BIOENERGETICS AND BIOMECHANICS OF HANDBIKING

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SUMMARY
This study analyzed bioenergetics and biomechanics of handbiking (HB) of spinal cord injured athletes. Nine subjects (8 males and 1 female, age: 46.7±7.3 y, body mass: 72.6±11.8 kg, sport classes: 1 MH1.2, 6 MH2, 1 MH3 and 1 WH1.2) have been tested while handbiking (synchronously) at constant aerobical speeds (2.79±8.42 m s⁻¹) on an athletics track under metabolic and mechanical measuring with their own bikes. Motion capture was performed on four subjects cycling at their outdoor constant speeds on an indoor motorized treadmill. After combining outdoor and indoor results, metabolic power showed to increase exponentially over speed, while total mechanical power (\(W_{\text{tot}}\)) increased more smoothly. \(W_{\text{tot}}\) components resulted (% \(W_{\text{tot}}\), all speeds pooled): centre of mass mechanical power 27.6±2.8, rolling resistance power 53.4±9.4, air drag power 15.4±10.4 and kinematic internal mechanical power 3.6±0.4. Mechanical energy recovery and efficiency decreased remarkably over investigated speed range showing values of 44.8±2.1 and 20.9±5.1%, respectively. Muscular mechanical power (measured with a powermeter) showed to be lesser than kinematics-derived (to counteract rolling and air resistance) external mechanical power components. These results provide a clue to an unexpected pendulum-like energy saving mechanism featuring HB. This phenomenon may be due to synchronous HB action. Particularly more biomechanical analyses are needed to confirm this hypothesis.

INTRODUCTION
Over recent years, popularity of handbiking (HB) has increased among wheelchair users both as a competition sport and as a type of locomotion [1]. Aim of this study is to provide an overall description about bioenergetic and biomechanical variables featuring sub-maximal HB. Specific goals are to quantify a) metabolic power; b)1) mechanical power due to centre of mass kinematics, b2) mechanical power to counteract rolling resistance and air drag, b3) mechanical internal power; and c) mechanical efficiency [2,3,4].

METHODS
Nine spinal cord injured subjects (8 males and 1 female, age: 46.7±7.3 y, body mass: 72.6±11.8 kg, sport classes: 1 MH1.2, 6 MH2, 1 MH3 and 1 WH1.2) have been tested while handbiking (synchronously) at constant aerobical speeds (2.79±8.42 m s⁻¹) on an athletics track with their own bikes. Breath by breath oxygen consumption (COSMED K4b²) and crank mechanical power (SRM, \(W_{\text{SRM}}\)) have been measured, rolling resistance and aerodynamic drag have been estimated. Four subjects cycled at their outdoor constant speeds on an indoor motorized treadmill. Motion capture (Vicon) has been performed.

Outdoor metabolic power (\(W_{\text{met}}\)), indoor centre of mass mechanical power (\(W_{\text{com}}\)), outdoor rolling resistance and air drag power (\(W_r\) and \(W_a\)) and indoor kinematic internal mechanical power (\(W_{\text{int}}\)) have been calculated [2,3,4].

Mechanical energy recovery (rec, %), a known variable witnessing capacity to save mechanical energy by means of a pendulum-like continuous exchange between kinetic and potential energy, has been calculated too [5]. By combining outdoor and indoor measures (\(W_{\text{SRM}}+W_{\text{com}}\cdot\text{rec}=W_{\text{com}}+W_r+W_a\), e.g., external mechanical power [5]), each bout’s aerodynamic coefficient has been calculated.

RESULTS AND DISCUSSION
While metabolic power showed to increase exponentially over speed (\(W_{\text{met}}=70e^{0.37\cdot\text{speed}}, R^2=.90, n=44\)), total mechanical power (\(W_{\text{tot}}=W_{\text{com}}+W_r+W_a+W_{\text{int}}\)) increased more smoothly (\(W_{\text{tot}}=23.91\cdot\text{speed} – 36.86, R^2=.96, n=35\)). \(W_{\text{tot}}\) components resulted (% \(W_{\text{tot}}\), all speeds pooled): \(W_{\text{com}}\) 27.6±2.8, \(W_r\) 53.4±9.4, \(W_a\) 15.4±10.4, and \(W_{\text{int}}\) 3.6±0.4, rec and mechanical efficiency (i.e., \(W_{\text{tot}}/[W_{\text{met}}\cdot\text{resting metabolic power}], \%\) decreased remarkably over investigated speed range showing (grand) values of 44.8±2.1 and 20.9±5.1%, respectively.

HB metabolic power showed a pattern over speed similar to able-bodied’s (leg) cycling. Yet, recorded muscular mechanical power (\(W_{\text{SRM}}\)) showed to be lesser than kinematics-derived (\(W_{\text{com}}\)) plus physics-derived (\(W_r\) and \(W_a\)) external mechanical power components. Difference may be due to synchronous HB action determining a pendulum-like muscular mechanical energy saving mechanism. Mechanical efficiency resulted similar to (asynchronous) cycling.
**CONCLUSIONS**

Subjects’ functional heterogeneity makes hard studies like this. Nevertheless, this study provides a clue to an unexpected pendulum-like energy saving mechanism featuring HB. Particularly more biomechanical recordings and subsequent calculations are needed to confirm this hypothesis.

**REFERENCES**