WHCH types investigated.

Material and methods

Subjects: six well trained paraplegic males volunteered for the study (age 25–35 years: body weight 69 ± 9 Kg).

Wheelchairs: Two light weight daily active use commercially avallable WHCHS were investigated. Type A. foldable. 13.95 Kg; type B. demountable. 13.35 Kg. The main differences in geometrical configuration were in the horizontal location of the wheel axle. in the seat surface height and in the back seat position.

Wheelchair ergometer: A WHCH roller ergorneter (Sopur, Ergotronic mod.) was used. The ergometer consists of a platform with two rollers with negligible friction. where the distance covered and the speed are provided.

Protocol: 4 exercise bouts of 9 minutes each were required at submaximal speeds (2, 5, 7 and 9 Km/h) at 2 days interval while using wheelchalr type A or B. In different days. the remaining wheelchair was used applying exactly the same protocol.

Variables investigated: Oxygen uptake ($\dot{V}O_2$, ml O_2/min); pulmonary ventllatlon ($\dot{V}E$, l/min) and heart rate (HR, beats/min) were determined at rest and at the last 2 min of each exercise bout by open circuit (Douglas bag) method. Venous blood was taken before and at the 5th min of recovery for lactic acid concentration (LA. mmol/l). From the ratio of $\dot{V}O_2$ above resting divided by, the speed and by the body plus WHCH weight. the energy cost of locomotlon (C, ml O_2/Kg.m. i.e. the amount of O_2 required to cover 1 m distance per unit mass) was calculated at the various speeds.

Results and discussion

In flg. 1 are shown the individual values and the best flt regression lines of the net oxygen consumption observed at steady state during locornotlon with both WHCH A and B. Even if the variability at the same speed is quite large due to the dlfferent ability of the subject to move the whch, it clearly appears that at any given speed the oxygen consumption is much higher while propelling WHCH A than B ($p<0.05$).

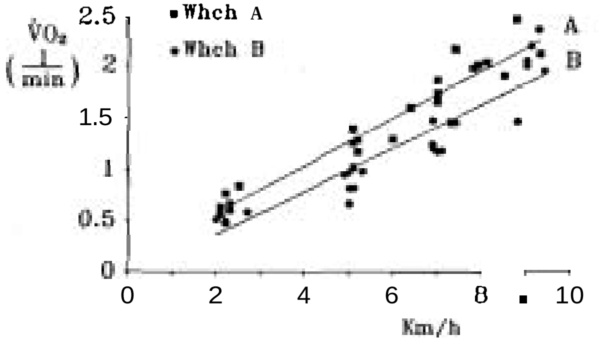


Fig. 1: Oxygen consumption values (above resting) are shown as a function of speed of locomotion using wheelchair A and B.

The increase above resting of lactate concentration (Δ [LA]) was practically negligible after the 9 min task at 2 km/h (fig. 2). However with Increasing the speed It changed significantly, reachfng. at about 9 Km/h while using WHCH A. values up to about 8 mmol/l, not too far from the maximal value (about 10 mmol/l) that can be observed with upper limb maximal exercise.
On the contrary, at the same speeds wlth WHCH B the values were significantly lower (5.5 mmol/l at 9 Km/h). Even if the anaerobic contribution to the total energy required is small, the large difference in LA concentration observed indicates that presumably WHCH A requires, at any given speed. a higher contribution of isometric effort in active muscles or a larger engaged muscle mass. particularly of the trunk.

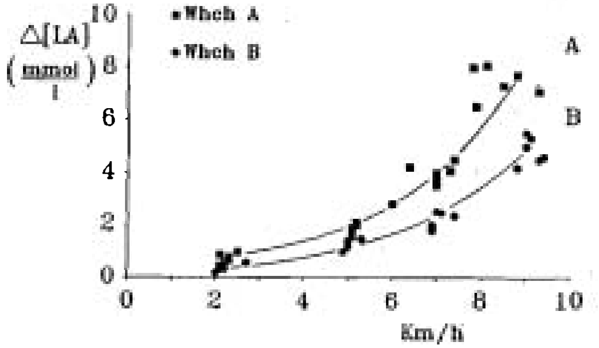
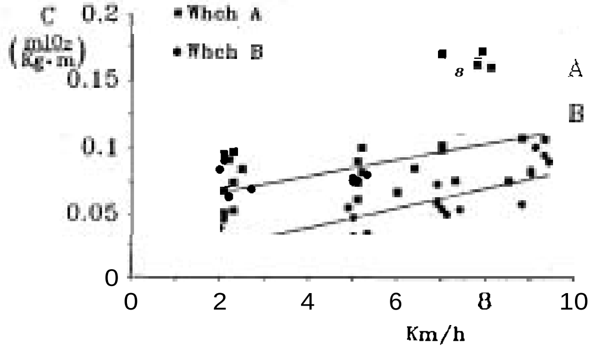


Fig. 2: Venous lactate concentrations above resting values are given as a function of speed of locomotion using wheelchair A and B.

