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BOOK OF ABSTRACTS Open Access

Effects of gear, imposed resistance and crank mode on the mechanical efficiency and physiological parameters during sub-maximal handcycling in healthy men

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Introduction

Handcycling is an important alternative to the manual wheelchair, especially for daily outdoor transportation. An add-on handcycle is often used and has multiple gears, so that higher speed and longer distances can be reached. Initially, the handcycle was based on bicycle technology and had an asynchronous crank mode (asyn). Nowadays, they are all equipped with a synchronous crank mode (syn)(Hettinga et al., 2010; van der Woude, Dallmeijer, Janssen, & Veeger, 2001). The aim of this study was to investigate the effects of gear, imposed resistance and crank mode on the mechanical efficiency and physiological parameters. We hypothesize that a lower gear (higher cadence), a higher resistance and an asynchronous crank mode are more straining in sub-maximal handcycling.

Methods

Twelve non-disabled men rode in an instrumented handcycle on a motorized treadmill at 1.94 m/s. We changed the gear, imposed resistance and the crank mode, all in a counterbalance order. The participants handcycled three sessions in each crank mode. Across the three sessions, we changed the resistance (PO1: 15.9 ± 3.4 W, PO2: 26.2 ± 4.1 W and PO3: 36.2 ± 3.7 W). Every session consisted of three blocks of four minutes exercise, over which we changed the gear (1: 70 rpm, 2: 60 rpm, and 3: 52 rpm). Oxygen uptake (VO2, ml/min), carbon dioxide output (VCO2, ml/min), and heart rate (HR, bpm) were continuously measured (Cosmed Quark CPET, Cosmed, Rome, Italy). The mechanical efficiency (ME, %) was calculated according the following equation:

$$ME(\%) = \frac{PO_{syn}}{Energy\ Expenditure} \cdot 100\% = \frac{2 \cdot F_{tan,syn} \cdot v_{linear,syn}}{((4.94 \cdot VCO_2/VO_2 + 16.04) \cdot VO_2)/60} \cdot 100\%$$

To ensure steady state, we calculated mean ME, VO2, and HR over the last minute of every block. The effects were analyzed with a repeated measures ANOVA (P<0.05) with gear, resistance and crank mode as within-subject factors (SPSS 24, SPSS Inc., Chicago, Illinois, USA).

Results

The mechanical efficiency is lowest when handcycling with a high cadence, a low resistance and with an asynchronous crank mode (figure 1, left). The heart rate and oxygen uptake increase with an increase in cadence and resistance, which is more prominent in the asynchronous mode (figure 1 middle, right). Gear, resistance and crank mode all have a large significant effect on the physiological parameters during sub-maximal handcycling and interaction effects with crank mode are found (table 1).

Discussion and Conclusions

Based on the results, we suggest that a low cadence (Gear 3: 52 rpm) with a higher resistance is more efficient, especially with a synchronous crank mode. In agreement with the literature, we suggest that asynchronous handcycling is more straining, due to the stabilization of the trunk

(Dallmeijer, Ottjes, de Waardt, & van der Woude, 2004). There is an extra need for control of the front fork motion in this crank mode, since steering is not allowed on a treadmill.

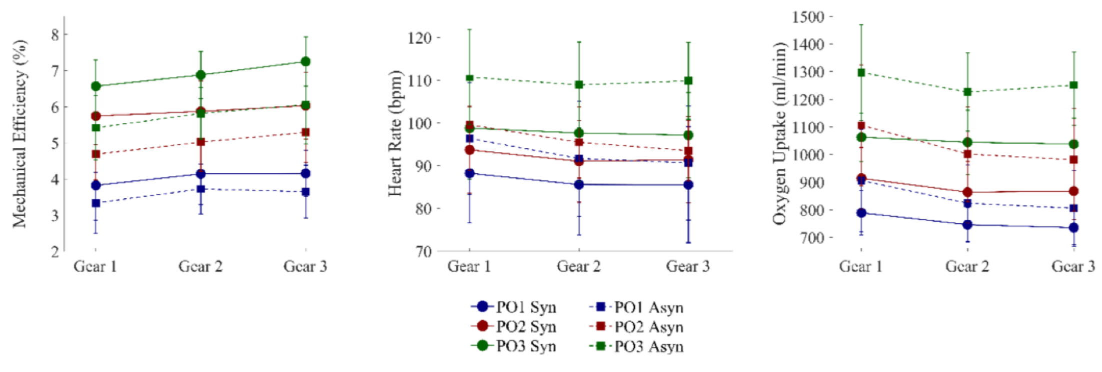

Figure 1. The mean value and the standard deviation (n = 10) are given for ME, HR and VO2 for all 18 conditions.

Table 1: Results repeated measures ANOVA

n=10		ME (%)	HR (bpm)	VO_2 (ml/min)
Gear	*F*(df)	13.16 (2,18)	14.71 (1.09,9.81)†	27.51 (1.26,11.35)†
	P value	<0.001*	0.003†*	<0.001†*
	η^2_p	0.59	0.62†	0.75†
Resistance	*F*(df)	98.26 (2,18)	25.11 (2,18)	77.55 (2,18)
	P value	<0.001*	<0.001*	<0.001*
	η^2_p	0.91	0.74	0.90
Crank mode	*F*(df)	44.29 (1,9)	29.96 (1,9)	28.81 (1,9)
	P value	<0.001*	<0.001*	<0.001*
	η^2_p	0.83	0.77	0.76
Gear*Resistance	*F*(df)	0.78 (4,36)	2.13 (4,36)	2.31 (4,36)
	P value	0.545	0.098	0.077
	η^2_p	0.08	0.19	0.20
Gear*Crank mode	*F*(df)	0.77 (2,18)	4.97 (2,18)	7.82 (2,18)
	P value	0.477	0.019*	0.004*
	η^2_p	0.08	0.36	0.465
Resistance*Crank mode	*F*(df)	7.76 (2,18)	2.40 (2,18)	9.17 (2,18)
	P value	0.004*	0.119	0.002*
	η^2_p	0.46	0.21	0.51
Gear*Resistance*Crank	*F*(df)	0.73 (4,36)	1.86 (4,36)	1.64 (4,36)
	P value	0.576	0.140	0.184
	η^2_p	0.08	0.17	0.15

†Sphericity not assumed, Greenhouse-Geisser
*Significant at $P<0.05$

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Key words: Handcycling, mechanical efficiency, cadence, heart rate, oxygen consumption

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