The energy cost of locomotion, C. is given for each individual subject in fig. 3. C increased linearly wlth speed with both WHCHS with similar slope. However. at any speed the values observed wlth WHCH A are much higher. The back extrapolation of the C vs speed lines, i.e. the Intercepts of the two equations. may provide an estlmate of the energy requlred in ml O_2/Kg by the isometrically contracted muscles to maintain the posture and the equilibrium for the locomotion. This energy is much higher with WHCH A than B, showing that even small differences In geometric dimensions of the WHCHS affect enormously the posture.



Flg. 3: Energy cost of locomotfon (ml/O_2 above resting per Kg of body + wheelchair weight) as a function of speed using WHCH A and B. Back extrapolation to speed 0 of the lines provides an estimate of the oxygen required to maintain posture and equilibrium during locomotion.

Heart rate increased linearly wlth the speed for both the WHCHS (fig. 4) and was higher. even If not statistically, while using WHCH A than B. particularly at the higher speeds. At about 9 km/h HR reached maximal values durlng locomotion wlth WHCH A and was slightly lower wlth WHCH B.

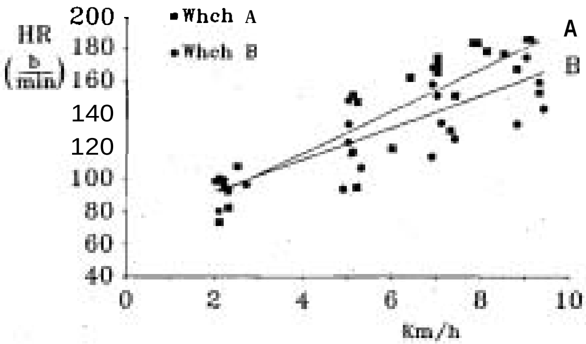


Fig. 4: Heart rate changes durlng locomotion with the two WHCHS.

Ventilation above resting is plotted as a function of the net oxygen consumption in fig. 5. For comparable oxygen uptake VE was similar for both WHCHS. thus showlng that. even with different WHCHS. ventilation is dependent upon the energy metabolism.

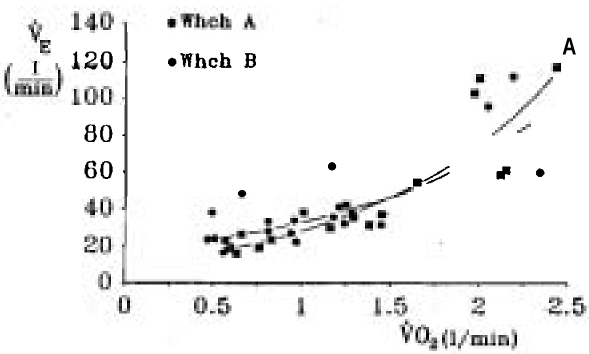


Fig. 5: Pulmonary ventilation as a function of net oxygen consumption during locomotion at speeds from 2 to 9 Km/h.

In table 1 Is shown a comparison of the physiological variables observed during locomotlon at 5 km/h with the two WHCHS. Values are means calculated on the basis of the relatlonshlps between each variable indicated vs speed. for each individual subject.
Statistical analysis showed that. wlth the exception of HR, the difference Is at $p<0.05$ level.

At 5 Km/h

	TYPE A	TYPE B	Δ %
$\dot{V}O_2$ (l/min)	1.27	0.99	28
$\dot{V}_E$ (l/min)	38	25	52
HR (b/min)	129	121	7
Δ [LA] (mmol/l)	1.95	1.25	58
C (mlO_2/kg·m)	0.13	0.09	44

Tab. 1: Mean values of oxygen consumption. pulmonary ventila- tion, heart rate. increase of lactic acid over restlng and energy cost of locomotion observed at 5 km/h with WHCH type A and B.

Conclusions

The main results of this study concern the large difference existing In the energy cost of locomotlon and In the lactate production in the same subject when two different wheelchairs, even if apparently similar, are used. In partlcular. the much hlgher cost and lactate production suggest that wheelchair design seems to affect the posture. the equilibrium and the limb and trunk movements in such a way that the metabolism of some muscle group requlres a greater particlpatlon of anaerobic mechanism of energy supply, thls leading to early onset of muscular fatigue. Further studies. in particular the combined biomechanlcal analysis of user and wheelchair during locomotlon. are required to increase the optimum fitting of wheelchair–user interface.